

THE DEVELOPMENT OF THE PALMAR SWEAT
INDEX AS AN APPLIED MEASURE IN CLINICAL
PSYCHOLOGY.

KEITH JOHN CLEMENTS

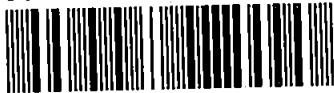
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Abstract

Five studies are described, examining the validity of the Palmar Sweat Index (PSI) as an alternative to traditional measures of electrodermal activity (EDA). A review of research using the PSI identified four topics which needed to be addressed, before the PSI could be accepted as an alternative to measures of EDA.

The first of these topics concerns the reliability of the PSI. A preliminary analysis confirmed that the PSI could be scored reliably.

The second topic to be examined, was the relationship between the PSI and measures of EDA. The PSI was found to correlate significantly with several parameters of EDA. These results provide some support for models of EDA involving a single effector. More importantly, the PSI response was observed to show rapid recovery, and in one study the PSI was observed to show adaptation over the course of the session, while skin conductance level did not. The difference in the temporal patterning of the responses shown by the two measures provides an explanation for previous reports of a dissociation between the PSI and EDA.

The final topics to be examined concerned the effects of psychological stress and anxiety, respectively, on the PSI. Stressful cognitive tasks were observed to lead to increased palmar sweating. Previous claims that the PSI may decrease in response to stress were not supported. More ecologically-valid stressors were less consistently associated with

elevated levels of sweat gland activity. There was some support for a relationship between the PSI and experienced anxiety. It is suggested that this may explain the raised sweat gland activity observed during stressful tasks.

Data are also presented from three collaborative studies. This data was collected by other workers and demonstrates the utility of the PSI for applied clinical research.

Chapter 1
Introduction

1 Psychophysiological Research

Psychophysiology has been defined as that area of psychology which uses non-invasive physiological measures to study psychological processes (Stern, 1964). Such processes include information-processing (e.g. Van der Molen, Somsen & Orlebeke, 1985; Hillyard & Hansen, 1986), emotion (e.g. Levenson, 1988; Ney & Gale, 1988), individual differences (e.g. Gale & Edwards, 1983) and psychopathology (e.g. Zahn, 1986; Turpin, 1989a). Typical psychophysiological measures include peripheral measures such as heart rate (HR) and electrodermal activity (EDA), central measures such as the electroencephalogram (EEG) and event-related potentials (ERPs) and biochemical variables such as hormonal activity (for detailed reviews of psychophysiological measurement the reader should consult the following: Martin & Venables, 1980, Coles, Donchin & Porges, 1986, Cacioppo & Tassinari, 1991).

The approaches used by psychophysiology are inevitably constrained by the techniques available. Psychophysiological research traditionally uses the polygraph, a sophisticated system for transducing, amplifying and recording several channels of physiological information simultaneously. The use of the polygraph to measure variables such as electrodermal activity or heart rate tends to confine research to the laboratory, restricting ecological validity and the applicability of findings. In contrast, field studies using less complicated methodology often sacrifice the control provided by laboratory studies. The development of portable equipment (e.g.

Tarrier et al., 1979), ambulatory monitoring techniques (e.g. Turpin, 1985) and the use of telemetry (eg White & Charles, 1983) have reduced the intrusiveness of traditional psychophysiological measures, and have allowed research to be undertaken in more natural settings. However, such equipment is expensive and not generally available. In addition, the training needed to use such equipment would limit the use of psychophysiological measures in applied psychology.

An alternative to the use of sophisticated electronic systems for psychophysiological recording is to use simple measures that can be obtained without the need for extensive equipment. This thesis examines the Palmar Sweat Index (PSI), a measure of sweat gland activity which requires a minimum of equipment. Because the PSI can be administered without extensive training, and is sufficiently portable to be used in virtually any setting, it may allow the extension of research into field settings. Simple physiological measures such as the PSI would also allow the development of clinical applications based on the findings of research, provided that it is possible to generalise from laboratory research concerning skin conductance to field measurements using the PSI. The work described attempts to demonstrate that such generalisation is possible, and that the PSI is a suitable measure for applied research.

2 Electrodermal Activity

Electrodermal activity refers to changes in the electrical properties of the skin, reflecting the activity of the sweat glands. The term includes both skin conductance measures and the, less commonly used, skin potential measures. The publication guidelines for electrodermal measurement of the Society for Psychophysiological Research (Fowles et al., 1981) state that skin conductance measures

are to be preferred to skin potential measures. For this reason the thesis will be restricted to consideration of skin conductance measures. Chapter two provides an overview of existing knowledge about the structure and function of the sweat-glands and the nature of electrodermal activity.

Skin conductance is recorded by the application of a small voltage between two electrodes placed on the skin, usually on the palm or fingers, although other placements are possible. In part because of the apparent simplicity of EDA recording, in comparison to other psychophysiological measures such as the EEG, skin conductance is one of the most widely used psychophysiological measures. EDA has been shown to be related to a wide variety of psychological constructs (see Prokasy & Raskin (1973) for an illustration of the extent of research using EDA). In particular, electrodermal activity has shown considerable promise as an applied measure in clinical psychology. Electrodermal activity has been claimed to be related to a wide range of disorders including depression (e.g. Ward & Doerr, 1986; Thorrell, 1987), schizophrenia (e.g. see Turpin, TARRIER & Sturgeon, 1988), psychopathy (e.g. Hare, 1978) and anxiety disorders (e.g. Lader, 1975).

The measurement of skin conductance requires subjects to be fitted with electrodes, which is a fairly intrusive procedure and may be anxiety-provoking. In addition the equipment needed to measure skin conductance is relatively expensive and, in general, not portable. These factors limit the range of clinical research with EDA and present barriers to its application. While other measures of sweat gland activity exist (e.g. Strahan, Todd & Inglis, 1974; Silverman & Powell, 1944a), and such measures have been used in clinical research (e.g. Silverman & Powell, 1944b), these measures have generally been

neglected in comparison to EDA.

3 The Palmar Sweat Index

The Palmar Sweat Index (PSI), developed by Sutarman & Thompson (1952), provides a technique of sweat gland measurement which is portable and relatively non-intrusive. The PSI is one of a number of techniques which attempt to directly assess the activity of the sweat glands, either by providing an estimate of the proportion of the glands which are active, or by measuring the amount of sweat secreted. The PSI consists of a count of the number of active sweat glands in a given area on the tip of a finger. The count is obtained from a plastic impression of the fingertip. Prints can be obtained repeatedly at one-minute intervals using a minimum of equipment. The simplicity of the PSI, together with its portability, provides the main advantage of the technique for applied research. The PSI requires little training to administer and is cheap to use, so that the technique would also be suitable for use in clinical practice.

Despite these advantages the PSI has not been widely used, and there remain several questions concerning the basic measurement properties of the index. In addition there are inconsistencies in the literature regarding the effects of factors such as stress or attention upon the PSI which are in need of clarification (e.g. see Weisenberg et al., 1976). The literature concerning the PSI is reviewed in chapter three.

4 The Programme of Research

The programme of research aims to demonstrate that the PSI can provide a valid alternative to electrodermal activity. The PSI can be considered to be equivalent to any other psychological test. Therefore

the same criteria used for the validation of any psychological test ought to be applied to the PSI. These include the measure's reliability, criterion-related validity and construct validity (Anastasi, 1988, Strube, 1991).

4.1 The Reliability of the PSI

The basic criterion for reliability is that the measure should be replicable; taking the measure under equivalent circumstances should produce the same results. For standard psychological tests reliability is divided into inter-rater or parallel form reliability, test-retest reliability and various measures of consistency such as split-half reliability.

For the PSI, inter-rater reliability is important with regard to the scoring of the prints. As the prints are scored by eye there is the possibility of experimenter bias. Therefore, inter-rater reliability needs to be examined by comparing the same prints scored by different raters. The test-retest reliability of the PSI is less important. It is expected that physiological measures will vary over time, so that the temporal stability of such measures would be predicted to be low. While an interesting question in it's own right, the temporal stability of the PSI is, therefore, less important for the acceptance of the measure. The consistency of the PSI needs to be examined with regard to possible differences between prints taken from different sites. This could also be viewed as a type of parallel forms reliability. Prints could be taken from different hands, different fingers, or from different areas of the same finger. If the correlation between measures taken from different sites is low then the PSI can not be accepted as an index of central states such as arousal or anxiety. Furthermore, significant differences between hands

or fingers would make the interpretation of the PSI very difficult.

In addition to these measures of reliability other factors also need to be considered. Environmental factors, such as temperature or humidity, and subject characteristics, such as sex or age, may influence the PSI and, thereby, reduce the replicability of results obtained using the measure. Furthermore, the PSI may be scored in different ways. The reliability and sensitivity of these different scoring methods needs to be considered.

4.2 The Validity of the PSI

Criterion-related validity refers to the relationship between a test and other tests measuring the same, or related, constructs. One form of criterion-related validity, concurrent validity, concerns the relationship between tests administered at the same time. If such measures are not correlated then the validity of one or both of the measures must be called into doubt. For the PSI the criterion against which it must be compared is provided by electrodermal activity. It needs to be demonstrated that the PSI does, in fact, correlate significantly with EDA.

Earlier work with the PSI has reported acceptable correlations between the PSI and skin conductance level (SCL) (Johnson & Landon, 1965; Venables & Martin, 1967; Johnston & Johnston, 1974). The relationship between the PSI and other parameters, such as response frequency or amplitude, has not been examined in earlier studies. In part, this is because interest in other parameters of EDA is a relatively recent phenomenon. Given the evidence for some degree of dissociation between different parameters of EDA (e.g. Martin & Rust 1976) the PSI will be compared to several different parameters of electrodermal activity.

As well as concurrent validity, there is another form of criterion-related validity, that is predictive validity. This refers to the ability of a test to predict subsequent behaviour. With regard to the PSI predictive validity can be considered to be the extent to which the PSI is predictive of psychological factors. Where electrodermal activity has been shown to be predictive of a given psychological state or process, the PSI should also show a similar relationship. It is to be expected that both the PSI and EDA will respond to experimental manipulations in similar ways. Where electrodermal activity has been found to be predictive of factors such as symptomatology or psychiatric diagnosis, it is to be expected that the PSI will also discriminate between the same groups.

Examination of the predictive validity of the PSI can be combined with an assessment of its construct validity. The assessment of the predictive validity of the PSI will primarily concentrate on the effects of experienced stress or anxiety on the PSI.

The second type of validity which needs to be investigated is the construct validity of the measure. The construct validity of a psychological test refers to the extent to which it provides a valid index of the psychological construct which it is claimed to measure. Construct validity, therefore, is partly dependent upon the psychological theory underlying the test.

The PSI has been most commonly used as an index of stress or anxiety. However, the assumption that the PSI can be used as an index of stress may not be warranted. The existing literature is contradictory, with some studies (eg Faust & Melamed, 1984) assuming that the PSI, like skin conductance, increases in conditions of stress or anxiety. In contrast, other studies have assumed that stress leads to an inhibition of palmar sweating. This assumption is based on work

carried out by Harrison, Mackinnon & Monk-Jones (1962), who found a long-term depression of sweating in surgical patients following operations.

In order to clarify this situation several experiments will be described which evaluate the response of the PSI to different "stressful" situations. It is claimed that the existing confusion stems partly from a failure to specify the nature of the stimuli used. The assumption that all "stressors" are equivalent is unjustified.

The distinction between Harrison et al's "anhidrotic response" and the short-term increases in sweating reported in other studies (eg Dabbs, Johnson & Leventhal, 1968) also raises the question of the time-course of changes in the PSI. The duration of the response will be examined, both directly and by the use of a video technique allowing continuous assessment of sweat-gland activity. This will extend the data concerning the relationship between the PSI and EDA, allowing the examination of both phasic and tonic changes in activity in both measures.

As the Palmar Sweat Index is potentially suited for applied use, the predictive validity of the measure will also be examined with regard to areas of clinical psychology where measures of EDA have been shown to be of use. The experimental section of the thesis will conclude with a review of several collaborative studies providing direct evidence for the utility of the PSI in clinical settings and in relation to several different disorders. A review of prior research into three specific disorders which have been found to be related to electrodermal activity is provided in chapter four.

4.3 Summary

The major research questions to be addressed by this thesis are

as follows.

- 1) Does the PSI show acceptable reliability and what factors are likely to influence the reliability of the measure?
- 2) Is the PSI a valid alternative to measures of electrodermal activity?
- 3) How does the PSI respond to psychological stress?
- 4) Does the PSI provide a valid index of anxiety?

Chapter 2

Measures of Sweat-Gland Activity

1 Introduction

This chapter will provide an introduction to measures of sweat gland activity, with particular emphasis on electrodermal activity. The physiological basis of sweating will be reviewed, together with a discussion of various measures of sweat gland activity. Theoretical models which have been proposed to explain the observed phenomena of electrodermal activity will also be discussed. The final section will then review the environmental and psychological factors which are thought to influence electrodermal activity. For a more detailed discussion of many of the topics covered here see Fowles (1986). Venables & Christie (1980) also provide a good introduction to electrodermal activity.

2 The Physiological Basis of Sweat Gland Activity

2.1 The Structure of the Skin

The skin forms an interface between the individual and the environment. As part of this role the skin performs a defensive function, protecting the body from harm by external pathogens, physical stressors and extremes of temperature. The skin also has a sensory function, nerve endings in the skin providing tactile information and mediating the perception of ambient temperature. In addition the skin contributes to motor behaviour, fine control of movement depends on feedback from sensory organs in the skin, and the surface properties of the skin provide the right amount of friction

necessary for a secure grip. In order to balance the demands made by these different roles the skin is much more than just a passive barrier. The skin has a complicated structure and is supplied with a variety of organs which actively control it's properties in response to situational demands. The discussion which follows will concentrate primarily on the eccrine glands, as a full discussion of the structure of the skin is beyond the scope of this thesis (see Rook, Wilkinson & Ebling, 1979 for more detailed coverage).

Microscopic examination of the skin reveals a division into two broad layers; the dermis and the epidermis (see Figure 1). The dermis is a layer of connective tissue which is richly supplied with blood vessels and contains the various sensory receptors, hair follicles, sebaceous glands and eccrine sweat-glands. The epidermis is a stratified epithelium, graduating from living cells at it's base to a dead layer, largely composed of the protein keratin, at it's surface.

The epidermis can be subdivided into a number of layers. Cells are produced at the base of the epidermis and migrate upwards, undergoing a process of transformation. The uppermost layer of the epidermis is the stratum corneum. The stratum corneum is composed of the flattened remains of once-living cells, their cell membranes being replaced by keratin. Most of the skin is relatively porous. Fluids are able to diffuse out from the dermis to the lower layers of the epidermis. The stratum corneum is also able to absorb water. A barrier, thought to lie in the lower levels of the corneum, prevents the loss of body fluid through the skin. The state of hydration of the corneum may contribute to electrodermal activity, both by directly altering the conductivity of the corneum, and by influencing the absorption of sweat secreted by the sweat glands.

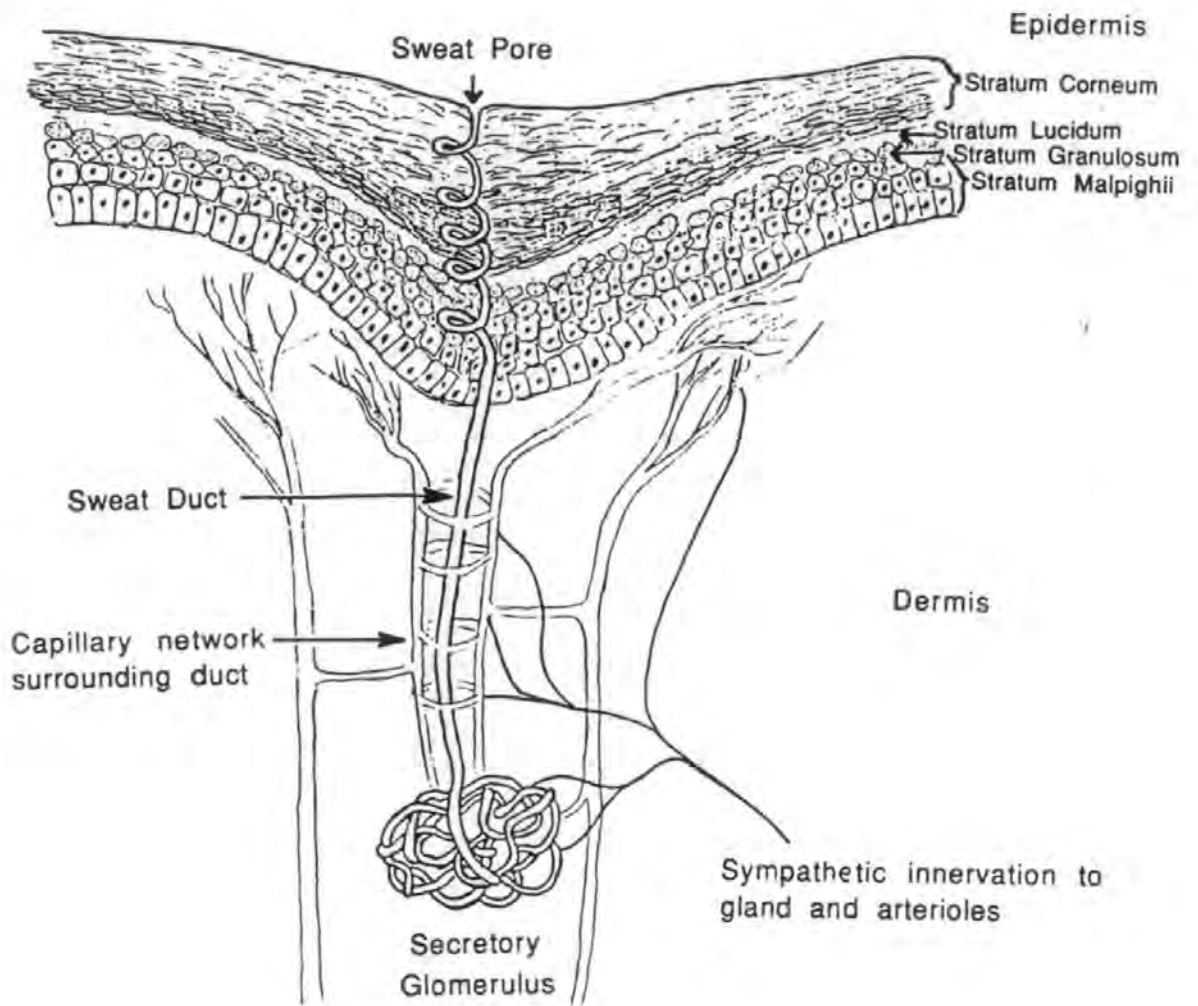


Figure 1: Schematic representation of the structure of the skin, showing an eccrine sweat gland

2.2 The Sweat Glands

2.2.1 Structure of the sweat glands. There are two types of sweat glands, eccrine glands and apocrine glands. The majority of the sweat glands are eccrine glands, secreting fluid from intact cells. Apocrine sweat glands, are thought to secrete sweat by "pinching off" part of the secretory cells. Apocrine glands exist in large numbers only in some parts of the body, such as the axilla, the aureole of the breast, the circumanal region and the genitals. These glands are not found in those areas from which electrodermal activity is usually recorded, and are thought to contribute little to the amount of sweating.

Eccrine sweat glands occur over the whole body surface, although there are wide variations in gland density. Glands are most common on the palms of the hands and the soles of the feet. An eccrine gland is illustrated in Figure 1. Structurally, eccrine sweat glands consist of a long tubule. The secretory portion of the gland is tightly coiled into a compact ball. Secretory glands are found in the dermis, generally located under dips in the dermis-epidermis boundary. The sweat duct extends from the gland through the dermis and epidermis to the pore. The portion of the duct running through the stratum corneum is coiled into a spiral. On the palms, sweat glands are regularly spaced along the ridges of the fingerprint.

2.2.2 Innervation of the sweat glands. The sweat glands are innervated by fibres from the sympathetic nervous system (SNS). In contrast to other branches of the SNS, which use noradrenaline as a transmitter, postganglionic fibres to the sweat glands are primarily cholinergic. The possibility of adrenergic innervation of the sweat glands has been the subject of much debate; the weight of recent evidence supports an additional adrenergic input (see Shields et al.,

1987). It is apparent that administration of adrenaline or noradrenaline can produce sweating measurable by several different techniques (e.g. Allen & Roddie, 1972; Szabadi et al., 1980). However, adrenergic agonists are generally found to be less potent than cholinergic agonists in the production of sweating (e.g. Szabadi et al., 1980; Sato, 1977) and adrenergic blocking agents are comparatively ineffective in reducing naturally occurring sweating, as opposed to the sudorific response to injected catecholamines. Atropine, in contrast, will drastically reduce both thermal and emotional sweating (e.g. Forster & Weiner, 1970; Allen, Jenkinson & Roddie, 1972). In man, as opposed to other mammals (see Robertshaw, 1977), adrenergic influences on sweating appear to have little functional significance and most probably represent a phylogenetic vestige.

The stimulatory effects described above should be distinguished from the inhibitory effect of catecholamines described by Harrison & Mackinnon (1963, 1966; Mackinnon & Harrison, 1961; Mackinnon, 1964). While long-lasting "fatigue-like" depressions of sweating have been noted after both adrenergic and cholinergic stimulation of the glands (e.g. Sonnenschein et al., 1951; Collins, Sargent & Weiner, 1959), the "Anhidrotic response" of Harrison & Mackinnon is produced by central, rather than peripheral mechanisms (see Harrison & Mackinnon, 1963).

2.2.3 Hormonal influences. The studies referred to above indicate that circulating catecholamines may exert two effects on palmar sweating. Studies reviewed by Shields et al. (1987) demonstrate that circulating catecholamines will produce a local increase in sweating, possibly followed by a longer-lasting depression of sweating. The work of Harrison & Mackinnon (1963, 1966; Mackinnon & Harrison, 1961; Mackinnon, 1964), which will be reviewed in more detail in chapter 3,

demonstrates a depression of sweating lasting at least an hour, produced by systemic administration of large doses of catecholamines. This response appears to be mediated by the central nervous system. Other hormones are also thought to influence sweat gland activity (see Venables & Christie, 1973).

Mackinnon & Harrison (1961) demonstrated that administration of adreno-cortico trophic hormone (ACTH) produced a depression of sweating with a latency of around five and a half hours. The depression lasted for the remaining three hours of the experiment. Progesterone also produced a similar long-lasting depression of sweating about three hours after administration. They suggest that both effects reflect an effect of progesterone on palmar sweating, ACTH acting via its stimulation of the adrenal cortex to release progesterone.

Aldosterone, another adrenal cortical hormone is also thought to influence the sweat glands. Aldosterone acts to conserve sodium by increasing reabsorption in the kidney. Aldosterone also leads to a reduction in the sodium content of sweat a day, or more, after the start of administration. This change can take even longer to reverse after aldosterone administration stops (see Morimoto, 1978). Changes in sweat concentration are unlikely to alter skin conductance values, however measures of skin potential are likely to be influenced by such changes. The long-latency and persistence of such effects may pose real problems for research using these measures.

There has been speculation that anti-diuretic hormone (ADH) may also produce homeostatic changes in sweat gland activity to conserve water. However at present there is no evidence for such an effect (see Morimoto, 1978).

2.2.4 The functions of the sweat glands. The primary role of the sweat glands is believed to be thermoregulation. While the role of temperature in eliciting sweating on the general body surface is not in doubt, palmar and plantar sweating (that on the palms and soles of the feet) is much less sensitive to temperature. Kuno (1956) reports that the sweat glands on the palms do not respond to heat, unless the heat is sufficiently intense to lead to heat stroke. While other studies have shown that palmar sweating is responsive to increases in temperature (e.g. Mulsby & Edelberg, 1960; Wilcott, 1967), it is clear that palmar sweating is largely determined by factors other than thermoregulation.

In addition to increased temperature, sweating can also be induced by stressful, novel or emotional stimuli. This "mental sweating" is usually claimed to be restricted to the palms and soles of the feet at room temperatures (e.g. Kuno, 1956). However, Shields et al. (1987) conclude that emotion-evoked sweating probably occurs at all sites, but may be easier to detect on the palms, due to the greater density of sweat glands there.

A review of the psychological factors thought to cause mental sweating will be provided in section 4.2. The current discussion will consider the functional significance of mental sweating. Several explanations have been proposed for the occurrence of sweating in response to psychological stimulation. All assume that mental sweating is a functional response occurring in preparation for fight or flight.

The simplest explanation of mental sweating is that suggested by Edelberg (1972b, 1973), who claims that it may be a special case of thermoregulatory sweating, serving to counteract the increase in temperature caused by fight or flight behaviour. This is particularly important as threatening stimuli also produce vasoconstriction, which

reduces blood loss from wounds, but also impairs heat loss.

Other hypotheses suggest that mental sweating occurs in order to increase corneal hydration. Several workers have noted that hydrated skin is more resilient and less easily damaged than dry skin (Edelberg, 1961a; Wilcott, 1966). Thus, increased sweating might serve a useful protective function in times of threat. There is also evidence that increased sweating can lead to improved friction and better grip from the palms and soles of the feet (Adams & Hunter, 1969; Adelman, Taylor & Heglund, 1975). Palmar and plantar sweating might also have evolved as part of a preparation for running and/or climbing to escape danger.

Electrodermal activity has also been shown to lead to increased tactile acuity (Edelberg, 1961). Thus, electrodermal activity might facilitate fine motor activity as well as coarse activity like running or climbing. However, this effect appears to be secondary to direct neural effects of sympathetic activation on receptor sensitivity, rather than an effect of corneal hydration (see Edelberg, 1972b; Wilcott, 1967).

3 Measures of Sweat Gland Activity

3.1 Electrodermal Activity

3.1.1 Introduction. Fere (1888) is widely credited as the first worker to examine electrodermal activity (EDA). Initially the mechanism underlying the response was unclear. It is now known that changes in skin conductance (SC) are largely (if not entirely) due to the activity of the sweat glands. Removal of sympathetic innervation either by pharmacological blockade (e.g. see studies referred to in section 3.2 above), or by section of peripheral nerves (Richter, 1927;

Richter & Woodruffe, 1941) eliminates electrodermal responding. Electrodermal activity has also been demonstrated to correlate with direct indices of sweat gland activity (Wenger & Gilchrist, 1948; Thomas & Korr, 1957; Martin & Venables, 1966; Juniper, Blanton & Dykman, 1967). Neuman & Blanton (1970) provide a review of the early history of research into electrodermal activity.

A wide range of psychological factors have been found to influence electrodermal activity. The textbook devoted to research using EDA, edited by Prokasy & Raskin (1973), while somewhat dated, gives an illustration of the range of psychological variables thought to relate to EDA. These factors will be reviewed in section 4.

3.1.2 Measurement of electrodermal activity. The publication guidelines for electrodermal activity (Fowles et al., 1981) provide a good introduction to it's measurement. More detailed coverage can be found in Venables & Christie (1980). Earlier chapters include those by Edelberg (1967, 1973), Venables & Christie (1973) and Brings (1974). Skin conductance activity is recorded using two electrodes, placed on the skin. Electrodermal activity can be recorded from either the palm of the hand or the foot, other sites show much less activity (Rickles & Day, 1968). For simplicity, the hand is the preferred site. The medial phalanges of the fingers are the most commonly used sites, due to the ease of attachment of electrodes. If the fingers are used it is recommended to use either the index and middle fingers or the ring and little fingers. This is in order to avoid using fingers which receive different innervation. The two pairs of fingers are in different dermatomes.

Silver/Silver Chloride (Ag/AgCl) electrodes are the standard electrodes for the measurement of electrodermal activity. Electrodes

should be filled with an electrolyte which is of a similar concentration to sweat, in order to avoid changes in electrolyte concentration due to dilution with sweat. Electrode gels containing large ions have been shown to lead to elevated levels of recorded conductance (Edelberg, Greiner & Burch, 1960). Edelberg (1967) recommends the use of 0.05M NaCl. There is less agreement concerning the choice of a base to increase the viscosity of the gel. Fowles and Schneider (1974) showed that an hydrating base, agar-agar, lead to decreasing levels of skin conductance level and responsivity over time. A non-hydrating base did not. While it is not clear which of these effects is the "real" pattern of changes, they suggest that epidermal hydration might lead to closure of sweat gland pores, implying that non-hydrating bases are preferred.

To measure skin conductance, a constant voltage is applied across the electrodes and the resulting current flow is measured. The current being proportional to the conductance of the skin between the electrodes. Suitable circuits are given in Fowles et al. (1981) and Venables & Christie (1980). The use of a constant voltage, rather than a constant current, method is recommended as this allows direct measurement of conductance, rather than resistance. Conductance is preferred since it is directly related to the activity of the sweat glands. See Venables & Christie, 1980, for discussion of the advantages of conductance.

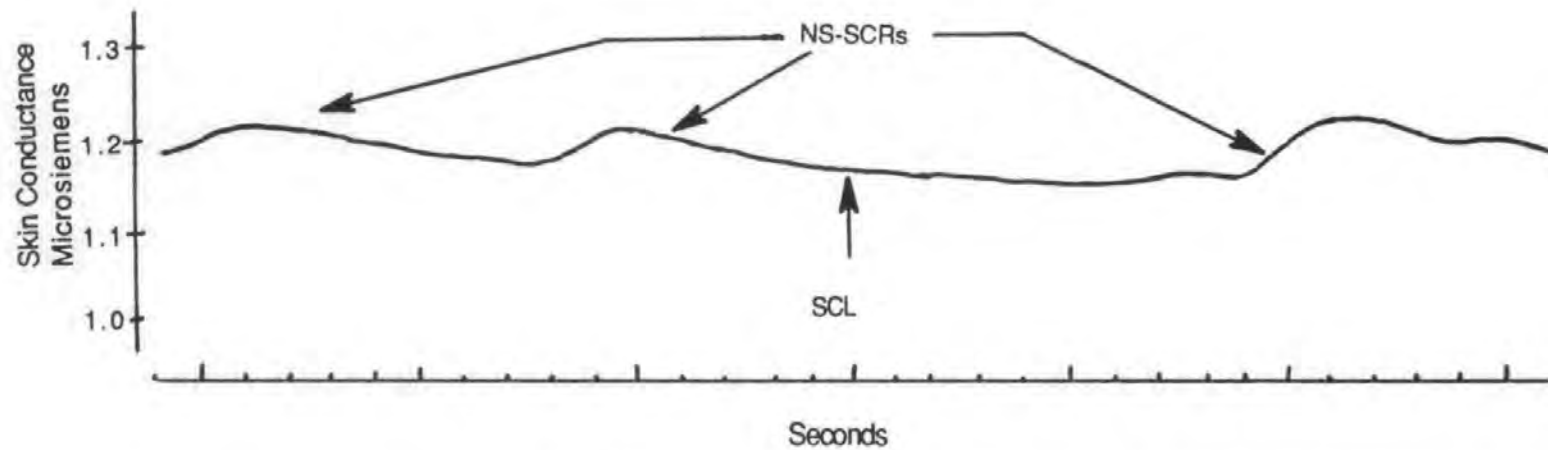
3.1.3 Parameters of electrodermal activity. Despite the apparent simplicity of the phenomenon many different parameters of EDA can be measured. These parameters can be separated into measures of tonic and phasic activity. Tonic activity refers to background activity not time-locked to any event. Such activity is assumed to be relatively

stable over short periods of time, so that measures taken at one point within a given period would be expected to be similar to measures taken at another point. Measures of tonic activity might include measures of baseline activity prior to an experiment or measures of activity sampled throughout a task. Phasic activity is synonymous with the skin conductance response (SCR), which is directly related to a specific event, and shows variation over time.

3.1.4 Tonic measures. there are two common indices of tonic skin conductance activity these are skin conductance level (SCL) and the frequency of non-specific (or "spontaneous") skin conductance responses (NS-SCRs). Skin conductance level refers to the background level of conductance upon which the individual responses are superimposed (see figure 2). NS-SCR frequency is a simple count of the number of responses, which exceed a given minimum amplitude, within a time period. Both measures are widely used.

While early data implied that the two measures were similar (Miller, Cohen & Shavonian, 1959), more recent studies demonstrate that they are not redundant measures (e.g. Katkin 1965, Martin & Rust, 1976). Recent evidence implies that SCL may often reflect prior rather than current status and that previously reported dissociations between SCL and NS-SCR frequency (e.g. Katkin, 1965; Miller & Shavonian, 1965; Kilpatrick, 1972) represent the effects of hydration artifacts (Bundy & Mangan, 1979). Recording EDA for long periods of time may lead to a build-up of sweat under the electrodes, particularly if the level of activity is high. This hydration may cause an elevation of SCL which may not return to baseline when activity declines. This hydration does not appear to influence measures of NS-SCR frequency. For this reason NS-SCR frequency is the preferred measure.

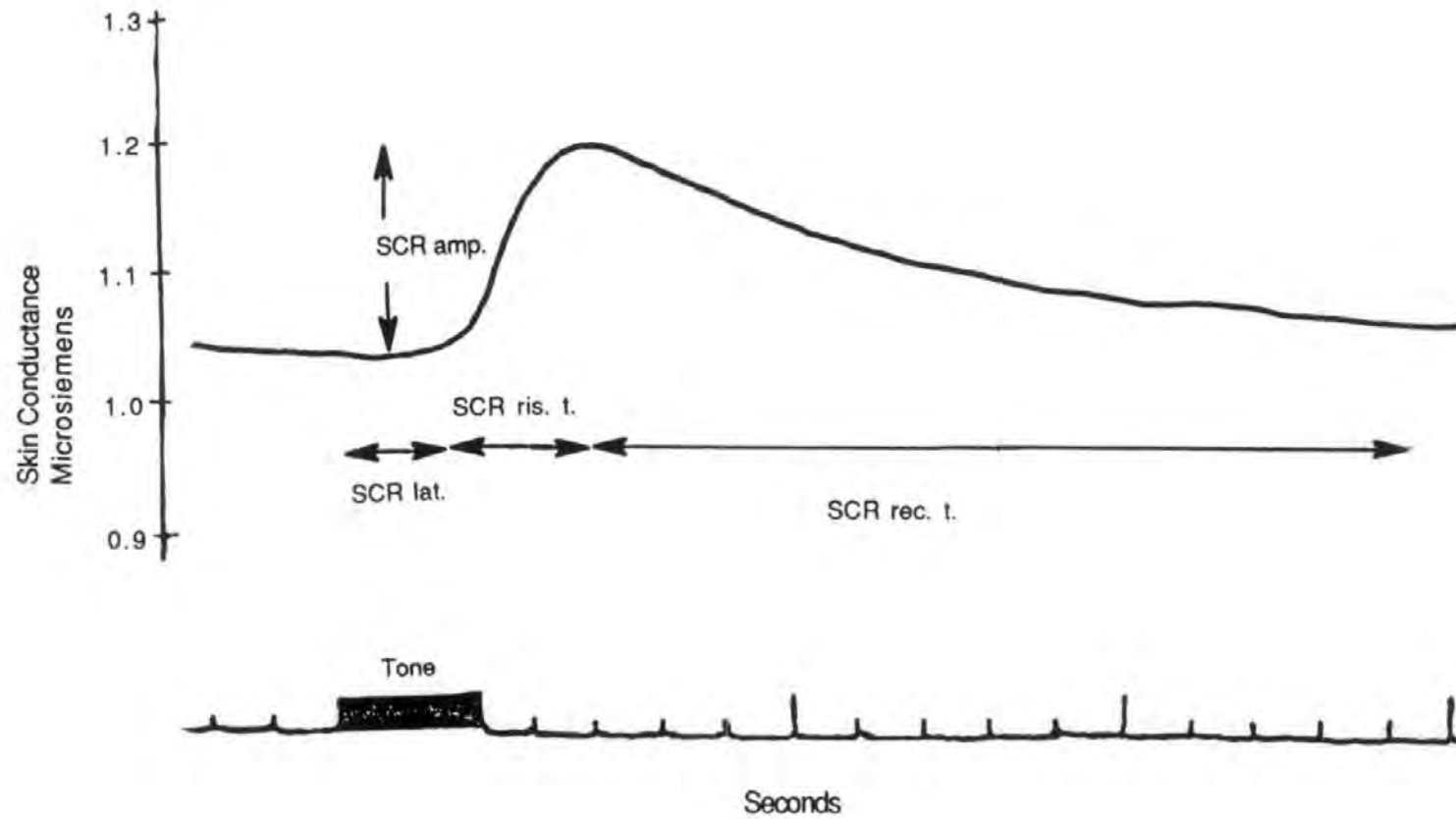
Figure 2: Measures of Tonic Electrodermal Activity



SCL (at point shown)=1.15 microsiemens

NS-SCR frequency= 3 responses/30 seconds or 6 responses/minute

Figure 3: Parameters of the Skin Conductance response



3.1.5 Phasic measures. A wide variety of parameters may be measured from the skin conductance response (SCR), see figure 3. These measures may be subdivided into response-amplitude measures, parameters of habituation and temporal parameters of the response.

The measurement of response amplitude (SCR amp.) is relatively self-explanatory, although such responses may be adjusted in various ways to allow for baseline effects. Such transformations include the use of covariance to statistically remove any effect of prior baseline, the use of range-correction, expressing responses as a fraction of the largest response obtained, and various transformations such as the change in log conductance or the log of the change in conductance. Edelberg (1972b) provides a discussion of the relative merits of such transformations.

Several aspects of the habituation of the skin conductance orienting response (SCR-OR) can be measured (see Siddie, Stephenson & Spinks, 1983). The two most common measures are number of trials to reach a specified habituation criterion and response magnitude (SCR mag.). Three successive non-responses is the most common criterion for habituation, although Levinson & Edelberg (1985) recommend two (see also Vossel & Zimmer, 1988). Response magnitude is defined as the mean response on all trials, including those on which no response was produced. These zero values are excluded from the calculation of response amplitude. The slope of magnitude decrement, obtained either as a difference score between blocks of trials or from a regression analysis, may be used as an index of habituation rate.

Temporal parameters of the response include onset latency (SCR lat.), recovery time (SCR rec. t) and rise time (SCR ris. t). While SCR amplitude and habituation rate remain the focus of much research activity, interest in temporal parameters of the response has waned

following the demonstration that SCR recovery time may be largely a function of prior activity (Bundy & Fitzgerald, 1975; Edelberg & Muller, 1981). More detailed coverage of the debate concerning the independence of different parameters of the SCR will be given in section 3.3.

3.2 Other Measures of Sweat-Gland Activity

In addition to electrodermal techniques other means of assessing the activity of the sweat glands have been developed. Kleinknecht & Bernstein (1979a) produced an excellent unpublished review of measures of sweat gland activity. Several measures exist which involve the direct assessment of the quantity of sweat secreted. These include the measurement of changes in total body weight due to the evaporation of sweat (Darrow & Freeman, 1934), the collection of sweat in previously weighed pads (Weiner, 1945) and the assessment of the vapour content of gas passed over the skin (Edelberg, 1964; Wilcott, 1962). A related technique involves the collection of sweat in a bottle of distilled water, whose conductivity is then recorded (Strahan, Todd & Inglis, 1974).

Other techniques involve the estimation of the density of active sweat glands (as indicated by droplets of sweat) in the area studied. This can be obtained by direct observation (Jurgensen, 1924; Netsky, 1948), by the use of chemical indicators which react with secreted sweat (eg Wada & Takagaki, 1948; Silverman & Powell, 1944a; Mowrer, 1953) or by the use of plastic impressions of the skin, preserving holes corresponding to water droplets (Sutarnan & Thomson, 1953; Harris, Polk & Willis, 1972). The Palmar Sweat Index, a plastic impression technique, is the measure evaluated in this thesis. It should be noted that the colorimetric technique developed by Mowrer

(1953) is also sometimes referred to as the Palmar Sweat Index. While colorimetric techniques have been widely used in psychological investigations (eg Paul, 1966), plastic-impression techniques are more commonly used by physiologists. Harris et al. (1972) report that the PSI, together with a similar silicone rubber-based technique, gave more accurate counts than two colorimetric methods. Research using the Palmar Sweat Index will be reviewed in detail in chapter three.

3.3 Models of Electrodermal Activity

As was stated earlier, EDA is largely determined by the activity of the sweat glands. Early theories concerning muscular (Siddis & Nelson, 1910) or vascular activity (Fere, 1888) have been rejected. However the exact relationship between sweat gland activity and recorded skin conductance may not be straightforward. The history of electrodermal activity demonstrates a steady increase in the complexity of the models used to explain the phenomenon.

The simplest explanation of EDA is that individual sweat glands provide conductive pathways through the non-conductive corneum allowing current to reach the inside of the body which, being "wet", forms a good conductor. Thus, as individual sweat glands become active they act as constant resistors connected in parallel. As resistors in parallel are additive, the total resistance is proportional to the number of sweat glands active at a given time. This implies that sweat-gland counts such as the PSI should correlate highly with SCL. This was demonstrated by Thomas & Korr (1957). However, they found that the slope of the regression line of skin resistance against active glands was (non-significantly) greater when sweating was increasing than when sweating was decreasing. In addition, the actual value of resistance obtained when no glands were visible was greater

than that predicted by their equation including only resistances connected in parallel, corresponding to active glands, and an additional fixed resistance. They interpret these findings to indicate the existence of a non-sudorific component in skin resistance, which they identify with the effects of epidermal hydration. Similar findings are reported by Adams & Vaughan (1965).

In addition to the resistive properties, described above, the skin is also known to have capacitative properties, resulting from the occurrence of polarization across membranes. This capacitance has little effect upon EDA recorded using direct-current methods. Essentially, the capacitative properties of the skin only give rise to effects when the current is switched on or off. Once a relatively steady current is established the effects of capacitance are negligible.

Adams has extended the evidence that corneal hydration contributes to EDA to include consideration of its time-course (Adams, 1966) and its effect on the shape of the skin conductance response (and also the skin potential response, Stombaugh & Adams, 1971). These studies demonstrate, using the cat footpad, that the corneum acts as a kind of reservoir and that, when the corneum is relatively dehydrated, sweat gland activity will not lead to visible production of sweat until the corneum is rehydrated. Corneal hydration also influences SCL and SCR amplitude. Skin conductance level is proportional to corneal hydration. Response amplitude, however, is greatest for intermediate levels of hydration. These findings imply that sweat can diffuse into the corneum directly from the sweat duct and that, when corneal hydration is low, increased sudorific activity may not lead to sweating detectable by techniques such as the PSI, while still producing small increases in SCL. In contrast when the corneum is

fully hydrated increased sweating may lead to little increase in skin conductance but a measurable increase in indices such as the PSI.

Edelberg (1983) has replicated Stombaugh & Adams' (1971) findings concerning the effects of corneal hydration, but also added a parameter corresponding to the degree of duct filling prior to the response. The degree of duct filling is assumed to influence the size of SCR recorded. Greater duct filling leading to larger SCRs. The exact nature of the interaction between duct filling and corneal hydration remains to be determined. The two approaches also seem to differ in the speed with which sweat is assumed to diffuse laterally from the sweat glands to the corneum.

Finally, both skin conductance and skin potential may reflect the activity of membrane processes in either the epidermis (Edelberg, 1972) or in the wall of the sweat duct (Fowles, 1974). Evidence for the existence of a membrane comes from a study by Edelberg, Greiner & Burch (1968) which demonstrated that a variety of treatments known to affect membranes had consistent effects on the size of the skin resistance response. Edelberg (1972a, 1972b) has produced an extensive theory integrating evidence for a membrane response with data on the nature of the SCR recovery limb and the psychological significance of the SCR. The theory proposes that an epidermal mechanism is involved with the active reabsorption of sweat. This mechanism reduces the hydration of the corneum, increasing tactile sensitivity, and also reduces the recovery time of the SCR. Thus goal-orientation is assumed to lead to SCRs with short recovery times. In contrast reduced activity of the membrane mechanism would increase corneal hydration increasing the resilience of the skin. Slow-recovery SCRs are thus assumed to reflect a defensive orientation.

However, several studies have demonstrated that SCR recovery time

is determined by the amount of prior EDA (Fowles & Schneider, 1974, Schneider & Fowles, 1978, 1979; Bundy & Fitzgerald, 1975, Edelberg & Muller, 1981). Although Venables & Fletcher (1981) demonstrate that the effect of prior activity on recovery rate may be relatively weak. Janes (1982) also reports that stimulus significance influenced SCR recovery rate when prior activity, and response amplitude, were held constant, implying that other influences on recovery rate do exist. At present the evidence for a separate, membrane-based, component of the SCR seems unconvincing, although some of the original evidence remains unexplained.

To summarise, it is incontrovertible that the primary source of electrodermal activity is the activity of the sweat glands. It is clear, however, that factors such as corneal hydration may influence the nature of the relationship between EDA and sympathetic activation, as well as providing a possible source of experimental artifacts. There is evidence suggestive of a second component of EDA, which independently influences SCR recovery. However, before this evidence can be accepted, further clarification is needed of the extent to which recovery rate is determined by prior activity and response amplitude.

4 Influences on Electrodermal Activity

Earlier sections have briefly described the physiological substrate of electrodermal activity and have reviewed models relating the phenomena of EDA to the underlying physiological processes. This section will provide an overview of the main environmental and psychological factors that are believed to influence EDA. Psychological influences will be further subdivided into psychological states and individual-difference factors.

4.1 Environmental Influences

The most obvious environmental factor which needs to be considered is temperature. From a psychophysiological viewpoint, temperature has usually been considered as a potential source of artifact. In contrast, thermoregulation is the main function of general sweating. However, thermal sweating seems to occur predominantly on the body and head. Palmar and plantar sweating is probably more related to the need to maintain the pliability and frictional properties of the skin. Kuno (1956, p144) reports that palmar sweating does not occur in response to heat, whereas sweating of the palms is readily provoked by "mental stress". He reports that stress only leads to sweating on the body when temperatures are also moderately high. Kuno also reports that low temperatures will inhibit "mental sweating" of the palms and that there can be a paradoxical inhibitory interaction between high levels of stress and high temperatures; both together appearing to lead to low levels of sweating, whereas either alone would be expected to produce increased sweating.

More recent studies have demonstrated that several aspects of palmar EDA are, in fact, sensitive to changes in temperature. Mulsby & Edelberg (1960) report low but significant correlations (around .2) between temperature and several temporal parameters of EDA. Higher temperatures leading to faster, shorter responses. They also report that, while SCL did not normally correlate with temperature, cooling the skin did increase skin resistance. Wilcott (1967) also reports that both emotional and thermal stimuli produced sweating on all sites tested. However, palmar and non-palmar sites differed with regard to their relative sensitivity to the two classes of stimuli. For

experimental purposes temperatures in the range 20 to 30 degrees are unlikely to influence results.

Humidity might also be expected to influence EDA by determining the rate of evaporation of sweat from the skin surface. Both Venables (1955) and Venables & Christie (1980) report significant correlations between humidity and SCL. Venables & Christie (1980) also report small but significant correlations between humidity and other aspects of EDA, such as SCR half recovery time. Several significant correlations between parameters of EDA and barometric pressure were also reported. The mechanism producing such correlations seems unclear. Venables & Christie's data came from a series of studies conducted in Mauritius, where the climatic conditions were not comparable to those faced by a researcher in England. Nevertheless, it seems clear that variations in meteorological factors may serve to increase the error variance in psychophysiological studies. Where the same subjects are run over two or more days changing weather patterns may also be the source of possible artifacts.

There are also reports of diurnal variations in electrodermal activity. Venables & Christie (1973) review the sparse literature on biological rhythms in EDA. They cite several studies finding a peak in SCL in the mid-afternoon, paralleling the pattern of diurnal variation in core temperature.

4.2 Psychological States and Electrodermal Activity

Electrodermal activity has been studied with regard to a number of psychological processes. These processes can be sub-divided into attention, arousal, stress and anxiety.

4.2.1 Attention and EDA: The orienting response. The skin

conductance response is a major component of the Orienting Response (OR), produced by novel stimuli or stimuli made significant by task demands (Sokolov, 1963). Books edited by Siddle (1983) and Kimmel, Van Olst & Orlebeke (1979) give detailed coverage of research into the OR. Unlike heart rate, however, which decreases during orienting but increases during startle or in response to aversive stimuli, the skin conductance components of the orienting, startle and defensive responses are identical (Graham, 1979; but see Turpin, 1986). This distinction between heart rate and skin conductance responses is very similar to Lacey's (1959) report of directional fractionation. Lacey observed that HR decreased in tasks requiring the intake of information but increased in tasks requiring environmental rejection. Skin conductance increases under both circumstances.

Phasic electrodermal activity, and particularly measures of habituation, may be interpreted in terms of attention (e.g. O'Han, 1979), depending upon the situation producing the response. Tonic EDA is less readily interpreted as reflecting patterns of attention, as, by definition, tonic EDA is not linked to any specific event.

4.2.2 Arousal and electrodermal activity. The last section suggested that electrodermal activity may be sensitive to a number of stimulus properties, including aversiveness, novelty and task significance. It would be parsimonious to subsume these distinct influences within one single theory. One explanation for this pattern of findings is that electrodermal activity provides an index of non-specific arousal. Such an hypothesis has been the basis, implicit or explicit, of a large part of the literature using measures of EDA. This hypothesis may be seen as plausible in view of the sympathetic innervation of the sweat glands. In addition there is experimental

evidence that EDA may be responsive to manipulations of arousal (e.g. see Raskin, 1973)

However, the concept of arousal is subject to many criticisms (e.g. see Neiss, 1988). The generality of the construct of arousal, together with the inverted-U hypothesis (Schlossberg, 1954), which can be used to explain both increases and decreases in performance, limits the experimental utility of the theory. Similarly, the evidence for dissociation between different physiological measures (Lacey, 1959) disproves the unitary concept of arousal, defined in terms of physiological activation.

Despite these criticisms, the concept of arousal retains some utility as an explanatory construct, especially with regard to psychopathology (e.g. see Lader, 1975). However, as Bale & Edwards (1986) point out, the term arousal can be operationalised in many different ways. While a concept which can link so many different experimental paradigms is appealing, it needs to be borne in mind that not all of the definitions of arousal may be interchangeable.

Electrodermal activity continues to be interpreted as a measure of arousal. However the same generality which permits arousal theory to encompass findings from diverse fields of psychology means that the concept of arousal has little to offer as regards the a priori interpretation of electrodermal activity. Explanations in terms of more precisely defined constructs are needed. Edelberg (1972b), in particular, has sought to provide a more sophisticated rationale for the use of EDA in terms of its biological significance in both thermoregulation and the control of epidermal hydration. While Edelberg's proposals concerning the significance of SCR recovery remain unproven (Bundy & Fitzgerald 1975; Venables & Christie, 1980; Edelberg & Muller, 1981) this type of specific analysis clearly

represents a step forward.

4.2.3 Stress and electrodermal activity. A related interpretation of changes in EDA is that such changes may provide an index of stress. Indeed such an interpretation could be subsumed under the heading of arousal, as stress is widely assumed to lead to increases in non-specific physiological activation. Here too the concept of a single stress response must be called into doubt. While Stress, as originally proposed by Selye (1936), consisted of a single, unitary response produced by "diverse noxious agents", this view has been questioned by several workers, most notably Mason (1975). Physiological indices of stress have been demonstrated to show differing patterns of activity (e.g. see Vingerhoets, 1986) and it seems clear that the view of a single unitary stress response is untenable. Current views of stress emphasise the role of the individual's perception of a stressful event and the effectiveness of coping strategies as determinants of the response to the event (e.g. Lazarus & Folkman, 1984). Thus, the physiological response to a stressful event is determined by the characteristics of the event (as perceived by the individual), the homeostatic demands imposed by the event and by the individual's response to the event. The same event may, therefore, lead to different patterns of physiological change in different people or at different times in the same person.

Individual physiological parameters may still be of use as indices of the response to a particular class of events but, for this approach to be valid, it needs to be specified what properties of the event, or what component of the response, the measure is presumed to reflect.

4.2.4 Anxiety and electrodermal activity. Recent approaches to the psychophysiology of both arousal and stress emphasise an interpretation of physiological measures in terms of more specific constructs. Thus, rather than non-specific constructs such as arousal, EDA would be interpreted as an index of a specific emotion. Electrodermal activity has been most commonly used as an index of anxiety. The presumed functional significance of EDA, acting to increase corneal hydration, both as a preparation for flight and to increase the resilience and damage-resistance of the skin makes such an explanation plausible.

Recently, Fowles (1980) has proposed a model of the relationship between physiological responses and components of arousal which proposes that EDA is a specific index of anxiety. The theory is based on the work of Gray (e.g. 1978), which describes two motivational systems. One system, the Behavioural Activation System (BAS), produces appetitive behaviour (including active avoidance); whereas the other system, the Behavioural Inhibition System (BIS), is involved in aversively-motivated behaviour (passive avoidance and frustrative non-reward). The activity of the BIS is claimed to underlie anxiety. Fowles' contribution was to link these two systems to psychophysiological measures. Studies undertaken by Elliot (1974) and Obrist et al. (1974) imply that heart rate is largely determined by bodily activity (i.e cardiac-somatic coupling). Other studies (e.g. Belanger & Feldman, 1962) also imply that incentive leads to graded increases in heart rate. On the basis of this evidence Fowles claims that activation of the BAS leads to increases in HR. BIS activation on the other hand is presumed to lead to increased levels of EDA, specifically spontaneous SCRs. While the evidence linking EDA and BIS activation is less convincing than that linking HR to the BAS, Fowles

(1988) cites several studies demonstrating that EDA does seem to provide an index of anxiety (e.g. Szpiller & Epstein, 1976; Roberts, 1974).

The attraction of this theory is that it makes fairly specific predictions as to the nature of the stimuli which should influence these two physiological systems, and can be easily tested. Surprisingly, then, this theory has not, so far, generated much research. Only Fowles and his co-workers have tested its predictions, with results being generally favourable (Fowles, Fisher & Tranel, 1982; Tranel, Fisher & Fowles, 1982; Fowles, 1983; Tranel, 1983).

More detailed coverage of the literature on electrodermal activity and anxiety will be given in chapter 4.

4.3 Electrodermal Activity and Individual Differences

Many workers have attempted to use EDA as a measure of individual differences. This work will be considered from three viewpoints. The first section will review the evidence for a relationship between EDA and psychometric measures of personality. Section 4.3.2 will then introduce the use of EDA in research into psychopathology. Finally, an alternative approach will be considered, whereby groups are selected using psychophysiological measures. An example of this approach is the study of electrodermal lability.

4.3.1 Electrodermal activity and personality. Psychophysiological measures have been used to investigate the biological underpinnings of a number of personality measures. Unfortunately, as Gale & Edwards (1986) point out, such research has commonly suffered from a number of methodological short-comings and few conclusions can be drawn from the

literature. Gale & Edwards (1986) provide a critical review of research into the psychophysiology of individual differences. O'Gorman (1977) has also provided a thorough review of the relationship between measures of habituation and personality (see also O'Gorman, 1983).

The most commonly-investigated personality dimension has been Eysenck's dimension of Extraversion-Introversion (e.g. Eysenck & Eysenck, 1969). In his initial review O'Gorman (1977) concluded that extraverts showed faster habituation of the SCR than introverts. He also suggested several methodological factors which might obscure this relationship. However, in a more recent paper (O'Gorman, 1983) he lists several articles which have failed to find a relationship under favourable conditions. At present, the existence of a relationship between extraversion and SCR habituation cannot be accepted as proven.

O'Gorman (1977) also reviewed the evidence for a relationship between measures of trait anxiety and habituation. He concludes that habituation of electrodermal responding does not appear to be related to trait anxiety, although habituation in other systems may be. This is in contrast to the evidence from clinical anxiety groups to be reviewed in chapter 4.

In their review of non-electrodermal measures of sweat gland activity, Kleinknecht & Bernstein (1979a) conclude that such measures do not generally correlate significantly with measures of trait anxiety. Measures of specific forms of anxiety, such as dental anxiety, however may correlate significantly with sweat gland counts under some circumstances.

In general, there is little evidence to support an association between electrodermal activity and personality. Conflicting findings are common in studies attempting to link psychophysiological measures to subjective measures of personality. The literature on electrodermal

lability, reviewed below, provides an alternative approach, which may prove more fruitful.

4.3.2 Electrodermal activity and psychopathology. Many workers have used measures of EDA to investigate psychopathology (see Zahn, 1986; Turpin, 1989 for reviews). Some of these approaches have been concerned with differences in the sort of variables described above, such as anxiety, attention or arousal. For example, findings of shorter SCR recovery times in some groups at risk for schizophrenia (Mednick & Schulsinger, 1968; Mednick, 1974; Mednick et al., 1978) have been explained as reflecting chronic "openness to the environment" (Venables, 1974). Similarly, the common finding of higher baseline activity and slower habituation in anxious patients (see Lader, 1975 for a review of early research) is usually interpreted in terms of persistent states of high anxiety.

An alternative approach is to use physiological measures as markers in their own right. While unlikely to be of diagnostic use, such markers may provide an alternative to the use of diagnoses in research. Such an approach seems warranted in the case of depression, where there is extensive evidence that lowered SCL may be a marker for depression (e.g. Iacono et al, 1985; Thorell et al. 1987a, 1987b; Thorell, 1988; Thorell & d'Ellia, 1988). A more detailed review of the evidence for the clinical utility of measures of sweat-gland activity will be presented in chapter four.

4.3.3 Psychological correlates of differences in electrodermal activity. An alternative approach to the search for psychophysiological differences between groups selected using psychometric or diagnostic criteria, is to compare the performance of

groups selected using psychophysiological measures. In clinical research this is known as the biological high-risk approach (e.g. Siever & Coursey, 1985). This approach is complementary to the more common strategy of examining subjects at heightened genetic risk for a disorder, in an attempt to identify vulnerability markers. The biological high-risk approach selects groups of subjects using biological criteria, believed to be associated with vulnerability for the disorder, and then studies their current or future psychological health. High-risk research will be reviewed in more detail in chapter 4.

Similar strategies can be used in theoretical research. One aspect of EDA which has been proposed as a relatively stable individual characteristic is Electrodermal lability. The term was coined by Lacey & Lacey (1958), based on the observation that individuals showed reliable differences in the number of spontaneous SCRs emitted (Mundy-Castle & McKiever, 1953). Individuals showing high resting response rates are deemed "Labiles", while less active individuals are called as "Stabiles". The concept has since been extended to include resistance to extinction of the SCR-DR (Crider & Lunn, 1971), which is generally, although not invariably, found to correlate well with resting response frequency (e.g. Siddle & Heron, 1976).

Labiles and stabiles are consistently found to show performance differences, the most common finding being a reduced vigilance decrement in labiles (e.g. Davies & Parasuraman, 1982, Vossel & Rossman, 1984). Electrodermal lability has also been reported to correlate with a range of psychophysiological parameters, both within and outside the electrodermal system (Bull & Gale, 1973; Schell et al., 1988), although other studies have failed to find such differences

(e.g. Lader & Wing, 1966). Electrodermal lability does not appear to correlate reliably with subjective measures of personality (e.g. Hastrup & Katkin, 1976), but is predictive of performance on a number of different tasks (e.g. D'Gorman & Lloyd, 1988; Wilson & Graham, 1989).

While there are several inconsistencies in the literature, the range of data demonstrating that electrodermal lability is predictive of characteristics in other domains of measurement is impressive. At present, however, the nature of the underlying substrate of this dimension is in need of clarification. By studying several aspects of performance, on tasks which are relatively well understood, greater clarity is possible than when investigations are restricted to psychometric tests, which often lack a clear theoretical basis. Although, the observation of a given difference in performance may still be open to conflicting explanations (cf. Katkin, 1975; Crider, 1979).

5 Summary

This chapter has presented a, necessarily brief, overview of existing measures of electrodermal activity and has attempted to describe some of the areas of research in which such measures have been utilised.

Several distinct parameters of electrodermal activity can be recorded. There are a number of models which attempt to relate the observed phenomena of EDA to the underlying physiological mechanisms. In addition to the activity of the sweat glands, such models acknowledge the presence of other influences on EDA. The effects of factors such as corneal hydration and the hypothesised membrane response might produce a dissociation between electrodermal activity and more direct measures of sweat gland activity under some

circumstances.

The final section of this chapter summarised the, presumed, psychological correlates of electrodermal activity. A number of different psychological factors have been claimed to produce increased EDA, but at present there is no clear definition of the psychological variables which EDA measures. Progress has been hampered by the imprecise definition of many of the psychological constructs studied.

There is little evidence to indicate that electrodermal activity is associated with individual differences in traditional measures of personality, in the normal population. However, the literature on electrodermal lability indicates that individual differences in EDA may still have psychological significance.



Figure 4: The Palmar Sweat Index

Chapter 3

The Palmar Sweat Index

1 Introduction

Developed by Sutarman and Thoenson (1952), this measure provides an index of sweat gland activity which is quick and easy to use, highly portable and may be less intrusive than traditional measures of electrodermal activity. The PSI consists of a count of the number of active sweat glands in an area 4mm x 4mm centred on the central whorl of a fingertip. The print is obtained using a plastic solution, which produces an impression of the fingertip. Because the solution is immiscible in water, the droplets of sweat which occur on top of active sweat glands produce holes in the film (see figure four). The technique also allows inactive sweat glands to be counted, as the graphite, which is included to increase the visual contrast of the prints, tends to pool in the pores of inactive glands, giving rise to dark spots.

This chapter will provide a review of prior research using the PSI, and will concentrate on the reliability and validity of the measure. Both concurrent validity (with regard to other measures of sweat gland activity) and construct validity (as a measure of constructs such as arousal, stress or anxiety) will be examined.

The review will be restricted to studies using the plastic impression technique. Studies using other types of sweat gland count will not be reviewed in depth, except where their findings are of direct relevance to the topic under discussion.

2 The Reliability of the PSI

There are several different measures of reliability. Factors

important for the reliability of the PSI are inter-rater reliability, temporal stability and site of measurement effects.

2.1 Inter-Rater Reliability of the PSI

Several studies report reliability coefficients for the scoring of individual prints (Johnson & Dabbs, 1967; Martens, 1969; Martens & Landers, 1970; Melamed & Siegel, 1975; Melamed et al. 1975; Weisenberg et al., 1976; Kleinknecht & Bernstein, 1978; Landers, Bauer & Feltz, 1978; Koehler, Weber & Voegele, 1990). All agree that inter-rater reliability is very high.

Johnson & Dabbs report inter-rater reliabilities ranging from .87 to .98, however all raters scored the same area and these correlations were between change scores. When one rater scored the same prints several days apart the correlation was .99. Melamed & Siegel found that when two raters scored the same area the correlation between their ratings was .93. By scoring the same area variation across the fingertip is excluded from the reliability estimate. Thus, these two studies probably overestimate the reliability of the PSI.

Other studies make no mention of any attempt to ensure that raters were scoring the same area. This would be assumed to give a more realistic estimate of the reliability of the PSI. Weisenberg et al. report a range of reliabilities for single counts from .93 to .99. Koehler, Weber & Voegele (1990) report a mean inter-rater reliability of .87, and range from .70 to .96, using a 2mm x 2mm scoring area. The use of a smaller area would be expected to reduce the reliability of the technique. The other studies all report single correlations between .95 and .99. Thus, the literature implies that sweat prints can be reliably scored.

2.2 Stability of the PSI

A separate issue concerns the test-retest reliability of the PSI. The traditional form of test-retest reliability, between measures taken at different times, is less important for a measure such as the PSI. As indicated in chapter two, physiological measures are more often used as indices of transient states than as measures of stable individual differences. Very high temporal stability would be as problematic as very poor stability. There is virtually no published data concerning the temporal stability of the PSI, however in an unpublished paper M. Johnston (1972) analysed data provided by Mackinnon & Harrison (1961) producing correlations of .83 and .55 between measures taken thirty minutes apart.

A study by Mackinnon, Gould & Harrison (1962) implies that the reliability of the PSI might be subject to individual variation. They report that a group of subjects showed significant heterogeneity of variance for a series of palmar sweat indices taken at daily intervals over one to four weeks. The group could be divided into two groups. A large (n=14) group of subjects showed "irregular sweating" with large variances, whereas six subjects showed "regular sweating" with variances an order of magnitude less. In order to test this post hoc division, two equal-sized groups of subjects were re-tested over two months later. This re-test revealed a surprising degree of consistency in the variability of the two groups. Mackinnon et al. interpret this finding in terms of relatively stable individual differences in the variability of sweating. However, they also report that the level of sweating differed significantly between the two groups. A simpler explanation might be that this difference in level of sweating was the fundamental difference between the groups and that the differences in variance were due to the upper limit on sweating as

recorded by the PSI (i.e. the total number of glands in the area scored). So that the difference in variance represented a corollary of the law of initial values. Thus the difference in variance might be considered to provide further support for some degree of consistency in the amount of sweat gland activity, rather than evidence for individual differences in the variability of sweating.

While there is little evidence concerning the test-retest reliability of the PSI, Kleinknecht & Bernstein (1979) review data from several studies using alternative sweat gland counts. These studies agree that the stability of these measures is high, most report correlations of around .6 to .7 for measures taken several days apart.

2.3 Comparisons Between Different Sites of Measurement

As well as temporal stability, psychological tests are expected to show internal consistency. For a measure such as the PSI the important criterion is the correlation between simultaneous measures taken from different hands or fingers. This comparison provides the closest analogue of the test-retest reliability of the PSI, although in actuality it can also be considered to be a kind of parallel-form reliability. Data concerning this type of reliability are also, sadly, rare. Only three studies report such correlations and their results conflict. Bailes (1983) failed to find significant correlations between either the number of active glands or the percentage of the visual field occupied by active glands taken from the left and right hands ($r = .15$ for number of glands & $.23$ for percentage area).

In contrast Voegelé, Burchett & Koehler (1988) report significant mean between-subjects and within-subject correlations from a set of 26 measures taken over a series of stressors from different fingers

(within-subject mean $r=.49$, $p<.01$; between-subjects mean $r=.68$, $p<.01$). Koehler, Weber & Voegele (1998) also report correlations between PSIs taken simultaneously from different fingers. Both within- and between-subjects these correlations averaged around .7, indicating that the PSI shows moderate consistency across fingers.

The discrepancy between these findings may be explicable in terms of the methodological differences between these studies. Bailes' data is from a group of children under resting conditions, while the other studies took measures from young adults over the course of a series of stressors and rest-periods. Thus Bailes' measures might have been taken at a time of relatively low activation, which would reduce the correlation between the two measures, whereas the inclusion of measures representing a wide spectrum of activation would elevate the correlations obtained by Voegele et al. and Koehler et al..

Additionally, the fact that the two studies finding significant correlations compared different fingers on the same hand, whereas Bailes compared different hands, may be important. Koehler et al. compared the middle and forefingers, which receive a common neural input. Depending upon which fingers were used (their report does not say) the two fingers used by Voegele et al. may also have been in the same dermatome, and thus subject to the same innervation, whereas the fingers used by Bailes clearly were not. Lateral differences in sweat gland activity may have functional significance, possibly as an index of differential hemispheric activation (e.g. see LaCroix & Cooper, 1979; Gruzelier & Manchanda, 1982), although such claims are controversial (see Hugdahl, 1984; Miossec et al., 1985). Finally the two studies differed in terms of the scoring techniques used. While both Voegele et al. and Koehler et al. scored their prints by eye, Bailes used an image-analysis system to automate scoring.

The results of Koehler et al. demonstrate that the PSI can show moderate reliability. Further research is needed concerning the reliability of the PSI. Evidence from other measures of sweat gland activity (reviewed by Kleinknecht & Bernstein, 1979a) indicates that measures taken from different fingers on the same hand may correlate quite highly, although there may be consistent differences between fingers, with regard to the amount they sweat (Winter, Ferreira & Ransom, 1963).

3 The Effects of Age, Sex and Race on the PSI.

In addition to the direct tests of reliability reviewed above, a handful of other studies have investigated the importance of factors such as age, sex and race which might be expected to influence physiological measures and act as possible confounds in research using such measures.

3.1 Subject Age and the PSI

Mackinnon (1954a) reports decreasing numbers of active sweat glands with age. A negative relationship between sweat gland activity and age has also been reported for electrodermal (e.g. Shmavonian, Miller & Cohen, 1968) and non-electrodermal measures (e.g. Ferreira & Winter, 1965).

Not all studies agree, however, Mellon & Lind (1956) did not observe differences in palmar sweating between younger and older men. When the PSI technique was applied to record sweating on the back older subjects did show a slower onset of thermal sweating. While Catania et al., 1980 also report decreased SCL and sweat gland counts with age, their results also imply that the interrelationships between SCL, SCR amplitude and sweat gland counts may vary with age. They

found SCL to correlate more highly with sweat gland counts in younger subjects, whereas the relationship between SCR amplitude and their colorimetric measure of sweating was stronger in older subjects. they interpret this result as an effect of the lower hydration of the cornea in older subjects.

Bailes (1983) reports a series of consistent age effects on the PSI. Children were found to show a greater number of active glands than their parents. Children aged 12 to 15 tended to show greater numbers of active glands than those aged 16 to 18. Levels of skin conductance paralleled the differences in the PSI. This effect was not present when the percentage of the visual field occupied by active glands was the dependent variable. However, the results reported by Bailes probably do not reflect the same factors as Mackinnon's findings. The inclusion of young children means that actual finger size would vary with the age of his subjects. As the number of sweat glands remains constant throughout life, the number falling within the area to be scored would be greater for younger, and therefore smaller, subjects than for older subjects. This would inflate the number of active glands counted. The absence of an age effect for Bailes' percentage measure may signify that this measure controls for finger size, although this would only be expected if glands which were closer together were also smaller. Mackinnon controlled statistically for the surface area of her subjects.

One study (Ferreira & Winter, 1965) reports data from very young children. In contrast to older subjects, who showed the usual decrease in sweating with age, children showed a rapid increase in sweating from birth to seven. It is possible that the colorimetric technique they used may have been insensitive to the small sweat droplets produced by the tiny sweat glands of very young subjects.

Alternatively there may be developmental changes in the responsivity of the sweat glands over the first few years of life.

The literature is relatively consistent in demonstrating that sweat gland activity decreases with age in adults and older children. The cause of the decline is unclear. Catania et al. (1980) implicate reduced hydration of the corneum in their finding of reduced SCL in older subjects. This mechanism would not however explain a reduction in the PSI. Other explanations are differences in arousal between younger and older subjects and physiological changes associated with aging, although it is open to doubt whether such effects would explain the occurrence of decreasing activity with age in children. The effects of growth on sweat gland density might partly account for the age-related decrease in sweating in children.

3.2 Sex Differences in Palmar Sweating

Finger size is also relevant to the examination of sex differences in sweat gland activity. Weisenberg et al. (1976) took the PSI in a dental waiting room and once again when subjects were seated in the dentists chair. They obtained total numbers of sweat glands, as well as the number of glands active and the ratio of active over total glands. Females scored more highly on all three measures. They interpret this as being due to finger size, females tending to have smaller fingers than males. For the number of active glands and the ratio of active over total glands, however, there was a sex by treatment interaction. Females tended to sweat more in the dentists chair than in the waiting room, whereas males showed similar levels of activity in both situations. This interaction is interpreted as reflecting differences in coping strategies. Examination of the ratio measure indicated that both sexes started from the same level of

activation. Thus it seems that a simple measure of the number of glands active in a given area may be biased in the event of group differences in finger size. However, Weisenberg et al. report that their number of active glands correlated highly with the ratio measure ($r=.91$ pre-treatment and $.92$ post-treatment), implying that under most circumstances the two scores may give very similar results.

One study using a colorimetric sweat gland count also found higher levels of activity in females (Ferreira & Winter, 1965). While reports of sex differences in EDA also exist (e.g. Kimmel & Kimmel, 1965; Kopacz & Smith, 1971; Eisdorfer, Doerr & Follet, 1980), results are inconsistent. Several studies, however, seem to imply that females show faster habituation than males (see O'Gorman, 1983 for a review). The existence of differences in social experience and possible experimenter effects (e.g. Fisher & Kotses, 1974) make the interpretation of observed sex differences in physiological responsivity difficult. In contrast to the absence of consistent differences in EDA, measures of sweat secretion more commonly report greater secretion in males (see Morimoto, 1978).

The number of glands active appears to be subject to variation over the menstrual cycle. This is probably a result of fluctuations in hormone levels. A series of studies by Mackinnon and co-workers (Mackinnon, 1954b; Mackinnon & Mackinnon, 1955; Mackinnon & Harrison, 1961) has demonstrated that palmar sweating is lower during the luteal phase of the menstrual cycle and during the first and third trimesters of pregnancy. Similar effects have also been found to occur for SCL (Little et al., 1974). Furthermore, intramuscular injections of progesterone lead to suppression of sweating. Fluctuations in the level of progesterone alone cannot provide a sufficient explanation for the other findings, since the patterns of change in sweat gland

activity do not parallel the known course of changes in plasma progesterone during pregnancy and the menstrual cycle.

There is little clear evidence for stable differences in sweat gland activity between the sexes, when differences in finger size are controlled for. However, it is clear that the PSI varies over the course of the menstrual cycle in female subjects. There is also evidence that male and female subjects may respond differently to some experimental manipulations. For these reasons care needs to be taken when attempting to generalise from studies using subjects of the same sex. In addition it needs to be emphasised that it is necessary to consider the social aspects of an experiment when planning research and when interpreting the results obtained (Gale & Baker, 1981).

3.3 Ethnic Differences in Sweating

The study by Weisenberg et al. (1976), mentioned above, also included subjects of different races. They found no difference between black American, white American and Puerto Rican subjects on any of the measures they examined. Johnson & Landon (1965) also failed to find significant differences in active sweat glands between black and white subjects, although their black subjects did show lower skin conductance levels. A similar difference in EDA is reported in a study using resistance measures by Johnson & Corah (1963). Other studies have found sweating, measured by both electrodermal and colorimetric techniques, to be lower in black or dark-skinned subjects than in white subjects (Juniper & Dykman, 1967; Malao, 1965; Bailes, 1983).

Thus, two studies using the PSI have failed to find racial differences in sweat gland activity, although SCL is consistently found to be lower in black subjects than in white subjects and colorimetric sweat print techniques have also indicated lower sweat

gland activity in black subjects. In view of the small number of studies examining ethnic differences in the PSI the negative results must be accepted with some caution. Observed racial differences in responsivity (e.g. Tursky & Sternbach, 1967) may be complicated by similar social and cultural factors to those discussed with regard to sex differences.

3.4 Summary

To summarise, there is evidence that sweat gland activity does decrease with age. The literature also indicates that there may be ethnic differences in sweating, although such results have not been reported using the PSI. There is little evidence for physiological differences in sweat gland activity between the sexes, although males and females have been found to respond differently to experimental manipulations, most probably as a result of differences in psychological factors such as coping. The possibility of experimenter effects and differences in coping strategies poses problems for research into age, sex and race effects. Groups differing on these factors may also differ in other ways, altering their perception of the experiment, their interaction with the experimenter and their response to the manipulation.

4 Relationship Between the PSI and Electrodermal Activity

If the PSI is to provide a valid alternative to measures of electrodermal activity it is necessary to demonstrate that the two measures are in fact correlated, and that this correlation is unaffected by situational or between-subjects factors. By far the majority of studies have only examined the correlation between the PSI and SCL, other parameters of EDA have received less attention.

The study by Johnson & Landon (1965) referred to above, which examined racial differences in SCL and the PSI, examined the correlations between the two measures. The correlation between measures taken at approximately the same time was .648 for black subjects and .344 for white. Other correlations between measures taken under less comparable conditions were, if anything, slightly higher. The tendency for black subjects to show greater concordance between the measures was only significant for one of the four correlations they report, although the trend was clearly present in all of them.

A study by Venables & Martin (1967) examined the effects of locally-applied l-hysocamine (atropine), a cholinergic antagonist, and neostigmine, a cholinergic agonist, on the PSI and on skin potential and conductance. They report that the PSI and SCL were significantly correlated ($r=.4$). Skin potential did not correlate significantly with either of the other measures. In addition, SCL and the PSI responded similarly, both to the administration of the two drugs and to the control conditions used (iontophoresis of the inert d- isomer of hysocamine and passage of a comparable current using only distilled water).

Bailes (1983) also reports correlations between both the number of active glands and percentage area occupied by active glands and several parameters of EDA. Of no less than 120 reported correlations, only 16 are significant with the highest correlation being .3. While a greater number of significant correlations than would be expected by chance, this hardly represents overwhelming evidence for the similarity of the two measures. However, Bailes' measurements of EDA and the PSI took place in different places and on different days so that a wide variety of factors could have served to reduce the correlation between the two measures. It is open to doubt whether

measures of EDA taken at these distinct times would have correlated significantly.

Studies by Johnston & Johnston (1974) and Voegele & Steptoe (1986), which are described in more detail in the next section, examined the response of both the PSI and SCL to different types of stress. Voegele & Steptoe (1986) report a correlation of .66 between the PSI and SCL, taken after surgery, although this value fell just short of significance ($p < .1$). Johnston & Johnston (1974) report within-subject correlations between the two measures, taken while subjects were performing mental arithmetic and carrying out physical exercise. Out of 12 correlations only 3 failed to reach significance and only one was negative (-.06). Both studies demonstrated that the two measures of sweating responded similarly to the stressors used.

A recent study by Voegele, Burchett & Koehler (1988) also reports correlations between the PSI, SCL and SCR frequency. The mean within-subject correlations between the PSI and SCL and between the PSI and SCR frequency were .46 and .51 respectively. None of the individual correlations reported were negative.

Koehler, Webber and Voegele (1990), report within- and between-subject correlations between the PSI and both SCL and SCR frequency. Within-subject correlations with SCR frequency were always positive, but fairly small (mean = .45 with the PSI from the forefinger, .37 with the PSI from the middle finger). Because of problems with missing data, few within-subject correlations were calculable between SCL and the PSI. When between-subject correlations were examined, all of the correlations between middle finger PSIs and SCR frequency were significant, of six correlations involving the PSI taken from the forefinger, three were significant (mean values .64 with middle finger PSI, .42 with forefinger). As these workers recorded EDA from the

hypothenar eminence, they suggest that the greater proximity of their electrodes to the middle finger might account for the difference. Between-subject correlations with SCL were lower, only two out of ten being significant, both were for baseline measures. Between-subject correlations between SCR frequency and SCL were equally low.

In addition to the correlation coefficients reported, all of the studies described above report that the PSI responded to experimental manipulations in the same way as did electrodermal measures. One final study which included both measures did not find such consistency. Turpin, Takata & Tutton (1986, experiment 1) examined the response to two periods of mental arithmetic. Neither the PSI nor skin conductance level or response frequency were sensitive to the level of task difficulty or to an evaluative-threat manipulation. However, both skin conductance measures showed the predicted increase during the two task periods relative to baseline measures taken before the tasks. In contrast the PSI showed reduced sweating as a result of the task, levels obtained after the task being below those recorded prior to the relevant task period, and also below the baseline for the other task period. This finding does seem to cast doubt on the concurrent validity of the PSI. If the PSI provides a valid alternative to EDA then the two measures should respond similarly to environmental stressors. One observation which may explain the apparent discrepancy in the results of this study is that the two measures were not taken at the same time. While electrodermal activity was recorded continuously throughout the task, the PSI was only administered after the task.

To summarise, all these studies indicate that, for measures taken at the same time, the PSI correlates significantly with SCL. While Koehler, Webber and Voegelé (1990) report low between-subject

correlations between the PSI and SCL, these correlations were comparable to those obtained between two different parameters of EDA. In absolute terms, however, the correlations reported are of only moderate size. More promising, however, is the consistency in response between the two measures. In virtually all the studies so far reported the two measures responded similarly to the manipulations used. The data reported by Turpin, Takata and Tutton (1986) are alarming because they imply that this consistency may not be inevitable. If it is possible to produce a dissociation between the two measures then the PSI can not be considered to be an alternative to EDA. It needs to be established whether the decision to obtain the PSI after the task in this study might account for the difference from the electrodermal measures taken during the task.

The distinction between measures taken during a "stressor" and those taken afterwards will be discussed in more detail in the next section. This section will examine the psychological correlates of the PSI.

5 Psychological Effects on the PSI

5.1 Introduction

This section will examine the construct validity of the PSI. Prior research using the PSI will be reviewed, in order to assess the relationship between changes in the PSI and psychological factors such as anxiety. Many of the studies described are also relevant to the concurrent validity of the measure. If the PSI is a valid substitute for electrodermal activity, then the two measures should respond similarly to psychological manipulations. Studies such as that reported by Turpin, Takata & Tutton (1986), described above, which appears to demonstrate a dissociation between the PSI and

electrodermal activity, cast doubt upon the concurrent validity of the PSI. The fact that the measures in that study were taken at different times may account for the differences obtained. However, other studies also appear to show a decrease in the PSI following a stressful task. Electrodermal activity, in contrast, is usually assumed to increase in response to stress.

While not including concurrent measurement of EDA, an early series of studies by Mackinnon & Harrison also appear to show such an "anhidrotic response" to stress from the PSI under conditions where EDA might be expected to increase. These studies represent the largest, single body of research using the PSI and have led several other workers to use the measure. The studies which examine Mackinnon and Harrison's anhidrotic response will be reviewed in the first section assessing the construct validity of the PSI.

5.2 The "Anhidrotic Response to Stress"

5.2.1 The anhidrotic response to surgery In 1962 Harrison, Mackinnon & Monk-Jones demonstrated that surgery produced a long-lasting depression of sweating. They obtained daily sweat gland counts from 20 male and 20 female patients undergoing a wide variety of operations. Their results revealed that sweating began to decrease from the first print, taken two days before surgery. This decrease continued until the print taken the morning after surgery. Sweating then gradually returned to the initial level. This recovery was fairly rapid in female patients, taking about four days. In males, however, sweating did not reach levels comparable to those on admission until thirteen days after operation. Ten patients admitted for non-surgical procedures showed no such decline.

As Mackinnon (Mackinnon, 1954b; Mackinnon & Mackinnon, 1955) had

already demonstrated similar long-term decreases in sweating in the luteal phase of the menstrual cycle and during pregnancy, a hormonal mechanism was suggested. Mackinnon & Harrison (1961) examined the effects of pituitary-adrenal cortical hormones, known to be responsive to stress, and hormones involved in the sexual cycle on palmar sweating. Adrenocorticotrophin (ACTH) was found to produce a suppression of the PSI some five and a half hours after injection, this depression lasting for the remaining two and a half hours of the experiment. Progesterone also produced a long-lasting depression of the PSI. This depression was apparent three hours after injection and continued until the end of the experiment. Neither Chorionic Gonadotrophin nor several cortico-steroids (including oestradiol and androsterone) produced any significant effect on the PSI. In view of the difference in speed of onset, they conclude that the most likely explanation is that it was progesterone which was responsible for the reduction in sweating and that injections of ACTH are effective because they stimulate the adrenal cortex to release progesterone.

In a later study Harrison & Mackinnon (1963) extended their examination of the hormonal basis of the palmar anhidrotic response to adrenal medullary hormones. They demonstrated that subcutaneous injections of adrenaline would produce a depression of the PSI which was apparent within ten minutes of the injection and continued for at least fifty-five minutes. Phenoxybenzamine, an adrenergic blocking agent, prevented this effect. Their results also show that the depression of sweating is due to the central effects of adrenaline, rather than to a direct effect on the sweat glands, as the effect occurred for sweat glands on both hands even when the blood flow to one arm was occluded prior to injection. The effect was also apparent following injections of noradrenaline. In an attempt to rule out a

possible mediating effect of the vasoconstriction produced by the catecholamines a vasodilator, phentolamine, was administered prior to injection. While the vasodilation produced by Phentolamine was visible only in the unoccluded arm, the anhidrotic response was apparent, and of similar intensity, for both arms. This well designed study demonstrated that, in contrast to the peripheral facilitatory effects of adrenaline, which may be accompanied by a localised, secondary inhibition (e.g. Sonnenschein et al., 1951; Collins, Sargent & Weiner, 1959), catecholamines may suppress sweating via their effects on the CNS.

5.2.2 The anhidrotic response to other stressors Harrison (1964) demonstrated that other stressors, in addition to the unique stress of surgery, might produce an apparent depression of palmar sweating. Subjects performing straight-leg raising, holding one leg outstretched for as long as possible, showed a depression of sweating immediately after the test in comparison to levels obtained before the task. Levels of sweating returned to baseline by ten minutes after the task. Threat of injection also seemed to produce a reduction in sweating, sweating gradually returning to baseline when the threat was removed. A "photic stimulation stress test", retinal stimulation by a stroboscope, did not lead to a reduction in sweating. Harrison also examined the hormonal response to the straight-leg raising test and reports that the task did lead to elevations in both plasma cortisol and catecholamines.

In a companion paper, Mackinnon (1964) examined the hormonal basis of the response to straight-leg raising and produced evidence implying that both adrenal-cortical and adrenal-medullary mechanisms may be involved. She reports that 13 subjects who had had their

pituitaries removed produced only a slight depression of the PSI following the stressor. This depression did not reach an acceptable level of significance. Similarly, blocking of adrenergic receptors by Phenoxybenzamine also prevented an anhidrotic response. This appears to demonstrate that the response to straight-leg raising is mediated by the hormonal response to the task. What is not clear is the relationship between pituitary-adrenocortical and sympathetic-adrenomedullary axes, whether both systems independently act to reduce sweating or whether the systems are dependent on one another. Mackinnon suggests that the release of adrenaline may in turn act to stimulate the pituitary-adrenocortical axis.

The relationship between pituitary and adrenal responses to straight-leg raising and the resulting depression of sweating formed the basis of the next paper in the series (Harrison & Mackinnon, 1966). The first set of results consists of a replication of the demonstration that straight-leg raising leads both to a depression of the PSI and to elevated levels of plasma cortisol and catecholamines. As in the previous study injection of phenoxybenzamine was found to inhibit the anhidrotic response. The second set of results presented examined the effect of straight-leg raising and the injection of adrenaline in patients who had undergone hypophysectomy (removal of the pituitary). Only five out of ten of these patients showed a drop in sweating following straight-leg raising (as opposed to nine out of ten controls). However all of these patients responded to injections of adrenaline with a depression of sweat gland activity. This implies that adrenaline has a direct effect on sweating and does not suppress palmar sweating via an effect on the pituitary. They conclude that catecholamine release is primarily responsible for the anhidrotic response to stress although an additional contribution from the

pituitary-adrenocortical axis cannot be ruled out.

The final study in which Mackinnon (1969) examined the anhidrotic response compared the responses to both straight-leg raising and adrenaline injection in normal subjects and in schizophrenic patients, as well as two psychiatric control groups. The normal groups showed the predicted depression of sweating following both treatments. The two schizophrenic groups ("acute" with illness duration under two years and "chronic" with illness duration greater than two years) showed no anhidrotic response to either treatment, and the chronic group showed increased sweating five minutes after the injection of adrenaline, followed by a small decrease. The two psychiatric control groups (one group of depressed patients and a group of "miscellaneous", mostly anxious, patients) also failed to show a significant anhidrotic response to the stressful task, although the data does appear to show a small decrease in both groups. They did not receive the injections of adrenaline. Mackinnon suggests that these findings may represent abnormal functioning of inhibitory reticular mechanisms in schizophrenia. A review of the evidence for abnormalities in electrodermal activity in schizophrenia will be provided in the next chapter. At present it can be said that this hypothesis remains unproven. The absence of a significant depression of sweating in the two clinical control groups, together with the differences in diet, lifestyle and medication between the hospitalised clinical groups and Mackinnon's normal group make the interpretation of these results difficult.

5.2.3 Summary The above series of studies presents a clear picture of a hormonally-mediated decrease in sweating produced in response to several different stressors. This finding conflicts with

the extensive evidence demonstrating that EDA increases in response to a wide variety of stressful situations (e.g. Mathews & Lader, 1971) including the threat of injection (Juniper, Blanton & Dykman, 1967), as employed by Harrison (1964). Other studies using the PSI, to be described in the later sections, have also shown an apparent increase under stressful situations. Indeed, while Harrison, Mackinnon & Monk-Jones (1962) demonstrated a decrease in sweating following surgery, which they interpret as representing the effects of stress, several studies by Melamed and co-workers (see Melamed, 1977), investigating the effect of preparation for surgery in children, interpret increased sweating as revealing increased anxiety. Although these studies did not take measures within the period immediately after surgery, where Harrison et al. found the anhidrotic response.

Two points need to be stressed at this point. Firstly surgery is a complex stressor, including physical trauma, medication, psychological distress and disruption of the usual pattern of physical activity. Any of these factors might influence physiological measures in various ways. As Mackinnon & Harrison did not include alternative measures of stress the contributions of these components can not be separated. Secondly electrodermal measures were not taken in any of the studies, so that the response of electrodermal activity to surgery or straight-leg raising is unknown.

5.3 Later Studies Examining the Anhidrotic Response

5.3.1 Surgical studies Four studies have since attempted to replicate the original finding of a decrease in sweating after surgery. Three were successful, and their results demonstrate that the decrease is modified by psychological factors consistent with an

interpretation in terms of a stress response.

Lindeman & Stetzer (1973) examined the importance of pre-operative preparation for surgical patients. They compared patients who had received a pre-operative visit from the operating room nurses with those who had not. In addition to measures of post-operative complications, length of hospitalization and need for analgesics, they also administered the PSI one hour before and twenty-four hours after surgery. While their other measures of distress largely failed to respond to the manipulation, PSIs were lower after surgery than before. Furthermore, for those patients receiving minor surgery, the PSI taken after surgery was higher for patients who had received a visit than for patients who had not. The type of surgery also influenced the level of sweating after surgery. Levels of sweating being inversely proportional to the severity of surgery. There was also a decrease in sweating with age. Sweating before the operation did not respond significantly to the manipulation. These findings are consistent with a drop in sweating after surgery. Furthermore, this depression of sweating seems to be sensitive to the degree of stress involved, being less for minor surgery, and, when the degree of physical stress is slight, responding to a psychological manipulation which would be expected to reduce stress and anxiety.

It seems that the PSI does respond to the stress of surgery with a reduction in activity. This is contrary to the usual finding that skin conductance increases in response to stress. However, none of the studies described above have included skin conductance measures. It is possible that skin conductance may also decrease after surgery. Rather than a general stress response, Mackinnon & Harrison's anhidrotic response may represent the effects of fatigue or some other

more specific process associated with the unique conditions of surgery. Voegele & Steptoe (1986) obtained several physiological measures, including both the PSI and measures of skin conductance after surgery. Their results showed that, while the PSI fell after surgery, SCL was also reduced post-surgery. Heart rate also rose over the same period. Several questionnaire measures correlated with the reduction in sweating after surgery. Post-operative pain, and several scales of mood disturbance (the Profile of Mood States; McNair, Lorr & Droppleman, 1981) correlated negatively with both SCL and the PSI. In addition, pre-operative preoccupation with the approaching operation and scores on the chance scale of the Locus of Control (Levenson, 1981) correlated with the drop in SCL after the operation. This study confirms that the PSI is depressed by surgery, but also demonstrates that the anhidrotic response can be obtained using skin conductance measures. The anhidrotic response to stress is therefore clearly not an artifact of the Palmar Sweat Index. The pattern of correlations between the autonomic response and various self-report measures also makes an interpretation in terms of some kind of stress response plausible.

In the first of a pair of studies examining the effects of surgery on the PSI Dabbs, Johnson & Leventhal (1968) examined the change in palmar sweating from the day before surgery to five or six days after surgery. The two PSIs did not differ significantly. This result however cannot be accepted as a failure to replicate the findings of Harrison, Mackinnon & Monk-Jones (1962). The second measure was not obtained until at least five days after surgery, which is sufficient time for the levels of sweating to have recovered. The female patients in the original study by Harrison, Mackinnon & Monk-Jones (1962) showed normal levels of sweating by four days after the operation and

twenty-eight of the forty subjects in the Dabbs et al. study were female. Thus this study may have failed to find a depression of sweating because their post-operative measure was too late and missed the peak of the response. Dabbs et al. report that the change in sweating between the two times of measurement did not correlate with self-reported fear, depression, anger, happiness or lethargy but was correlated with the change in self-reported arousal.

In a second study Johnson, Dabbs & Leventhal (1970) replicated the depression of the PSI on the first 4 days after surgery in a sample of 62 female patients. They examined the correlations between the PSI and scores on a mood adjective checklist, the Taylor (1953) Manifest Anxiety Scale and the Internal-External locus of control scale (Rotter, 1966). Only PSI measures taken on the two days immediately after the operation produced significant correlations and the pattern of correlations on the two days were quite different. High levels of sweating on the first day correlated significantly with higher preoperative worry, depression, fear and total mood disturbance and with higher current fear. High levels of sweating on the first post-operative day also correlated with the manifest anxiety scale and with an external locus of control. These correlations are consistent with an explanation of higher sweating as being indicative of greater distress. Implying that the depression of sweating, which was the predominant response of the PSI, was not related to distress. However correlations with the PSI taken on the second day after surgery are different. High levels of sweating on the second post-operative day correlated significantly with higher current happiness and arousal, with less reported pain and with a shorter stay in hospital, as well as with an internal locus of control. These findings seem to imply that higher sweating is associated with less distress and thus are

consistent with an explanation of the anhidrotic response as an index of stress. Johnson et al. also calculated mean within-subject correlations between the PSI and their mood adjective checklist data. As in the earlier study the PSI appeared to be most strongly related to self-reported arousal.

In both studies, Dabbs et al. suggest that a depression in the PSI may reflect rejection of the environment and internally-directed attention, while increased sweating reflects active interaction with the environment. However this is a post hoc explanation and the division of situations into those involving environmental rejection or intake seems somewhat arbitrary. The pattern of correlations in the second study are particularly difficult to explain. Johnson et al. claim that the pattern of correlations may represent the differing responses of patients with internal and external loci of control. This explanation however is not particularly compelling.

5.3.2 The PSI and exercise Given that the study by Voegele & Steptoe (1986) provides support for the similarity of the PSI and SCL, other evidence for the anhidrotic response warrants closer inspection. In an unpublished study, Johnston & Johnston (1974) recorded skin conductance and took the PSI from subjects performing the straight-leg raising task, as well as doing mental arithmetic. Their results show that both indices of sweat gland activity increased during the two tasks. They failed to find any evidence that sweating was depressed after straight-leg raising. Furthermore, this study included an assessment of subject's reports of experienced stress. These showed that subjects felt most stress during the task, rather than immediately afterwards, implying that Harrison & Mackinnon's measures were not taken at the time of greatest stress. This study clearly

implies that the time at which the PSI is taken may have strong implications for the results obtained. In particular, the evidence reported by Turpin, Takata & Tutton (1986, experiment one) that mental arithmetic increased skin conductance but led to decreases in the PSI may be explained by the timing of the measures. While skin conductance was recorded continuously during the task, the PSI was obtained after each block. If the response to the task shows rapid recovery the PSI may have declined to resting levels by the time the "task" measures were taken.

The second experiment Turpin, Takata & Tutton (1986) report may also be relevant to the research on the straight-leg raising task. They examined the response of the PSI to three levels of exercise. Their results show that exercise was relatively ineffective at raising levels of palmar sweating. Only the group performing the most intense exercise showed an increased PSI during the task. Furthermore this group showed a transient drop in sweating after the task. In contrast the Low and Medium exercise groups showed a gradual decline in sweating throughout the experiment. Thus, this study too might have led to different conclusions had measures been taken only after the task. It seems to demonstrate that physical exercise does lead to increased palmar sweating, although only at high levels of exertion. However, this may be followed by a "rebound effect" with a depression of sweating for a short while after the exercise.

5.3.3 Other studies examining the effects of "stress" on the PSI

Several other studies are relevant to the discussion of the anhidrotic response to stress. Two widely cited papers by Johnson and Dabbs (Johnson & Dabbs, 1967; Dabbs, Johnson & Leventhal, 1968) demonstrate

the utility of the PSI, as well as providing details of the technique. Furthermore these papers provide an alternative explanation of the apparent decreases in sweating obtained in some studies. The first paper (Johnson & Dabbs, 1967) provides data from twelve female subjects on three different occasions. The first measures were taken before and after an examination. The PSI was administered again three weeks later before a statistics class. A final set of measures were obtained after a further month, before, during and after subjects worked on multiplication problems. Their results are difficult to interpret. The first three measures (before and after an exam and before a statistics class) were significantly higher than the measures taken while subjects worked on arithmetic problems. However the measures taken at the time of the exam were not significantly higher than the measures taken before a regular class, although such a trend is apparent in the raw data. The data from the multiplication problems revealed an M shaped curve, sweating peaking at the beginning and end of the problems but returning to baseline while the problems were being solved. This implies that, at the very least, increased sweating is not an inevitable consequence of performing this sort of task. Furthermore this pattern of activity is consistent with an actual decrease in sweating as a result of the task.

To explain these results Johnson & Dabbs (1967) suggest that the changes in the PSI may reflect changes in concentration. They suggest that internally-directed attention, while carrying out mental arithmetic or coping with a stressor such as straight-leg raising, may lead to a depression of the PSI. This categorisation of situations is, however, post hoc and the division of tasks into those requiring internally-directed attention and those demanding active interaction

with the environment is not readily operationalised. However, several other studies have used this theory to explain, otherwise puzzling, results.

The second paper (Dabbs, Johnson & Leventhal, 1968) reports data from three studies. In the first prints were obtained from nine subjects in an aircraft before, during and after flight and on the ground after flying. The results revealed increased sweating during the flight, with a large decrease below baseline on leaving the aircraft. The increase in sweating during flight correlated with increased subjective happiness and arousal and with decreased anger and depression while flying. Dabbs et al. do not comment on the drop in sweating after the flight, although this pattern seems similar to the response to straight leg raising, where increased sweating during a situation is associated with a marked suppression after the situation. Dabbs et al. also provide brief results from a study examining the response to surgery. This study has already been discussed in detail in section 5.3.1 above. They failed to find a significant anhidrotic response following surgery. Of six mood scales only the change in reported arousal correlated significantly with post-operative sweating, greater arousal being correlated with a higher PSI. The final study reported in this paper examined the effects of a task involving the recognition of words spelled backwards on palmar sweating. The results revealed an increase in sweating on starting the task followed by a gradual decline in sweating over time. This pattern is similar to the increased arousal followed by adaptation which would be expected if a measure of EDA had been used. Dabbs et al. suggest that the PSI is associated with feelings of arousal and repeat the suggestion that readiness to interact with the

environment may also influence the PSI.

A study reported by Gruder, Stumpfhauser and Wyer (1977) used the PSI to examine the effects of deception and subsequent debriefing on later performance. Debriefing concerning the deception did lead to improved performance, irrespective of the nature of the deception. However, neither deception nor debriefing produced any change in the PSI. Their manipulation also failed to produce any effect on self-report measures of distress and anxiety. In the absence of any evidence that the manipulation was, in fact, stressful few conclusions can be drawn from this study.

A study undertaken by Voegele, Burchett & Koehler (1988) assessed the responses of both the PSI and EDA to a variety of standardised "stressors". The "stressors" used were mental arithmetic, mirror drawing and the cold pressor. Their results revealed that the PSI, as well as SCL and NS-SCR frequency, increased in response to all of the stressors, there was no evidence of an anhidrotic response. Within subjects correlations between the PSI and the two measures of EDA were moderate but positive (around .5) providing some support for the concurrent validity of the measure. That the diverse stressors used by this study failed to lead to a decrease in sweating must cast doubt on Johnson & Dabbs' (1967) suggestion that internally-focussed attention may suppress sweating. The cold pressor task, in particular, should lead to the same sort of preoccupation with internal sensations which, they claim, occurs in response to straight-leg raising.

The next study to be described was reported by Koehler, Weber & Voegele (1990). This study also compared the PSI with measures of EDA during laboratory stressors. Both measures of sweating increased while subjects were watching a stressful film, and while subjects were doing

mental arithmetic. In common with the earlier studies there was no evidence for a dissociation between the two measures.

The study reported by Koehler, Webber and Voegelé (1990) was later successfully replicated (reported by Voegelé & Koehler, 1989). In the same article Voegelé and Koehler also report that the PSI increase produced by watching an action film was reduced by the administration of a tranquiliser. While other physiological measures increased while watching the film, only for the PSI, and two self-report measures, was the effect of the tranquiliser significant.

5.3.4 Conclusions concerning the "anhidrotic response to stress

Table one provides a summary of the findings of those studies which have examined the anhidrotic response to stress. What conclusions can be drawn from these studies? It is clear that at least one stressor, surgery, does lead to a reduction in sweating which is apparently related to the stressful properties of the experience, although the results of Johnson et al. (1970) indicate that the relationship between the anhidrotic response and the subjective effects of surgery is far from straightforward. Surgery, however, is possibly the most extreme stressor ever faced by many people, and has several unique characteristics which make it difficult to generalise from surgery to more everyday stressors. The other stressor studied by Harrison & Mackinnon, straight-leg raising, seems to lead to two different responses. One, during the task, involving an increase in sweating and another, after the task, leading to decreased sweat gland activity. Johnston & Johnston (1974) imply that it is the increase in sweating which occurs in association with the experience of stress. On the other hand the series of studies carried out by Harrison and Mackinnon

demonstrate that the decrease after the task is mediated by the hormonal response to the task. This hormonal response is almost a defining characteristic of a stressful situation. It would be premature to attempt to define one pattern as the PSI response to stress, not least because the concept of stress itself is so poorly defined.

The studies reported by Voegelé, Burchett & Kohler (1988) and Koehler, Weber & Voegelé (1990) demonstrate the importance of using an approach based on converging operations. By using several different "stress" manipulations it may be possible to draw conclusions about the general nature of the PSI response. Concentration on one particular manipulation, while allowing detailed examination of the nature of the response to that manipulation, does not allow findings to be generalised to other settings. These studies imply that psychological "stressors" may not produce an anhidrotic response.

The main conclusion to be drawn from these studies is that greater attention needs to be given to the timing of the Palmar Sweat Index. The response may decline rapidly after a task, possibly to be replaced by a different response, although the relationship between the increase during the straight-leg raising task and the suppression occurring afterward has not been directly examined. It is possible that the two measures might be quite closely related. The two papers by Johnson & Dabbs (Johnson & Dabbs, 1967; Dabbs, Johnson & Leventhal, 1968) demonstrate that the PSI response to "real-life" stressors may show considerable temporal variation and emphasise the need for continuous measurement.

Table 1: Studies examining the anhidrotic response to stress

Study	Subjects	Manipulation	Results
Dabbs, Johnson & Leventhal (1968)	Surgical patients, 12M, 28F.	Surgery.	No change. PSI correlated with self-reported arousal.
	Volunteers, 4M, 5F.	Flying.	PSIs during flight > pre-flight PSIs.
	? 8F.	Identifying words spelled backwards. Two difficulty levels.	Transient increase. No effect of difficulty.
Gruder, Stumpfhauser & Wyer (1977)	Students, 80, sex?	IQ test, with false feedback, one group debriefed prior to second session.	No effect of feedback or debriefing on the PSI. PSIs were lower after sessions than before.
Harrison (1964)	Students. Both sexes.	Straight-leg raising.	SLR depressed the PSI.
		Threat of injection.	Threat lowered the PSI.
		"Photic stress test"	No effect.
Harrison & Mackinnon (1963)	? Both sexes.	Injection of adrenal medullary hormones.	Adrenaline & Nor-adrenaline suppressed the PSI. Not due to peripheral effects.

Study	Subjects	Manipulation	Results
Harrison & MacKinnon (1966)	Staff & students. Sex?	Straight-leg raising.	SLR reduced sweating. Adrenergic blockade abolished the effect.
	hypophys-ectomised patients. Female?	Straight-leg raising.	Smaller reduction in sweating. Adrenaline suppressed sweating.
Harrison, Mackinnon & Monk-Jones (1962)	Patients, 20M, 20F.	Surgery, non-surgical control group.	Surgery depressed the PSI. Faster recovery in Females.
Johnson & Dabbs (1967)	Students, 12F.	Measures taken pre- & post-exam, before a stats class, & during mental arithmetic.	Exam measures = classroom PSI. All three > MA measures. U-shaped curve during MA.
Johnson, Dabbs & Leventhal (1970)	Surgical patients, 62F.	Surgery.	Surgery suppressed sweating. Varying correlations with subjective measures.
Johnston & Johnston (1974)	? 8M, 4F.	Straight-leg raising.	Increased PSI (& SCL) during SLR. No depression of sweating after.
		Mental Arithmetic.	Increased PSI (& EDA). Return to baseline after.
Koehler, Webber & Voegelé (1990)	? 12F, 7M	Stressful film Mental arithmetic.	Both stressors increased the PSI (& EDA)

Study	Subjects	Manipulation	Results
Lindeman & Stetzer (1973)	Surgical patients, 73F, 103M.	Preparatory visit by operating room staff.	Reduced PSI. Larger drop after major surgery. Preparation reduced the drop only after minor surgery.
MacKinnon (1964)	hypophys-ectomised females.	Straight leg raising.	Response to SLR depends on the pituitary.
Mackinnon (1969)	Psychiatric patients, mostly male.	Straight-leg raising. Adrenaline injection.	No anhidrotic response. Patients' PSIs < than normals' PSIs. No decrease in schizophrenics. Normals show long-lasting decrease.
MacKinnon & Harrison (1961)	Staff & students, Both sexes.	Injection of Adrenal cortical hormones.	ACTH & Progesterone suppressed sweating. Response to ACTH had longer latency.
Turpin, Takata & Tutton (1986) Experiment I	Students, 12M, 16F.	Mental Arithmetic, two levels of threat.	No effect of threat. PSI was below baseline post-task (higher EDA during task).
Turpin, Takata & Tutton (1986) Experiment II	Students, Sex?	Three levels of exercise	Only High exercise group sweated more. Their PSIs dropped below baseline after.
Voegele, Burchett & Koehler (1988)	Volunteers, 30F.	Mental Arithmetic, Mirror drawing & Cold pressor.	All three tasks lead to increased PSIs (& EDA). PSI & EDA correlated.

Study	Subjects	Manipulation	Results
Voegele & Steptoe (1986)	Surgical patients, 8M, 7F.	Surgery. One Major & one minor operation.	Decreased PSI (& EDA). Larger drop after major surgery. PSI correlated negatively with mood disturbance.
Voegele & Koehler (1989) Study 4	? 18M	Action film	Film increased sweating (& EDA)
Study 5	? 20M	Action film with or without tranquiliser	Decrease from pre-drug to post-drug was greater for tranquiliser group.

In addition, the situations in which the PSI is taken need to be more closely defined. For example the threat of injection, surgery and straight-leg raising differ in many more ways than they are similar. The response to one situation may be independent of the response to another, and similar responses do not necessarily imply similar causes.

While Mackinnon and Harrison carried out a series of well-designed experiments which stimulated several other workers to use the PSI, such programmes of research are the exception rather than the rule in work on the PSI. Many studies have been "one off" investigations and have often used the PSI as a manipulation check or dependent measure without consideration of the validity of the index. Remaining studies using the PSI will be discussed in the following sections. Where several studies have used the PSI in similar situations these will be discussed together.

5.4 The PSI and Preparation for Surgery

5.4.1 Review of Research Melamed and her co-workers (Melamed & Siegel, 1975; Melamed et al., 1975; Melamed et al., 1976; Melamed, 1977; Melamed, Dearborn & Hermeicz, 1983; Faust & Melamed, 1984) have used the PSI to examine means of reducing the stress of surgery. However, in contrast to the work inspired by Harrison, Mackinnon & Monk-Jones (1962), these studies assume that the PSI increases in response to anxiety. The studies to be described examine the effectiveness of modelling, using either a film, or a comparable slide & tape presentation, in reducing the anxiety felt by children undergoing surgery.

Melamed & Siegel (1975) demonstrated that the film, "Ethan has an operation", led to increases in palmar sweating, whereas a control film produced lower sweating post-film than before. However, the group who had seen the preparatory film were less physiologically aroused both on the evening before their operation and on returning to the hospital for a check-up three to four weeks later. Observer ratings of anxiety were greater for the control group at these two times as well. The control group reported more hospital fears at all times. They interpret these results as demonstrating that the film produced temporary anxiety, by acting as a reminder of the forthcoming operation, but that the film was effective in reducing anxiety about the operation. Their results also revealed an interaction between age and sex, older boys having higher PSIs than younger boys while older girls had lower sweat gland counts than younger girls.

The next study to be carried out extended these findings by manipulating the variables of age, amount of other preparation and time of viewing. These results are reported by Melamed et al. (1976) although their groups are not balanced for age or sex. Melamed (1977) reports what appear to be the same data but with smaller, balanced, groups, presumably obtained by excluding some subjects.

The results published by Melamed et al. (1976) reveal an interaction between time of viewing and amount of preparation. Viewing the film on the day of surgery led to less post-operative sweating when combined with standard preparation for surgery. However when the film was seen a week before surgery minimal preparation seemed to lead to lower anxiety after the operation. However there were age, sex and race effects which make these results difficult to interpret. Young children (aged 7 and less) showed lower physiological arousal after

surgery when they saw the film immediately before surgery, both in relation to older children seeing the film at the same time and to younger children who saw the film a week before. The sex effect concerned the measures taken after the film. Immediately after viewing the film, males had lower PSI scores than females. Black children who saw the film a week before surgery sweated more prior to the film than did white children. This pattern was reversed for the groups seeing the film on the day before surgery. A variety of measures showed children to be less anxious after seeing the film. This is consistent with the conclusions of Melamed & Siegel (1975), although this study did not include a no-film control group.

In the second paper (Melamed, 1977) it is reported that only the group who saw the film a week before surgery showed an increase from pre- to post film. Presumably the group seeing the film on the day of admission were already highly anxious. This increase in sweating occurring as a result of viewing the film may represent the effects of emotional processing, activation of fear schemata being necessary for their modification (Foa and Kozak, 1986). They do not report the interaction of time of preparation with degree of preparation but do report an interaction between age and time of viewing. Older children showed the same pattern of higher arousal post-film but less pre- and post-operative sweating reported by Melamed & Siegel (1975) when they saw the film one week before surgery. Whereas younger children only benefitted from seeing the film on the day of admission. Younger children reported more medical concerns overall and showed increasing concern from pre- to post-operative assessment. Whereas older children reported fewer concerns after the operation.

While the results of this study have implications for the optimal

timing of surgical preparation in children they are difficult to interpret with regard to the validity of the PSI. The failure of younger children to benefit from early preparation seems explicable in terms of their stage of cognitive development. However the explanation of the interactions found can only be post hoc. There also seems to be less agreement between the changes in the PSI and in the other measures of anxiety they included than in the study by Melamed & Siegel (1975).

Melamed (1977) also reports data from two other studies. In one the change in palmar sweating from pre- to post-film was found to predict the change in attitudes towards medical scenes and personnel, greater sweating being correlated with a greater shift towards a more favourable attitude. This is consistent with the theory put forward by Foa and Kozak (1986), who suggest that fear reduction occurs primarily through the activation of the cognitive representations of feared stimuli. Such activation may be indexed by a physiological response similar to that produced by the feared object itself. In the third study Melamed (1977) reports an analysis of the data obtained by Melamed & Siegel (1975) in relation to later reports from the parents of the children as to the strategies they customarily used for situations in which their child might be fearful. Several of these measures were predictive of the PSI response their child had shown to the operation. Sweating before the operation was positively correlated with the father's use of punishment and negatively related to the father's use of modelling and reassurance. The inconsistent use of reinforcement by both parents correlated negatively with the PSI at follow-up while inconsistent use of modelling and reassurance was positively related to sweating post-film. Similar relationships

emerged between the measures of parental strategy and other measures of anxiety. Both of these studies are consistent with the interpretation of the PSI as an index of anxiety.

Melamed, Dearborn & Hermez (1983) used a slide tape presentation to examine the effect of prior surgical experience. They found that experienced children showed an increase in sweating as a result of watching the presentation, whereas naive children showed a decrease. This is explained as representing a sensitization effect in children with prior experience of surgery. The film was particularly ineffective in young children with prior experience of surgery. The increase in sweating over the course of the film correlated positively with an index of disruptiveness in the operating room. This result conflicts with the findings of earlier studies, where a larger response to the film was associated with better subsequent coping. It should be noted that the film used in these studies differed from that used in earlier research. For control subjects, who saw a non-hospital film, increased sweating from pre- to post-film also correlated with a longer hospitalization and with more complications after surgery. It is possible that changes over the course of the film were indicative of factors other than the film itself. As films were seen on the night before surgery it is possible that palmar sweating was increasing due, in part, to anticipatory anxiety.

While this study implies that extensive preparation for surgery may not always be beneficial, it does not change our view of the PSI. Here too the results are consistent with an interpretation in terms of anxiety. Furthermore, the results imply that the PSI might have importance as a predictive measure.

The finding of sensitization in children with prior surgical

experience as a result of viewing the film was replicated by Faust & Melamed (1984). In addition children entering hospital for "walk-in" surgery also showed an increase pre- to post-film, whereas children viewing the film in hospital the day before showed a decrease over the course of the film. Self-reported medical fears showed a similar pattern of results. As in the previous study a reduction in sweating after viewing the film was correlated with a shorter stay in hospital and with fewer complications, although only for the group seeing the film on the same day as surgery.

In a similar study, Johnson & Stockdale (1975) examined the effectiveness of a puppet presentation in reducing children's anxiety prior to surgery. Their results reveal that children viewing the presentation showed a decrease in sweating from before the presentation to afterwards, whereas children who did not see the presentation showed increased sweating over the same period. Their results also reveal that children who received preparation showed a large drop in sweating from the initial measure, taken at admission, to the post-operative measure, taken on the evening after surgery. The control group showed roughly equivalent levels of sweating at the two times. There were no effects or interactions involving sex. They interpret the decline from before to after surgery for the experimental group as reflecting decreased anxiety.

Pinto and Hollandsworth (1989) carried out a study very similar to those undertaken by Melamed. Children saw either one of two preparatory films or a neutral film prior to surgery. Children either saw their film alone or in the company of a parent. Watching the film with a parent led to reduced palmar sweating prior to surgery. The two preparatory films produced lower preoperative PSIs than did the

control film. The effectiveness of the preparatory films was confirmed by other measures of preoperative anxiety, and by an index of post-operative recovery. Pinto and Hollandsworth also obtained PSIs from the parents in their study. Parents also had lower preoperative PSIs as a result of watching the preparatory film.

5.4.2 Preparation for other stressful procedures. Following the success of Melamed's program other studies have used a similar approach, including the use of filmed modelling and the PSI, in preparation for other stressful procedures. Gilbert et al. (1982) attempted to use modelling to teach insulin self-injection to diabetic children. Adding a film to conventional training. Their film did improve skill acquisition, although only for older girls. However, there was little evidence of anxiety prior to the manipulation. Accordingly, neither the PSI nor self-report and observational measures of anxiety changed significantly as a result of the manipulation.

One study by Melamed et al. (1975) used a similar methodology to help children cope with dental treatment. Sixteen children were rated for the amount of disruptive behaviour they displayed and were administered the PSI and a fear survey at each of three sessions at the dentists. At the start of the second session, which took place on the same day as the first, children saw either a preparatory film or a control film. The first two sessions consisted of prophylactic treatment and an examination. On the third session, a week later, children received at least one filling. Ratings of disruptive behaviour and of apparent fear revealed that the experimental group was less disruptive and less anxious than the control group at the third session. The control group revealed a large increase in fear

from the second to the third session. The PSI, however, did not significantly differentiate the groups. There was, however, a trend towards lower levels in the experimental group. The fear survey revealed a similar, non-significant, trend.

5.4.3 Discussion of the PSI and preparation for surgery. Table 2 presents a summary of the findings of studies reviewed in this section. While the results of this series of studies are complex, in general they seem consistent with a role for the PSI as an index of anxiety. The failure to observe a decrease in the PSI following surgery, such as that seen by the studies described in section 5.3 and summarised in Table 1, is most probably due to the timing of the post-operative measures used by Melamed and her co-workers. All post-operative measures were taken at the time of a physical examination several weeks after surgery. This is sufficiently long for any anhidrotic response to have recovered. The levels of sweating observed at this time most probably represent the level of anxiety produced by the return to the hospital rather than a direct effect of the operation itself.

The failure of Johnson & Stockdale to observe a decrease in sweating in the control group in their measure, obtained on the evening after surgery, is more puzzling. A possible clue may be that they took the PSI in the evening whereas Harrison, Mackinnon & Monk-Jones (1962), Johnson, Dabbs & Leventhal (1970) and Vogele & Steptoe (1986) all obtained their measures in the morning. Lindeman & Stetzer (1973) who also found an anhidrotic response to surgery report that their post-operative measure was taken 24 hours after surgery, but do not state at what time of day. Two explanations are possible.

it may be the case that the anhidrotic response is slow to develop and does not appear until the morning after surgery. An alternative, although less plausible, possibility is that the anhidrotic response may only occur in the morning.

Several of the studies demonstrate that the relationship between palmar sweating and other indices of disturbance may be complex. While these studies provide little evidence for a dissociation between the PSI and subjective measures of anxiety, direct measures of behaviour do not always parallel the presumed changes in anxiety. Melamed et al. (1975) reduced disruptive behaviour by modelling, but no effect was apparent on the PSI. Other studies present differing conclusions regarding the significance of changes in sweating as a result of viewing a preparatory film. In older subjects increased sweating was associated with better subsequent coping (Melamed, 1977). In younger children, in contrast, particularly when they had prior surgical experience, an increase in the PSI from pre- to post-film was associated with more disruptive behaviour (Melamed, Dearborn & Herbecz, 1983). In both cases, the increased sweating observed probably indicates that the films were successful in activating the childrens' representations of the feared situation. The effects of this activation differed however, as a function of age, experience and, possibly, characteristics of the film itself. More work is needed to identify those circumstances when modelling will be effective in reducing fear and those where exposure will lead to sensitization and greater fear.

Table 2: Preparation for surgery and the PSI

Study	Subjects	Manipulation	Results
Faust & Melamed (1984)	Children, both sexes. Some with prior experience of surgery.	Surgery with preparatory presentation on the same or the night before.	Night-before preparation lead to a decrease in the PSI. Experienced children sweated more, inexperienced less, after the presentation. Increase correlated with poor outcome.
Gilbert et al. (1982)	Diabetic Children. 15F 13M	Film modelling insulin self-injection, neutral film control.	Neither the PSI or state anxiety changed from pre- to post-film.
Johnson & Stockdale (1975)	Children, Both sexes.	Surgery with preparatory puppet show.	Show decreased the PSI. Preparation reduced PSIs after surgery.
Melamed et al. (1975).	Children, Both sexes.	Dental treatment with preparatory or neutral film.	No effect of film on the PSI. Film did reduce disruptive behaviour.
Melamed (1977) Experiment II	Children, Both sexes. Two age groups.	Surgery, with preparatory film either one week before or immediately before admission. Two levels of additional preparation.	Pre-admission PSIs were lower with early preparation. Early group showed increased PSIs after the film. Young children only showed less arousal with same-day film.

Study	Subjects	Manipulation	Results
Melamed (1977) Experiment IV	Children, 37M, 23F.	Surgery.	Parent's reported handling of fearful situations correlated with child's PSI.
Melamed, Dearborn & Hermezc (1984)	Children, Both sexes. Some with prior surgical experience.	Surgery with prep- aratory presentation.	Experienced subjects sweated more, inexperienced less after the presentation. For preparation and control groups increased PSIs after the film correlated with poor outcome.
Melamed & Siegel (1975)	Children, 37M, 23F.	Surgery, with prep- aratory film.	Film increased sweating. Film group sweated less pre- & post-operation.
Melamed et. al. (1976)	Children, 23M, 25F. Two age groups.	Surgery, with prep- aratory film either one week or immediately before admission. Two levels of additional preparation.	Pre- & post-op. PSIs showed interaction between time of film and amount of other preparation. Young children showed less arousal with late preparation. Older subjects showed least with early preparation.
Penticuff & Melamed (1975)	Children, Both sexes.	Preparatory film used above. No surgery.	Film increased sweating. Increase correlated with change in attitude toward medical matters.

Study	Subjects	Manipulation	Results
Pinto & Hollandsworth (1989)	Children, 40F, 20M	Preparatory video, Children watched with parents or alone. No- video control group.	Video groups had lower pre-op PSI. Watching with parents produced lower PSIs than watching alone. Parents in no-video condition showed higher pre-op PSIs.

5.5 Dental Fear and Palmar Sweating

The studies described above used the PSI as an index of fear of surgery, in a clinical setting. Several other studies have used the PSI to assess dental fear, either in the dental surgery or using experimental analogues. One such study, by Melamed et al. (1975), has already been described. Melamed et al. (1975) used filmed modelling to reduce uncooperative behaviour during dental treatment. While the film was effective in reducing disruptive behaviour, the effects on the PSI did not reach significance.

Weisenberg et al. (1975, 1976) examined the response of three ethnic groups to dental treatment. Measures were taken from Black, White and Puerto Rican subjects in a dentist's waiting room and again in the dentist's chair prior to treatment. There were no differences in palmar sweating between the racial groups, but there was a sex difference in the response to treatment. Female subjects showed greater levels of sweating in the dentist's chair than in the waiting room, whereas males showed similar physiological activity at both times. Females also tended to report more anxiety than males. However, an ethnic difference in reported anxiety, Puerto Ricans tending to describe themselves as more anxious, was not paralleled by differences in physiological activation. The PSI also did not correlate significantly with any of their subjective measures of anxiety or fear.

Kleinknecht has carried out several studies using the PSI to examine dental fear (Early & Kleinknecht, 1978; Kleinknecht & Bernstein, 1978, 1979b; Brandon & Kleinknecht, 1982). Early & Kleinknecht (1978) compared the responses of subjects rated as Repressors or Sensitizers on the Byrne (1961) Repression-Sensitization

scale to two sounds, a dentist's drill and a wind-up toy car (which produced a similar sound). Subjects were informed as to the source of the sounds. Their results showed that sensitizers gave greater responses than repressors, both when listening to the sounds and when relaxing. Furthermore, for both groups the drill produced higher levels of sweating than the sound of the toy car. There has been considerable criticism concerning the validity of the repression-sensitization scale (e.g. see Budd & Clopton, 1985), as the R-S scale has been shown to correlate highly with scales measuring trait anxiety (e.g. Golin et al., 1967; Sullivan & Roberts, 1969; Linden et al., 1986). These results may, therefore, reflect differences in trait anxiety rather than attention to threatening sounds.

A study carried out by Kleinknecht & Bernstein (1978) examined the consistency of different assessments of anxiety in a dental setting. They obtained subjective reports of fear and of expected and actual pain from dental patients. They also obtained objective measures consisting of the PSI, administered at several points during the visit, and observer ratings of anxious behaviour from videotapes taken during treatment. The self-report measures revealed that older (40+) subjects were less anxious than younger subjects. Dental fear was associated with greater expected pain, although not with the difference between actual and expected pain. The PSI data revealed a triple interaction between fear level, sex and time of measurement. Low-fear subjects of both sexes showed steadily reducing levels of sweating. High-fear subjects showed no difference between measures taken in the dentist's chair prior to treatment and those taken immediately before administration of the local anaesthetic. However,

after treatment males showed a significant drop in sweating, whereas females showed significantly higher levels of sweat gland activity. High-fear subjects also showed greater movement in the dentist's chair than low-fear subjects. Other, more direct expressions of anxiety were virtually absent. They report that the PSI did not correlate significantly with self-reported fear.

A later report by Kleinknecht & Bernstein (1979b) provides evidence of the use of the PSI as an outcome measure in a single case study, examining the treatment of dental fear. Two case studies are reported, but PSI data was only available for one subject. PSIs were taken on two occasions, once before treatment and again after the course of treatment. On both occasions, measures were taken at three times in the dentist's surgery, although only an oral examination was carried out on the first occasion. Prior to treatment the subject showed elevated levels of sweating over the course of the session. After treatment the subject showed very high initial levels of sweating, but levels declined rapidly over the course of the session. The high initial level post-treatment is explained by the subject's expectations, as she knew she was to have three fillings on that occasion. After treatment of her fear, the PSI data reveal a pattern of adaptation, similar to that shown by low fear subjects in the previous study (Kleinknecht & Bernstein, 1978). Data from both subjects reveal that treatment was also effective in reducing dental avoidance and subjective fear.

The experiment undertaken by Brandon & Kleinknecht (1979), in contrast to earlier studies, found a difference in overall level of palmar sweating between subjects high and low in dental fear. This was an analogue experiment in which subjects were asked to view a

videotape of a dental operation from the patient's point of view. Subjects who scored highly on a dental fear survey sweated more than did low-fear subjects. High-fear subjects also reported greater experience of anxiety and physiological arousal (both sweating and heart rate, respiration rate, muscle tension and temperature). They also found a sex difference in sweating, females showing greater sweating. Sweating for all groups was lower at the end of the tape than at earlier times.

These studies, summarised in table 3, also seem to support the hypothesis that the PSI is positively related to anxiety. Although the PSI response may not directly parallel the response in other systems. Such desynchrony has been widely reported when other physiological measures are used (e.g. Lang, 1968; Rachman & Hodgson, 1974). The sex differences reported in three studies appear similar. In two studies, females showed increasing levels of sweating whereas males showed a tendency towards decreasing sweat gland activity. However, Weisenberg et al. (1975) and Kleinknecht & Bernstein (1978) obtained measures at different times so that the results are not directly comparable. In the third study, females sweated more at all times. It should be remembered that the studies carried out by Kleinknecht did not control for finger size. Higher levels in females might, therefore, reflect smaller size rather than greater physiological activation. This observation is not sufficient to explain the findings of a difference between the sexes in the pattern of responses over time. Such differences may represent a difference in physiological responsivity. Alternatively, the difference in sweating might be secondary to a psychological difference in the perception of the situation or in the coping strategies used to deal with it.

Table 3: Dental fear and the PSI

Study	Subjects	Manipulation	Results
Brandon & Kleinknecht (1979)	Students 24M, 24F. Split on dental fear.	Film of dental treatment.	Females > males. High-fear > low-fear. PSIs were lower after the film.
Early & Kleinknecht (1978)	Students, 60F. Split into sensitizers /repressors.	Listening to dentist's drill or toy car.	Sensitizers > repressors. Drill produced a larger response than the car.
Kleinknecht & Bernstein (1978)	Dental patients, 72M, 56F. Split on dental fear	Dental treatment.	Low-fear subjects showed decreasing PSIs. In the high- fear group, only males showed a drop in sweating after treatment
Kleinknecht & Bernstein (1979)	Dental patient, Female.	Treatment of dental fear. Measures taken during two dental appointments.	Before treatment PSIs increased during visit. After treatment PSIs showed adaptation.
Weisenberg et al. (1976)	Dental patients, 40M, 35F.	Dental treatment.	Females had higher PSIs. For females only, treatment PSI > pre-treatment PSI.

5.6 The PSI and Psychopathology

A small number of studies have used the PSI to examine the psychophysiology of various forms of psychopathology. Most attention has focused on the anxiety disorders.

5.6.1 Anxiety and the sensitivity of the PSI to pharmacological stimulation A series of studies by Bradshaw and Szabadi (Iskandar, Bradshaw & Szabadi, 1980; Maple, Bradshaw & Szabadi, 1982; Van Den Broek, Bradshaw & Szabadi, 1984; Bucetta, Bradshaw & Szabadi, 1985) used a variant of the Palmar Sweat Index, taken from the forearm, to assess the responsiveness of the sweat glands in clinical anxiety. The technique used in these studies was developed by Clubley et al. (1978) to provide an assessment of the sensitivity of the sweat glands to pharmacological agents. Only those studies using the technique to assess the effects of psychological variables will be described here.

Iskandar, Bradshaw & Szabadi (1980) investigated the responsiveness of forearm sweat-glands to carbachol (a cholinceptor agonist) in ten anxious patients and in a control group of eleven healthy volunteers. The resulting dose-response curves revealed that, while the dose required to produce a half-maximal response was similar for both groups, the size of the maximum response was greater for the anxious patients. Anxious patients also showed higher levels of "spontaneous" activity, i.e. activity prior to the pharmacological manipulation, presumably when subjects were at rest.

These results are comparable to those obtained using skin conductance (e.g. Lader & Wing, 1966) which show that anxious patients commonly have higher levels of baseline EDA. Although, following the law of initial values, higher baseline levels of EDA are often found

to be associated with smaller responses in anxiety patients (Lader & Wing, 1966; Bond, James & Lader, 1974), rather than the larger drug-induced response found in this study.

The findings of a higher level of spontaneous activity and a larger response to pharmacological stimulation in anxious patients was replicated by Maple, Bradshaw & Szabadi (1982) using both Carbachol and Phenylephrine (an adrenoceptor agonist). They compared a group of female anxious patients with a female control group. They also compared healthy subjects of both sexes. The anxious patients had higher levels of "spontaneous" activity and were more responsive to both drugs than healthy females. They also found that healthy males showed a larger response to the two drugs than did their healthy female subjects, although the two groups did not differ in terms of the level of "spontaneous" activity. They hypothesised that the difference in responsivity between anxious and normal subjects may represent a process of sensitisation by the anxious patients' presumed higher levels of sympathetic outflow.

To investigate this possibility Van den Broek, Bradshaw & Szabadi (1984) studied the effects of a psychological stressor and of raised temperature on the pharmacological responsiveness of the sweat glands. Both a mental arithmetical task and raising the temperature to 35 degrees centigrade produced higher tonic levels of activity, although the increase did not reach significance for the temperature manipulation. In addition, both manipulations led to a greater maximal response to carbachol, similar to the differences found between anxious patients and controls. This finding supports the suggestion that the greater responsivity of sweat glands in anxious patients may be due to sensitisation produced by a higher rate of stimulation by

the sympathetic nervous system. Thus, the differences in sweating between subjects differing in this form of trait anxiety may be secondary to differences in the experience of state anxiety.

While Iskandar, Bradshaw and Szabadi (1980) studied patients of both sexes, the other two studies comparing anxious and healthy subjects described above all used female subjects. The final study in this series compared patient and healthy groups of both sexes. Buceta, Bradshaw & Szabadi (1985) found that, for both males and females, anxious subjects produced a larger response to carbachol. In addition, as in the earlier studies, anxious patients had higher levels of "spontaneous" activity, although the difference just fell short of significance for the males. The study also replicated the finding of Maple, Bradshaw & Szabadi (1982) that healthy males had more responsive sweat glands than healthy females, although there were no sex differences between the patient groups. They suggest that the absence of a sex difference in the anxious group may indicate that their sweat glands were maximally active due to anxiety, masking any sex effect.

This series of studies indicates that the palmar sweat index, or at least this variant of the PSI, responds similarly to electrodermal measures when obtained from anxious patients. The persistent finding of differences in the responsivity of the sweat glands of the two sexes is interesting. These studies bear out the findings of other studies using the PSI (e.g. Weisenberg et al. 1976) that there are no differences in baseline sweating between the sexes. It should be noted, however, that the studies carried out by Bradshaw and Szabadi did not control for arm size and so may have over-estimated the level of baseline activity in females. While this study indicated that males

showed greater peripheral responsivity, studies examining dental fear seem to imply that females show a greater response than males. However these findings are not contradictory, given the many differences between the studies. The response of the sweat glands to released acetyl choline is only the last step of a long chain ending in the physiological response to fear-inducing stimuli, such as dental surgery. Factors acting at higher levels of the chain, such as appraisal of the situation, may be of much greater importance in determining the final response than peripheral factors, such as those studied by Bradshaw & Szabadi.

5.6.2 Other disorders and the PSI A small number of studies have used the PSI to examine other forms of psychopathology. These studies have used the PSI to examine the psychophysiology of Alzheimer's disease (Laab, Bradshaw & Szabadi, 1983) and depression (Bagg & Crookes, 1966). An additional study has also used the PSI as a measure of anxiety in a study investigating the prevention of phobias (Posner & King, 1975).

A study by Laab, Bradshaw & Szabadi (1983) used their variant of the PSI, described in the previous section, to examine sweat gland activity in Alzheimer's disease. They examined the response to choline and carbachol of a group of female patients suffering from Alzheimer's disease. They also assessed the reactivity of old, non-demented females and of young subjects of both sexes. Their results replicated previous findings of differences in responsivity between females and males, although only the difference in the response to choline reached significance. The sexes did not differ with regard to their level of baseline activity. Their results revealed that there were no differences in "spontaneously" active

sweat glands between young females and older healthy females, nor between demented and non-demented older females. However the three groups were ordered in their responses to the two drugs, young females showing the largest responses and patients with dementia of the Alzheimer type showing the smallest. The findings concerning Alzheimers disease are consistent with an explanation in terms of impaired functioning of peripheral cholinergic neurones, parallel to the degeneration known to affect central cholinergic neurones in this disorder. However, an alternative explanation is that the reduced responsivity of demented patients may represent an acceleration of the normal changes which occur with ageing. The occurrence of a difference in responsivity between young and old females supports similar findings of reduced PSI scores with age (e.g. Mackinnon, 1954). It is surprising that this study only found differences in responsivity and not in baseline activity, as other studies using the PSI have found differences in resting activity.

Bagg & Crookes (1966) examined the level of sweating in depressed patients using the PSI. They found that palmar sweating was lower for their first three measures, when subjects were depressed, than for their last measure, taken just prior to discharge. Scores on the Maudsley Personality Inventory generally did not correlate with the PSI, only one correlation being significant. This correlation was between neuroticism and the change between the first PSI measure and the measure taken on the morning before receiving ECT ($r = -.47$). Subjects scoring higher on the scale sweated less before ECT. They also report that the change in the PSI tended to correlate positively with the change in pulse rate. Bagg & Crookes conclude that depression leads to reduced sweat gland activity, which they interpret, following Harrison, Mackinnon & Monk-Jones (1962) as indicating greater anxiety.

At the time no studies had deliberately examined sweat gland activity in depression. Recently, however, several studies (to be reviewed in Chapter four) have used electrodermal measures to examine sympathetic activation in depressed subjects. The results are consistent with those of Bagg & Crookes (1966), depressed subjects are consistently found to have lower levels of SCL than non-depressed controls.

The final study to be described in this section is complementary to the modelling studies undertaken by Melamed. Poser & King (1975) used the Palmar Sweat Index as a measure of anxiety in a study examining the effectiveness of modelling procedures in the prevention of phobias in children. They examined the effects of films involving subjects displaying either mastery (the absence of fear) or coping (overcoming their fear) and a control film featuring snakes on children who were not previously snake phobic. On a behavioural approach test the mastery films led to greater approach than either the coping film, the control film or a no film control. Poser & King report that the PSI also revealed less arousal (presumably lower scores) in the mastery group than in the other groups. This study seems to provide further support for the validity of the PSI as an index of anxiety.

While the small number of studies in this section is disappointing, there is considerable support for the utility of the PSI in the investigation of various disorders. Also encouraging is the similarity between the results obtained using the PSI and those obtained by other studies using electrodermal measures. Table 4 provides a summary of the results of studies examining the PSI and psychopathology.

Table 4: The PSI and psychopathology

Study	Subjects	Manipulation	Results
Bagg & Crookes (1966)	Depressed patients, 18F.	ECT.	Higher PSIs after recovery.
Buceta, Bradshaw & Szabadi (1985)	Anxiety patients + controls, 6M, 6F of each.	Pharmacological stimulation.	Anxious patients' responses > those of controls. Anxious females had higher resting PSIs than non-anxious. Healthy males responded more than healthy females.
Iskandar, Bradshaw & Szabadi (1980)	Anxiety patients, 3m, 7F. Plus controls.	Pharmacological, stimulation.	Anxious subjects had higher resting PSIs & gave larger responses than controls.
Lamb, Bradshaw & Szabadi (1983)	Alzheimers' patients, 6F. Plus old females & young of both sexes.	Pharmacological stimulation.	Males' responses > those of females. Responses of young females > those of old females. Old non-demented females gave larger responses than demented.
Maple, Bradshaw, & Szabadi (1982)	Anxiety patients, 6F plus 6M & 6F controls.	Pharmacological stimulation	For Healthy subjects, males' responses > females'. Anxious females had higher resting PSIs & responded more than female cotrols.

Study	Subjects	Manipulation	Results
Poser & King (1975)	Children 33, sex?	Modelling films to prevent snake phobia.	"Mastery" condition produced less arousal than "coping" or neutral films.
Van den broek, Bradshaw & Szabadi (1984)	Staff & students, 6M.	Pharmacological stimulation during mental arithmetic or high temperatures.	MA raised baseline PSIs. Both stressors increased responsiveness.

5.7 Threat of Shock and the PSI

Three studies have examined the effect of electric shock, or the threat of shock, on the PSI. In a study to examine the effects of stress on attitude change, Helmreich & Hamilton (1968) gave subjects either weak shocks, described as "painless stimulation", or painful shocks. Subjects were lead to expect further shocks, with the shock group being told that the shocks would increase in intensity. Not surprisingly, the high stress group scored much higher on the PSIs taken immediately after each shock. The fear manipulation was also effective in producing greater incidental attitude change.

Dabbs, Leventhal & Hornbeck (1969) examined the effect of perceived control on the physiological response to shock. In their first experiment, using female subjects, they found that subjects who believed that they could escape from inescapable shock sweated more after a shock than they did 60 seconds before, whereas subjects who believed that their response had no effect showed a decrease in sweating after the shock. The level of shock had no effect. This pattern seems consistent with Johnson & Dabbs' suggestion concerning the effects of attention, the no-control group, who could only passively cope with the shock, revealing decreased sweating, while the escape group, who had an active response, sweated more. Although the "escape" group's self-perceived failure might also account for the difference.

Unfortunately, their second experiment revealed slightly different results from the first. In this study measures were taken 60 seconds before shock and again 20 seconds before. This study used equal numbers of male and female subjects. In addition to the groups described above, an avoidance group, who believed they could avoid shock, and a control group who believed shocks were random, were

included. While the escape and escape-no control groups received shocks, the avoidance and avoidance-no control groups did not. Dabbs et al. found two significant effects. Firstly there was an overall main effect of time, subjects sweating less a minute before shocks were expected than immediately before or after, implying that the shocks lead to increased sympathetic activation. This effect was modified by an interaction with perceived control and escape/avoidance. Two groups showed a pre-shock peak in sweating, these were the escape-no control group and the avoidance-control group.

Procedural differences make the two experiments difficult to compare, and even within the second experiment the fact that some groups received shock while others didn't limits the conclusions that can be drawn. A possible explanation is that the expectation of an uncontrollable shock may have led to higher sweating in the escape-no control group prior to the shock. The peak in sweating in the avoidance-control group, who believed they were successfully avoiding shock, may have reflected preparatory arousal associated with the avoidance response.

The main conclusion to be drawn from the studies undertaken by Dabbs, Leventhal & Hornbeck (1969) is that the physiological response to the task shows considerable variation over time and is related to the psychological nature of the situation rather than to gross factors such as the presence or absence of shock. Relatively subtle differences in the timing of the PSI or in the manipulation used may lead to changes in the nature of the physiological response observed.

Martens & Landers (1970) examined the effects of the threat of shock on motor performance in children. The PSI and heart rate (HR) were included as manipulation checks. They used three levels of shock

threat, no shocks were actually given. Performance scores revealed the predicted inverse-U relationship to stress, performance being best in the medium threat group. The task led to increased heart rate. During the task, HR increased over time in the high-threat group but not for the other two groups. The PSI results are puzzling, there was no evidence for an increase in sweating during the task, the PSI declined steadily over the course of the experiment. Furthermore, the three stress groups showed a graded difference in sweating, with the high stress group displaying significantly lower PSI scores than the other groups.

These results appear to imply that a strong threat manipulation, which lead both to differences in self-reported stress and to measurable differences in performance, produced a suppression of sweating. Martens & Landers claim that this may represent another example of internally-directed attention reducing sweating, although, while subjects were not actively reacting to the stressor, the threat of shock was described as dependent on their performance. However, it should be noted that the physiological measures were not taken during the task itself, or at the time shock was expected after the task. PSIs were taken between trials of the task. For this reason the PSIs taken may not represent an adequate index of the response to the task, or of the level of state anxiety. Self-reported trait anxiety did not relate to either physiological measure.

The results of these studies, summarised in table 5, demonstrate some contradictions. While Helmeich & Hamilton (1968) demonstrated that shock leads to increased sweating, the studies reported by Dabbs, Leventhal & Hornbeck (1969) revealed no effect of shock per se on sweating. Rather the anticipation of shock and the degree of perceived control appeared to be the main determinants of the level of sweating.

Table 5: Threat of shock and the PSI

Study	Subjects	Manipulation	Results
Dabbs, Leventhal & Hornbeck (1969) Experiment 1	Students 20F	Inescapable shock. One group was told escape was possible.	For "escape" group post-shock PSI > pre-shock PSI. For "no-control" group pre>post.
Dabbs, Leventhal & Hornbeck (1969) Experiment 2	Students 8M, 8F	One group received shock, another did not. In each group, half were told shock was random, half were told they could control shock.	Shock/no control & no shock/control groups showed pre-shock peak in sweating.
Helreich & Hamilton (1968)	Students, 86M.	Shock, two levels of intensity.	High-intensity shocks produced higher PSIs.
Martens & Landers (1970)	Children 90M, three levels of trait anxiety.	Manual task with three levels of shock threat.	Low threat group > High threat. PSIs decreased over time. Task measures were below baseline.

Martens & Landers (1970) even appeared to find a reduction in sweating as a result of shock threat. The methodological problems of this study mean that the effect found cannot confidently be attributed to the shock itself. Because measures were not taken at a time when the threat of shock was particularly salient, the effects of the threat might be masked by the sort of temporal variation in sweating found by Dabbs, Leventhal & Hornbeck (1969).

If one were to ignore ethical considerations, it is possible to specify what sort of program would be required to clarify the relationship between the PSI and threat of shock. What would be needed is a series of studies systematically investigating the effects of shock, perceived control, success and timing of measurement, rather than a series of disparate studies, using different threat manipulations, different tasks and taking measures at different times.

5.8 Audience Effects and Palmar Sweating

The simplicity of the PSI has encouraged several workers to use the measure as an index of "arousal" in experiments investigating the phenomenon of social facilitation and inhibition. The first study to use the PSI in this way was undertaken by Martens (1969a, 1969b, 1969c). Martens (1969a) had subjects learn a complex motor task either alone or in the presence of a passive audience. His results show that subjects being observed showed a larger increase in sweating from baseline to task than did subjects in the alone condition. As predicted by social facilitation theory (Zajonc, 1965), subjects in the audience condition also made more errors during learning.

In separate papers Martens (1969b, 1969c) provided more detail concerning this study. After the learning phase of the experiment subjects continued to perform the task, either alone or with an

audience. Two conditions of learning crossed with two performance conditions giving four groups in all. While the presence of the audience during learning led to more errors at the start of the learning phase, the presence of an audience for performance led to fewer errors towards the end of the experiment. The increased PSI found in the audience condition during learning carried over into the performance phase. There was also an additional increase in sweating in those subjects who had an audience during performance, so that the learn-audience/perform-audience group sweated most during performance and the learn-alone/perform-alone group sweated least.

Subjects were also subdivided into groups scoring high and low on the Taylor manifest anxiety scale. Anxious subjects did not sweat more than low anxious subjects. However anxious subjects did perform better toward the end of the learning phase and during the performance phase.

This study has since been criticized by Landers, Bauer & Feltz (1978, 1979). They raised two points. One concerned the scoring of the task Martens used (see Martens, 1979 and Landers, Bauer & Feltz, 1979 for further discussion). The second point they raise concerns the formula for the PSI used by Martens. Martens used the standard formula suggested by Johnson & Dabbs (1967). Using this formula Landers et al. (1978) could only obtain prints from 21 out of 60 subjects. Not surprisingly, their results did not reveal a significant effect on the PSI of their audience manipulation. Landers et al. report that their PSI measures decreased from below pre-task levels during the task, although the change was not significant. The change was greatest for the no-audience group, i.e. sweating was higher in the presence of an audience. They suggest that the PSI formula should be modified to contain twice as much graphite (40gms versus 20gms per 100ml of solvent) in order to produce more durable prints. This modification is

attributed to Harris, Polk & Willis (1972). However Harris et al. recommended that the amount of graphite be increased in order to provide greater contrast, rather than to increase the durability of the measure. It is not clear what role, if any, the graphite plays in the actual formation of the print. Indeed some workers (e.g. Vogeles & Steptoe, 1986) successfully use the PSI with no graphite at all. While the results of Landers et al. did not reveal a significant increase in sweating, they agree that the social facilitation effects demonstrated in their own data and in those of Martens are indicative that "autonomic arousal may be the underlying mechanism".

Cohen has also carried out two studies examining the occurrence of audience effects on the PSI and on task performance (Cohen & Davies, 1973; Cohen, 1979). In the first study Cohen & Davies (1973) contrasted the "mere presence" hypothesis of audience effects (Zajonc, 1965) with the "evaluation apprehension" theory (Cottrell, 1968). Subjects were given a series of anagram problems. The first 13 anagrams gave the name of an animal, producing a problem-solving set. The next four anagrams had an additional, easier, solution. The last anagram could only be solved by breaking the set. Their subjects were divided into eight groups consisting of every combination of three different factors. These were 1) audience status, student peers versus faculty members, 2) observation by the audience versus evaluation and 3) current evaluation through a one way mirror versus later evaluation on videotape. Overall, the results provided some support for both hypotheses. All audience conditions led to fewer non-set solutions than the control conditions, demonstrating that the presence of an audience does affect performance. However, the evaluation groups showed fewer non-set solutions than did the observation groups, implying that the effect is exacerbated by evaluation. Closer analysis reveals a

more complicated pattern. In the extinction phase the video groups produced more errors than the mirror groups (a non-set response being required to solve the anagram). The control groups (who took part in the same rooms, but with no mention of the, fictitious, audience) also gave more non set solutions in the mirror condition, implying that the video camera itself may have led to greater arousal. For the performance phase these results are complicated by an interaction with the time of observation factor. Video recording led to more non-set solutions than did observation via a one-way mirror, but only in the evaluation condition, there was a non-significant trend in the opposite direction in the observation condition.

The PSI data imply that the video condition produced greater arousal. Subjects in the video condition showed little overall change in sweating over time, whereas subjects in the mirror condition showed the typical pattern of adaptation over time. The PSI did not respond to the other factors in the experiment.

Both the PSI data and some of the performance findings are consistent with higher arousal in the video condition than in the mirror condition (as indicated by palmar sweating and fewer non-set solutions). However, the complexity of the performance results makes firm conclusions impossible.

In a later study Cohen (1979) attempted to resolve some of the ambiguity of the results of this experiment. The basic design of this study was similar to that of the Cohen & Davis study. All subjects were given the same anagram task in a room containing a video camera. For the control group the camera was not operating. The experimental groups were told either that the camera was recording, producing a permanent record of their behaviour, or that the camera was connected to a monitor in another room, where the audience were watching. Half

of the experimental subjects were told that the audience were peers and half were told that the audience consisted of authority figures.

In the performance trials the permanent record conditions led to fewer non-set solutions, implying that these conditions do lead to greater arousal. As predicted the control group gave more non-set solutions than the experimental groups. The PSI data revealed that the permanent record groups had higher scores than the non-permanent record groups. However the control group did not differ significantly from the experimental groups. Furthermore, measures taken while performing the task, or more accurately in between the trials, were lower than those prior to the task or during debriefing.

Within the experimental groups the PSI gave results consistent with the behavioural data, implying that the PSI may be sensitive to the arousal produced by the manipulation. The absence of a significant difference between the experimental and control groups is surprising. In particular it is apparent from Cohen's data that the control group showed little sign of the decreased sweating during the task revealed by the experimental groups. This may be another example of a situation where the PSI appears to decrease in response to a manipulation which would be expected to lead to an increase. Within the experimental groups, however, the results supported an increase, between subjects, in response to the presence of an audience. The decrease in sweating in the experimental groups might represent another occurrence of a "rebound" decrease in activity after a task, as Cohen did not obtain the PSI while subjects were actually solving the problems.

While not undertaken within the framework of social facilitation theory, the findings of another study demonstrate an effect of evaluation anxiety on the PSI. Gill (1980) compared the response of two measures of sweating, and of the state form of the State-Trait

Anxiety Inventory (STAI) to pre-competition anxiety. The other measure of sweating used was the Sudorimeter, a device which assesses the density of palmar sweat prints photometrically. Gill reports that all three measures were higher when obtained before a volleyball competition than when obtained prior to a regular practice session, although the difference was non-significant for the STAI. The size of the effect was larger for the PSI than for the sudorimeter, implying that the PSI was more sensitive to the evaluative anxiety aroused by the impending competition than the other measures. However correlations between the measures were small and non-significant.

Two studies have examined the effect of a mirror on palmar sweating. In one, Paulus, Annis & Risner (1978) gave subjects a prose-copying task. One group of subjects were told the task was a test of ability and intelligence, the high-evaluation group, half were given neutral instructions, the low-evaluation group. Additionally, half of the subjects in each group were facing a mirror for the second task period. This experiment was intended to compare another explanation of audience effects, the objective self-awareness theory (Duval & Wicklund, 1972), with the evaluation theory. The objective self-awareness theory claims that audience effects arise because the presence of an audience leads to increased self-awareness and a greater motivation to meet standards. The mirror was predicted to produce increased self-awareness, producing a "social facilitation" effect in the absence of increased arousal.

Performance on the task revealed an interaction between the mirror and evaluation manipulations. Subjects in the low-evaluation group copied more prose when a mirror was present than with no mirror. Subjects in the high-evaluation group, however, performed worse in the presence of a mirror. Paulus et al. suggest this may reflect an

inverse-U relationship between performance and evaluation. Either the mirror or high-evaluation instructions alone serving to increase performance, but when both were present the degree of evaluation was sufficiently high to interfere with performance. The PSI data, however, did not reveal similar effects as a result of the two different manipulations. The high-evaluation instructions led to increased sweating after the task, presumably due to the imminent evaluation of performance. The mirror, in contrast, produced a decrease in sweating after it was revealed. Paulus et al. explain these results by reference to Johnson & Dabbs' (1967) proposal that changes in the PSI may reflect the direction of attention. Specifically they suggest that the presence of a mirror may increase self-awareness and so lead to inwardly-directed attention and a decreased PSI. Evaluation, in contrast, may lead to increased motivation and increased attention to the source of evaluation, in this experiment, the experimenter. Externally-directed attention is claimed to lead to increased sweating.

Carver & Scheier (1981) point out that neither Paulus, Annis & Risner (1978) nor Martens (1969a, b, c) took sweat prints during their task. There is, therefore, no direct evidence that the performance effects obtained in these studies are, in fact, related to the differences in sympathetic activation found.

Carver & Scheier (1981) examined the effects of a mirror, the presence of the experimenter and no manipulation on sweating before, during and after the task used by Paulus, Annis & Risner (1978). Performance on the task replicated the findings of Paulus et al., subjects in the mirror and audience conditions copied more letters than control subjects after the manipulations were introduced. They did not include a group which received both manipulations, so the

predicted disruptive effects of both manipulations together were not examined. Their physiological data did not replicate the findings of Paulus et al.. The only significant effect of the manipulations was a significant increase in sweating in the audience group at the time the manipulation was introduced, in between the two task periods. The mirror produced a slight, non-significant increase, relative to the control group. The measures taken during the task revealed similar levels in all of the groups. However, for both task periods, levels during the task were significantly below those recorded in the rest periods. These results support the findings of earlier studies, demonstrating that the presence of an audience does lead to increased sweating. However, more surprising is the evidence that the task used, copying german prose, apparently led to a decrease in sweating, relative to a resting baseline.

5.8.2 Implications of research into audience effects for the interpretation of the PSI. Table 6 provides a summary of the results of studies using the PSI to investigate audience effects. The results of these studies seem to support a relationship between the PSI and the arousal believed to be produced by the presence of an audience. The exact nature of this arousal needs to be defined. Prior research indicates that an audience does not produce a non-specific increase in all possible indices of sympathetic activation. While research using the PSI and electrodermal measures provides support for increased arousal in the presence of others, research using cardiovascular measures has failed to reveal any such effects (Moore & Baron, 1983).

The exact cause of the effects is also in need of clarification. Zajonc (1965) claims that increased arousal occurs automatically, as a result of the mere presence of an audience, independently of any

specific evaluation anxiety. Cottrell et al. (1968), in contrast, claim that this arousal is largely the result of apprehension concerning possible evaluation. The results described here imply that it is this evaluation apprehension to which the PSI is responding. In particular the two studies described by Cohen demonstrate that observation alone may not lead to increased sweating. Only when a permanent record, with the possibility of closer scrutiny, is made do subjects show greater sympathetic activation. Landers, Bauer & Feltz (1978) report that Martens (1979 a,b,c) also videotaped his subjects, so that the results of this study are also consistent with an increase in response to permanent recording, rather than observation per se. This conclusion is consistent with the results of the applied studies described in sections 5.4 and 5.5 which imply that the PSI may be sensitive to other forms of anxiety.

At present it is unclear what effect the presence of a mirror has on palmar sweating. Paulus, Annis & Risner (1978) found a significant decrease in sweating as a result of the presence of a mirror. Carver & Scheier (1981) report a non-significant increase under similar circumstances.

One point which needs to be emphasised is that two of the studies covered in this section, those by Cohen (1979) and Carver & Scheier (1981), reveal a decrease in the PSI while subjects were performing a task. Carver & Scheier (1981) took measures while subjects were actually performing the task, so the decrease in sweating appears to be a product of the task itself, rather than an effect of adaptation or a measure of recovery after the task.

Table 6: Audience effects and the PSI

Study	Subjects	Manipulation	Results
Carver & Scheier (1981)	Students 24M, 16F	Prose copying with audience or mirror.	Task reduced sweating. No effect of mirror. Audience increased the PSI.
Cohen (1978)	Students, 60M, 60F.	Solving anagrams in front of a camera. two levels of audience status plus observation vs recording.	Recording > observation. Task depressed the PSI.
Cohen & Davis (1973)	Students, 100M, 100F.	Solving anagrams in front of one-way mirror or camera. Two levels of audience status plus evaluation vs observation.	Mirror condition < video condition. Mirror group showed adaptation, video group did not. No effect of audience status or evaluation vs observation.
Gill (1980)	Students 18F	Measures taken prior to a volleyball match and a practice session.	Match > Practice. PSI did not correlate with state anxiety or colorimetric sweat gland count.
Landers, Bauer & Feltz (1978)	Students, 60M.	Learning a motor task while being videotaped observed.	No significant effects. N.B. only 21 subjects had usable PSIs.
Martens (1969a)	Students, 48M	Learning a motor task in the presence of an audience.	Audience group > alone group. All learning measures were above baseline.

Study	Subjects	Manipulation	Results
Martens (1969b)	Students, 48M, Split on trait anxiety.	Learning & performing a motor task in the presence of an audience.	No effect of anxiety. Presence of an audience during learning or performance produced independent increases in the PSI during performance.
Paulus, Annis & Risner, 1978	Students 40F, 15M	Prose copying in the presence of a mirror. Two levels of evaluation.	Mirror reduced sweating. Evaluation increased the PSI.

The most important conclusion to be drawn from the work on audience effects is that the PSI is sensitive to social manipulations. This has implications for the design of experiments using the PSI, as the PSI may be influenced by the presence of the experimenter. Such a possibility is not restricted to the PSI, Caccioppo et al. (1990) provide a discussion of the implications that work on audience effects has for psychophysiological research in general. However, this is particularly important as the PSI, unlike electrodermal measures, requires the experimenter to be with the subject throughout the experiment. The possible effects of the experimenter's presence need to be considered when designing and interpreting studies. Care is also needed to reduce the possible influence of experimenter effects. For example, by using a single experimenter for all subjects.

6 Summary

This chapter has reviewed the literature concerning the Palmar Sweat Index. The variety of the literature, together with the scarcity of methodologically adequate studies, makes it difficult to draw firm conclusions. Three properties of the PSI need to be demonstrated before the PSI can be accepted as a useful research tool.

Firstly it needs to be shown that the PSI has acceptable reliability. There is considerable agreement that the PSI shows very high inter-rater reliability. With regard to the test-retest reliability of the PSI, the degree of temporal stability shown by the index, there is little evidence. Two studies do however imply that there may be considerable stability in the amount of sweating shown by individuals at different times. It is unclear what significance this stability might have. While the studies reported by Bradshaw, Szabadi and co-workers provide evidence that clinical anxiety may lead to

individual differences in sweat gland activity, studies examining dermal fear have largely failed to find significant individual differences in the PSI as a function of trait anxiety, even under threatening circumstances. Thus at present it seems unlikely that this temporal stability is related to stable psychological factors. The degree of consistency shown by the PSI, together with the extent to which the PSI is influenced by psychological traits is in need of further investigation.

Studies by Bailes (1983) and Voegelé et al. (1988) imply that the reliability of the PSI may be moderate to zero when prints taken from different sites at the same time are compared. If this finding were to be replicated this would cast doubt on the utility of the index. This is clearly one question in need of further investigation.

The second question to be addressed is the relationship between the PSI and electrodermal activity. Studies which have compared measures taken at the same time have generally demonstrated that the PSI does correlate significantly with SCL. Such correlations are, however, generally found to be fairly small. There is a need for a comparison between the PSI and other parameters of EDA, particularly NS-SCR frequency.

The final topic to be discussed is the validity of the PSI as an index of psychological constructs such as arousal, anxiety or "stress". The series of studies carried out by Harrison & Mackinnon, together with several replications demonstrate that physical stressors (surgery and straight-leg raising) lead to a hormonally-mediated suppression of palmar sweating following the stressor. However, such an effect has not been reliably demonstrated following psychological stressors and does not appear to occur during, as opposed to after, physical stress.

The immediate response to psychological stressors appears more mixed. Tasks such as mental arithmetic or anagram solving do not seem to lead to a consistent increase in sweating. Johnson & Dabbs' suggestion that concentration may lead to a suppression of sweating is worthy of investigation as several different studies seem to show a decrease in sweating in association with this type of task. The time course of the PSI response is also in need of further investigation as many studies have not obtained the PSI during the task itself. If the response shows rapid recovery, these measures may not reflect the effects of the manipulation.

The most reliable relationship appears to be with fear or anxiety. The studies investigating modelling and fear of surgery, as well as the majority of studies examining dental fear, all demonstrate increased sweating with increased fear. Although, in common with EDA, increased sweating, as measured by the PSI, may not be correlated with the report of anxiety. Studies examining audience effects may also be taken as supporting a relationship between the PSI and anxiety. The studies carried out by Cohen imply that, rather than the mere presence of an audience, it is conditions arousing evaluation apprehension which give rise to increased sweating. One conflicting finding is that reported by Martens & Landers (1970). This study appears to demonstrate a decrease in sweating as a result of the threat of electric shock, despite effects on performance and on self-reported anxiety. As this study did not assess sweating during performance of the threat-motivated task examination of the time course of the response to threat may clarify the results of this study.

The studies involving surgical and dental fear provide a good example of the utility of the PSI in a clinical setting. The studies carried out by Bradshaw & Szabadi, as well as Bagg & Crookes' (1966)

demonstration of lower sweat gland activity in depressed patients, show that the PSI may provide a useful tool for the investigation of the psychophysiology of behavioural disorders. Electrodermal activity has been widely used to examine the nature of various types of psychopathology. As an illustration of potential areas of application of the PSI these clinical applications of EDA will be reviewed in chapter 4.

Chapter 4

Clinical Applications of Electrodermal Activity

1 Introduction

1.1 The use of Psychophysiological Measures in Clinical Psychology

Measures of electrodermal activity have been studied in relation to many areas of psychopathology (for reviews see Zahn, 1986; Turpin, 1989). Such interest dates back to the very earliest research using electrodermal measures. One rationale for the use of psychophysiological measures in clinical research is that such measures may be more directly related to the presumed underlying causes of psychopathology than are subjective measures or patterns of symptomatology.

Psychophysiological techniques may be used in two, not unrelated, ways. Firstly, such measures may serve as biological markers (see Iacono & Ficken, 1989), that is, psychophysiological measures may allow the identification of clinically significant groups not apparent from other observations.

Biological markers are traditionally associated with the search for a genetic basis to psychopathology. Markers which reveal the presence of an inherited predisposition are termed genetic markers. However, other types of marker are possible (see Zubin & Steinhauser, 1981). Such markers may serve several purposes. They may provide prognostic information, for example by identifying sub-groups likely to respond to a particular treatment. Such markers might also be used as diagnostic aids, revealing similarities between individuals who may show apparently different patterns of symptoms or, conversely,

identifying homogeneous subgroups within a single disorder.

Biological markers may be vulnerability markers, present in remission or prior to the development of a disorder, or they may be state markers, present only during illness episodes.

The second use to which psychophysiological measures may be put is as indices of psychological processes. Variables such as electrodermal activity may be used as indirect indices of processes such as arousal or anxiety. Such process measures may be used to identify sub-groups of patients in need of specific interventions, such as stress management training, or as an outcome measure, for example as an index of anxiety reduction (see Haynes, Falkin & Sexton-Radek, 1989; Turpin, in press). Psychophysiological measures may also provide direct measures of symptomatology in disorders such as migraine or hypertension.

Obviously these two interpretations are not mutually exclusive. State measures may be used as markers of relatively stable individual differences and, conversely, once valid markers are identified for a given disorder they may be interpreted in terms of differences in variables such as attention or arousal, providing evidence concerning the psychological or physiological mechanisms underlying the disorder.

The next section will review existing models of psychopathology, in order to provide a conceptual framework for the use of psychophysiological measures within the study of psychopathology.

1.2 Models of Psychopathology

In contrast to early biomedical models of disease, recent approaches to the etiology of disease, whether physical illness or psychopathology, emphasise the interactional nature of the disease process. It is recognised that biological pathogens alone are

inadequate to explain the development of disease. Social and psychological factors may influence both the onset of disease and the course of the disorder. Solely environmental or behavioural explanations of disease are also seen as inadequate (O'hagan, 1981b). Such models fail to take account of the influence of predisposing factors, and are clearly inappropriate for disorders, such as schizophrenia, which include a genetic component (Kety et al., 1983)

With regard to psychopathology the interactional view is typified by the development of diathesis-stress models of psychiatric disorder (e.g. Zubin & Spring, 1977). Such models see psychopathology as the result of an interaction between an existing predisposition, including both genetic and acquired factors, and environmental influences which lead to the onset of the disorder. One particular class of triggering events, which have been shown to be associated with the onset of a variety of psychiatric disorders, is stressful life-events (see Katschnig, 1986).

Diathesis-stress models offer several possibilities for the use of psychophysiological techniques. Such models emphasise the importance of vulnerability factors which exist prior to the onset of clinical disorder and overt symptomatology. Psychophysiological measures may provide indices of such vulnerability factors. In addition, physiological variables are often claimed to be sensitive to experienced stress. Thus, there is reason to believe that psychophysiological techniques might also be of use in assessing the stress component of the diathesis-stress interaction (e.g. see Turpin, Tarrrier & Sturgeon, 1988). Finally, the use of biopsychosocial models requires an integration between factors acting at biological, psychological and social levels. Psychophysiological theories have much to offer this type of integrative approach and such models may

include psychophysiological constructs as mediating variables (e.g. Nuechterlein & Dawson, 1984).

1.3 Problems of Research in Clinical Psychophysiology

In any area of research the conclusions to be drawn from a study are limited by the accuracy with which the independent variables are specified. Thus, clinical psychophysiology is dependent upon the accuracy and reliability of psychiatric diagnosis. While recent advances in the reliability of diagnosis, represented by such systems as the research diagnostic criteria (Spitzer et al. 1977), have resolved many of the problems encountered by earlier studies, there are still difficulties in the definition of many forms of psychopathology. Thus, patient groups used in different studies may not be comparable, particularly when studies are undertaken at different times, or in different countries. There may also be distinct sub-groups, possibly with differing patterns of physiological activity, within a single diagnostic category.

Studies using clinical populations also need to control for such factors as medication status. Psychotropic medication may have effects on psychophysiological activity, leading to artifactual differences between patient and control groups. Conversely, such medication might serve to normalise physiological activity in psychiatric groups, removing meaningful group differences. Hospitalized patients may also differ from non-hospitalized controls in other ways unrelated to their psychopathology. Factors such as activity level, diet and the social environment may lead to artifactual differences in EDA.

Psychiatric groups may also show atypical responses to the experimental situation, so that differences obtained may reflect non-specific factors such as anxiety, or a failure to follow

instructions, rather than abnormal physiological or psychological functioning. Gale & Baker (1981) provide a critical view of the social psychology of psychophysiological experimentation. It is likely that psychiatric groups may be especially sensitive to the influences they describe.

The following sections will provide an overview of research in three areas of psychopathology, anxiety, schizophrenia and depression, in which EDA has been applied. These sections will also highlight areas where the PSI might contribute to research.

2 Electrodermal Activity and Anxiety

2.1 The Psychology of Anxiety

Anxiety can be experienced both as a severe clinical condition and as a transient emotion in everyday life. Furthermore, the symptoms of clinical anxiety do not appear qualitatively different from those of "everyday" anxiety. Clinical anxiety disorders may, therefore, be viewed as merely the extremes of the distribution of trait anxiety. Anxiety disorders can take several forms. Anxiety may be general or specific with regard to both time and place. More specific forms of anxiety, such as phobias, may not interfere with social functioning to any appreciable extent. For these reasons, anxiety has been studied from a slightly different viewpoint to the other disorders to be covered in this chapter. While some workers have investigated the use of psychophysiological variables as markers for anxiety disorders, comparing patient groups with normal subjects, there has been more interest in the use of measures such as electrodermal activity as process measures, indicating the strength of anxiety within both clinical and normal populations.

An important distinction in the psychology of anxiety is that

between trait and state anxiety (Spielberger, 1966, 1972). Trait anxiety refers to a general predisposition to experience anxiety under appropriate circumstances, while state anxiety refers to the actual emotion itself. Individuals differing in level of trait anxiety may only have different levels of state anxiety in anxiety-provoking situations. Physiological measures are presumed to reflect state rather than trait anxiety.

While trait anxiety might be expected to correlate with indices of state anxiety under threatening circumstances, such scales are rarely found to be good predictors of behavioural or physiological indices of anxiety (e.g. see Hodges, 1976; Levitt, 1967). Attention has recently been focused on the effect of coping strategies and response style on the relation between trait scales and behavioural measures (e.g. see Kiable & Posnick, 1967; Weinberger et al., 1979; Asendorpf & Scherer, 1983). Individuals high on traits labelled variously repression, defensiveness or self/other deception may be less willing to report and/or less aware of unpleasant or threatening information and so may score low on trait anxiety scales even though they may show signs of higher anxiety on physiological or behavioural measures.

In addition to general trait anxiety, various forms of specific anxiety can be assessed including test anxiety, social anxiety, various phobias etc. State anxiety has also been sub-divided into various different states. The most common division is that between cognitive and somatic forms of anxiety, often called Worry and Emotionality (Liebert & Morris, 1967; Schwartz, Davidson & Goleman, 1978). Worry refers to mental preoccupation with possible negative outcomes. Whereas Emotionality refers to the awareness of emotional arousal, including physiological symptoms. Although it is the

awareness of these symptoms which is addressed by scales of emotionality, rather than the symptoms themselves. High emotionality may not imply high levels of autonomic activity (e.g. Morris & Liebert, 1978; Holroyd et al., 1978).

Autonomic activation is perceived to be a central part of anxiety. Folklore attributes sweaty palms to anxiety. Electrodermal activity, together with other measures such as heart rate and EMG measures of muscle tension, is commonly used as an index of anxiety. However, as mentioned in chapter two, such measures generally show only weak covariation (Rachman & Hodgson, 1974). In particular measures of sweat gland activity are not generally found to correlate with measures of trait anxiety, and correlations with questionnaire measures of state anxiety may be weak. Thus EDA and other autonomic variables are not considered to be pure measures of anxiety, rather they are seen as correlates of one component of a multifaceted response including cognitive and behavioural components, as well as physiological responses.

Research into the psychophysiology of anxiety has also benefitted from a more theoretical approach than similar research into depression and schizophrenia. In particular, Lang has proposed an influential model for the integration of responding in these three systems (Lang, 1968, 1977, 1979, 1985; Lang et al., 1983). Lang views emotions as being organised into propositional networks combining stimulus, response and meaning propositions. Response propositions may exist for responses in any or all of the three systems, physiological, cognitive or behavioural. Phobias would represent highly coherent networks and can be considered to be emotional prototypes. While influential, this theory leaves several questions unanswered. Both the three-systems model of fear (Hugdahl, 1981) and Lang's views on the role of

emotional imagery (Watts & Blackstock, 1987) have been criticized. Several aspects of the model are poorly specified and, while the model has generated a considerable body of research, there has been little attempt to specifically test the adequacy of the model.

Another theory which directly addresses the role of psychophysiology in anxiety has already been mentioned in chapter two. That is Fowles' (1980) integration of Gray's view of motivation (e.g. see Gray, 1977) and psychophysiology. This theory treats anxiety as the product of a specific neural system, underlying passive avoidance behaviour. This system, the Behavioural Inhibition System (BIS), inhibits on-going behaviour in response to novel stimuli or stimuli associated with punishment or non-reward. Fowles (1980) suggests that the activation of the BIS may lead to an increase in skin conductance response frequency. Thus he proposes that EDA may be a specific index of anxiety. Although Fowles points out there are almost certainly other influences on EDA. The model of anxiety used is fairly specific, so that not all situations commonly believed to be anxiety-provoking would lead to the activation of the BIS. In particular active avoidance behaviour is claimed to have a different neural substrate, which Fowles links to increased heart rate.

The next two sections of this chapter will review research on two forms of anxiety which have received a great deal of research attention. These are phobic anxiety and test anxiety. The review of phobic anxiety will primarily concentrate on social phobias, as the program of research includes an investigation into the relationship between social anxiety and the PSI. The second type of anxiety, test anxiety, is of interest both because of the availability of student subjects and because of the potential detrimental effects this form of anxiety may have on performance. The program of research to be

described also includes an investigation of test anxiety.

2.2 Electrodermal Activity and Phobic Anxiety

Phobias are specific fears of particular objects or situations. They are distinct from free-floating anxiety or forms of anxiety centred on panic attacks, which may have no apparent cause. Phobias range from specific fears of single objects such as snakes or spiders, through fear of general situations such as public speaking to more general fears such as social phobia.

Phobias are most common with regard to a very limited set of objects. It has been suggested that phobias may be an example of biologically-prepared learning (Seligman, 1971). While the acquisition and extinction of phobias are believed to follow the normal rules of learning, it is claimed that some objects are more easily associated with fear than others. This preparedness is a result of evolutionary selection for avoidance of objects or situations which may have been associated with potential danger in man's past.

The preparedness theory of phobias has been tested using electrodermal measures of fear conditioning (see McNally, 1987 for a recent review of this research). There is evidence from a number of studies that skin conductance responses aversively conditioned to prepared stimuli, such as snakes, show greater resistance to extinction than responses conditioned to non-prepared stimuli (e.g. Ohman, Eriksson & Olofsson, 1975). Predictions of more rapid acquisition of fear to prepared stimuli and reduced dependence of such conditioning on cognitive processes have not been adequately supported.

Ohman, Dimberg & Ost (1985) extend the biological analysis of phobic anxiety to an examination of the implications for different

phobias. They specifically concentrate on animal and social phobias. Animal fears, they claim, are an example of a fear based on physical threat and so are primarily directed towards escape or avoidance of the threatening stimulus. In addition, animal fears should emerge when humans would be most vulnerable to predators, i.e. in infancy. In contrast, they trace social phobias to mammalian social behaviour. They claim social fear is biologically prepared to maintain the status quo in dominance hierarchies. This type of fear will be less organised around active avoidance and should be typified more by enhanced alertness and passive avoidance. Social fear should also emerge later than animal fears.

There is evidence in support of these claims. Animal and social phobias typically show different ages at onset, with animal phobias emerging in infancy, while social phobias typically appear after puberty (Marks, 1969). The claimed greater avoidance component of animal phobias would imply that animal phobias would be more strongly associated with heart rate acceleration than social phobias. As skin conductance orienting appears to be as strongly related to increased attention as to emotional responding, socially-anxious subjects should show equal or greater electrodermal responsivity to animal phobias. This pattern was found by Lang et al. (1983). Snake phobics showed higher heart rate than socially-anxious subjects when confronted with a snake, however when giving a talk both groups showed similar elevations in heart rate, presumably due to the physiological demands of the task. Thus, only snake phobics showed excessive heart rate reactions to their feared situation. For skin conductance responses both groups showed elevated conductance in response to the relevant situation. When speaking socially-anxious subjects showed significantly higher SCL than snake phobics.

2.3 Test Anxiety

Test anxiety provides an ecologically valid form of anxiety which can be studied under relatively controlled conditions. For this reason test anxiety has been widely studied, both as a model of anxiety in general, and with a view to countering the supposed detrimental effects of test anxiety on performance. As mentioned earlier, many workers have stressed the importance of cognitive components of anxiety as determinants of exam performance (Liebert & Morris, 1967, Deffenbacher, 1980; Morris et al., 1981; Deffenbacher, 1986). This approach splits test anxiety into two components, termed worry and emotionality. Worry refers to cognitive preoccupation with the exam, whereas emotionality includes perceived emotional and physiological arousal. Emotionality is generally not found to correlate well with objective measures of autonomic activation, rather emotionality seems to reflect the degree of attention given to the signs of arousal (Morris & Liebert, 1970; Deffenbacher & Hazaleus, 1985).

It has been found that worry is usually a better predictor of examination performance than emotionality or physiological activation (see Deffenbacher, 1980; Holroyd et al., 1978). However, recent studies imply that the relationship between worry and performance may be artifactual. Two studies have found performance on previous examinations to be a much stronger predictor of future performance than either worry or emotionality (Sewitch, 1984, cited in Neiss, 1988; Galasi, Frierson & Sharer, 1981). These studies imply that the relationship between worry and performance may not be a result of the effects of worry-induced distraction during the exam. Rather such effects may be found because both worry and examination performance are determined by factors related to past performance. Test-anxious

students may worry more because they have performed poorly on tests in the past.

Despite the emphasis placed by many workers on cognitive factors in test anxiety, examinations have been shown to lead to changes in many physiological variables. Variables shown to respond to examination stress include heart rate (Deffenbacher, 1986), plasma levels of both adrenocortical and adrenomedullary hormones (Herbert et al., 1986), plasma levels of prolactin (Herbert et al., 1986; Vassend, Halvorsen & Norman, 1987) and blood pressure (Vassend, Halvorsen & Norman, 1987). Surprisingly, there has been little investigation of the effects of examination anxiety on skin conductance. Skin conductance has been found to increase in response to analogue tasks, intended to reproduce examination anxiety (Holroyd et al., 1978; Hollandsworth et al. 1979). Several early studies found examinations to increase other measures of sweat gland activity (Beam, 1955; Davis, 1957; Gladstone, 1953).

2.4 Electrodermal Activity and Clinical Anxiety

Several studies have compared groups undergoing treatment for various anxiety disorders with regard to electrodermal activity. Despite a tendency for early studies to combine groups suffering from different disorders, the results are quite consistent. In general, patients suffering from anxiety disorders are found to show higher tonic EDA and to show slower habituation than normals (e.g. see reviews by Lader, 1975; Zahn, 1986). When patients with different anxiety disorders are compared, only patients with simple phobias are found to differ, showing normal rates of habituation (Lader, 1967). Simple phobics have also been found to show more normal levels of cardiovascular activity (Kelly, 1980).

Subjects with temporally discrete forms of anxiety disorder, phobias and panic disorders, have been found to show increased electrodermal activity in times of anxiety. Phobics have been found to show larger SCRs and more frequent NS-SCRs in response to the presentation of their phobic stimulus (e.g. see Sartory, 1986). The experience of naturally-occurring panic attacks has also been shown to be associated with heightened EDA (Lader & Mathews, 1970; Cohen, Barlow & Blanchard, 1985). However, panic induced in the laboratory is not consistently found to involve increased EDA, despite increases in heart rate (Knott, Chaudry & Lapierre, 1981; Lapierre, Knott & Gray, 1984; Freedman et al., 1984). Electrodermal activity has also been found to increase during obsessional rumination (Rabavilas & Boulougouris, 1974).

2.5 Electrodermal Activity and the Treatment of Anxiety

In clinical studies there has been extensive interest in the relationship between EDA and treatment of anxiety. Several studies have shown that drugs which are effective in reducing anxiety lead to reductions in both tonic and phasic EDA (Lader & Wing, 1966; Bond, James & Lader, 1974; Zahn, Insel & Murphy, 1984), although there are negative findings (Kelly, Brown & Shaefer, 1970; Taylor, Kenigsberg & Robinson, 1982). However, most attention has been focused on the treatment of anxiety by behaviour therapy.

In studies of systematic desensitization, the physiological response to the stimuli is usually found to parallel their perceived fearfulness (Van Egeren, Feather & Hein, 1971; Lang Melamed & Hart, 1970). There is also evidence that high levels of autonomic activation may be indicative of poor response to desensitization. Marks, Boulougouris & Marset (1971) found higher levels of NS-SCRs, and also

high heart rate, to predict poorer clinical outcome after desensitization. Similarly Lader, Gelder & Marks (1967) found correlations of .49 and -.47 between treatment outcome and SCR habituation rate and NS-SCR frequency respectively.

As non-specific response frequency usually correlates well with speed of habituation, these findings imply that speed of habituation may be the critical factor. If habituation during desensitization is a major determinant of treatment outcome, then direct assessment of habituation during treatment should correlate with other indices of outcome. Two studies indicate that heart rate habituation correlates significantly with treatment outcome (Lang, Melamed & Hart, 1970; Kozak, Foa & Steketee, 1988), although neither study found a significant relationship between electrodermal response habituation and outcome. Kozak et al. (1988) explain their findings in terms of Foa & Kozak's (1986) model of emotional processing. They suggest that the physiological response is an index of the activation of the mental representation of the feared stimulus. Habituation of the response, they claim, provides an index of the modification of that representation.

Treatment of anxiety by flooding has also been the subject of psychophysiological investigations. In contrast to desensitization, high levels of autonomic activity, both to feared and neutral stimuli, seem to be predictive of a favourable response to flooding (Marks, Boulougouris & Marset, 1971; Watson & Marks, 1971; Stern & Marks, 1973; Boulougouris, Rabavilas & Stefanis, 1977), although correlations between EDA and physiological outcome measures are a more frequent finding than significant correlations between EDA and other measures of the response to treatment. Mathews et al. (1976) failed to find a significant correlation between electrodermal activity and treatment

outcome.

The apparent difference between desensitization and flooding, with regard to physiological predictors of treatment outcome, implies that the two treatment methods might involve slightly different processes. There is evidence to imply that desensitization may involve habituation, so that high levels of autonomic activation, which slows habituation, may interfere with treatment. Flooding can be viewed as a process of extinction by the prevention of avoidance responses. Autonomic activation may serve to increase the efficiency of this conditioning process. In addition, the process depends upon an initial motivation to avoid the feared stimulus. High levels of autonomic activity may also serve to identify those subjects who show the strongest fear.

2.6 Summary

Electrodermal activity seems to be strongly related to both clinical and less severe manifestations of anxiety. The experience of anxiety is associated with elevated levels of EDA, both between and within individuals. Furthermore, level of EDA prior to treatment seems to be predictive of the response to treatment, although the direction of this relationship seems to differ for desensitization and flooding. One conclusion which stems from these findings is that subjects with different levels of responsivity should respond optimally to different treatments. Thus, measures such as the PSI might be useful as assessment instruments prior to behaviour therapy.

Recent emphasis on the multidimensional nature of anxiety also stresses the need for assessment and treatment of responses in all three domains. The three systems model of anxiety implies that "anxiety" comprises a variety of different states, characterised by

different patterns of responding. Individuals responding primarily in different systems may require different treatments. Thus, recognition of the existence of individual response specificity necessitates assessment of all three domains of anxious expression, cognitive, behavioural and physiological.

In contrast to the other disorders to be reviewed, recent theoretical developments provide a framework for the use of measures of electrodermal activity in anxiety research. The use of portable measures such as the PSI might allow such research to be extended beyond the use of artificial stimuli in student populations. At present most non-clinical research uses either pictures of stimuli such as snakes or faces or has subjects imagine their feared situation. Even when forms of anxiety with greater ecological validity, such as test anxiety or public-speaking anxiety are studied, experiments often use analogue designs, whose relationship to the real focus of the anxiety is questionable. Portable measures would allow the investigation of test or social anxiety in field settings, using stimuli with greater ecological validity.

3 Electrodermal Activity and Schizophrenia

3.1 The Psychology of Schizophrenia

Schizophrenia is a serious disorder affecting about 1% of the population. It is an episodic condition, in one study around 28% of patients relapsed within nine months of recovery (Vaughn & Leff, 1976). Even after recovery, a high proportion of schizophrenics show impaired social functioning (Johnstone et al., 1984). The core symptoms of schizophrenia are hallucinations, delusions and thought disorder (Schneider, 1959). However, the symptoms experienced during

the disorder may vary enormously, both between and within individuals. Because of the variety of symptoms that may be displayed, schizophrenia is often characterised as a cluster of heterogeneous disorders rather than a single entity.

Schizophrenia seems to provide a classic example of a stress vulnerability interaction, as both genetic (e.g. Gottesman & Shields, 1982) and social factors (e.g. Turpin, Tarrrier & Sturgeon, 1986) have been shown to influence the disorder. Neale and Oltmans (1980) provide a comprehensive overview of the topic of schizophrenia.

The nature of the symptoms of schizophrenia, which have been attributed to abnormalities in attention (McGhie & Chapman 1961), in the regulation of arousal (Claridge & Clark, 1982), disturbances of limbic function (Venables, 1973) and of cerebral lateralisation (e.g. Flor-Henry, 1969), offers wide scope for the use of psychophysiological techniques. Accordingly, there has been a great deal of research interest in the psychophysiology of schizophrenia. Unfortunately, the extent of this interest has not been matched by the depth of current knowledge of the relationship between schizophrenia and electrodermal activity. There is still considerable disagreement concerning the status of electrodermal measures as markers for schizophrenia.

To a large extent this confusion represents the practical problems involved in research on schizophrenic subjects. Schizophrenia poses major problems of diagnosis, having no single defining symptom. Even modern operationalised criteria may differ with regard to their handling of some types of disorder (Brockington et al., 1978; Endicott et al., 1982).

There is also much debate concerning the importance of various sub-classifications of schizophrenia. It is apparent that

schizophrenia is a heterogeneous disorder, but there is little agreement regarding the important subdivisions within the disorder. Commonly used subtypes include paranoid and non-paranoid (e.g. Gruzelier, 1981) and process versus reactive types (e.g. Nuechterlein, 1977). Attention is also focused on the distinction between positive and negative symptoms (e.g. Andreasen, 1985; Nuechterlein et al., 1986). It is hoped that psychophysiological markers may aid in the identification of important subtypes of schizophrenia and may identify abnormalities in psychological functioning underlying the differences in overt symptomatology.

The nature of schizophrenic symptoms may also lead to under-representation of some groups in experimental samples due to the problems of obtaining cooperation and the need to find subjects who can comply with experimental instructions.

The ubiquitous use of neuroleptic medication means that it can be difficult to obtain subjects who are medication free. If such groups are available, high rates of relapse may lead to selection bias in drug-free samples. In addition long-term use of medication may lead to changes in receptor sensitivity, so that the effects of medication may persist for some time after medication has been withdrawn.

The size of the literature on EDA and schizophrenia prevents the presentation of a complete review here. Earlier work will be reviewed briefly, with more attention being given to more recent studies. Ohman (1981) produced an excellent review of work on the status of electrodermal activity as a marker for schizophrenia prior to 1981. Zahn (1986) and Dawson, Nuechterlein & Adams (1989) provide more recent reviews of psychophysiological approaches to schizophrenia.

3.2 EDA as a Marker for Schizophrenia

In studies comparing schizophrenic patients with controls there are reports both of hyperactivity and hypoactivity in the schizophrenic sample. Tonic measures such as SCL or NS-SCR frequency are not consistently found to discriminate individuals with schizophrenia from normal subjects.

3.2.1 Electrodermal non-responding The most commonly studied parameter of EDA in schizophrenia is the skin conductance orienting response. The literature using this paradigm provides some clarification of the inconsistencies in the literature concerning other measures. When subjects diagnosed schizophrenic are compared to controls the most consistent finding is that a higher proportion of the schizophrenic sample are non-responders, failing to produce an OR to the first tone (e.g. Bernstein et al., 1982). The proportion of non-responders reported varies from 0% to 75% in schizophrenics, with a figure around 40% being typical. Between 0% and 40% of the normal population are non-responders, typically 10%. Several studies which have used unmedicated samples have still found elevated rates of non-responding, implying that non-responding is not solely produced by anti-psychotic medication.

Schizophrenic non-responding is usually thought to be specific to non-signal tones (Bernstein et al., 1980). If the tones are made significant by the experimental instructions then schizophrenic subjects display much higher rates of responding, at least temporarily. Schizophrenic non-responding also appears when finger pulse volume is the dependent variable, (Bernstein et al, 1988). These findings imply that non-responding in schizophrenia may be secondary to a central deficit in attention.

While a high proportion of non-responders is a common, although

not universal, finding, there is less agreement concerning the nature of the responses shown by those schizophrenic patients who do produce an OR. Bernstein has found schizophrenic responders to habituate more rapidly than controls (Bernstein, 1970; Bernstein et al., 1981), implying that the schizophrenic group as a whole is hyporesponsive. Gruzelier consistently reports that schizophrenic responders are slow habituators (Gruzelier & Venables, 1972; Gruzelier et al., 1981a; Gruzelier et al. 1981b), so that the schizophrenic sample has a bimodal distribution of trials to habituation. Other studies (e.g. Ohman, Nordby & d'Elia, 1981) have produced results showing schizophrenic responders to have normal rates of habituation. One possible resolution to this controversy has been suggested by Levinson et al. (1984), they demonstrate that the rate of habituation found is dependent upon the scoring window used. A longer scoring window of five seconds revealed a cluster of schizophrenic non-habituators. Using a shorter, three second, window the same sample of schizophrenics were found to be fast habituators. This implies that differences in habituation rate may be due to the mis-classification of NS-SCRs as orienting responses using a large response window.

3.2.2 Other measures of electrodermal activity. The responder/non-responder distinction also provides an explanation for the conflicting data concerning tonic activity in schizophrenia. Schizophrenic non-responders are usually found to show lower levels of tonic EDA, both SCL and NS-SCR frequency, than responders (e.g. Gruzelier et al. 1981a; Ohman, Nordby & d'Elia, 1989). The two groups seem to differ most clearly on spontaneous SCR frequency. It is less clear whether either of the two groups differ from normal. The possible confounding effects of medication need to be considered when

comparing schizophrenic samples with controls. Anti-psychotic medication has been found to reduce SCL (Bernstein 1967) and may also reduce NS-SCR frequency (Gruzelier & Hammond, 1978). Several studies have found schizophrenic responders to show higher levels of SCL and higher NS-SCR rates than normals (e.g. Rubens & Lapidus, 1978) although other studies have not (e.g. Straube, 1979). Only for NS-SCR frequency have non-responders been reported to show lower levels of activation than controls (e.g. Straube, 1979). As medication may reduce EDA the finding of lower spontaneous response rates in non-responders may well be an artifact. However the reports of higher levels of activity in responders can be more readily accepted.

Amplitude of SCRs does not appear to be consistently abnormal in schizophrenia. Studies exist reporting larger, smaller and normal response amplitude in schizophrenic patients. One other parameter of phasic activity which has been found to discriminate schizophrenic subjects from controls is SCR recovery time. Several studies have found shorter recovery times in schizophrenic groups (e.g. Rubens & Lapidus, 1978; Zahn et al., 1981a; Ohman, Nordby & d'Elia, 1989). Chlorpromazine has been found to reduce SCR recovery times (Kugler & Gruzelier, 1980; Patterson & Venables, 1981), although several studies have found shorter recovery in unmedicated samples (e.g. Zahn et al., 1981a). Evidence from high-risk studies, to be described later, implies that recovery rate may be a vulnerability marker for schizophrenia and appears prior to the occurrence of any disorder.

Flor-Henry (1969) proposed that schizophrenia may be associated with dysfunction of the dominant hemisphere. This suggestion has prompted research examining electrodermal laterality in schizophrenia. Almost inevitably, the results of these studies are inconclusive. Several studies have found larger SCRs from the right hand in

schizophrenic subjects, with controls showing no difference or a smaller difference (Gruzelier, 1973; Gruzelier & Venables, 1974; Patterson & Venables, 1978; Gruzelier et al., 1981a). However there are a larger number of negative studies. More recently Gruzelier (1981) has provided evidence that there may be subgroups with differences in laterality and symptomatology. Gruzelier reports that a group with larger left than right responses was found to have more florid symptomatology, including paranoia. While a group with larger right hand responses revealed a pattern of negative symptoms and withdrawal. This finding of an association between negative symptoms and higher right hand activity has recently been replicated by Green, Nuechterlein & Satz (1989). At present the status of electrodermal laterality as a marker for schizophrenia remains unproven.

The main conclusion to be drawn from the literature on electrodermal activity in schizophrenia is that there is no finding which has been replicated by every study. Schizophrenic individuals appear to show great variability in EDA, either due to the heterogeneity of the group or due to confounding factors such as medication status or susceptibility to social influences associated with the recording situation. Several more specific conclusions are possible however. The finding of a large group of non-responders is well supported. In addition the responding group appears to show higher levels of tonic activity. As O'Han (1981) states the two groups appear to be hyporeactive (non-responders) and hyperactive (responders). The habituation behaviour of responders is in need of further clarification.

3.2.3 Correlates of responder status. Studies examining adult subjects indicate that EDA is not a marker for schizophrenia itself,

but has promise as a marker for specific subgroups of schizophrenia. Furthermore, groups selected on the basis of differences in EDA appear to show different patterns of symptomatology. Several earlier studies imply that non-responding is associated with a confused, withdrawn clinical picture in which negative symptoms predominate, while responders have more florid positive symptoms (Gruzelier, 1976; Straube, 1979; Bernstein et al., 1981). Two recent studies, however, imply that non-responders may show more symptoms of both kinds. A study undertaken by Alm et al. (1984) found that non-responders showed more positive symptoms than responders, the opposite of the usual pattern. Green, Nuechterlein & Satz (1989) found a non-significant trend for greater frequencies of both positive and negative symptoms in non-responders. A study by Ohaan, Nordby & d'Elia (1989) found no differences in symptomatology between schizophrenic groups differing in responsivity.

Responder status may also be related to prognosis. Two studies have found non-responders to show greater improvement during acute episodes (Frith et al., 1979; Zahn, Carpenter & McGlashan, 1981b). However non-responders may show a worse long-term prognosis. Ohaan et al. (1989) found non-responders to show poorer social outcome. It is possible that such results might occur if responsivity was secondary to severity of illness, particularly if there were differences in the rate of change of either variable with relapse or recovery. Iacono (1982) found that schizophrenics in remission also showed a clear division into responders and non-responders, implying that the differences may represent an enduring vulnerability factor rather than an effect of current symptomatology. However, an earlier study (Depue, Dubicki & McCarthy, 1975) reports changes in EDA with clinical improvement. Further research is necessary in this area.

Overall, the results of studies investigating the psychophysiology of schizophrenia are quite promising. The evidence that EDA may be related to acute prognosis clearly warrants further study. The evidence that skin conductance orienting may discriminate two distinct sub-groups within the disorder is also of theoretical and practical interest.

3.3 High-Risk Studies

One additional area of research not covered so far is the use of EDA in the examination of groups believed to be at high risk for schizophrenia. Such research may allow the separation of factors associated with the predisposition for schizophrenia from those related to current clinical state. It is hoped that this research may lead to the identification of vulnerability markers, allowing the identification of those individuals most at risk for the disorder, prior to the development of symptoms.

Two complementary approaches have been used in the selection of high-risk groups. Starting with the pioneering work of Mednick & Schulsinger (1968) there have been several studies using the offspring of schizophrenic parents, who have a heightened risk of developing the disorder. The book edited by Watt et al. (1984) provides extensive coverage of the results of genetic high-risk studies. An alternative strategy is that used by Chapman & Chapman (Chapman, Chapman & Raulin, 1976; Chapman & Chapman, 1980). These workers have produced scales assessing presumed aspects of the schizotypic personality. Several studies have compared subjects selected using these scales, claimed to be at risk for the development of schizophrenia or borderline states, with controls.

3.3.1 Genetic risk studies. The first, and most well-known, genetic high-risk study was carried out by Mednick & Schulsinger (1968). Their work provides a very clear picture of electrodermal hyperactivity in subjects at high-risk for schizophrenia. They found that the children of process schizophrenics showed higher SCL, larger SCRs, especially to the aversive UCS, less habituation and shorter latency and recovery of SCRs than a matched control group. In particular, SCR recovery rate was found to be an important marker for the genetic predisposition for schizophrenia. They found that SCR recovery rate discriminated those members of the high-risk group who went on to develop schizophrenia or borderline conditions from high-risk subjects who remained well. Later reports (Mednick, 1970; Mednick & Schulsinger, 1974; Mednick et al., 1978; Mednick, Schulsinger & Venables, 1979) examined the contribution of various environmental factors to the pattern of electrodermal activity. Electrodermal hyperactivity appeared to be determined by both genetic and environmental risk factors. In contrast, faster SCR recovery was predicted solely by the genetic factor.

Unfortunately, the results of more recent high-risk studies have shown the sort of variability that is all too common in schizophrenia research. Differences in responsivity consistent with the findings of Mednick and Schulsinger were reported by Salzman & Klein (Salzman & Klein, 1978; Prentky, Salzman & Klein, 1981) and by Van Dyke, Rosenthal and Rasmussen (1974). The former study failed to find differences in latency or recovery times between index and control groups. In addition, index subjects appeared to show a smaller increase in SCL over the course of the experiment, which is inconsistent with hyperactivity in high-risk subjects.

Two, more recent, studies have produced findings which contradict

those of Mednick and Schulsinger. Neither the New York high-risk project (Erlenmeyer-Kimling et al., 1984a, 1984b), nor a study by Kuglemass, Marcus and Schauli (1985) found evidence of hyperactivity in high-risk samples. Both found indications of slower, not faster, SCR recovery in index subjects. In common with other recent studies, the New York study only included subjects from intact homes. Erlenmeyer-Kimling et al. (1984a) point out that Mednick & Schulsinger (1968) found electrodermal abnormalities only in those subjects from broken homes.

The results of genetic risk studies implicate electrodermal hyperactivity as a putative vulnerability marker. Although there is variation between studies with regard to the exact nature of the difference between high-risk subjects and controls. Studies with adult schizophrenics indicate that non-responding is also associated with schizophrenia. Non-responders do not appear to be over-represented in the offspring of schizophrenic parents. Whether this is because non-responding is an acquired characteristic, which develops in later life, or is associated with schizophrenic sub-types under-represented in genetic studies (Venables et al., 1978) needs to be determined.

3.3.2 studies using other risk markers. One line of work which has consistently identified non-responders in high-risk samples uses questionnaire measures to identify subjects believed to be at high risk for schizophrenia. One such scale was developed by Chapman, Chapman & Raulin (1976). The Physical anhedonia scale assesses a relative lack of enjoyment of everyday experiences. Anhedonia is a common characteristic of schizophrenics and has been assigned etiological significance by Meehl (1962). Chapman, Chapman & Raulin (1976) also produced a scale to assess Perceptual aberration, another

presumed risk factor for schizophrenia. Evidence from psychophysiological studies using this scale has, however, been less consistent in demonstrating abnormalities in high-scoring subjects (e.g. see Simons, 1981; Bernstein & Riedel, 1986; Miller, 1986).

Simons (1981) has found subjects selected using the Physical anhedonia scale to show higher rates of non-responding than controls. Thus, this high-risk group may contain the non-responders not commonly found in genetic studies. Other physiological measures also reveal schizophrenic-like abnormalities in this group (Simons & Katkin, 1985; Miller, 1986).

Before this research can be accepted as evidence for the interpretation of electrodermal non-responding as a potential vulnerability marker for schizophrenia, it needs to be demonstrated that high-risk subjects selected using this questionnaire are actually at increased risk for schizophrenia. The follow-up studies necessary to demonstrate that Physical anhedonics are more likely to develop schizophrenia than controls have yet to be carried out.

3.4 EDA and Schizophrenic Relapse

Studies by Frith et al. (1979) and Zahn, Carpenter & McGlashan (1981) appear to show that electrodermal non-habitulators show slower recovery from acute episodes than non-responders. Research using a slightly different approach also implies that EDA may be of use as a prognostic measure. This research appears to show that EDA serves as a process measure sensitive to types of stress known to play a role in triggering schizophrenic episodes.

3.4.1 models of schizophrenic relapse. Diathesis-stress models of

schizophrenia propose that schizophrenia results from an interaction between a pre-existing vulnerability factor and environmental stressors which may trigger an acute episode. One particular model was proposed by Nuechterlein & Dawson (1984). They include autonomic hyperreactivity as a vulnerability factor, on the basis of the evidence from some of the high-risk studies. In addition autonomic hyperarousal is included as one of three inter-related intervening states, which result from the interaction between vulnerability and environmental stressors. This model implies autonomic over-activation may be an important process in the chain of events leading to schizophrenic relapse and that electrodermal activity might allow the assessment of this process, possibly allowing prodromal changes to be detected prior to the onset of measurable symptomatology.

One form of stress known to affect rates of schizophrenic relapse is the experience of stressful life events (see Turpin & Lader, 1986). Such events are usually rated retrospectively using a questionnaire or interview. There have been a number of criticisms of the use of retrospective reporting of life events, particularly using questionnaires (e.g. see Zimmerman, 1983; Paykel, 1987). Despite these criticisms, life-event scales have been widely used as an index of experienced stress.

The first studies to assess the relationship between stressful events and schizophrenic onset were carried out by Brown & Birley (Brown & Birley, 1968; Birley & Brown, 1970). They found that schizophrenic patients reported a clustering of events in the three week period before onset. 46% reported events in this period, as opposed to an average of 12% reporting events in the preceding three three-week periods. The control group reported similar levels of life events in all of the periods. Later studies (reviewed by Rabkin, 1980)

have generally supported the influence of life events on schizophrenic relapse. However, by no means all schizophrenics report such triggering events and, conversely, the experience of such events does not guarantee the onset of a schizophrenic episode.

One other form of stress, which has been implicated in the onset of schizophrenia, is social stress associated with a critical and over-involved family environment. Brown, Birley & Wing (1972) developed a structured interview to measure this pattern of family interaction, termed expressed emotion (EE). The presence of a relative high on expressed emotion has been found to seriously increase the risk of a schizophrenic relapse (Brown, Birley & Wing, 1972; Vaughn & Leff, 1976). Furthermore, EE appears to interact both with medication status and life-event experience in determining relapse (Vaughn & Leff, 1976; Leff & Vaughn, 1980). Recent intervention studies have shown that reducing relatives' expressed emotion may prevent, or at least delay, relapse (Leff et al., 1982, 1985; Falloon et al., 1985; Hogarty et al., 1986, 1988; Tarrier et al., 1988b, 1989b).

If the model proposed by Nuechterlein & Dawson (1984) is correct, then both the experience of stressful life events and the presence of a relative high on expressed emotion should lead to increased EDA. As the next sections will demonstrate, there is experimental evidence to support this claim.

3.4.2 Life-events and electrodermal activity. There is relatively little evidence concerning the effects of stressful life-events on electrodermal activity in schizophrenia. A study by Tarrier et al. (1979) examined the NS-SCR rates of schizophrenic subjects in their own homes. The study was primarily intended to investigate the effect of social stress on electrodermal activity. This aspect of the study

is described below. In addition, TARRIER et al. compared the EDA of seven subjects who had experienced a life-event in the three weeks preceding a recording session, with that shown by the same subjects on other, event-free, sessions. Their results revealed that the experience of a stressful life-event led to significantly higher non-specific response rates, but that the difference was only apparent in the second half of the session, after the entry of a relative. After an event subjects failed to show the usual decrease in EDA, interpreted as reduced arousal or anxiety, in the presence of relative. A similar effect of life-events on electrodermal activity has since been reported in another study. Ventura, Dawson & Nuechterlein (1986) examined the EDA of a group of 21 schizophrenic out-patients. Their results show that the 3 subjects who had experienced a recent major life event in the last four weeks had significantly higher NS-SCR rates than those subjects who had not experienced an event. These findings are consistent with the claimed role of EDA as a mediator of the harmful effects of stress. However both studies had relatively small numbers of subjects who had experienced events and there is a need for a larger replication of these studies.

3.4.3 Expressed emotion and electrodermal activity. Several studies carried out over the last decade have consistently demonstrated that Electrodermal activity is sensitive to the EE rating of a patient's relative (see Turpin, TARRIER & Sturgeon, 1986). TARRIER and his co-workers (TARRIER, COOKE & LADER, 1978; TARRIER et al., 1979) examined the electrodermal activity of schizophrenic patients currently in remission in their own homes. When a relative entered the room, EDA recorded from the patient was sensitive to the

relative's EE status. On the first testing occasion only, schizophrenics with high-EE relatives showed an increase in NS-SCR frequency in response to the entry of the relative, whereas those subjects with low-EE relatives showed a decrease. The social setting was important in eliciting differences between the groups, subjects from high and low-EE homes did not differ with regard to EDA when tested in hospital (TARRIER et al., 1978).

A similar study was carried out by Sturgeon et al. (1981, 1984). They examined the electrodermal activity of hospitalised patients in the acute phase of the disorder. In this group the differential response to the entry of a relative found by TARRIER and co-workers did not appear. Rather schizophrenics with high-EE relatives showed higher rates of NS-SCRs at all times. An intervention designed to reduce relatives' EE had no effect on levels of electrodermal activity recorded from the subject at follow-up nine months later. Levels of EDA recorded when acutely ill were predictive of later relapse rates.

A single case study reported by TARRIER & BARROWCLOUGH (1987) also found that the overall level of activity shown by a patient was unresponsive to changes in the EE level of his relatives. This study indicates that an increase in NS-SCR frequency in response to the entry of a high-EE relative appeared only during acute episodes of the disorder. The increase in response to a relative high on EE appeared predictive of relapse within the next nine months. However, this differential response was superimposed on a high NS-SCR rate, comparable to that observed in the acutely ill group by Sturgeon et al. (1984).

In an on-going study, TARRIER (1989; TARRIER et al., 1988a) recorded EDA from patients taking part in an intervention to reduce relatives' EE (see TARRIER et al., 1988b, 1989). The initial test during

admission (TARRIER et al., 1988a) replicated the finding of a differential response to the entry of a relative, in both NS-SCR rates and SCL, from patients with high- or low-EE relatives.

On re-testing, in remission, the response to the entry of a relative showed habituation. Four and a half months after discharge the increase in NS-SCRs which occurred in response to the entry of a high-EE relative was no longer apparent. The SCL response to a relative high on EE was still present at four and a half months, but disappeared nine months after admission. The results for SCL revealed that the group with the highest expected risk of relapse, those with high levels of contact with a high-EE relative, maintained some heightened autonomic activation in the presence of the relative. There was a weak difference in SCL on those occasions when subjects had experienced a life event in the preceding three weeks. On such occasions subjects showed higher SCL than on event-free sessions. TARRIER (1989) does not comment on the differences between NS-SCR frequency, which showed habituation, and SCL which appeared to maintain some discrimination. The two measures may differ in their sensitivity, or merely in their rate of recovery.

These studies appear to show two differing prognostic markers. Some of the studies (Sturgeon et al., 1981, 1984; TARRIER & Barrowclough, 1987) imply that high levels of overall activity may be a trait-like vulnerability marker predictive of long-term relapse rates. Overall level of activity does not appear to be directly determined by relative's current EE status. The electrodermal response to a relative, in contrast, appears to vary with acute state and relates to more immediate risk of relapse.

The interpretation of electrodermal activity recorded from subjects engaged in conversation raises a number of problems. Patterns

of EDA may be secondary to differences in speech rate or style, or to differences in the content of conversation. In addition, the social behaviour of a patient's relatives will be partly determined by the patient's own behaviour. Links between relative's expressed emotion and patient's autonomic activation may operate in both directions.

The results of studies examining the effects of expressed emotion are as complex as those from other areas of schizophrenia research. While overall results are similar, the exact findings of individual studies show some inconsistencies. Results agree that high levels of EDA are predictive of poor short-term prognosis, both in acute episodes and in remission. It is not clear to what extent this relationship is mediated by enduring characteristics of the patient and to what extent it is determined by the patient's environment.

3.5 Summary

The literature on electrodermal activity in schizophrenia reveals a number of findings with sufficient support to warrant further research. There is abundant evidence that EDA can distinguish two sub-groups within schizophrenia. While it is not clear whether the distinction between non-responders and responders is best conceptualised as a continuum or as a dichotomy, the evidence that groups of subjects selected on this basis show different clinical characteristics implies that they might be two relatively homogeneous sub-types. What is needed is a more integrated approach, relating electrodermal activity in schizophrenia to other research into the significance of electrodermal activity and the psychology of schizophrenia. While it has been demonstrated that non-responders and responders differ with regard to symptomatology, there is no clear explanation of the significance of non-responding, or of the

relationship between electrodermal activity and the sort of symptoms that distinguish between the two groups.

Research on electrodermal activity and EE is at a similarly early stage. Social interaction is a complex process and may be particularly so when one individual of the dyad is schizophrenic. While expressed emotion can be reliably assessed, this pattern of interaction is still poorly understood. Questions still to be answered include the relative importance of the components of expressed emotion for schizophrenic onset and the causes of high expressed emotion. Perhaps the major advance that this research represents is a consideration of the role of the social environment in clinical research. The finding of Tarrrier et al. (1979) that differences between patients with low or high EE relatives only appeared when patients were tested in their own homes implies that some processes may not be amenable to study within the confines of the laboratory. Psychiatric patients may be particularly responsive to the social effects of the traditional laboratory setting (e.g. see Gale & Baker, 1981; Turpin, 1983, 1985). The palmar sweat index provides an alternative to the portable equipment used by Tarrrier and his co-workers and would allow this work to be extended by simplifying the process of data collection. By avoiding the use of electrodes and complex equipment it is hoped that the PSI might be less intrusive and intimidating, and therefore less likely to lead to excessive anxiety.

4 Electrodermal Activity and Depression

4.1 The Psychology of Depression

The affective disorders consist of syndromes involving depression

and mania. While depression often occurs without episodes of mania or hypomania, individuals experiencing manic episodes usually also experience episodes of depression (Depue & Monroe, 1978). When both extremes are experienced the disorder is termed bipolar affective disorder. Unipolar affective disorder refers to the condition where only attacks of depression occur. In rare cases where individuals experience manic or hypomanic episodes in the absence of depression they are usually classified as suffering from a bipolar disorder. Unipolar disorders are common, affecting around 10% of males and 20% of females. Bipolar disorders are rarer, with a lifetime risk of around 1% (e.g. Weisman & Myers, 1978).

Depression is a heterogeneous disorder and there are several subdivisions within the category which may be of relevance. Unfortunately there is little agreement as to the important dimensions of depression. The same terms may often be used to refer to different entities, especially in earlier studies. Kendell (1976) provides a review of the literature regarding the classification of depression (see also Katschnig, Pakesch & Egger-Zeider, 1986).

One of the most important divisions is that between endogenous and non-endogenous depression. Originally the term endogenous was used to refer to depression occurring in the absence of precipitating stress, as opposed to exogenous, or externally-triggered depression. However, this distinction has not been supported empirically (Katschnig, Pakesch & Egger-Zeider, 1986), and endogenous (or endogenomorphic) depression is now used to refer to a particular cluster of symptoms. Endogenous depression is characterised by a severe depression with a unique character (i.e. outside the normal range of experience) and by early morning wakening, diurnal variation in mood and motor retardation. Attention has recently been focused on

possible biological markers for the endogenous sub-type (e.g. Feinberg & Carroll, 1982).

A similar distinction is that between psychotic and neurotic depression. These terms are used less consistently than the endogenous vs non-endogenous distinction. Psychotic depression can be used to refer to the presence of symptoms such as delusions or hallucinations, but is more commonly used synonymously with endogenous depression.

Other workers may concentrate on the presence or absence of specific symptoms such as retardation vs agitation, anxiety or hostility. For this reason, much of the research using physiological variables has been directed at the development of biological markers, either for depression itself or for particular sub-types. The wide variety of diagnostic schemes for affective disorders produces special problems in the comparison of the results of different studies.

Like schizophrenia, the onset of depression has been shown to be associated with environmental stressors (see Brown & Harris, 1978; Lin, Dean & Ensel, 1986). There is also evidence that depression is, in part, genetically determined (e.g. see Gershon, 1976). Depression, therefore, is commonly viewed as the result of a vulnerability-stress interaction (e.g. Akiskal & McKinney, 1973, 1975). Most psychophysiological research, however, has concentrated on the vulnerability side of the equation.

There is very little research using electrodermal activity to investigate bipolar affective disorder. The discussion that follows will, therefore, concentrate primarily on unipolar depression. Recent reviews of the psychophysiology of affective disorders are provided by Zahn (1986) and Henriques & Davidson (1989).

4.2 Electrodermal Activity in Depression

4.2.1 Electrodermal activity as a marker for depression. Lader & Wing (1969) carried out one of the first studies to examine EDA in depressed subjects. The results they obtained are largely consistent with those reported by later studies. They found that patients with motor retardation had lower SCL and fewer NS-SCRs than controls. Retarded patients also showed fewer and smaller SCRs than controls. In contrast, depressed patients displaying agitation showed higher SCL and more frequent NS-SCRs than controls.

This finding of lower EDA in severe depression has been replicated by several more recent investigations (Byrne, 1975; Dawson, Schell & Catania, 1977; Mirken & Coppen, 1983; Giedke, Bolz & Heiman, 1980; Lapierre & Butter, 1980; Iacono et al. 1983, 1984; Storrie, Doerr & Johnson, 1981; Thorrell, 1987; Thorrell, Kjellman & d'Elia, 1987a, 1987b; Ward, Doerr & Storrie, 1983; Ward & Doerr, 1986). However there are negative findings (Toone, Cook & Lader, 1981; Albus et al., 1982). Reduced SCL is generally found to be confined to sub-types referred to as endogenous, psychotic or retarded. Two studies (Ward, Doerr & Storrie, 1983; Ward & Doerr, 1986) report figures for the sensitivity and specificity of specific SCL criteria. Both studies found that both sensitivity and specificity were around 90%. Thus, abnormally low SCL may meet the requirements for a biological marker for depression, being present in 90% of depressed patients and only 10% of non-depressed individuals.

4.2.2 Electrodermal activity and depressive sub-types. In general, workers who have examined patients described as neurotic, non-endogenous or agitated depressives have replicated Lader & Wing's (1969) finding that these groups show levels of electrodermal activity

and responsivity above those of controls (Noble & Lader, 1971; Byrne, 1975; Frith et al. 1982), although this finding seems less reliable than reports of lower activity in severe depression. One study (Lapierre & Butter, 1980) found lower SCL in agitated as well as retarded depressives and several others have found normal levels of EDA in agitated or non-endogenous patients (Toone, Cook & Lader, 1981; Dawson, Schell & Catania, 1977; Mirken & Coppen, 1980). Bagg & Crookes (1966), using the PSI also failed to find differences between "Neurotic" and "Endogenous" depressives, although they do not state what criteria were used to make the diagnoses. In general, non-endogenous depression is less well defined than the endogenous sub-type and these studies were not necessarily using comparable patient groups.

Other subdivisions of depression do not seem to differ with regard to electrodermal activity (Williams et al., 1985; Thorrell, Kjellman & d'Elia, 1987a).

A study by Breyer-Pffaf, Gaertner and Giedke (1982) found that habituation rates might be predictive of the response to tricyclic antidepressants. Rapid habituators appeared to show a better response to treatment than subjects who habituated more slowly. The data provided by Breyer-Pffaf, Gaertner and Giedke (1982) indicate that this distinction is not secondary to differences between endogenous and non-endogenous depression. If this result can be replicated, it implies that habituation rates might be an important prognostic indicator.

One other distinction, of great clinical significance, does seem to be associated with reduced skin conductance responding within the depressed group. Two recent investigations have found that suicidal patients who have actually attempted suicide, particularly by violent

means, may show lower skin conductance responsivity than those who merely report suicidal ideation, or have made attempts with a "cry for help" character (Edman et al., 1986; Thorrell, 1987). Thorrell (1987) reports that, as well as producing smaller SCRs, suicidal depressed patients also habituated faster and showed fewer NS-SCRs than depressed patients with no history of suicide attempts.

As yet, there is little evidence concerning the mechanism responsible for reduced SCL in depression. Bernstein et al. (1988) report that, in contrast to schizophrenia, increased non-responding in depression is not restricted to non-signal stimuli and appears only in the electrodermal channel. They conclude that depressive non-responding represents a peripheral process rather than a central deficit in attention. Bernstein et al. suggest that depression may involve a deficit in peripheral cholinergic transmission.

4.2.3 Laterality and depression. One other difference between depressed subjects and normal controls has been reported. This is greater responding from the left than right hands (Gruzelier & Venables, 1974; Myslobodsky & Horeish, 1978; Schneider, 1983). In their study of subjects claimed, on the basis of questionnaire scores, to be at high risk for bipolar affective disorder, Lenhart & Katkin (1986) also found larger left than right hand responses in the high-risk group, but not in controls. This finding has been replicated using a group selected on the basis of high genetic risk for bipolar disorder (Zahn et al., 1987). Other workers, however, have failed to find such differences (Storrie, Doerr & Johnson, 1981; Toone, Cook & Lader, 1981; Iacono & Tuason, 1983). Furthermore, Iacono & Tuason (1983) report that not only were there no consistent laterality effects for any group but the test-retest reliability of laterality was close to

zero.

Differences in EDA laterality are usually attributed to differences in hemispheric function, such as those proposed by Flor-Henry (1969) as a basis for depression. The study by Schneider (1983) included direct EEG measures of hemispheric activation, as well as perceptual tests claimed to reflect hemispheric dominance. While the EDA data revealed lateral differences, neither of these measures did. Despite significant correlations between the laterality of different parameters of EDA, these measures largely failed to correlate with laterality as assessed by other means. Thus, there is no evidence to support an explanation for electrodermal laterality effects in depression as being due to over- or under-activation of one cerebral hemisphere. The lack of agreement among studies, as well as the difficulties in interpreting lateral differences in EDA (see Hugdahl, 1984) make interpretation impossible.

4.2.4 Electrodermal activity and vulnerability. There is evidence to indicate that some cases of affective disorder are associated with an inherited vulnerability factor (e.g. Gershon et al., 1976). Like schizophrenia, depression has been explained in terms of a vulnerability-stress interaction (e.g. Akiskal & McKinney, 1973, 1975). This raises the possibility that psychophysiological markers observed in acute episodes might be vulnerability markers, present prior to onset and persisting into remission.

Lowered EDA has been reported to persist into remission (Noble & Lader, 1971; Dawson, Schell & Catania, 1977; Storrie, Doerr & Johnson, 1981; Iacono et al., 1984). Lenhart has also found similar differences between questionnaire-selected groups claimed to be at high-risk for bipolar affective disorder and controls (Lenhart, 1985; Lenhart &

Katkin, 1986). Thus there is support for the contention that lowered EDA may constitute a marker for the vulnerability to depression rather than the state of depression itself.

However, this conclusion might not be justified, a study carried out by Zahn et al. (1987) found that the level of EDA, in contrast to electrodermal laterality, was normal in a group at high genetic risk for bipolar disorder. With the exception of the study undertaken by Iacono et al. (1984), the studies examining depressed patients in remission all re-tested patients less than three weeks after recovery. One study which used a longer time period (Thorrell & d'Elia, 1988) did not find EDA in patients to be significantly different from controls. A study recently reported by Zahn, Brier & Albus (1988) also found currently well patients to show greater electrodermal activity than currently depressed patients. In addition, two early papers report an increase in SCR amplitude following ECT treatment (Stern & Sila, 1959; Stern, Sila & Word 1961), although no details are given concerning the diagnosis of the patients studied. The study carried out by Bagg & Crookes (1966), using the PSI, also found an increase in sweating after ECT, although it is not clear whether sweating returned to normal levels in this study. Thus, while some reports imply that reduced EDA may persist into remission, there may be some normalisation of EDA.

It is clear, from studies examining depressed adults, that electrodermal activity does not directly parallel changes in symptomatology. However, EDA may show a more gradual return to normal levels. The only study to examine subjects at high genetic risk for affective disorder produced negative results (Zahn et al., 1987). Lenhart's studies using questionnaire-selected subjects (Lenhart, 1985; Lenhart & Katkin, 1986) may be explained in terms of differences

in current mood and/or symptomatology. The General Behaviour Index used in these studies (Depue et al., 1978) was developed to detect sub-syndromal cyclothymia and has also been demonstrated to detect clinical forms of bipolar disorder. Thus the groups studied by Lenhart could be considered to be already suffering from a mild disorder, rather than at risk of future disorder. What is needed to clarify the trait/state nature of reduced EDA in depression is a replication of the high-risk study undertaken by Zahn et al. (1987), examining currently well individuals who can be assumed to carry the predisposition to depression.

4.3 Summary

There is considerable evidence that severe depression, particularly of the endogenous subtype and including motor retardation, may be accompanied by abnormally low levels of EDA, both tonic and phasic. Furthermore, there is evidence that low EDA may be both sensitive to depression (present in a high proportion of the target group) and specific for depression (rare in the normal population). While there is less evidence on this point, it is also possible that reduced EDA may be a vulnerability marker; present in individuals at risk for depression in the absence of overt symptomatology. However, this point is in need of further clarification, in the light of conflicting evidence.

Electrodermal activity seems to have promise as a marker for depression. By allowing the extension of research to larger samples, the PSI might allow this promise to be fulfilled. Specific topics in need of further research include the extent of normalisation of EDA in remission and whether lowered EDA exists prior to the development of

affective disorder. Specifically, is lowered sweat gland activity a marker for vulnerability to depression or a result of current depressed mood? In addition the possibility of consistent differences in electrodermal laterality in depression warrants further examination.

5 Opportunities for Research Using the PSI

Earlier sections have covered several areas where a measure such as the PSI might have advantages over skin conductance measures of sweat gland activity. Several of these areas will be reviewed here. As outlined in the introduction to this chapter, psychophysiological measures might serve several functions. Such measures may identify groups at risk for a disorder, they might identify sub-groups within a disorder and, finally, psychophysiological measures may provide an index of changes in psychological processes during assessment and treatment. The three disorders reviewed earlier provide evidence that EDA might serve all three functions.

In the case of anxiety disorders, the evidence is clearest for the use of electrodermal activity as a process measure. Skin conductance techniques are already used as component measures of treatment outcome in the treatment of anxiety disorders. There is also evidence that physiological responsivity may predict the outcome of desensitization or flooding (e.g. Lader, Gelder & Marks, 1967), most probably because EDA provides an index of the processes underlying anxiety reduction. The PSI would allow an extension of the use of such measures in the treatment of anxiety. The PSI could also contribute to research into the physiological basis of anxiety. Because the PSI may be suited to use in field research, the PSI would allow the investigation of ecologically valid forms of anxiety, rather than the,

presumed, analogue settings commonly used in research.

With regard to schizophrenia, there is evidence that electrodermal activity might be used in all three roles. The evidence from high-risk studies (e.g. see Ohman, 1981) implies that electrodermal hyperreactivity might be a vulnerability marker for schizophrenia. In addition, studies examining adult schizophrenics generally reveal two distinct patterns of EDA, with possible differences in symptomatology (e.g. Straube, 1979) and prognosis (e.g. Zahn, Carpenter & McGlashan, 1981). Thus, electrodermal activity may also discriminate meaningful sub-groups within schizophrenic samples. Finally, electrodermal activity has been shown to be sensitive to factors thought to predict schizophrenic relapse (see Turpin, Tarrier & Sturgeon, 1986). Electrodermal activity, therefore, also has promise as a measure of one type of stress with important prognostic significance. The advantage of the PSI in this type of research is that it is simple to administer and would allow rapid testing of large samples. Prospective high-risk research needs large samples in order to include sufficient numbers of subjects who will go on to develop schizophrenia. Even in genetic risk studies, only around 10%-15% of the high-risk sample are likely to develop schizophrenia (Gottesman & Shields, 1982). Similarly, the sort of repeated testing required by a prospective investigation of the prognostic significance of sweat gland activity would also be simpler using a measure such as the PSI. While not likely in the near future, a cheap and simple measure such as the PSI would be essential were psychophysiological measures to be used in clinical practice.

Electrodermal activity also seems to have promise as a marker for depression (e.g. Ward & Doerr, 1986). The main area in need of further investigation is the state/trait nature of reduced EDA in depression.

This could be investigated using a genetic high-risk study, or by a twin or adoption study. As explained above, the main advantage of the PSI for this type of research is its simplicity, allowing data to be collected relatively quickly without the need for expensive equipment or highly-trained staff.

It can be seen that the PSI might be used in number of different fields. However, before this potential can be fulfilled it is necessary to establish the validity of the PSI and to determine the optimum technique for administering and scoring the index.

Chapter 5

The Programme of Research

1 Aims

The aim of the research to be undertaken is to investigate the validity of the Palmar Sweat Index as an applied measure, with special reference to clinical psychology. Previous research using electrodermal activity (some of which is reviewed in chapter four) has demonstrated that measures of sweat gland activity may make a considerable contribution to clinical research and practice. It is hoped that the PSI might extend this contribution by allowing clinical psychophysiology to move beyond the laboratory into field settings. Thus, the programme of research undertaken is intended to investigate the suitability of the PSI for use as an alternative to EDA in field settings.

This programme can be sub-divided into three questions which should be addressed. Firstly, the reliability of the Palmar Sweat Index needs to be examined. Previous research using the measure has failed to clarify several basic issues concerning the measurement properties of the PSI. This investigation will also examine the advantages and disadvantages of various methods of scoring the PSI. Secondly, the concurrent validity of the measure with regard to electrodermal measures of sweating needs to be examined. As the rationale for the use of the PSI is as an alternative to EDA, it needs to be demonstrated that the two measures are correlated. Finally, the construct validity of the measure should to be examined. The relationship between the PSI and important psychological factors such as stress or anxiety needs to be investigated. While prior research

using the PSI has commonly assumed that the PSI is an index of these constructs, there are several outstanding questions which have not been resolved.

2 Topics to be Investigated

2.1 Methodological Issues

A direct assessment of the inter-rater reliability of the PSI will be presented prior to the programme of research. A comparison will also be made between manual scoring and scoring of prints using an image analysis system. Image analysis provides considerable practical advantages over manual scoring. Automated scoring also removes the possibility of subjective bias in the scoring process.

Investigation of the reliability of the PSI should also include a consideration of the influence of other factors on the PSI. Temperature is the most obvious possible extraneous influence, although other factors, such as humidity, may also serve to increase error variance. In addition, procedural factors concerned with the administration and scoring of the PSI may also have relevance for the reliability of the measure. Investigation of the effects of temperature, hand used etc. on the values obtained will be undertaken using data obtained as part of the assessment of the construct validity of the PSI.

Few studies have considered the effect of finger size on the PSI. One method of controlling for possible differences in finger size is provided by Weisenberg et al. (1976). They scored their prints in the usual way, but counted active and inactive glands to obtain a ratio of active over total glands. This ratio measure should be independent of gland density. The ratio measure used by Weisenberg et

al. (1976) will be compared directly with the more usual count of active glands. Both measures will be obtained in each experiment, providing a range of data for the comparison of the two measures.

A related issue concerns the statistical handling of PSI data. Physiological data may be transformed in various ways to control for individual differences in baseline activity. Removing irrelevant differences between subjects will increase the sensitivity of the analysis. Differences in baseline may also result in differences in the size of the response which is observed. Where a physiological parameter has an absolute ceiling, as is the case for the PSI, high baseline levels of activity will limit the maximum response which can be observed. This effect is called the law of initial values (LIV; Wilder, 1950). A number of procedures exist which account for differences in baseline and/or the effects of the LIV. These different transformations, however, will have different effects on the sensitivity of the measure. Different transformations may also be preferred depending on the extent to which the PSI is subject to the LIV. The best means of investigating the effects of different transformations is to examine the effects of a number of procedures on the same data set (e.g. see Giesen & McGlynn, 1977).

Thus data collected will be subjected to various transformations in order to compare the effectiveness of different statistical treatments of the PSI.

2.2 The Relationship Between the PSI and Electrodermal Activity

The second question to be addressed concerns the criterion-related validity of the measure with regard to electrodermal activity. Studies reviewed in chapter three indicate that the PSI is generally found to correlate significantly with skin conductance

level. However, the correlations reported are generally of only moderate size. In addition, the majority of studies have only examined correlations between the PSI and SCL. The relationship between the PSI and NS-SCR frequency or measures of habituation remains largely unexplored. The research to be carried out will include a comparison of the PSI and various parameters of electrodermal activity.

Both between-subjects and within-subject correlations will be examined. While between-subjects correlations are more commonly used, such correlations do not adequately reflect the responsiveness of physiological variables. Between-subjects correlations may not provide an adequate indicator of the similarity of the measures with regard to the way they change over time. Between-subjects comparisons may also be influenced by stable peripheral differences in factors such as skin thickness, sweat concentration or sweat gland density which might affect the PSI and EDA differently. It is also important to examine the effects of environmental factors on the correlations between the two measures. Inevitably, the correlations obtained will vary depending upon the conditions of measurement. This will be done by obtaining both measures in several different studies.

In order to demonstrate the criterion-related validity of the PSI it is also necessary to examine the response of the PSI and EDA to various psychological factors. Both the direction, magnitude and timing of the responses of the two measures need to be compared. Results such as those obtained by Turpin, Takata and Tutton (1986), appearing to show a decrease in the PSI accompanying an increase in EDA, cast doubt upon the comparability of the two measures. Thus, the programme of research needs to compare the effects of a number of psychological factors on both physiological measures. The investigation of the response of the two measures to tasks like mental

arithaetic can be combined with an investigation of the third area in need of investigation; the construct validity of the PSI.

2.3 Psychological Correlates of the PSI

The construct validity of the PSI will be assessed with regard to a number of psychological constructs. While previous research has generally used the PSI as an index of stress or anxiety, the index has also been claimed to respond to other factors, such as the direction of attention. It is hoped to clarify the nature of the factors which do affect the PSI. The review of the literature on the PSI in chapter three raised a number of questions concerning the psychological correlates of the PSI. This section will indicate how the programme of research attempts to answer these questions.

2.3.1 Stress and the PSI. Prior research using the PSI has generally used the measure as an index of the related constructs of stress, anxiety or arousal. The literature on the anhidrotic response to stress indicates that the relationship between the PSI and experienced stress is complex. While surgery and straight-leg raising clearly do produce a decrease in sweating, other stressors have been shown to lead to increased sweating.

The literature examining the anhidrotic response has studied a limited range of stressors. It is necessary to examine the response of the PSI to other types of stress. One particular type of stress, with important clinical consequences, is the experience of stressful life events. The experience of such events has been shown to be associated with the onset of a number of disorders. Furthermore there is evidence, reviewed in chapter four, indicating that, at least in a schizophrenic population, the experience of such events may lead to

increased electrodermal reactivity. Another study carried out by Pardine and Napoli (1983), using student subjects, indicates that life-event experience may also lead to delayed heart rate recovery after a laboratory stressor. This experiment assessed life-events retrospectively using a questionnaire. Thus, there is reason to believe that life-event stress might lead to measurable changes in physiological activity. A study will be undertaken examining the effects of retrospectively assessed life events on the PSI.

The examination of a range of other types of stress might allow the resolution of the apparent contradictions in the literature concerning the relationship between the PSI and experienced stress. Such a program might also provide evidence concerning the utility of the PSI as an applied measure. This will be done by using the PSI to examine a range of "real-life" stressors, such as examinations or the effects of public-speaking. In these studies the PSI will be obtained both during and after any stressor. The literature on the straight-leg raising task demonstrates that responses during the task may differ from those obtained after the task.

A related point concerns the need to allow adequate adaptation periods prior to any manipulation. The occurrence of adaptation, steadily reducing levels of EDA over the course of an experiment, is well documented (Linden & McEarchen, 1985). If similar adaptation occurs for the PSI, then measures taken after a task might be below a pre-task baseline, irrespective of the effect of the task itself. Adequate time should be allowed prior to the manipulation to allow such adaptation to occur, so that baseline activity is as steady as possible during the experiment.

2.3.2 Anxiety and the PSI. There is considerably more evidence to

indicate that the PSI might be associated with anxiety. Electrodermal activity has been shown to be elevated in clinical anxiety (see chapter four). Furthermore, Fowles (1980) has claimed that electrodermal activity may be a direct index of anxiety, although the model of anxiety he draws upon may differ from that implicit in some of the clinical research.

The literature on the PSI also provides considerable support for the use of the PSI as an index of fear or anxiety. Studies reviewed in chapter three report increases in the PSI in a variety of anxiety-provoking situations. Inevitably, there are a small number of contradictory studies. Some of these conflicting results may be due to procedural differences, such as the timing of the measures.

An investigation into the effects of anxiety on the PSI needs to include manipulation checks to ensure that the anxiety manipulation was successful, many of the studies mentioned above did not include alternative measures of anxiety. While questionnaire measures of state anxiety might not be expected to correlate with the PSI, such measures should be increased by a manipulation claimed to induce anxiety.

The definition of anxiety also needs to be considered. While anxiety is generally more clearly defined than stress, different definitions exist. One advantage of the model of anxiety proposed by Gray (1976), which Fowles (1980) makes use of, is that it clearly specifies the conditions which are claimed to produce anxiety. This model of anxiety would be suitable for use in an initial laboratory study. However this model of anxiety is less relevant to the types of clinical anxiety described in chapter four.

An alternative, and complementary, approach would be to examine several forms of anxiety and define anxiety by converging operations. Such investigations will be field-type studies examining forms of

anxiety with detrimental consequences, such as test anxiety or social anxiety. Both trait and state anxiety should be examined. A need to examine "real-life" stressors in field settings was identified above. The studies described here will also fulfil that objective.

Therefore, these studies will examine the effects of an exam or of public-speaking on individuals scoring high and low on scales of trait anxiety. Because self-report indices may be subject to reporting bias, the Marlowe-Crowne social desirability scale will also be included as an index of repression-sensitization. It is hoped that inclusion of this scale will clarify the relationship between scores on the questionnaire measures and presumed physiological indices of anxiety.

2.3.3 Audience Effects and the PSI. Several studies, most notably those in the area of social facilitation, have used the PSI as an index of arousal. Such use is compatible with a view of the PSI as responding to stress or anxiety, as both of these constructs would include increased arousal.

While a direct relationship between the PSI and non-specific arousal seems unlikely, the work on audience effects does raise one very important point for research with the PSI. This work demonstrates that social factors can influence the PSI. Administration of the PSI requires the experimenter to sit next to the subject and to interact with the subject to a limited extent. This may lead to increased evaluation anxiety, so that the process of measuring the PSI may lead to changes in some of the variables under study. Such an effect would threaten the validity of the PSI as an alternative to electrodermal measures of sweat gland activity. The existence and extent of this effect will be examined using skin conductance measures, as well as

direct microscopic recording of sweat gland activity, which can be measured continuously without the experimenter needing to be present.

2.3.4 Attention and the PSI. One other factor which may affect the PSI is cognitive activity. Johnson and Dabbs (1967) claimed that the PSI may be sensitive to the direction of attention. They claim that internally-directed attention, for example when carrying out mental arithmetic or passively coping with unpleasant sensations, may lead to depression of sweating. Externally directed attention, in contrast, is claimed to lead to elevated levels of sweat gland activity. This theory has received no direct experimental support. However there are persistent reports that seem to imply that some types of cognitive task lead to a decrease in sweating. Most of these studies measured the PSI after the task, rather than while subjects were performing the task. It seems most likely that the occasional reports of decreases in the PSI in association with some tasks are due to inappropriate timing of measurements, together with the problems of adaptation referred to above. However, the finding of such decreases in several studies in different laboratories, in addition to the evidence that there may be a decrease in sweating in response to other types of "stressor", warrants further investigation. Studies to be carried out will include tasks similar to those used in studies reporting an apparent decrease in sweating, with the PSI being taken during the task, as well as after the task.

3 Summary

Chapter six will describe the basic methodology used in the studies which follow. This chapter will also present data concerning the inter-rater reliability of the PSI. The following chapters will

then describe the series of experiments undertaken.

In order to allow a comparison with electrodermal measures, the first study to be undertaken will be a laboratory study. This experiment will examine the effect of anxiety on the PSI using the model of anxiety proposed by Gray (1976). Studies by Fowles and his co-workers have manipulated anxiety, and the corresponding positive motivational state, using performance feedback plus monetary incentives or penalties. In addition, this study will allow the investigation of the effects of a cognitive task on the PSI.

Later studies in the series will make use of the simplicity of the PSI to examine types of stressors with greater ecological validity. Two field studies will be described examining the effects on the PSI of public-speaking anxiety and examination anxiety. Both of these studies will examine the time-course of the PSI response to stress. The first will examine changes occurring in anticipation of stress, and in the recovery period immediately afterward. The second study will examine long-term effects stretching over several weeks.

A second laboratory study will examine the effects on physiological reactivity of life-events assessed by questionnaire. The questionnaire used will be validated on the population for which it is intended. This study will include measures of electrodermal activity and heart rate, allowing a further comparison of the PSI with other psychophysiological measures.

A final experiment will be described which attempts to determine whether the process of taking the PSI leads to changes in physiological activity. This study will use an alternative means of recording sweat gland activity using direct observation and video recording. By comparing measures taken when the PSI is being administered with those at other times it is possible to determine

whether the PSI is likely to be a reactive measure.

The data from each of the experiments will be examined for evidence concerning the advantages or disadvantages of different statistical treatments of the PSI. The effects of extraneous variables such as temperature or caffeine consumption will also be studied in each experiment.

The final experimental chapter will briefly review several collaborative studies which demonstrate the application of the PSI to the areas of clinical psychophysiology reviewed in chapter four. As well as demonstrating that the PSI is suitable for use in such settings, these studies are also intended to demonstrate that the PSI shows acceptable predictive validity. These studies show that the PSI can be used as an alternative to electrodermal activity.

Chapter 6 Methodology

1 Introduction

This chapter will present basic details of the methodology common to all or most of the studies which follow. In addition, this chapter will address the basic question of the reliability of the PSI.

The work described in the following chapters requires that the PSI be capable of being measured reliably. This chapter will present evidence concerning the inter-rater reliability of the PSI. That is, the extent to which different raters agree about the number of active glands present on a given print. Other aspects of reliability, temporal stability and inter-hand consistency, will be examined in later chapters.

The first section will describe the basic equipment used in the studies, and those elements of procedure common to all studies. This is presented here for brevity and to avoid repetition. Section three will then present evidence for the reliability of the PSI.

2 Apparatus and Procedures

2.1 Electrodermal Measurement

In a number of the experiments carried out, electrodermal activity was assessed in addition to the PSI. The same equipment was used each time. Skin conductance was recorded using a Contact Systems SC4 monitor. This measures skin conductance directly using a constant-voltage method, with an applied voltage of 0.6v. Adjustment of the basal level to compensate for shifts in SCL ("back-off") was

controlled automatically by the unit. The analogue output from the SC4 was fed into a Grass model 7D polygraph and output to a chart drive for visual scoring.

Skin conductance was recorded from the medial phalanges of the index and middle fingers of the non-preferred hand (for unilateral recording). 9mm diameter Ag-AgCl electrodes were used. Electrodes were secured by adhesive collars, which also limited the area of contact to 20 square millimeters, and, additionally, by adhesive tape.

The electrode gel was purpose made following the recommendations of Grey & Smith (1984). This paper suggests the use of .05M NaCl in a methyl cellulose base. Unfortunately, the paper contains a typographical error which was not spotted until after the first experiment. The formula given produces a solution which is too concentrated, .5M rather than .05M (see Clements 1989). This is the concentration which was used in experiment one. For consideration of the possible effects of this mistake see chapter thirteen. Later studies used a gel of the correct concentration. The correct formula for a .05M solution (after dilution with the methyl cellulose base) is 0.29g NaCl in 100g of water, or 0.46g in 160ml, rather than 4.8g in 160ml as stated in the original paper.

Skin conductance level was recorded directly from the chart output, allowing for the current back-off level. Skin conductance response frequency was also quantified. The number of responses which exceeded a criterion level (.015 microsiemens) were counted for one minute. This criterion was the smallest which could be judged accurately using the equipment available. Venables & Christie (1973) state that the range of response amplitudes is from .01 to 5 microsiemens/cm². With an area of contact of 0.2 cm² this range equates to an observed range of .002 to 0.982 microsiemens. Thus, all

but the smallest responses should be detected using this criterion. The criterion adopted compares well with those used in the literature, e.g. a multinational study by Bernstein et al. (1982) used a criterion of .05 microsiemens, in those laboratories using conductance measurement.

2.2 Heart Rate

Experiments one and four also included measurement of heart rate. This was undertaken using a Grass 7P4 amplifier and tachograph. The EKG was recorded from electrodes on each wrist, with a ground on the left forearm. Prior to attachment of each electrode, the skin was lightly abraded with an emery board. KY gel was used as an electrode gel.

Heart rate was calculated directly from the inter-beat interval by a tachograph triggered by the "R" wave of the EKG. Tachograph output, as well as output of the original EKG, was displayed via a chart recorder. Heart rate was recorded directly from the tachograph output, accurate to within one beat/minute.

2.3 The Palmar Sweat Index

The PSI was obtained using a formula derived from that given by Johnson & Dabbs (1967). The formula used is given below.

Polyvinyl Formal (Formvar)	5g
Butyl Pthalate	10ml
Semi-colloidal dispersion of graphite in ethanol	20g
Ethylene Dichloride	100ml

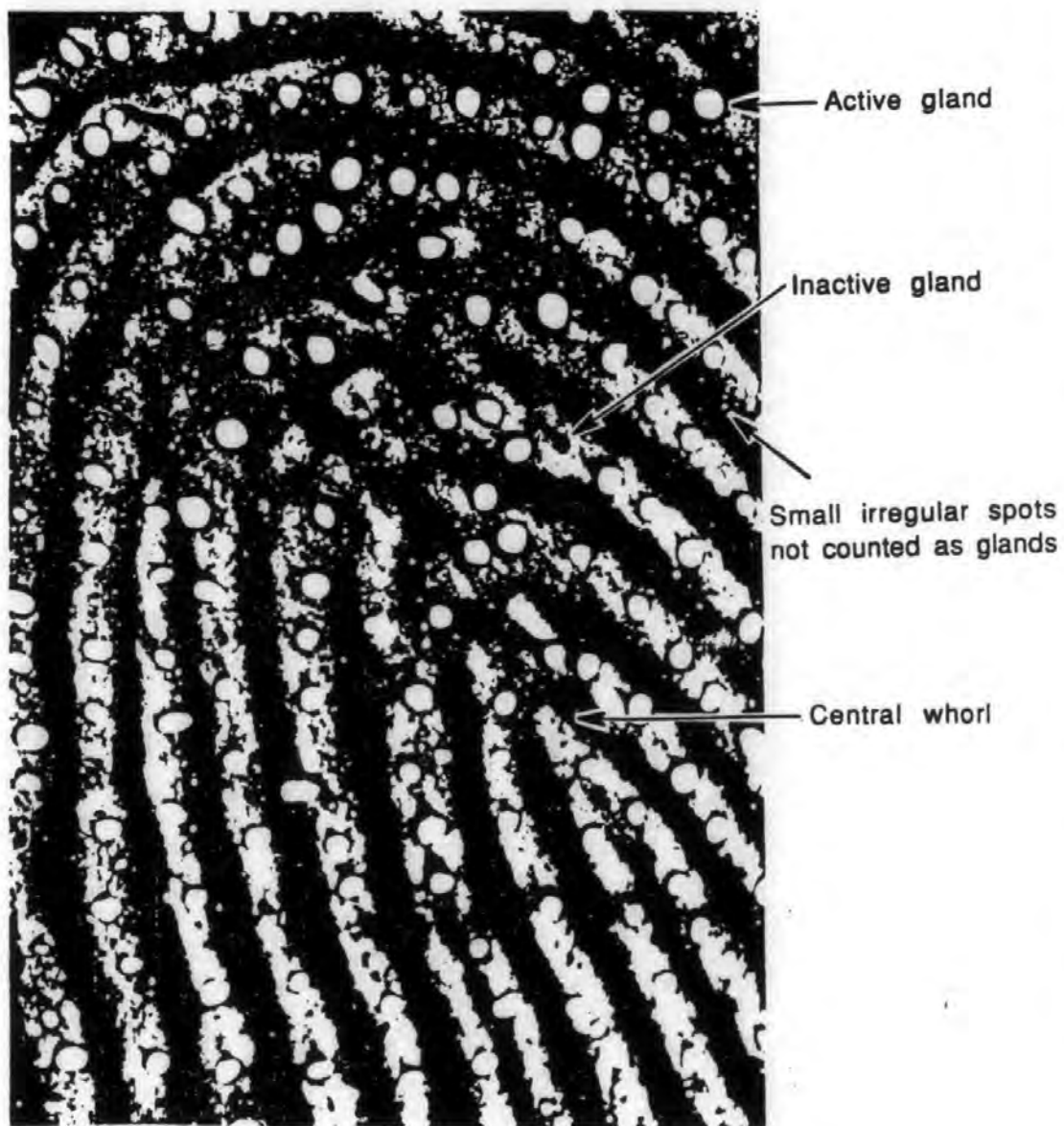


Figure 5: The Palmar Sweat Index, showing active and inactive glands

The Formvar is the "active ingredient" as it is immiscible in sweat, so that pores containing droplets of sweat produce holes in the impression. Butyl Pthalate acts as a plasticizer, giving strength to the print and graphite aids visibility by making the print darker, so that holes show up clearly.

The solution reacts with rubber and some plastics and must be kept in a glass flask with a glass or cork stopper. A standard conical flask with a glass stopper was used. Prints were applied using the stopper. After excess drops of the solution had been shaken off on the top of the flask, the flat end of the stopper was rolled over the finger once, from side to side, to produce an even, thin layer of solution. This layer dries in around twenty seconds and, once dry, was removed with ordinary household sellotape. The sellotape was applied and removed proximal to distal, as the print is less likely to break up when removed this way. Rubbing the sellotape a few times before removal aids the process of removal.

After removal, the sellotape was stuck onto a clear acetate sheet and scored under a microscope using 40X magnification. A template was used to define an area of 4mm x 4mm. Both the number of active glands and the total number of glands, active and inactive, were scored for each print. Active glands appear as distinct white holes on the, lighter, ridges of the fingerprint. Inactive glands show up as darker spots due to the accumulation of graphite in the pore, see figure 5. White openings on the grooves of the print are not counted as sweat glands. Where possible, counts were centred on the central whorl of the finger print, to ensure that successive prints came from the same area. If this area was torn or scudged the closest intact area was used. If no area large enough was available no attempt was made to score a smaller area and scale up. All prints used were scored by the

same rater. Detailed criteria were drawn up to standardise the scoring procedure (see appendix A).

The ratio of active glands over total glands was calculated for each print. The ratio measure should be less sensitive to variations in the total number of glands present than the absolute number of active glands visible. The number of glands present in the area to be scored might vary due to individual differences in finger size or when successive prints are taken from slightly different areas of the finger.

2.4 General procedure

2.4.1 Standard procedures. A number of standard procedures were used in all experiments. Firstly, all subjects were asked to wash their hands prior to the experiment. In laboratory studies this was done after subjects attended the experiment, all subjects complied. In the two field studies, experiments two and three, the experiment was not conducted in a room with a sink. In these experiments subjects were asked to wash their hands prior to attendance, but compliance was not monitored. Hand washing should standardise the time since subjects last washed their hands, which might be a source of error variance, and also seems to aid removal of palmar sweat prints.

Subjects were also given a period to acclimatise to the experimental setting prior to the experimental manipulation. This was generally done by instructing subjects to spend five minutes or so relaxing at the start of the session. Such an acclimatisation period should dissipate any effects of prior activity and should also allow initial anxiety to decline. Linden and McEarchen (1985) suggest that adaptation usually follows an inverse-J curve, being most rapid at the

start of the session. Allowing an initial adaptation period, therefore should provide relatively stable measures during the experimental phase. Linden and McEachern's suggestion (1985) of the use of individual adaptation times, using a criterion of stability, was not followed. Linden and McEachern report that the measures used in these studies are relatively stable and should adapt relatively quickly.

Koehler, Meber and Voegelé (1990) recommend that all studies using the PSI should reject the first two prints taken. They report that the PSI, and also skin conductance level, showed large decreases during the initial minutes of an adaptation period, even though subjects had been sitting in the experimental room for 30 minutes. They suggest that the procedure of administering the PSI may itself lead to elevated levels of sweat gland activity.

2.4.2 The digit-symbol substitution task. In several of the experiments a digit-symbol substitution task was used as a standard stressor. This task is presented in appendix B. The task consists of four rows of twenty-five boxes. Each box has a number above it. Subjects were told to fill in as many boxes as possible with a symbol corresponding to the number above the box, from a key at the top of the sheet. Subjects were given one minute to do the task. In order to produce a moderate degree of evaluation apprehension subjects were told that the task was "similar to those used on many IQ tests".

2.4.3 Ethical procedures. All subjects were volunteers and gave informed consent. Subjects were given the opportunity to ask questions about the experiment prior to participation. All subjects were also informed prior to participation of their right to withdraw. After each experiment was complete, subjects were debriefed as to the aims of the

experiment and given a further opportunity to ask questions.

2.5 Statistical Procedures

2.5.1 Missing values. A common feature of psychophysiological data is the presence of missing values. Rather than exclude subjects who had any values missing, which would have meant that the design was non-orthogonal, missing values were replaced by the GENSTAT macro MULTMISS (Alvey et al., 1980). This macro produces estimates of each missing value calculated from the other data from that subject, and the overall pattern of relationships between the variables. This treatment of missing values is the default for ANOVA using the GENSTAT package.

MULTMISS produces estimates using an iterative regression approach. Initially, each missing value is replaced by the mean for that variable, this is the first estimate of each missing value. Using the complete set of data, regression equations are constructed to predict each variable using the other variables. These equations are used to produce new estimates for each missing value on the basis of the other values for that subject. The estimated values are then inserted in place of the prior estimates. If the means for each variable differ from the original means, new regression equations are calculated and new estimates inserted. The process is repeated until the obtained means do not differ from the original means.

Where this procedure was used, a number of checks were carried out in order to ensure that the estimation procedure had not distorted the results obtained. Analyses including estimated values were repeated, excluding data from subjects with missing values. If these two analyses produced differing results, the estimated values were

examined and tested to identify any extreme values, defined as values more than 1.96 standard deviations from the mean of the original distribution.

Mean scores reported in tables and figures are based on the original data, excluding missing values. Estimated values were not included in correlational analyses.

2.5.2 Transformations. The distributions of the physiological variables were examined for deviations from normality. Where analyses indicated significant skew or, less commonly, extremes of kurtosis, electrodermal data were transformed prior to analysis. Two transformations are proposed in the literature. Schlossberg and Stanley (1953) found that, where transformation was necessary, a square root transformation was effective in normalising the distribution of SCL. More extensive comparisons by Venables and Christie (1980) found log transformation of SCL to produce the best results. Both transformations were examined. For the PSI and NS-SCR rate square root transformation was found to produce the best normalisation. On statistical grounds this transformation is recommended when data are in the form of counts (Howell, 1987, p302). For SCL, results were less consistent. In some studies log SCL gave normally-distributed scores, while in others this transformation over-compensated for the degree of skew and a square-root transformation was chosen.

No transformation of heart rate data was necessary. The transformations used are indicated in each of the relevant chapters.

2.5.3 Analyses involving repeated measures. Similar statistical analyses were undertaken in each experiment. All analyses involving

repeated measures were undertaken using multivariate methods (the SPSSX MANOVA procedure; Norusis, 1985, pp255-293). Univariate ANOVA with repeated measures requires that data meet the assumption of sphericity. One way in which this assumption may be violated is if data are not equally correlated. If all of the pairwise correlations between measures are equivalent, then the data will show sphericity. Physiological data usually does not meet this assumption, measures closer together in time are more likely to be correlated than measures at different ends of a series. These violations of assumptions can lead to drastically increased type one error rates. For this reason univariate ANOVA is not recommended for repeated measures designs involving repeated measurements taken at closely spaced intervals (Vassey & Thayer, 1987).

This problem can be surmounted by using MANOVA, which does not require sphericity, or by carrying out a conventional ANOVA and adjusting the degrees of freedom to compensate for the likely effect of violations of the assumption of sphericity. The MANOVA approach is preferred, both because it is likely to be more powerful and because it allows follow-up sub-tests which are also protected against inflated type one error rates.

2.5.4 Follow-up analyses. Post hoc follow-up analyses were typically adjusted for the number of tests carried out, using the bonferroni inequality. As SPSSX produces exact probabilities, these probabilities are given in the text, although only those effects achieving the level indicated by the Bonferroni procedure are reported. For example, if six tests are carried out then, in order to maintain an overall alpha of .05 or less, each test should have an alpha level of $.05/6=.008$. Only those tests with a calculated

probability of .008 or less will be reported as significant, although for clarity the actual probability given in the printout is reported.

2.5.5 Correlational analyses. Several studies involved correlational analysis of repeated measures. To give an indication of the relationship between such measures both between- and within-subject correlations were calculated. Between subject correlations were calculated for each pair of measurements. For example, if both the PSI and SCL were obtained five times during a rest period, five correlations would be obtained. The first would compare the first PSI with the first SCL measurement across all subjects, the second would compare the second pair of measurements, and so on. The mean of these five correlations would be reported. Within subject correlations on the same data would produce one correlation coefficient per subject. Each correlation would compare the PSI with SCL across all five measurements.

Both between- and within-subject correlations are presented as the mean of the set of correlations. Also given is a test of the significance of the mean correlation, i.e. whether the mean of the correlations differs significantly from zero. Prior to the test each correlation was subjected to Fisher's transformation to compensate for the range restriction inherent in correlation coefficients (Howell, 1987, p244).

3 The Reliability of the Palmar Sweat Index

3.1 Introduction

An investigation was undertaken to examine the reliability with which the PSI could be scored. Reports in the literature (reviewed in

more detail in chapter three) report inter-rater reliabilities ranging between .87 and .99 (e.g. Johnson & Dabbs, 1967; Weisenberg et al., 1976). Despite this evidence of impressive reliability, it was considered necessary to demonstrate that the scoring of the PSI in this thesis showed acceptable reliability.

All of the prints used in this research were scored by the same person. In order to examine the reliability of this scoring, a random sample of prints from the first experiment was scored by a second person, blind to the scores originally assigned to each print.

This investigation will also examine how the reliability of the print is influenced by the level of activity present and by the area scored. Prints were obtained during both rest periods and a stressful task, see chapter seven for details of the task used. It is possible that the level of reliability shown might differ when the level of activity present varies. If this is the case, then the reliability of the scoring should differ for the two types of print.

The density of sweat glands may differ at different points on the fingertip. It is also possible, although unlikely, that the reactivity of the sweat glands may show regional variation within a finger. Therefore, prints scored from different areas might show different numbers of active glands. This was investigated by arranging for the second scorer to score half of the prints in the same area as the original scorer. The area to be scored was not specified for the other prints, leaving the scorer free to choose a different area from that originally selected. If the area chosen does influence the result obtained, the reliability of the prints should be higher for those prints definitely scored from the same area.

In a further investigation, a sample of prints from later studies were scored automatically using an image-analysis system. Bailes

(1983) used an image-analysis system to score sweat prints, but his thesis doesn't report any comparison of this methodology with visual scoring. Image analysis provides considerable advantages in the analysis of PSI data. Scoring of the prints is the most time-consuming aspect of the PSI. Visual scoring is also open to the criticism that subjective factors may influence the scoring process. Non-specific factors such as boredom may introduce errors into visual scoring. More alarming, is the possibility that, without blind scoring, visual scoring of prints might lead to artifacts due to the expectancies of the scorer.

In order to investigate the practicality of automatic scoring, and as a partial check on the objectivity of visual scoring, batches of prints from experiments two and four, and from the first study from chapter twelve, were scored automatically by a Quantimet 520 image analysis system, the system used is described in more detail in the next section. The scores obtained from this analysis were then compared with those originally given to the prints by the human scorer.

3.2 Method

3.2.1 Selection of prints for inter-rater reliability. The prints used in the reliability check were randomly selected from those obtained in experiment one. When the prints were originally scored, half were marked indicating the centre of the area scored. This should allow the second scorer to score the same area as the original scorer. 40 subjects were randomly selected from the 72 who took part in this experiment. The only limitation on the selection was that half should have the prints marked for the location of scoring ("marked" prints),

while half had unmarked prints. For each of these 40 subjects, 3 prints were randomly chosen. Each subject had a total of 21 prints, 15 (71%) were from rest periods, while 6 (29%) were taken during a stressful cognitive task. The choice of prints was not constrained as to the period from which the print came. Of the 120 prints chosen 83 (69%) were from rest periods, while 37 (31%) were taken during the task. The ratio of resting to task prints was roughly equal for marked and unmarked prints (40:20 versus 43:17, respectively).

The second scorer was given the protocol, drawn up by the first scorer, in order to standardise the criteria used. The criteria appear in full in appendix A. As well as indicating the number of active glands present and the total number of glands, the second rater also gave each print a rating from 1 to 7, with 1 representing "excellent" and 7 representing "almost unreadable". Prints which could not be scored were given a rating of 8.

3.2.2 Prints for automated scoring. A second set of prints was selected for scoring by machine. These prints were chosen so as to include a range of levels of activation, and to cover a range of situations. Three batches of prints were selected. For the first batch, three prints were chosen from each of the subjects who took part in experiment two. For each of these nineteen subjects, prints were taken before, during and after a presentation in front of an audience of peers.

Prints were also selected from those taken in experiment four. Two prints were selected, one taken at rest and another taken in the middle of a digit-symbol substitution task. Because of limitations of time, only those prints from the first ten subjects in this batch were scored by machine.

The final batch selected were from one of the collaborative studies presented in chapter twelve. Prints were taken from 56 schizophrenic subjects at rest.

These three batches include one batch from a laboratory study (experiment four) and two taken under field conditions. The batch from the collaborative study consisted of prints administered by a different researcher, all the other prints being taken by the same person.

3.2.3 The quantimet image analysis system. For scoring the prints were placed under a microscope and scanned by a CCD camera. An area 4.13mm x 4.13mm was scanned, with a resolution of 512 x 512 pixels, giving .008mm per pixel. The output from the camera was fed into a Quantimet 520 image analysis system. The system identified all of the objects exceeding a fixed brightness threshold in it's area of analysis. Objects identified were further filtered to select objects with a certain range of diameters (.04 to .4mm) and with an approximately circular shape (shape parameter 1.0 to 1.8). The number of objects meeting these criteria was the score given to each print. The procedure used to identify active glands was developed on the basis of pilot studies.

The area of analysis was selected according to a fixed pattern. Initially the central whorl was identified and, if possible, this area was chosen. If the central area was unsuitable, either torn or too dark, the eight surrounding areas were examined, one after the other working clockwise from the top. If none of these was suitable the print was counted as being unscorable.

Table 7: The contribution of the site chosen to
the inter-rater reliability of the PSI

	Inter-rater Reliability	
	Number of active glands	Proportion of glands active
Site identified for second rater	.897	.920
Site not identified for second rater	.820	.867

All correlations significant at $p < .001$, one tailed.

Table 8: The contribution of time of measurement to
the inter-rater reliability of the PSI

	Inter-rater Reliability	
	Number of active glands	Proportion of glands active
Resting measures	.802	.873
Mid-task measures	.896	.901

All correlations significant at $p < .001$, one tailed.

3.3 Results

3.3.1 Inter-rater reliability of the PSI. There was good agreement between the two raters. Overall correlations between scores from the two markers were .858 for the number of active glands (PSI-A) and .894 for the ratio of active glands to total glands (PSI-R). These two correlations do not differ significantly, implying that the ratio measure does not show appreciably greater reliability than a simple count of the number of active glands.

When the effect of site of scoring was examined there was little evidence that site of scoring made any difference to the reliability of the PSI. Data for the inter-rater reliabilities of both PSI-A and PSI-R are given in table 7. As can be seen, identifying the area scored produced little improvement in reliability. For both measures, even when a one-tailed hypothesis was tested, the difference between the reliabilities of marked and unmarked prints fell short of significance (PSI-A $z=1.46$, $p=.072$; PSI-R $z=1.34$, $p=.090$).

When resting and task measures were examined there was a non-significant tendency for higher reliabilities for the task measures, see table 8. The amount of activity present seems to have little effect on the reliability with which prints can be scored.

The ratings given by the second rater were then examined to determine whether clear prints could in fact be scored more reliably than poorer quality prints. The initial seven point scale was collapsed to three categories for analysis. The categories chosen were selected so as to give reasonable numbers of prints in each category. "Good" prints were those rated 3 or below. "Average" prints were those rated 4 or 5. Prints given ratings of 6 or 7 were counted as "poor". The final rating, 8, was only given to unscorable prints which could

not be included in the analysis. The number of prints given each rating is displayed in table 9.

For the three quality ratings correlations were calculated between the scores assigned by the two raters. These are displayed in table 10. Surprisingly, the perceived quality of the print does not seem to influence the reliability with which it can be scored. Comparisons of the correlations for "good" prints with those for "poor" prints revealed that neither of the correlations differed significantly. Indeed "poor" prints had non-significantly higher correlations for the ratio measure.

To summarise, the reliability of the PSI was found to be acceptable. The increase in reliability following identification of the area to be scored did not achieve significance. Reliability also seemed to be relatively unaffected by the amount of activity present on the print. Furthermore, subjective quality of the print to be scored also did not seem to influence reliability. The two raters agreed equally whether prints were clear or of poorer quality.

3.3.2 Automated scoring of the PSI. The correlation between the score produced by the automated scoring system and that originally assigned to the prints was slightly lower than those reported above, but still acceptable. The scores produced by the image analysis system correlated .773 with the number of active glands counted and .772 with the ratio of active over total glands for the same prints.

In order to examine whether condition of measurement had any effect upon the reliability of scoring, data from the three different studies were separated. Correlations between the number of active glands scored by the two methods were examined for the three batches of prints. These correlations are displayed in table 11.

Table 9: The quality ratings of the prints

Rated Quality	Number of prints
Excellent (1)	6
Very Good (2)	16
Above average (3)	18
Average (4)	22
Poor (5)	22
Very Poor (6)	21
Almost unreadable (7)	8
Unreadable (8)	6

Table 10: The relationship between print quality
and inter-rater reliability

Rated Quality	Inter-rater reliability	
	Number of Active glands	Proportion of glands active
1-3	.862	.888
4 & 5	.877	.898
6 & 7	.812	.923

All correlations significant at $p < .001$, one tailed.

Table 11: The effect of condition of measurement on
the correlation between manual and automated scoring
of the PSI

Study	Correlation
Experiment two	.683
Experiment four	.713
Schizophrenia study	.816

All correlations $p < .001$, one tailed.

None of the three correlations differed significantly from any other. Thus, prints taken under laboratory conditions showed no greater agreement than the two sets from field studies, including one set of prints taken by another worker.

3.3.3 The sensitivity of automated scoring. Finally, an attempt was made to examine the sensitivity of the two methods of scoring. This analysis concentrated on the data from the public-speaking study. The three prints sampled show a wide range of activity, with the print taken during the talk showing a high level of activation and the print taken after the talk showing the lowest level. If the two scoring methods are equivalent they would be expected to be equally sensitive to the effect of the talk. A similar analysis was not undertaken for the data from experiment four because the overall effect of the task was relatively small (see chapter ten) and the sample of subjects selected for this comparison actually showed slightly lower levels of activity during the task than prior to the task. Comparison of effect

sizes relies on the assumption that a real effect is present, in the case of the data from experiment four this assumption may not be valid.

Both the number of active glands and the ratio of active glands over total glands showed significant variation across the three measures (PSI-A approx. $F(2,14)=4.58$, $p=.029$; PSI-R approx. $F(2,14)=6.23$, $p=.011$). The data from the automated analysis did not discriminate significantly between the three measures, although this is probably due, in part, to the higher rates of missing data in the automated analysis. Out of a total of 57 prints, 12 could not be scored by the image analysis system, as opposed to 3 missing points when visual scoring was used.

Effect sizes (omega squared; Dodd & Schultz, 1973) were calculated from the analyses. The conclusions were consistent with the results of the analyses. When the automated scoring system was used the effect of the talk was less than when active glands were scored by eye (omega squared = .051 versus .095, respectively). When the ratio of active glands to total glands was calculated from the manually-scored data this seemed to be more sensitive still (omega squared = .147).

These findings seem to imply that the image analysis system used does not lead to a more reliable, and therefore more sensitive, analysis of sweat gland counts. However, a number of cautions need to be considered.

Firstly, the system is only as good as the algorithm used to extract a count of active glands from the raw data. It is quite likely that a different choice of procedure, perhaps using different length or shape criteria, or greater pre-processing of the image, might lead to a more accurate count of the number of glands active. The algorithm used here was developed on the basis of a pilot analysis, more

detailed study would certainly produce a better algorithm.

Secondly, the test used here is somewhat arbitrary and does not constitute a particularly good criterion for choosing one measure over another. The comparison relies on the assumption that the talk did lead to a change in levels of sweat gland activity. While public-speaking has been found to lead to elevated levels of autonomic activity in a large number of other studies, there is no independent criterion for this comparison. The evidence that the talk did lead to increased sweating, and a large drop in sweating after the talk, comes from one of the two measures being compared (for detailed analysis of the data from this experiment see chapter eight).

Finally, there is the question of the interpretation of the findings. While visual scoring does seem to lead to a larger difference between the three measures, this may not necessarily be due to the differential sensitivity of visual versus automated scoring. One possibility is that visual scoring may introduce a subjective bias. The greater apparent effect with visual scoring may reflect an added artifact in the visually scored data.

At present all that can be said is that the data do not give support for using automated scoring over visual scoring on grounds of reliability. The ease and speed of automated scoring, however, are a definite advantage. In view of the high correlations between both methods of scoring, automated scoring does seem to be worthy of further investigation.

4 Discussion

The PSI does show acceptable inter-rater reliability. Different raters agree strongly as to the number of active glands present on a given print. This reliability holds whether raters attempt to score

the same area or not. Factors such as print quality or amount of activity present also seem to have little influence on the certainty with which prints can be scored. These results clearly justify the use of the PSI. The scoring procedure seems to be reasonably objective. The results do not provide any clues as to ways in which the reliability of scoring could be improved. None of the factors studied influenced the reliability with which prints could be scored. The reliability of the number of active glands is comparable to that of the ratio of active to total glands. Despite a priori reasons for expecting the ratio measure to have higher reliability, this did not seem to be the case.

Investigation of a system for automated scoring also demonstrated the reliability of visual scoring. The objective procedure agreed well with the traditional method of scoring. In view of the practical advantages of automated scoring, this procedure would be worthy of further study. Some means of automated scoring would be essential, were the PSI to be used in an applied setting.

The analyses carried out do not provide any justification for the use of automated scoring in preference to visual scoring, apart from the practical advantages of speed and convenience. Automated scoring did not seem to lead to a more sensitive measure, and automated scoring was associated with higher rates of missing data.

It must be admitted that the brief analysis carried out here does not do full justice to the automated scoring system. In addition to the count of active glands studied here, such systems can also provide other parameters, such as average gland size, total area covered by active glands etc. Such parameters may well provide information not available from visual scoring.

Image analysis systems also use a set of procedures for

extraction of data from an image. These procedures can be combined in various ways to "clean up" the image and identify desired features. The operations used here were selected on the basis of a number of trial studies. A more systematic analysis of the effects of the criteria used to select objects, and of various types of processing of the image prior to identification, would be needed prior to implementation of such a system. Such analysis would almost certainly lead to a better, in the sense of more reliable and sensitive, automated analysis system.

This study has demonstrated the potential of image analysis for the scoring of the PSI. Development of a full system to score sweat prints is beyond the scope of this thesis.

Having shown that the PSI can be scored reliably, the following chapters will go on to examine the validity of the measure. An examination of the test-retest reliability of the PSI will be presented as part of chapter nine. The PSI is not expected to show a high degree of stability across testing occasions and such stability is not essential for its use.

The first study to be presented will compare the PSI with electrodermal measures of sweat gland activity. Experiment one will also examine the relationship between the PSI and anxiety.

Chapter 7

Experiment One: The Effect of Feedback-Induced Anxiety and Level of Task Difficulty on the PSI and Electrodermal Activity

1 Introduction

The experiment to be described in this chapter was undertaken to examine the concurrent validity of the PSI, and investigated the relationship between the PSI and measures of EDA. Correlations between the PSI and both skin conductance level and non-specific response frequency were obtained from subjects, both at rest and while performing a stressful task.

Experiment one was also intended to investigate the construct validity of the PSI as an index of anxiety. As reviewed in chapter three, prior research with the PSI has produced conflicting evidence concerning the effects on the PSI of psychological "stressors". One such study, undertaken by Turpin, Takata & Tutton (1986, experiment 1) examined the effects on the PSI of evaluation anxiety using mental arithmetic problems. Subjects were given multiplication problems, with two levels of difficulty. These two levels of task difficulty, presented in counterbalanced order, were crossed with two levels of evaluative threat. Evaluative threat was manipulated between subjects using relevant task instructions. The results of the study revealed an apparent dissociation between EDA and the PSI. While both SCL and NS-SCR frequency were higher during the task, the PSI was lower when taken immediately after the task than when taken in the rest periods. Neither variable responded to level of threat or task difficulty. Examination of manipulation checks revealed that the threat

manipulation was ineffective, in comparison to the degree of anxiety evoked by the problems themselves. There was also evidence of an order effect in the difficulty manipulation.

This study raised several questions. The apparent dissociation between EDA and the PSI is in need of further investigation. As reviewed in chapter three, several other studies have revealed an apparent decrease in the PSI as a result of performing some types of cognitive task (e.g. Johnson & Dabbs, 1967; Cohen, 1978). Many of these studies, however, like Turpin, Takata & Tutton (1986), failed to obtain the PSI during the task (but see Carver & Scheier, 1981). Experiment one examined the effects on the PSI of a cognitive task, which would lead to the kind of inwardly-directed attention which Johnson & Dabbs (1967) suggested might produce a decrease in the PSI. This experiment included measurement of both EDA and the PSI during the task, as well as in the intervening rest periods. The results of the study described above also demonstrate that there is a need to separate any anxiety manipulation from the anxiety-arousing properties of the task itself.

The task chosen was a sentence verification task, as this task would be expected to be less inherently anxiety-provoking than the mental arithmetical task used in the earlier study and provides a simple means of adjusting the difficulty level of the task. Subjects were presented with two types of sentence which differed in their complexity. It was hoped that the use of two difficulty levels, together with self-report measures of mood will allow the separation of the effects, if any, of the task itself on physiological activity from the effects of task-induced anxiety. If, as Johnson and Dabbs (1967) suggest, inwardly directed attention inhibits sweating, the PSI should be depressed during the task, relative to resting levels. This

depression would be expected to be greater for "difficult" than for "easy" sentences. Alternatively, if the PSI is an valid alternative to electrodermal measures, it would be predicted to show an increase during the task.

An anxiety manipulation was sought which would allow the nature of the anxiety aroused to be clearly defined and which could be manipulated independently of the difficulty of the task. The manipulation chosen was based on Fowles' (1980) extension of Gray's (1976) model of anxiety. This theory, previously discussed in chapter four, predicts that tonic Heart Rate (HR) provides an index of appetitive motivation, whereas EDA is responsive to activity in the system underlying aversive motivation. The activity of the system which Fowles (1980) links to EDA is said to underlie anxiety. These two systems are the Behavioural Activation System (BAS) and the Behavioural Inhibition System (BIS).

Gray's theory proposes that the BAS activates behaviour in approach situations and in active avoidance. The system is responsive to stimuli indicating that behaviour will lead to positive outcomes, either reward or non-punishment. The Behavioural Inhibition system underlies passive avoidance and extinction, inhibiting appetitively-motivated behaviour in response to stimuli associated with non-reward or punishment. Gray (1977) argues that anxiolytic drugs act by antagonising the activity of the BIS. This provides one basis for his claim that the BIS constitutes the physiological substrate of anxiety.

Fowles (1983) provided a review of the experimental support for the psychophysiological aspects of the theory. In general, there is considerable evidence for a relationship between heart rate and appetitive motivation. Several studies undertaken by Fowles and his

co-workers have demonstrated that HR is sensitive to differences in the level of incentive, using a serial reaction time task (Fowles, Fisher & Tranel, 1982; Tranel, Fisher & Fowles, 1982). Electrodermal activity, in contrast, has not been found to be sensitive to level of incentive (Tranel, 1983). While less research has been carried out to investigate motivational effects on EDA, there is evidence to support Fowles' claims. For example, Roberts & Young (1971) demonstrated that a stimulus conditioned to shock, presented in a conditioned emotional response (CER) paradigm, produced an electrodermal response but an overall decrease in heart rate. Szpiller & Epstein (1976) also report that NS-SCR frequency was sensitive to the threat of electric shock whereas HR and SCL responded only to the amount of motor activity required. Tranel (1983) found that EDA, but not heart rate, showed an increase following the unexpected termination of feedback and monetary incentives, as the theory would predict.

As the model makes differential predictions concerning the effects of feedback on electrodermal measures and heart rate, the latter measure was also included. As both measures appear sensitive to motor activity, the response requirements were identical in both conditions. It was predicted that subjects receiving negative feedback and monetary penalties would show higher EDA than control or positive feedback subjects. Subjects receiving positive feedback and monetary incentives should show higher Heart Rates than those in the other two feedback conditions.

The theory predicts that the effect would be reversed if feedback was unexpectedly terminated. As Tranel (1983) found, the termination of monetary incentives should lead to increased EDA. As the theory is symmetrical regarding the two systems, the unexpected termination of monetary penalties should produce a similar increase in heart rate.

For this reason an "extinction" period was included. The extinction period might be expected to produce clearer results than the feedback trials. While the feedback indicating the receipt of an incentive or the loss of a penalty was made as salient as possible, implicit feedback of the opposite kind is inevitably available on other trials. For example, subjects in the incentive condition receive feedback indicating when they get a problem right. On trials when their solution is incorrect, the absence of a response from the computer can also be considered to be negative feedback. The theory specifies that non-reward would produce the same effect as punishment. For this reason the aversive motivational system might be activated in the incentive group as well as in the penalty group. However, due to the greater salience of the feedback signals, as well as the difference between actually losing money and merely failing to gain money, the relative activity of this system should be greater in the penalty condition. On extinction trials this possible confound will not occur as all trials will produce the same feedback. It was predicted, therefore, that the groups previously receiving positive feedback would show higher EDA during the extinction period than the other groups. Similarly, during the extinction period subjects who previously experienced negative feedback should have the highest heart rates.

A related point concerns the possibility of an interaction between the feedback manipulation and the difficulty of the tasks. While the difficulty level of the task will have predictable effects on the amount of feedback received, the literature is unclear whether this will influence the physiological response. Studies by Obrist, using shock avoidance, imply that either very high or very low success rates will lead to a loss of motivation and no heart rate increase

(Obrist, 1976). Several studies reported by Fowles and his co-workers, using monetary incentives, in contrast, indicate that HR responds primarily to the size of the incentives, and that success rate or expected earnings do not influence HR. One study (Fisher, 1982) did, however, find lower HR in a group with a very low (10%) success rate. In addition, Tranel (1983) found that heart rate was sensitive to total earnings in a task with a 100% success rate, although this is interpreted as reflecting an effect of reward per unit effort, rather than an effect of total reward per se. Thus, the evidence implies that, except at very low success rates, task difficulty is unlikely to influence the HR response to feedback and monetary incentives. There is no evidence concerning the effects of task difficulty on the relationship between EDA and feedback. The difficulty levels of the task used were selected to give success rates close to the 90% and 50% rates used by Fowles and his co-workers.

As a pilot study for later work, several questionnaires were administered, including the Marlowe-Crowne Social Desirability Scale (Crowne & Marlowe, 1964- used as a measure of repression sensitization), the trait scale from the Spielberger State-Trait Anxiety Inventory (Spielberger et al, 1970), the Beck depression inventory (Beck et al, 1961) and the Life-Event Scale for Students (Linden, 1984- see chapter ten).

In summary, it is hypothesised that both the PSI and measures of electrodermal activity will increase during the task. The feedback manipulation should lead to a dissociation between the measures of sweat gland activity and heart rate. Heart rate is predicted to be higher in the positive-feedback condition than in the no-feedback condition or the negative feedback condition. Electrodermal activity and the PSI should be higher in the negative feedback condition than

in the positive feedback or no-feedback conditions. The negative-feedback groups should also report more anxiety than the other groups. After feedback is terminated the physiological differences should reverse. The group who previously received positive feedback having higher sweat gland activity, while the group who had been receiving negative feedback should show higher HR.

It is expected that the PSI will correlate with EDA. While the PSI might also show some correlation with HR, reflecting non-specific effects of autonomic activation, this correlation should be lower than that with EDA.

2 Method

2.1 Subjects

The majority of subjects were undergraduates. All subjects were paid a minimum of £1.50 for participation. Some also received points in partial satisfaction of a course requirement. 77 subjects participated, 5 of whom were rejected due to missing data. The final sample contained 29 males and 43 females.

2.2 Apparatus

Electrodermal activity and heart rate were recorded continually throughout the experiment using the procedure described in chapter 6. Due to a typographical error the purpose-made electrode gel used was too concentrated. Rather than .05M NaCl, the gel contained .5M NaCl in methyl cellulose (see Clements, 1989). Skin temperature was recorded by a thermistor attached to the ring finger of the non-preferred hand.

Sentence-verification problems were presented using a BBC model B microcomputer. Problems were presented on a screen in front of the subjects. Subjects' responses on the task were recorded using two foot

pedals. A box with six buttons, labeled from one to six, was used to collect responses to manipulation checks, also presented by the computer. Both the foot pedals and the response box fed into the computer via an interface.

2.3 Procedure

After informed consent had been obtained, all subjects were seated in a soundproof room and asked to read the task instructions while electrodes were attached. The Marlowe-Crowne social desirability scale (used as an index of repression-sensitization) and the Spielberger trait anxiety scale were then administered. After completing the scales, each subject was requested to relax for 5 minutes while PSIs were administered each minute. Room temperature and skin temperature were recorded during this rest period. After the rest period, each subject was asked to complete the Profile of Mood States (POMS; McNair et al., 1981) describing how they felt at that moment. This questionnaire provides separate scales for Tension-Anxiety, Depression-Dejection, Anger-Hostility, Vigour, Fatigue and Confusion-Bewilderment.

After each subject had completed the questionnaires and had been given the opportunity to review the the instructions, the task was started. The task consisted of three blocks of eight sentences, each sentence being presented with a pair of characters. Problems were displayed on a computer monitor in front of the subject. Each block lasted approximately a minute. A PSI was administered in the middle of each block.

The sentences were of the form-

"THE LETTER IS A AND THE NUMBER IS NOT FOUR".

Subjects had 5.5 seconds in which to indicate whether each sentence correctly described the following pair of characters by pressing one of two pedals. Subjects were divided into six groups consisting of every combination of two levels of difficulty and three feedback conditions. The two difficulty conditions ("Easy" and "Difficult") were obtained by varying the nature of the sentences: The easy group received "and" sentences of the type shown above. The difficult group received "either-or" sentences as shown below.

"EITHER THE LETTER IS A OR THE NUMBER IS NOT FOUR"

The three feedback conditions were negative feedback, no feedback and positive feedback. Subjects in the negative feedback condition were told that they could earn a maximum of £2.24 for the experiment but they would lose 7p each time they got an answer wrong. This was indicated by the word WRONG flashing on screen after each incorrect response. The amount earned was present on screen throughout the task.

Subjects in the no feedback condition received no feedback during the task and were paid £1.50 at the end of the experiment.

Subjects in the positive feedback condition started the experiment with no money but earned 7p for each correct answer. Each correct answer was followed by the word CORRECT flashing on the screen. As in the negative feedback group the amount earned was present on screen throughout the task.

All subjects who would otherwise have earned less than £1.50 were paid £1.50 at the end of the experiment, although subjects were not informed beforehand that this would be the case.

After each set of eight sentences each subject was asked to

answer three questions on a six-point scale. These were "How difficult do you find the problems right now?", "How anxious do you feel right now?" and "How motivated do you feel right now?". These were designed to provide a crude assessment of the effects of the manipulation at the same time as the physiological data were recorded. In addition subjects were asked to complete the POMS again after the task.

There then followed another five-minute rest period identical to the first. This was followed by an extinction period in which feedback was unexpectedly stopped after the first block of problems. In all other respects this period was identical to the first task period. The POMS was administered again after the second task period. Finally there was a third rest period.

After the electrodes were removed and subjects had been debriefed subjects were asked to fill in the Beck depression inventory and the life-event scale for students. Subjects were allowed to complete these questionnaires in their own time

2.4 Data reduction and analysis

Skin conductance level (SCL) was quantified five times in each rest period at the same time as the PSI. During the task three SCL measures were taken in each set of sentences; one in the middle of the block (at the same time as the PSI) and one ten seconds from the start and end of the block. Heart rate (HR) was recorded as the average of the rates calculated from five successive inter-beat intervals. Heart rate measurements were taken at the same times as SCL was quantified. Skin conductance response (SCR) frequency was measured as the number of responses exceeding a threshold of .015 micromhos in one minute centred on each PSI.

The PSI was analysed both as the usual count of active glands

(PSI-A) and as a ratio of the number of active glands divided by the total number of glands (PSI-R), in order to allow a comparison of the sensitivity of the two measures.

Prior to the analysis missing data points for the physiological variables were estimated using a regression approach. The number of points replaced was as follows; HR 4 (0.17%), NS-SCRs 2 (0.13%), SCL 9 (0.38%), PSI 48 (3.17%). In order to investigate the possibility of distortion of the results by the process of estimation, the analysis of the physiological data was repeated excluding those subjects with missing data. Only where this analysis revealed differences from the balanced analysis will the results be reported.

Post hoc multiple comparisons within the three feedback groups were analysed using the Fisher's LSD test. This test was chosen as it is the most powerful procedure for post hoc comparisons and, provided no more than three means are compared, provides control over the overall error rate (see Howell, 1987, pp343-344).

Simple effects analyses were undertaken using significance levels adjusted using the Bonferroni inequality to offset the inflation of error rates. Probability values reported are those corresponding to the actual F value obtained. Only those effects reaching the Bonferroni significance level have been reported. For example, if three simple effects are examined only those effects with a calculated probability of $.017$ ($=.05/3$) or less are reported.

3 Results

3.1 Transformations

The distributions of the physiological variables were examined. All of the measures of sweat gland activity showed significant positive

skew, these variables were transformed prior to analysis. A square root transformation was chosen for NS-SCR frequency and for the number of active glands and the proportion of glands active from the PSI. For SCL a logarithmic transformation was initially examined, but this over-compensated for the degree of skew. A square root transformation was finally used for SCL as well.

3.2 Pre-Manipulation Data

Measures taken during the first rest period were analysed separately in order to test for any initial differences between the groups. A 2 (Difficulty) x 3 ("positive", "negative" or no feedback) analysis of variance on each of the questionnaire measures revealed no significant differences between the groups prior to the task. 2 (Difficulty) x 3 (Feedback) x 5 (Repetition) MANOVAs on the physiological measures revealed a significant Repetition main effect for all measures (all measures of sweating, $p < .001$; HR, $p = .01$) reflecting identical adaptation for all groups.

A Difficulty x Feedback x Repetition interaction for skin conductance level failed to reach significance when data from the one subject for whom values from this rest period were not available were replaced by estimated values (approx $F(8,128) = 1.87$, $p = .070$). However, when the subject with missing data was excluded from the analysis, this interaction was significant (approx $F(8,126) = 2.21$, $p = .031$). Simple main effects for this interaction revealed that only the Easy/No feedback and Easy/positive feedback groups showed significant adaptation (easy/no feedback approx $F(4,7) = 9.03$; easy/positive feedback approx $F(4,8) = 9.94$, both unadjusted $p < .008$).

The subject with missing data was in the easy task/no feedback group. When estimated values for that subject were included, the

simple simple effect of repetition was non-significant for that group. Examination of the estimated values revealed that the values tended to increase over the period. Mean values for other subjects in the group showed a declining trend. It seems that the estimated values may have been unrepresentative, masking the occurrence of adaptation in the easy task/no feedback group.

Differences in activity during the first rest period might be due to the effects of the task instructions, presented prior to the first rest period. However, the PSI data from the second rest period, to be described later, also indicate that the groups may have shown differences in resting activity. A post-hoc analysis on the last measure from the rest period showed that there were no significant group differences in conductance level immediately prior to the task.

3.3 Manipulation Checks

3.3.1 Mid-task measures In order to check the effectiveness of the difficulty manipulation, the number of correct responses given were analysed in a 2 (Difficulty) x 3 (Feedback) x 2 (Task Periods) MANOVA. A significant effect of Difficulty level was obtained ($F(1,66)=371.18, p<.001$) indicating that more correct responses were made in the "easy" than in the "difficult" groups ($\bar{X}= 21.98$ and 11.25 respectively). The feedback manipulation did not affect performance on the task. As might be expected, there was a significant difference between performance in task period one and task period two ($F(1,66)=30.21, p<.001$). Subjects' performance improved with practice (\bar{X} for period 1 =15.79, \bar{X} for period 2 = 17.43). The effect of practice did not interact with task difficulty or feedback condition.

Self-report measures obtained during the task were analysed separately for trials where feedback was given and for the "extinction" period. Thus for each scale a 2 (Difficulty) x 3 (Feedback) x 4 (Trials 1 to 4) MANOVA and a 2 x 3 x 2 (Trials 5 & 6) MANOVA were performed.

The tasks differed in their perceived difficulty (see table 12), the "easy" task being perceived as less difficult on both feedback ($F(1,66)=62.56, p<.001$) and extinction trials ($F(1,66)=34.60, p<.001$). There was also a significant main effect of Feedback in both feedback ($F(2,66)=3.98, p=.023$) and extinction ($F(2,66)=14.05, p<.001$) trials. However, the effects of feedback condition were different in feedback and extinction periods. When feedback was given, a Fishers' LSD test revealed that the group receiving negative feedback reported the task as more difficult than the positive feedback group ($t(66)=2.49, p=.015$) or the control group ($t(66)=2.40, p=.019$). When feedback was unexpectedly terminated, the group previously receiving positive feedback reported the task as more difficult than either the control group ($t(66)=4.59, p<.001$) or the negative feedback group ($t(66)=4.59, p<.001$). On trials where feedback was given there was also a significant main effect of Trial (approx $F(3,64)=8.01, p<.001$). This was modified, however, by an interaction with difficulty level (approx $F(3,64)=6.00, p=.001$). This interaction is displayed in figure 6. As can be seen the "difficult" group showed a greater decline in reported difficulty over time. Simple main effects revealed that the "easy" and "difficult" conditions differed significantly in their perceived difficulty at all times.

Figure 6: Difficulty by Feedback interaction for self-reported task difficulty

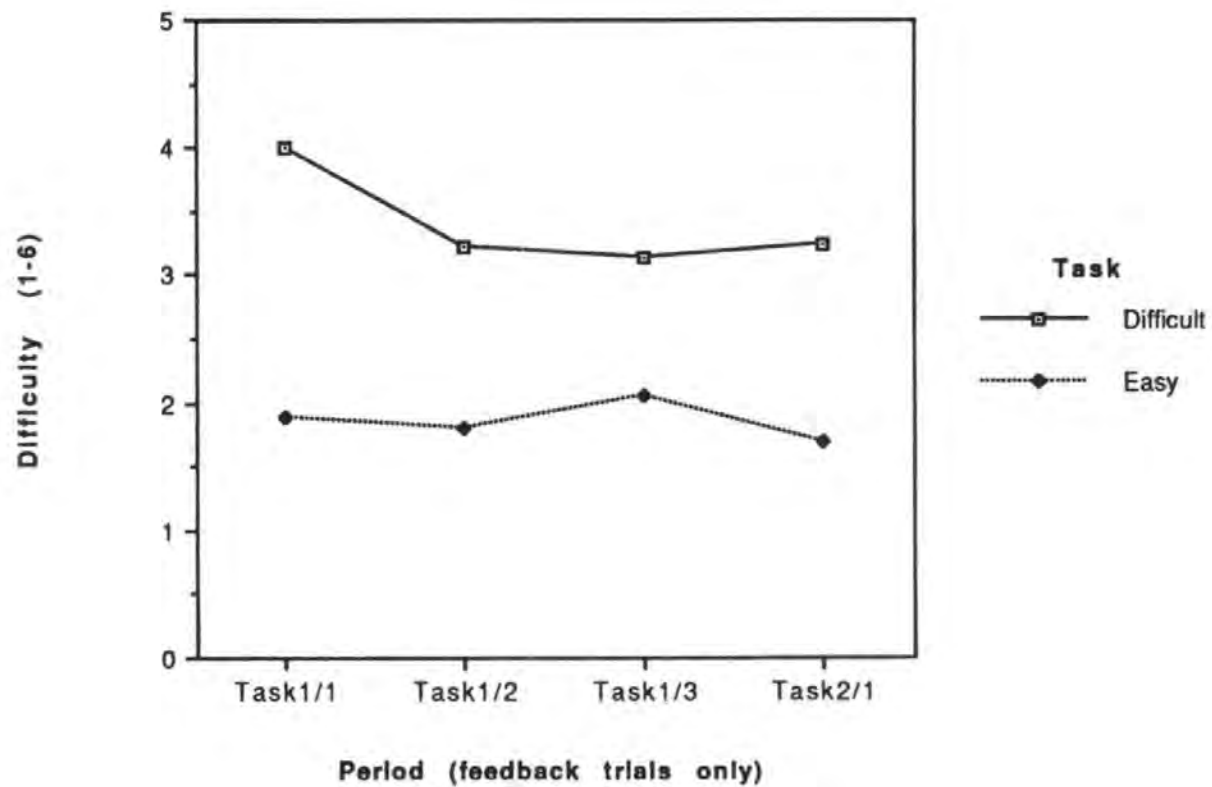


Table 12: Self-reported difficulty

Task	<u>Mean scores</u>			<u>Mean scores</u>		
	"Easy"			"Difficult"		
Feedback						
Condition	Negative	No	Positive	Negative	No	Positive
Period						
Feedback 1	2.06	1.89	1.81	4.08	3.19	3.08
Feedback 2	1.83	1.50	1.75	3.92	2.83	3.00
Extinction	1.75	1.54	2.63	2.71	2.92	4.54

Number of scores obtained; feedback 1- 3, Feedback 2- 1, Extinction- 2

Table 13: Self-reported Motivation

Task	<u>Mean scores</u>			<u>Mean scores</u>		
	"Easy"			"Difficult"		
Feedback						
Condition	Negative	No	Positive	Negative	No	Positive
Period						
Feedback 1	4.28	3.47	4.17	4.00	3.94	3.92
Feedback 2	4.33	3.50	4.17	3.67	3.83	3.58
Extinction	4.42	3.42	4.17	3.88	3.67	3.42

Number of scores obtained; feedback 1- 3, Feedback 2- 1, Extinction- 2

Table 14: Self-reported anxiety

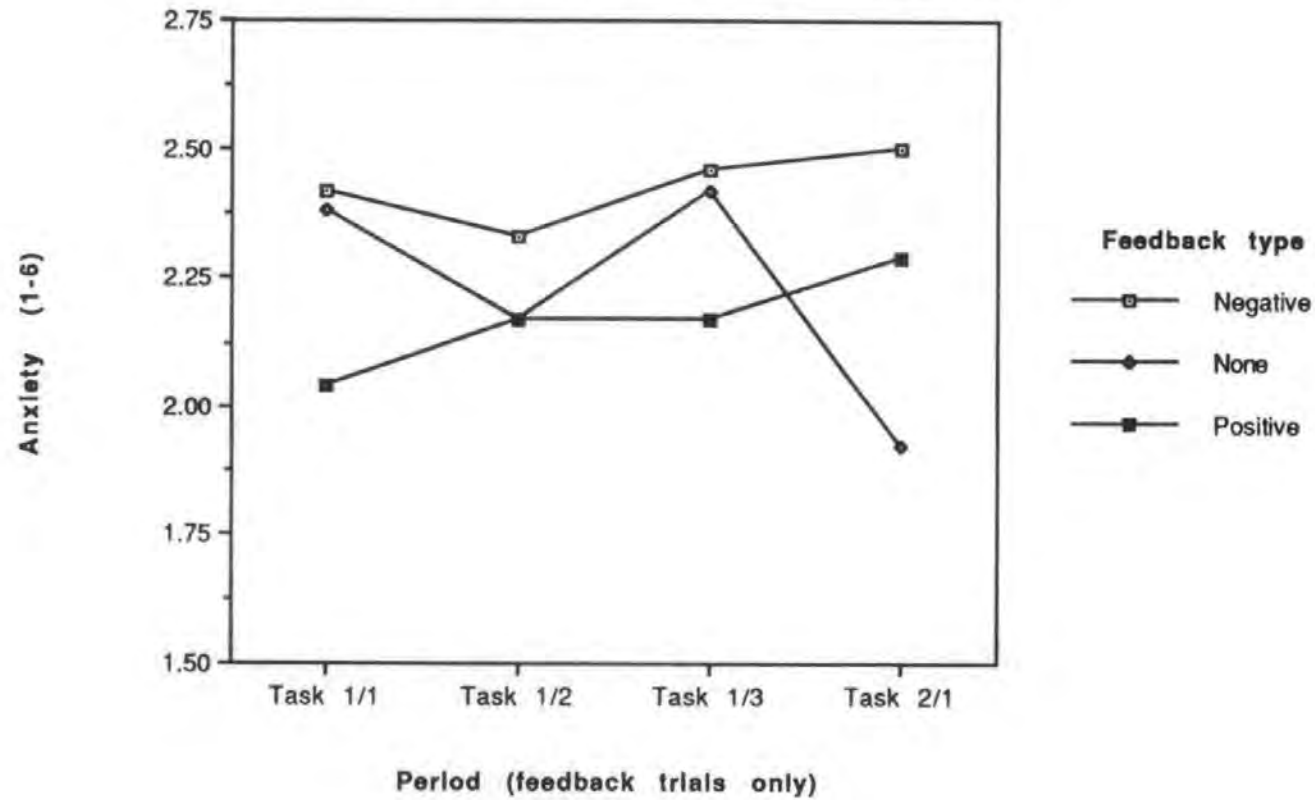
Task	<u>Mean scores</u>					
	"Easy"			"Difficult"		
Feedback	Negative	No	Positive	Negative	No	Positive
Condition						
Period						
Feedback 1	2.28	2.14	1.94	2.53	2.50	2.31
Feedback 2	2.17	1.58	1.92	2.83	2.25	2.67
Extinction	2.21	1.71	2.38	2.08	2.17	3.00

Number of scores obtained; feedback 1- 3, Feedback 2- 1, Extinction- 2

The measures of self-report "anxiety" and "motivation" administered during the task largely failed to show the predicted effects: Self reported "Motivation" was unaffected by any aspect of the experiment (see table 13). The "Anxiety" scale revealed that subjects in the difficult condition reported more anxiety during the first four trials ($F(1,66)=5.30, p=.024$).

Contrary to predictions, there was no effect of feedback on level of reported anxiety when feedback was actually given (see table 14). There was, however an interaction between the Feedback and Trials factors (approx $F(6,130)=2.19, p=.048$). This interaction is displayed in figure 7. The figure implies that the interaction is primarily due to the lower levels of anxiety reported by the no-feedback group in task period two. Simple effects analysis indicated that the three feedback groups did not differ significantly at any time.

Figure 7: Feedback by Repetition
Interaction for self reported Anxiety



On extinction trials, however, "anxiety" did behave as predicted. There was a significant main effect of feedback ($F(2,66)=4.05$, $p=.022$) and multiple comparisons revealed that the group previously receiving positive feedback tended to report more anxiety than the other two groups when feedback was terminated (positive vs control group $t(66)=2.76$, $p=.008$, positive vs negative group $t(66)=1.99$, $p=.051$).

Thus, the effectiveness of the difficulty manipulation is confirmed. Subjects in the difficult condition made more errors, and perceived the task to be more difficult than those in the easy condition. The feedback manipulation also influenced reported difficulty. Negative feedback led subjects to rate the task as more difficult on trials where feedback was given. Similarly, when subjects stopped receiving positive feedback they perceived the task to be more difficult. The feedback manipulation had no effect on the simple "motivation" scale administered during the task. The "anxiety" scale seemed to respond in much the same way as the subjective difficulty scale. The scale revealed anxiety in subjects performing the difficult task on feedback trials. On extinction trials the anxiety scale revealed higher anxiety in those subjects previously receiving positive feedback.

3.3.2 The Profile of Mood States. All POMS scales were analysed as change scores from the values obtained immediately before the first task period. Each of the six scales was subjected to a 2 (Difficulty) x 3 (Feedback) x 2 (Task Period) MANOVA. The Profile of Mood States largely failed to reveal a differentiated response to the manipulations, all of the scales behaved similarly. During the feedback trials, only the difficulty manipulation led to effects on

subjective mood. Subjects performing the difficult task reported more disturbance on several scales. An effect of Feedback only appeared in the extinction period. The unexpected termination of positive feedback led to an increase in reported mood disturbance.

Subjects performing the difficult task were higher on all scales, with the exception of vigour (see tables 15-20). Scales affected by difficulty level were Tension-Anxiety ($F(1,66)=4.15$, $p=.046$), Depression-Dejection ($F(1,66)=16.45$, $p<.001$), Anger-Hostility ($F(1,66)=10.02$, $p=.02$), Fatigue ($F(1,66)=4.50$, $p=.038$) and Confusion-Bewilderment ($F(1,66)=36.50$, $p<.001$).

Both Depression-Dejection ($F(1,66)=4.68$, $p=.034$) and Anger-Hostility ($F(1,66)=5.13$, $p=.027$) also revealed Difficulty x Task Period interactions. A similar interaction for Fatigue was almost significant ($F(1,66)=3.97$, $p=.051$). When data from each task period were analysed separately, both Depression-Dejection and Anger-Hostility were found to be higher in the "difficult" group after both task periods. After task period one, Depression-Dejection ($F(1,66)=10.24$, unadjusted $p=.002$, Anger-Hostility ($F(1,66)=5.84$, unadjusted $p=.018$). After task period two, Depression-Dejection ($F(1,66)=17.89$, unadjusted $p<.001$; Anger-Hostility ($F(1,66)=11.20$, unadjusted $p=.001$.) Fatigue was significantly higher in the "difficult" group only after the extinction period ($F(1,66)=17.89$, unadjusted $p<.001$). Surprisingly, the interaction indicates that the groups differed more after subjects stopped receiving feedback as to their performance (see figures 8 & 9).

In contrast to the effects of task difficulty, the feedback manipulation seemed to have had less effect on mood. No scale revealed a main effect for Feedback. There were interactions between the feedback condition and the difference between measures taken after the

two task periods for Tension-Anxiety ($F(2,66)=5.78, p=.005$), Depression-Dejection ($F(2,66)=14.24, p<.001$), Anger-Hostility ($F(2,66)=14.66, p<.001$) and Confusion-Bewilderment ($F(2,66)=23.66, p<.001$). In each case, analysis of the scores after the first and second task periods separately revealed that no scale was influenced by feedback condition after the first task period. After the second task period, all of these scales revealed a significant feedback effect. Multiple comparisons revealed that the group previously receiving positive feedback reported greater mood disturbance than one or both of the other groups (Tension-Anxiety- positive feedback vs negative $t(66)=2.41$, unadjusted $p=.019$; Depression-dejection- positive vs control $t(66)=3.11$, unadjusted $p=.003$, positive vs negative $t(66)=2.68$, unadjusted $p=.009$; Anger-Hostility- positive vs control $t(66)=2.49$, unadjusted $p=.015$, positive vs negative $t(66)=3.17$, unadjusted $p=.002$; Confusion-Bewilderment positive vs control $t(66)=3.12$, unadjusted $p=.003$, positive vs negative $t(66)=3.96$, unadjusted $p<.001$).

A Difficulty x Feedback x Task Period interaction for Anger-Hostility ($F(2,66)=4.06, p=.022$) appears to represent the large increase in Anger-Hostility in the group receiving positive feedback on the difficult task.

Tension-Anxiety was lower after the extinction period than after the first task period ($F(1,66)=16.02, p<.001$). Overall, both Vigour ($F(1,66)=8.03, p=.004$) and Anger-Hostility ($F(1,66)=10.38, p=.002$) differed significantly from resting levels, Vigour being lower and Anger-Hostility higher after performing the task.

Figure 8: Difficulty by Repetition
interaction for POMS Depression-dejection

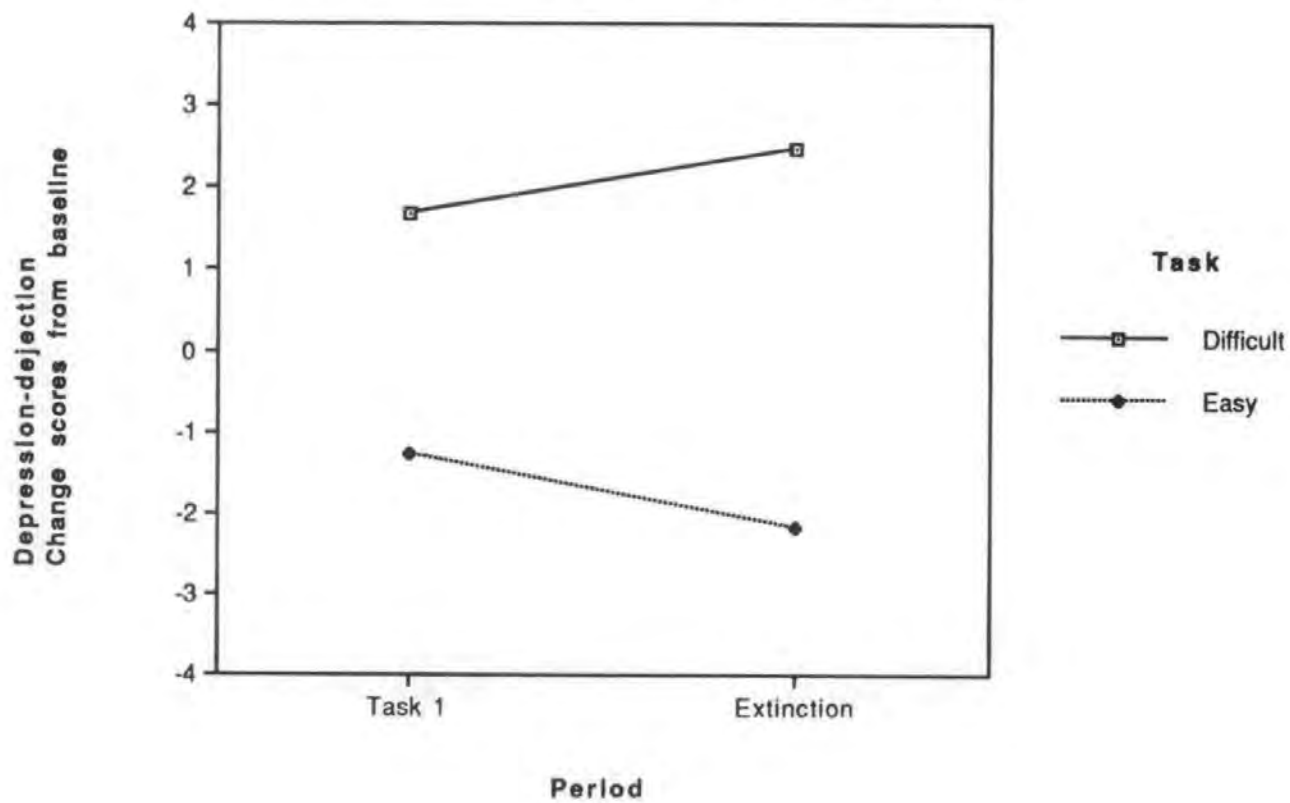


Figure 9: Difficulty by Repetition interaction for POMS Anger-hostility

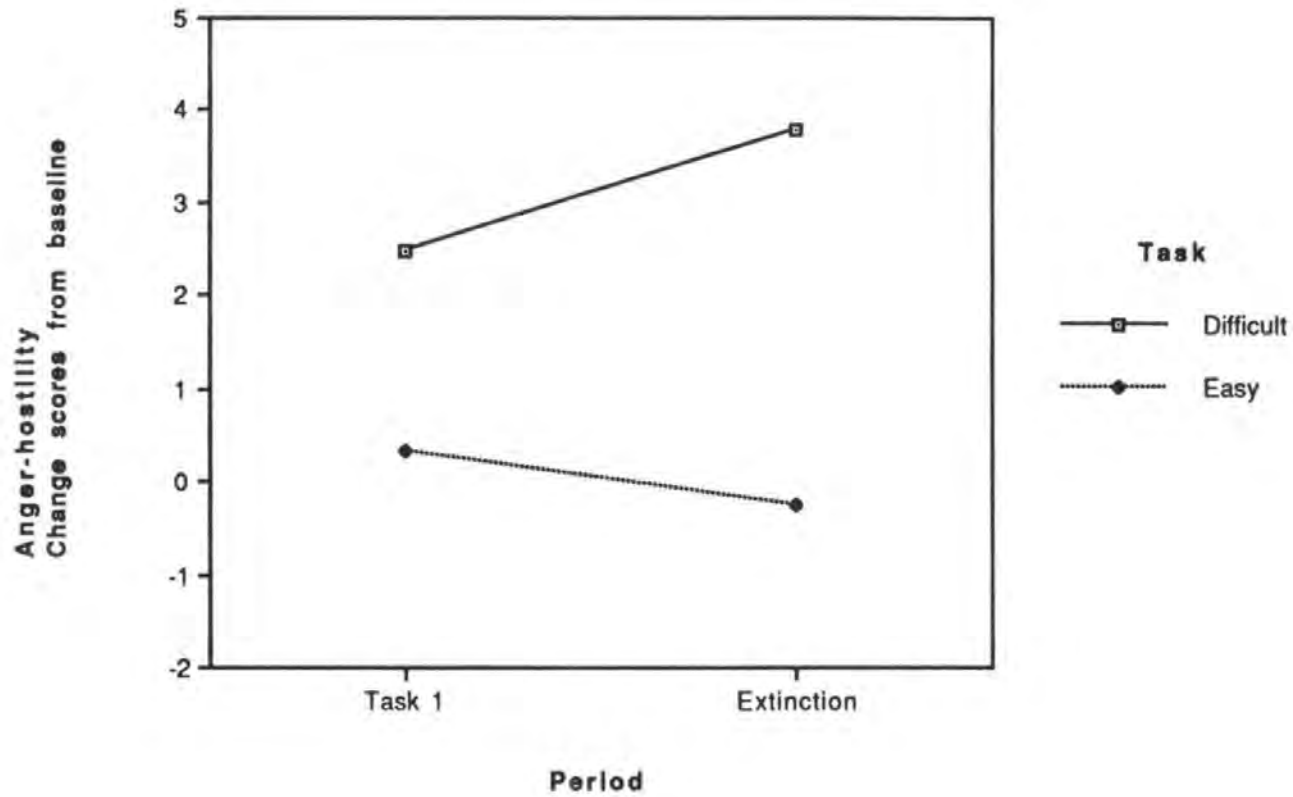


Table 15: POMS Tension-Anxiety scores

Change scores from first rest period

Task	"Easy"			"Difficult"		
	Negative	No	Positive	Negative	No	Positive
Feedback						
Condition						
Period						
Feedback 1	-1.83	0.33	-0.17	0.75	1.58	0.92
Extinction	-4.58	-3.33	-0.92	-1.67	-0.75	2.33

Table 16: POMS Depression-Dejection scores

Change scores from first rest period

Task	"Easy"			"Difficult"		
	Negative	No	Positive	Negative	No	Positive
Feedback						
Condition						
Period						
Feedback 1	-0.53	-2.00	-1.33	2.25	1.75	1.08
Extinction	-3.08	-3.08	-0.42	1.33	0.17	5.92

Table 17: POMS Anger-Hostility scores

Change scores from first rest period

Task	"Easy"			"Difficult"		
	Negative	No	Positive	Negative	No	Positive
Feedback						
Condition						
Period						
Feedback 1	1.08	-0.25	0.08	3.67	1.75	2.00
Extinction	-0.58	-1.17	1.00	2.33	0.92	0.08

Table 18: POMS Vigour scores

Change scores from first rest period

Task	"Easy"			"Difficult"		
	Negative	No	Positive	Negative	No	Positive
Feedback						
Condition						
Period						
Feedback 1	-1.50	-2.25	0.00	-0.25	-2.50	-1.50
Extinction	0.67	-1.67	-0.67	0.00	-1.00	-2.83

Table 19: POMS Fatigue scores

Change scores from first rest period

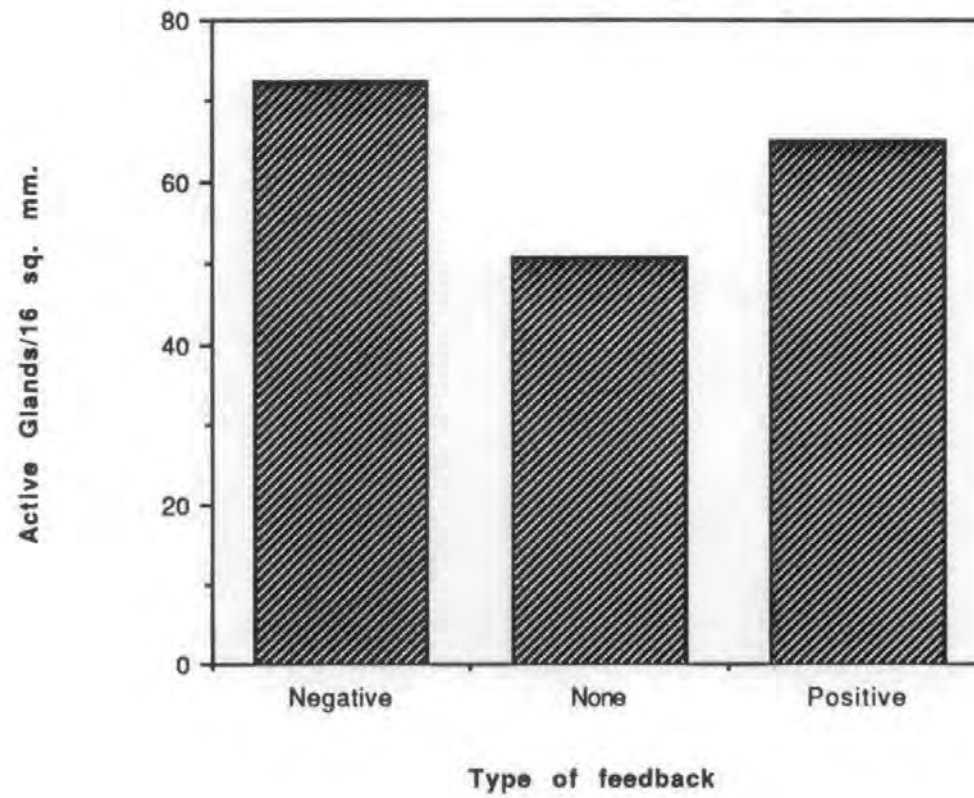
Task	"Easy"			"Difficult"		
	Negative	No	Positive	Negative	No	Positive
Feedback						
Condition						
Period						
Feedback 1	-1.17	-0.92	-0.67	0.50	1.33	-1.67
Extinction	-1.50	-1.42	-1.17	-0.42	2.42	-0.33

Table 20: POMS Confusion-Bewilderment scores

Change scores from first rest period

Task	"Easy"			"Difficult"		
	Negative	No	Positive	Negative	No	Positive
Feedback						
Condition						
Period						
Feedback 1	-1.67	-0.83	-1.50	3.00	3.33	2.17
Extinction	-3.17	-2.75	0.42	1.00	2.50	6.00

Figure 10: Feedback main effect for the Palmar Sweat Index in Task period one



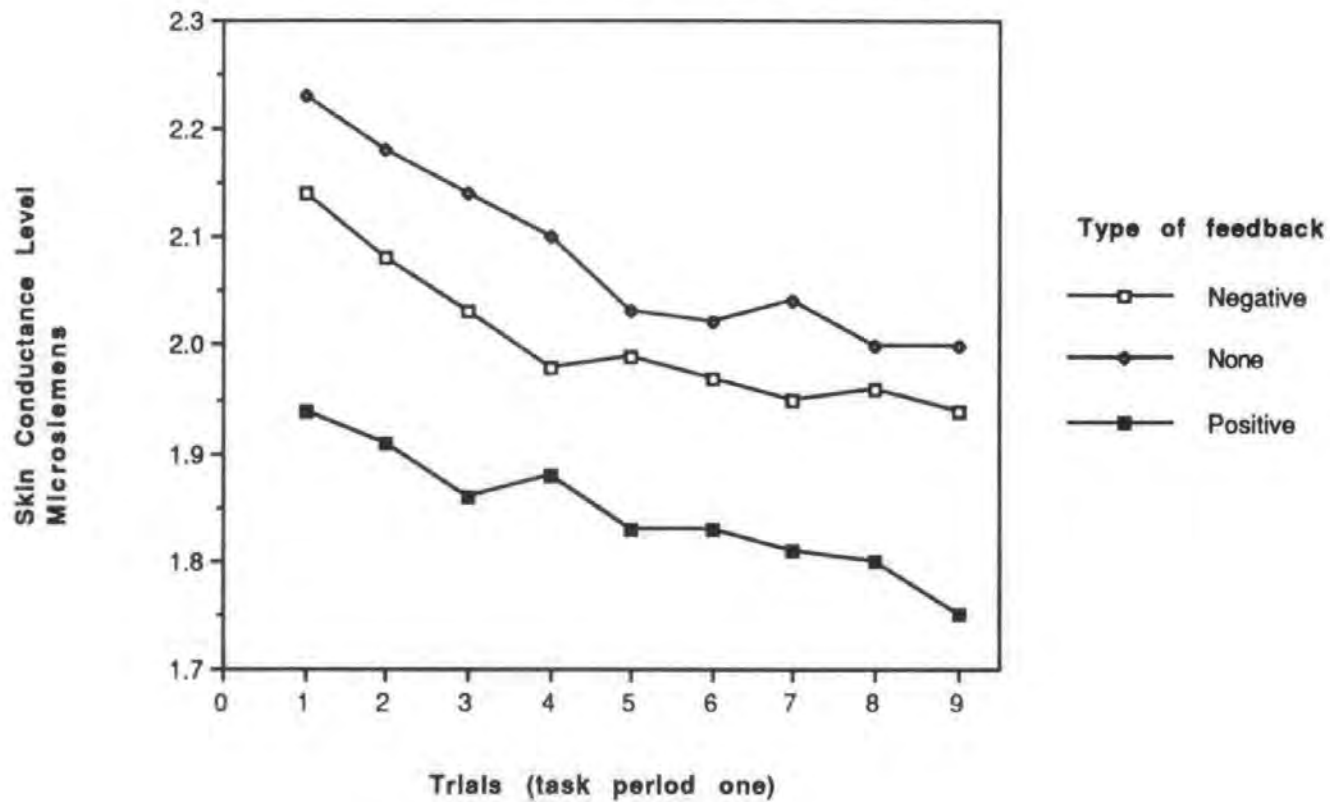
3.4 The Effect of Feedback on Physiological Measures

Because of the evidence for pre-manipulation differences in SCL, physiological variables were analysed both as raw scores (after appropriate transformations) and as change scores from the preceding rest period. Only the analysis of raw scores will be presented in detail. Where the two analyses revealed differences these will be described. The implications of these two analyses for the interpretation of the PSI will be considered later. For brevity, the analysis of the PSI will focus on the number of active glands. The analysis of the PSI-R will only be discussed where this produced different conclusions. Data from task period one, the first block of task period two and the extinction period were analysed separately.

3.4.1 Task period 1. All physiological measures were analysed in 2 (Difficulty) x 3 (Feedback) x 3 or 9 (Repetition) MANOVAs. In the analyses of difference scores, all of the mean scores were significantly different from zero (PSI-A $F(1,66)=110.02$; PSI-R $F(1,66)=120.70$; SCL $F(1,66)=76.59$; NS-SCRs $F(1,66)=41.23$; HR $F(1,66)=68.49$, All $p<.001$). All of the physiological measures increased during the first task period. There was no indication of a decrease in the PSI as a result of the task.

Analysis of the PSI-A data revealed a significant main effect of Feedback ($F(2,66)=3.90$, $p=.025$). This effect is displayed in figure 10. Fisher's LSD test revealed that, as predicted, only the negative feedback group had significantly higher counts than the no-feedback control group ($t(66)=2.76$, $p=.007$). The difference between the positive-feedback and control groups did not reach significance ($t(66)=1.73$, $p=.088$).

Figure 11: Feedback by Repetition interaction for Skin Conductance Level



The effect of Feedback was non-significant in the analysis of difference scores. There was also a Repetition main effect (approx $F(2,65)=40.51$, $p<.001$) reflecting the expected adaptation over the course of the period.

In the analysis of the proportion of glands which were active, the main effect of Feedback fell short of significance ($F(2,66)=2.90$, $p=.062$), although the effect achieved significance when 5 subjects with missing values were excluded. In other respects, analysis of PSI-R data lead to similar conclusions to the analysis reported above.

The other measures of sweating did not behave as predicted. Analysis of SCL revealed that the main effect of Feedback was non-significant. There was a Feedback x Repetition interaction (approx $F(16,120)=2.39$, $p=.004$) and a main effect of Repetition (approx $F(8,59)=9.59$, $p<.001$). Analysis of simple main effects revealed that linear trends, corresponding to the adaptation which is apparent for all groups (see figure 11), were significant for all three feedback groups (negative feedback $t(176)=4.09$, unadjusted $p<.001$; no feedback $t(176)=3.56$, unadjusted $p=.002$; positive feedback $t(176)=4.67$, unadjusted $p<.001$). Examination of the raw data fails to reveal any meaningful pattern.

Analysis of NS-SCR frequency revealed only one effect which reached significance. This was the Repetition main effect (approx $F(2,65)=56.81$, $p<.001$). Again this represents adaptation over the course of the period. Several of the interactions involving the Repetition factor came close to significance (Difficulty x Feedback x Repetition- approx $F(4,132)=2.37$, $p=.056$; Feedback x Repetition- approx $F(4,132)=2.27$, $p=.065$; Difficulty x Repetition- approx $F(2,65)=2.50$, $p=.090$). These interactions are displayed in figure 12.

Figure 12: Difficulty by Feedback by Repetition interaction for NS-SCRs

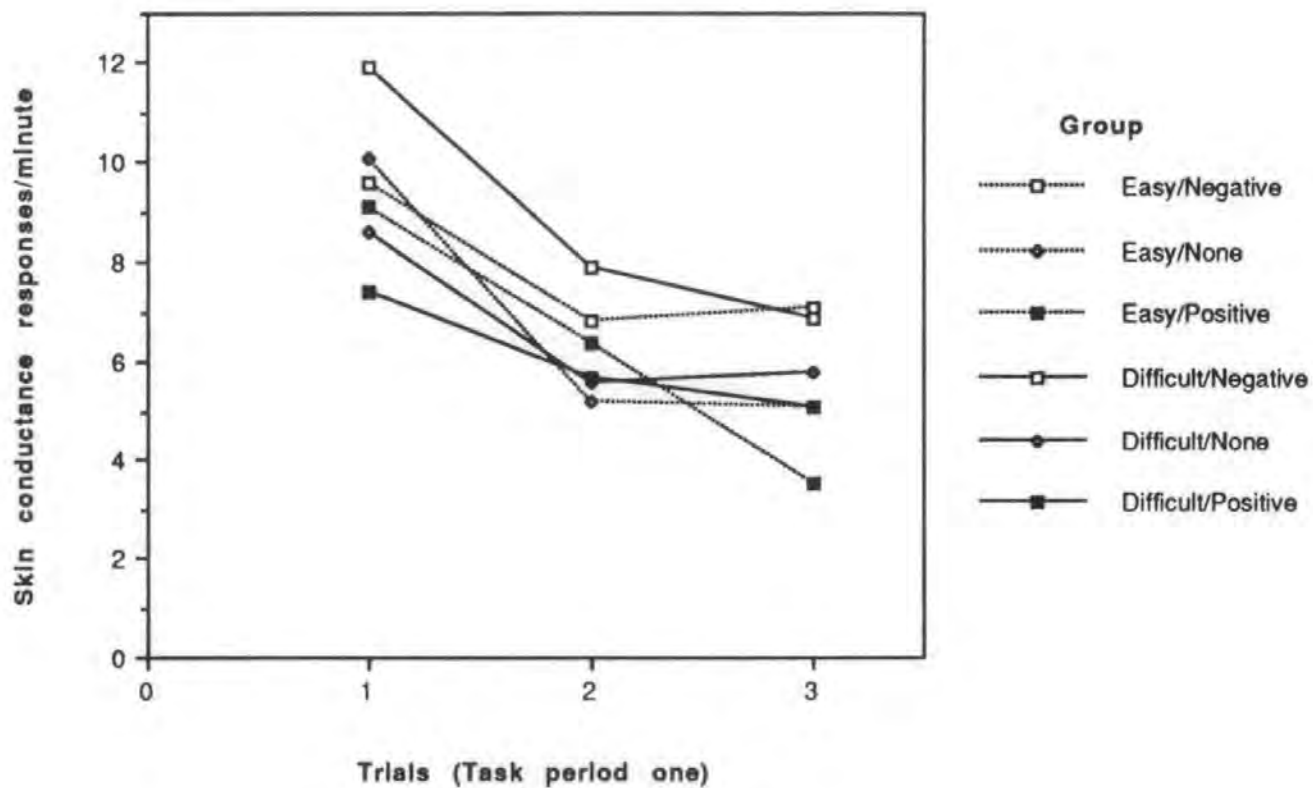


Table 21: Results of the Analysis of Heart Rate Data
from Task Period One

Effect	df	F	p
Feedback	2,66	4.00	.023
Difficulty	1,66	<1	ns
Repetition	8,59	5.80 (approx.)	<.001
Feedback X Difficulty	2,66	6.56	.003
Feedback X Repetition	16,120	1.10 (approx.)	ns
Difficulty X Repetition	8,59	2.28 (approx.)	.034
Feedback X Difficulty X Repetition	16,120	1.84 (approx.)	.033

Heart rate data from the first task period revealed a number of significant effects. For clarity, statistics for this analysis are presented in table 21. These effects included significant main effects of Feedback and Repetition. However, these main effects were modified by interactions with Difficulty level and a triple interaction involving Difficulty, Feedback and Repetition.

Examination of the raw data (see figure 13) indicates that the pattern of interactions in the analysis of the raw scores is largely due to elevated levels in the group performing the "easy" task and receiving negative feedback. As this group appeared to show atypical levels of electrodermal activity during the initial rest period, this result should be interpreted with care. Simple main effects for the double interaction between Difficulty and Feedback supported this interpretation, as only for the "easy" groups was the effect of Feedback significant ($F(2,33)=9.62$, unadjusted $p=.001$). For these groups the negative feedback condition produced higher heart rates than either positive feedback ($t(33)=3.10$, unadjusted $p=.004$) or control ($t(33)=4.17$, unadjusted $p<.001$) conditions.

Figure 13: Difficulty by Feedback by Repetition interaction for Heart Rate

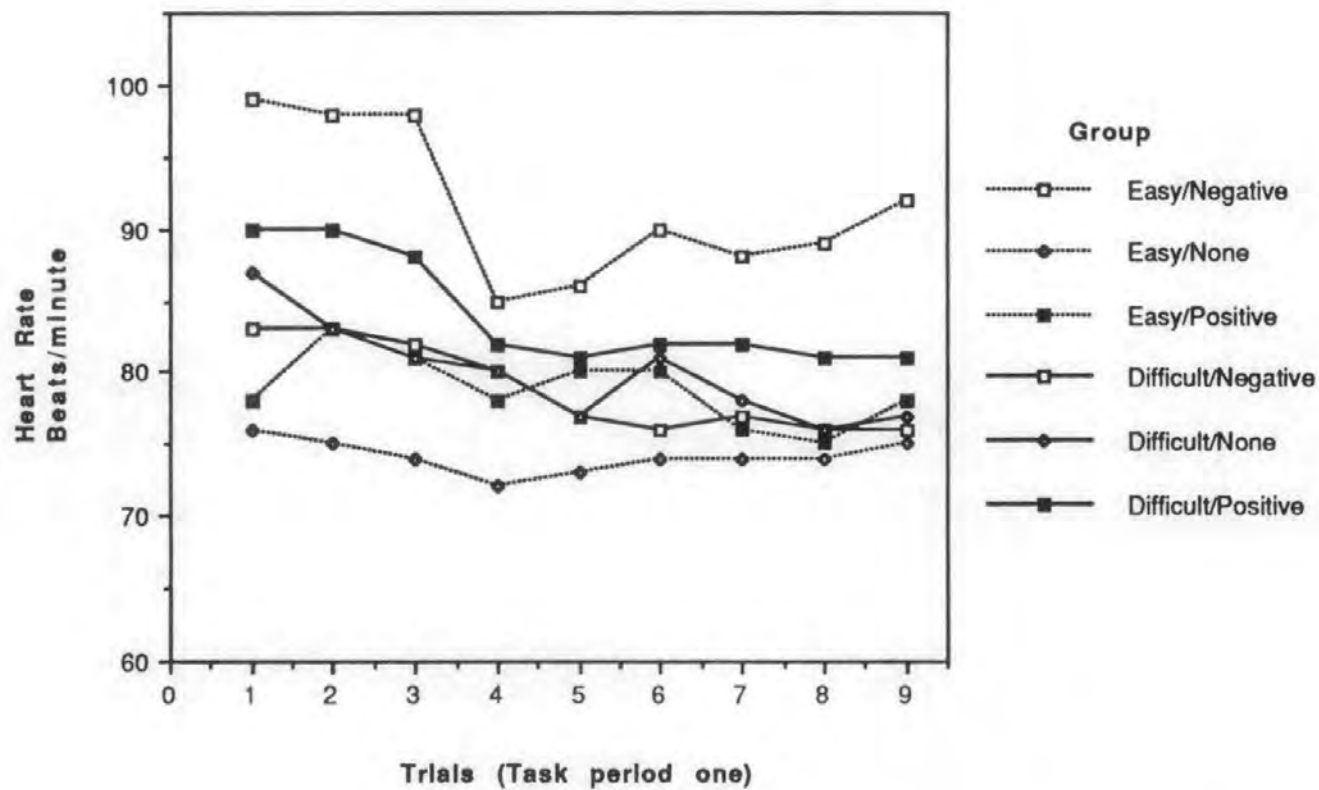
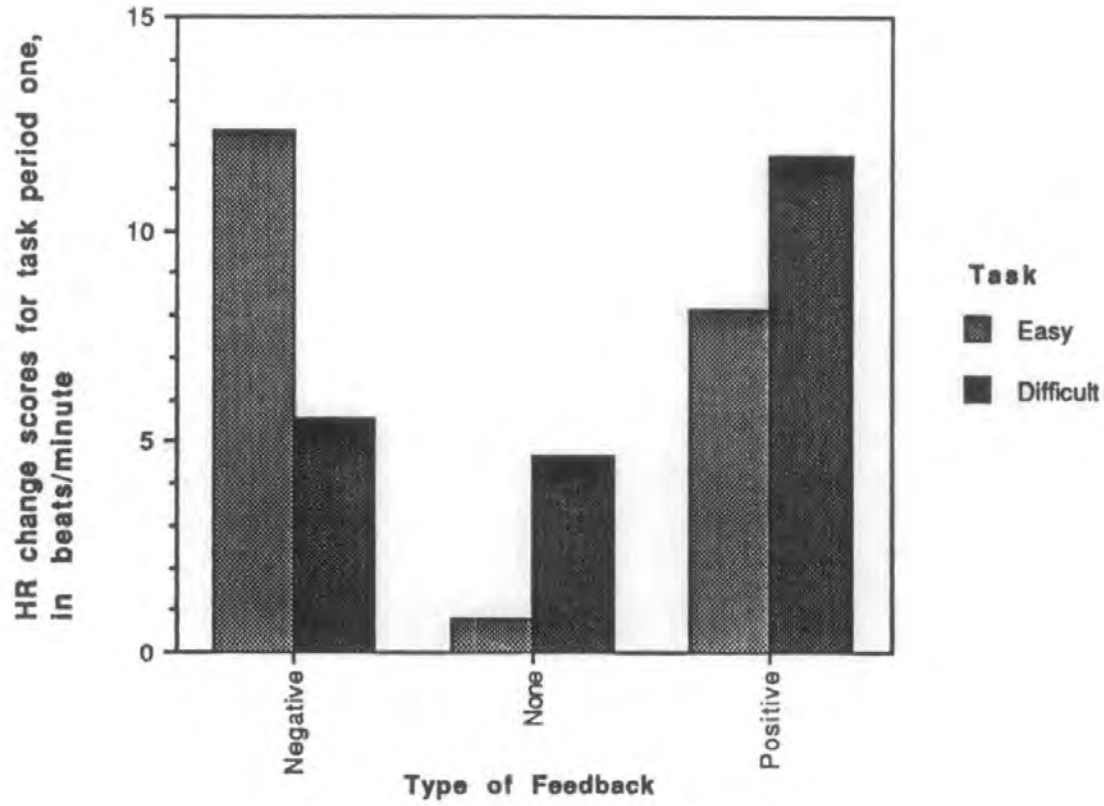


Figure 14: Difficulty by Feedback interaction for heart rate change scores

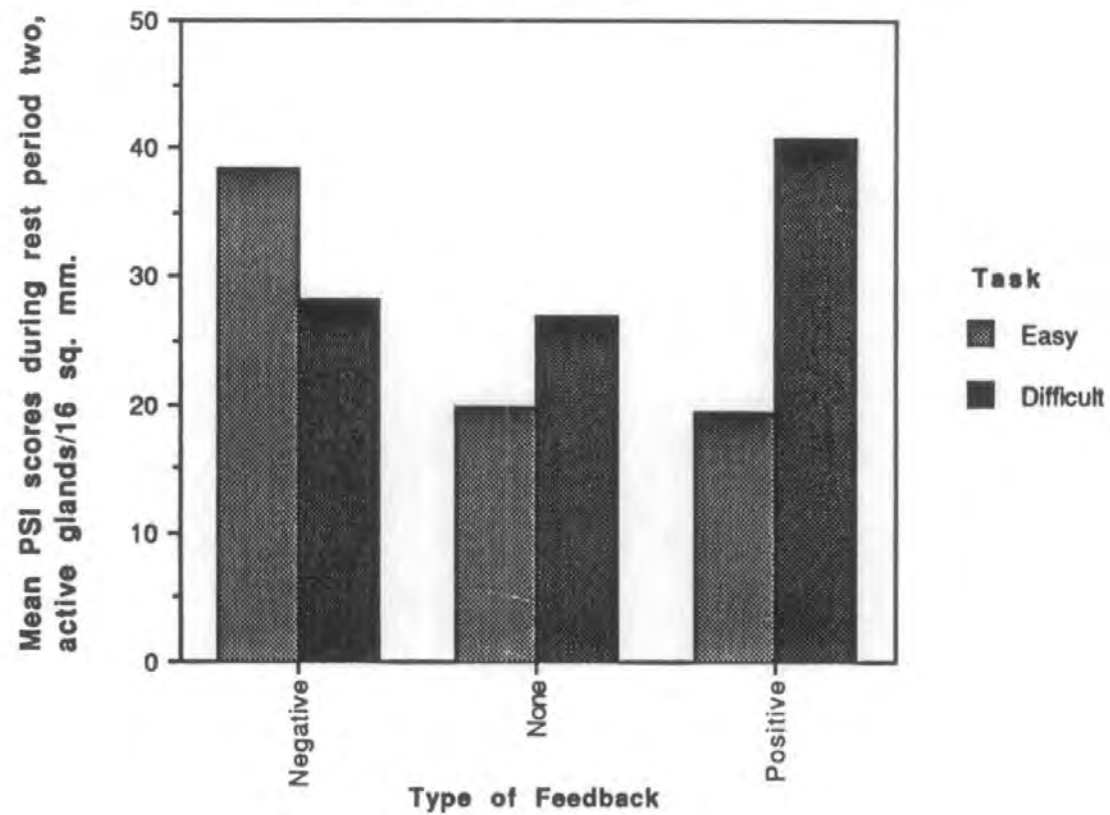


Analysis of simple main effects for the interactions involving the Repetition factor revealed that the linear trend corresponding to the effect of adaptation was significant for the difficult/negative feedback group ($t_{(88)}=4.52$, unadjusted $p=.001$) and for the difficult/no feedback group ($t_{(88)}=3.67$, unadjusted $p=.004$).

The analysis of HR change scores produced similar significant effects to the analysis of raw scores. However, the interpretation of the between-subjects effects is rather different (see figure 14). When the difference between current heart rate and the mean of the preceding rest period formed the dependent variable, analysis of simple main effects for the interaction between Feedback and Difficulty indicated that the effect of feedback was significant within both difficulty conditions (Easy task $F_{(2,33)}=5.49$, unadjusted $p=.009$; Difficult task $F_{(2,33)}=5.47$, unadjusted $p=.009$). However, the nature of the feedback effect appears different for the two difficulty conditions. For the "difficult" groups the positive feedback group was above both the control group ($t_{(33)}=3.04$, unadjusted $p=.005$) and the negative feedback group ($t_{(33)}=2.65$, unadjusted $p=.012$). Multiple comparisons within the "easy" groups revealed that the negative feedback group had higher HR than the control group ($t_{(33)}=3.26$, unadjusted $p=.003$). Therefore, difference scores revealed that feedback had the predicted effects for the difficult group, who received equal amounts of feedback. But for the easy group only the negative feedback group had higher heart rates.

To summarise, the analysis of the first task period revealed no evidence of dissociation between different measures of sweating. Both the PSI and the two parameters of EDA increased during the task. None of the physiological variables revealed a main effect of task difficulty.

Figure 15: Difficulty by Feedback interaction for the Palmar Sweat Index



Feedback produced effects on two measures, HR and the PSI. The effects on the PSI were in the predicted direction, the negative feedback group had significantly higher PSIs than the control group, the positive feedback group did not. These effects did not appear when difference scores were analysed. In view of the indication that one group may be atypical this observation should be interpreted with caution.

The effect of feedback on heart rate was modified by interactions involving difficulty level. For both raw and difference scores negative feedback produced higher heart rates during the easy task. When difference scores were analysed, positive feedback had the predicted effect only for those subjects performing the difficult task, producing higher heart rates than either negative feedback or the no-feedback control condition. The unexpected findings in the easy groups might be due to two factors. In view of the high success rates in the easy groups, positive feedback might be ineffective in sustaining motivation in these groups. Alternatively, the results might be due to atypical overall levels of activity in one group, the easy/negative feedback group.

3.4.2 The second rest period. Prior to the analysis of task period two, mean values during the preceding rest period were analysed in order to investigate the possibility of differences in baseline activity. Such differences were found only for the PSI. For both PSI-A and PSI-R measures there was a significant Difficulty x Feedback interaction (PSI-A $F(2,66)=3.83$, $p=.027$; PSI-R $F(2,66)=3.35$, $p=.041$). Mean scores during this period are presented in figure 15.

As can be seen from the preceding bar chart, the easy/negative feedback and difficult/positive feedback groups appear to show higher

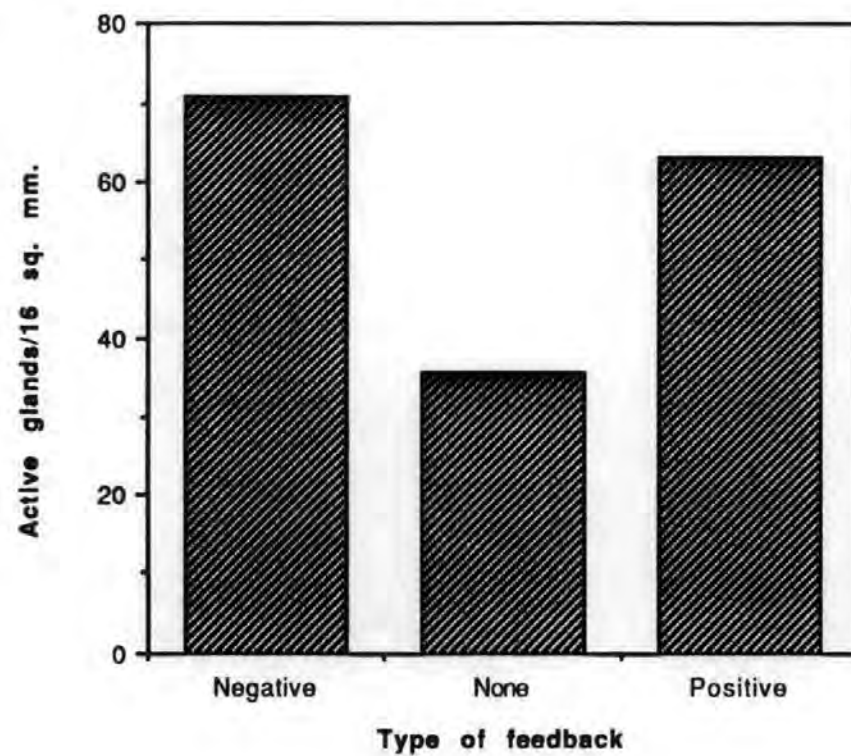
levels of sweating than the other groups. This may represent preexisting differences between the groups, or a carry-over effect from the preceding task period.

3.4.3 The first block of task period two. Measures from the first block of task period two, where feedback was also given, were analysed separately. For the PSI and NS-SCR frequency, Difficulty (2 levels) x Feedback (3 levels) ANOVAs were undertaken. SCL and HR were subjected to 2 x 3 x 3 (Repetition) MANOVAs. In view of the evidence for differences in baseline, measures from the second task period were also analysed both as transformed raw scores and as difference scores from the mean values obtained in the preceding rest period.

Once again, the constant effects in the analyses of difference scores were significant, indicating that all of the physiological measures increased from the preceding rest period (PSI-A $F(1,66)=69.70$; PSI-R $F(1,66)=56.12$; SCL $F(1,66)=49.50$; NS-SCRs $F(1,66)=61.73$; HR $F(1,66)=78.83$, all $p<.001$).

Analysis of the PSI taken in this period revealed a significant main effect of feedback condition for the PSI ($F(2,66)=7.96$, $p=.001$). Multiple comparisons revealed that both feedback groups had higher PSIs than the control group (positive vs control $t(66)=2.92$, $p=.005$, negative vs control $t(66)=3.82$, $p<.001$). This effect is displayed in figure 16. When difference scores were analysed the main effect of Feedback was significant only for the PSI-R measure ($F(2,66)=4.30$, $p=.018$). Multiple comparisons revealed that only the negative feedback group had significantly higher change scores than the control group (negative vs control $t(66)=2.92$, $p=.005$).

Figure 16: Feedback main effect for the Palmar Sweat index in the first trial of task period two



Analysis of SCL revealed only a main effect of Repetition (approx $F(2,65)=7.68$, $p=.001$). The analysis of difference scores also revealed a non-significant effect of Feedback ($F(2,66)=2.88$, $p=.063$), which was found to reflect higher levels in the negative feedback group than in the control group ($t(66)=2.32$, $p=.023$).

The analysis of NS-SCR frequency during the first block of the second task period also revealed a weak effect of Feedback ($F(2,66)=2.52$, $p=.089$). This effect was apparent in the analysis of both raw and difference scores. Comparisons within this effect revealed that the negative feedback group tended to have higher NS-SCR rates (Raw scores, negative feedback vs positive feedback $t(66)=2.11$, $p=.039$; Difference scores negative feedback vs control $t(66)=2.18$, $p=.033$).

For HR there was a significant Feedback main effect ($F(2,66)=4.01$, $p=.023$). This main effect was modified by an interaction with difficulty condition ($F(2,66)=6.75$, $p=.002$). Figure 17 displays mean heart rates for the six groups. There was also a main effect of Repetition (approx $F(2,65)=7.10$, $p=.002$). Only within the easy condition was the simple main effect of Feedback significant ($F(2,33)=8.76$, unadjusted $p=.001$). As in the first task period, the negative feedback group had higher heart rates than the control group ($t(33)=4.02$, unadjusted $p<.001$). The negative feedback group was also found to have higher HR than the positive feedback group ($t(33)=3.02$, unadjusted $p=.005$).

Analysis of heart rate difference scores revealed a similar pattern of significant effects. However, as in the first task period, closer examination indicated a different interpretation. Mean difference scores are displayed in figure 18.

Figure 17: Difficulty by Feedback interaction for Heart Rate

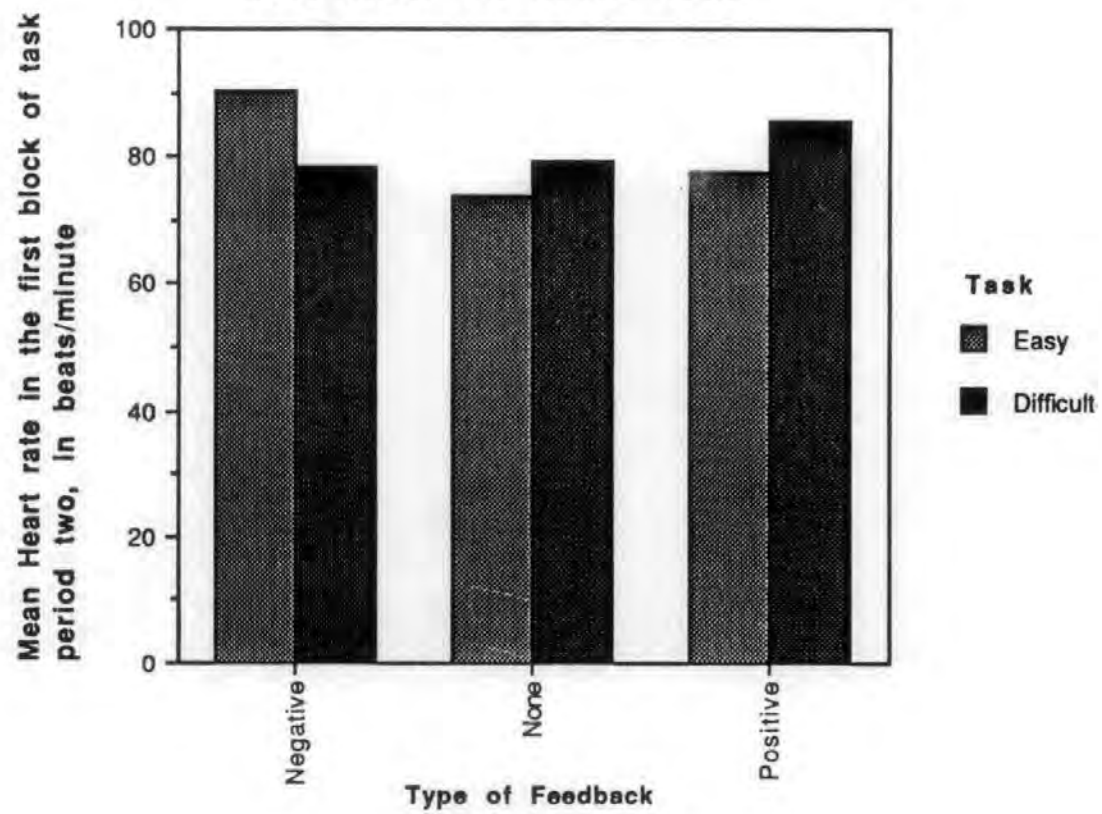
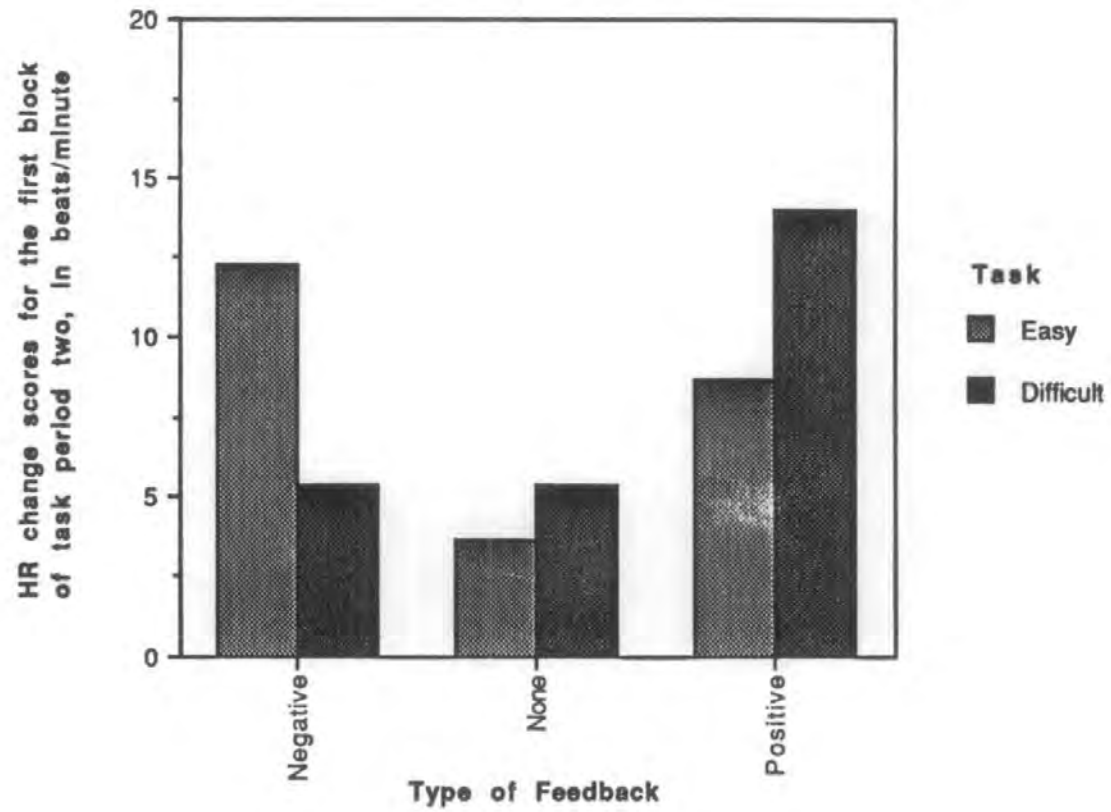


Figure 18: Difficulty by Feedback interaction for Heart Rate change scores



Simple main effects revealed that the effect of feedback within the easy condition did not reach the Bonferroni significance level ($F(2,33)=3.32$, unadjusted $p=.049$, critical p value $.025$), whereas the effect was significant for the difficult group ($F(2,33)=5.39$, unadjusted $p=.009$). In the difficult condition the positive feedback group had higher heart rates than both the negative feedback group ($t(33)=2.75$, unadjusted $p=.010$) and the control group ($t(33)=2.93$, unadjusted $p=.006$).

As in the first task period all of the measures increased during the first block of the second task period. Once again, none of the measures revealed a main effect of task difficulty. Evidence for the predicted effects of feedback was weak. The PSI revealed a non-specific effect of feedback, both feedback groups being above the control group. Although, when change scores were analysed only the negative feedback group had higher scores on the PSI-R measure. While both SCL and NS-SCR frequency revealed trends in the predicted direction, these did not reach acceptable levels of significance.

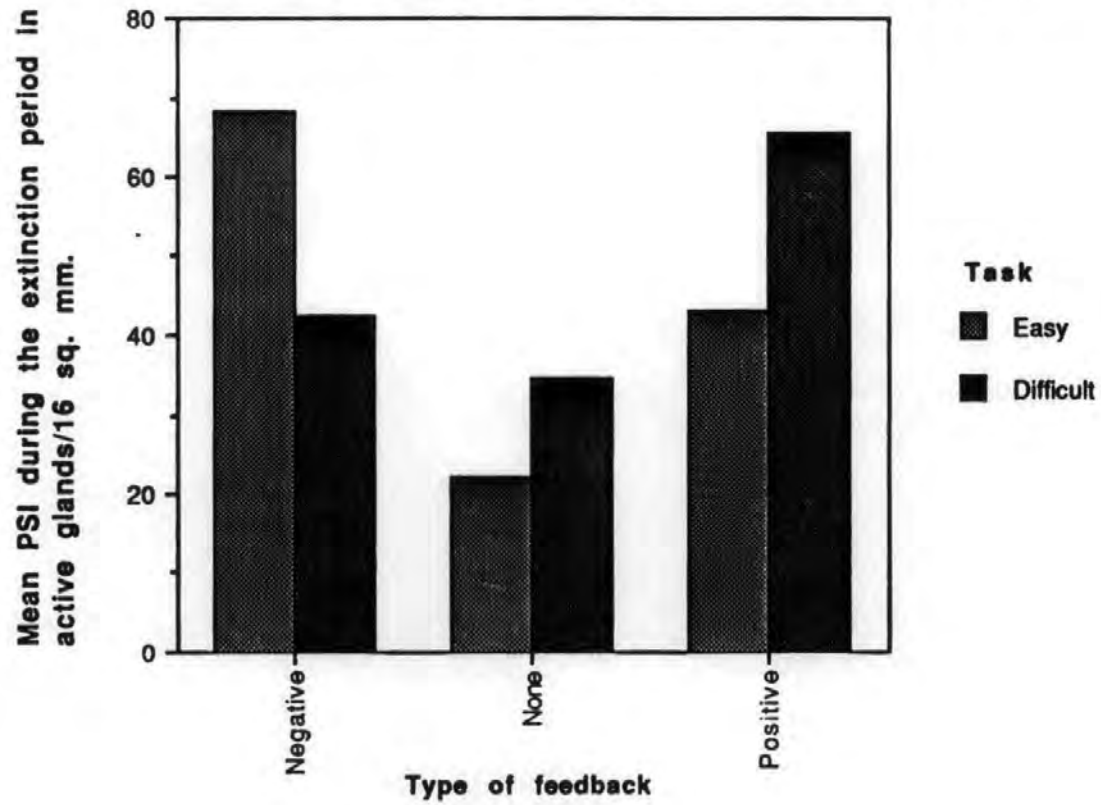
Analysis of heart rate produced similar results to those obtained in the analysis of the first task period. The effect of feedback was modified by an interaction with difficulty level. Furthermore, the pattern of results was different for raw and change scores. Raw scores revealed higher HR in the negative feedback condition for subjects performing the easy task only. When change scores were analysed, only the difficult task led to a significant effect of feedback, and that was in the opposite direction, i.e. positive feedback led to higher heart rates.

3.4.4 The extinction period. Measures taken during the extinction period were analysed using 2 (Difficulty) x 3 (Feedback) x 2 or 6 (Repetition) MANOVAs. The analysis of difference scores from this period used the mean of the preceding rest period as a baseline, rather than the first trial of the task period. Separate analyses revealed that mean scores during the extinction period were significantly lower than those in the preceding feedback trial, for all of the physiological measures. The unexpected removal of feedback did not increase levels of physiological activity.

As in the preceding analyses, constant effects were significant in all of the analyses of difference scores (PSI-A $F(1,66)=46.27$; SCL $F(1,66)=38.50$; NS-SCRs $F(1,66)=34.90$; HR $F(1,66)=43.55$; all $p < .001$).

Analysis of the PSIs taken during the extinction period revealed a main effect of Feedback ($F(2,66)=5.92$, $p=.004$), modified by an interaction with the Difficulty factor ($F(2,66)=6.22$, $p=.003$). This interaction is displayed in figure 19. For the number of active glands only, there was also a tendency towards an interaction between Feedback and the Repetition factor ($F(2,66)=2.63$, $p=.080$). Simple main effects for the Feedback factor revealed significant effects only within the easy group ($F(2,33)=8.93$, unadjusted $p=.001$). Subjects performing the easy task sweated more when previously given negative feedback (negative vs positive $t(33)=2.52$, unadjusted $p=.017$; negative vs control $t(33)=4.20$, unadjusted $p < .001$). For the PSI-A only, the simple main effect of feedback within the difficult task approached the necessary critical value ($F(2,33)=3.60$, unadjusted $p=.038$, Bonferroni critical $p .025$). The positive feedback group had significantly higher PSIs than the control group and non-significantly higher PSIs than the negative feedback group (positive vs negative $t(33)=2.19$, unadjusted $p=.036$; positive vs control $t(33)=2.44$,

Figure 19: Difficulty by Feedback interaction for the Palmar Sweat Index during the extinction period



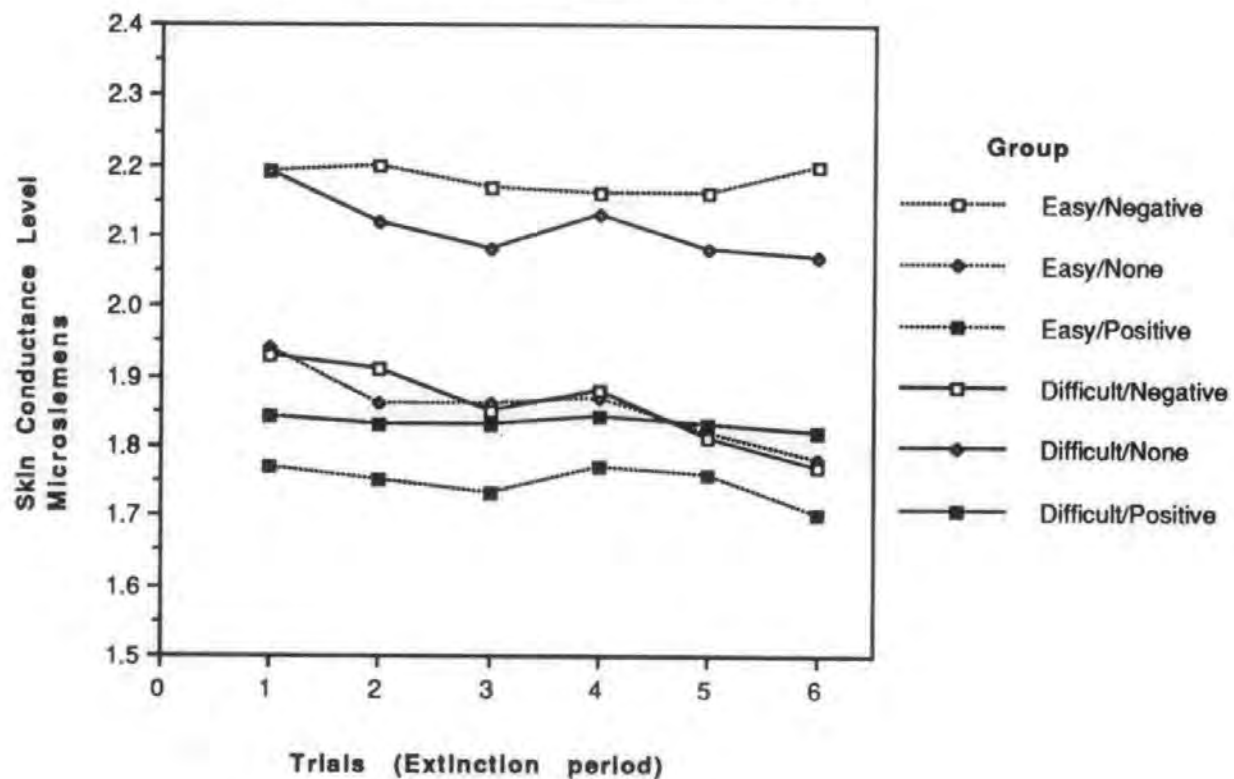
unadjusted $p=.020$).

Only for the PSI-R was the effect of feedback significant when difference scores formed the dependent variable ($F(2,66)=4.27$, $p=.018$). Both feedback groups had higher PSIs than the control group (negative vs control $t(66)=2.49$, $p=.015$, positive vs control $t(66)=2.57$, $p=.012$). When the four subjects with missing data were excluded from the analysis, a similar effect of feedback was significant for the PSI-A also ($F(2,62)=4.49$, $p=.015$). In view of the evidence that the groups differed prior to the task period, the failure of the interaction described above to appear in the analysis of difference scores implies that the interaction may be an artifact of differences in baseline. There was some similarity between the results for the PSI during the extinction period and those obtained for HR during feedback periods. In both, negative feedback led to higher physiological activation during the easy task, whereas there was some, slight indication that positive feedback might have produced greater activation when performing the difficult task.

Analysis of SCL during the extinction period failed to reveal a significant main effect of Feedback. However, there were interactions between the Feedback and Repetition factors (approx $F(10,126)=2.89$, $p=.003$) and a triple interaction between Feedback, Difficulty level and Repetition (approx $F(10,126)=2.21$, $p=.021$). There was also a main effect of Repetition (approx $F(5,62)=9.41$, $p<.001$).

Analysis of simple main effects for the double interaction revealed a pattern consistent with predictions, only the negative feedback and control groups showed decreasing SCL over the course of the period, as indicated by linear trends in the time main effect (Negative feedback $t(110)=3.72$, unadjusted $p=.001$; no feedback $t(110)=4.33$, unadjusted $p<.001$).

Figure 20: Difficulty by Feedback by Repetition interaction for SCL

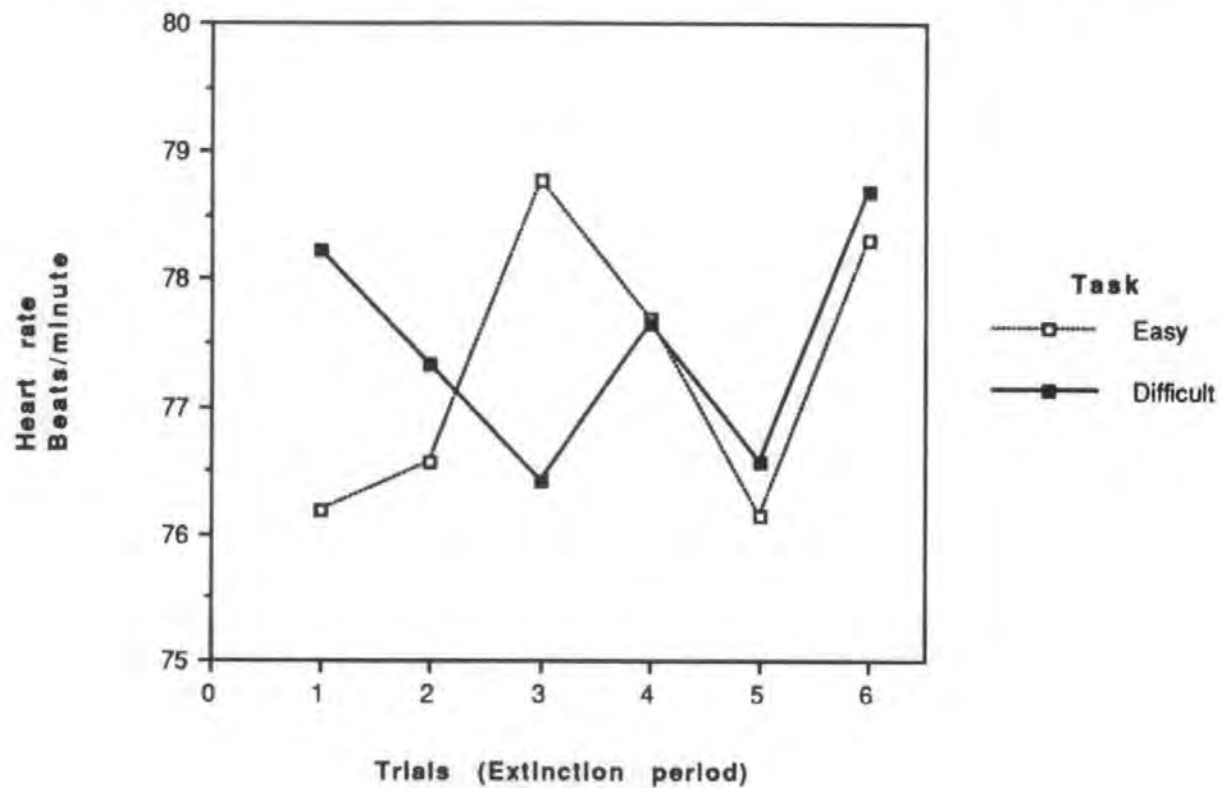


Simple main effects for the triple interaction produced similar conclusions, groups previously receiving positive feedback showed a failure to adapt. Only for the difficult task/negative feedback group did the linear trend reach the Bonferroni significance level of .008, although trends for the two no feedback groups approached significance (easy/no feedback $t(55)=3.1$, unadjusted $p=.010$; difficult/negative feedback $t(55)=4.13$, unadjusted $p=.002$; difficult/no feedback $t(55)=3.1$, unadjusted $p=.010$). Mean values for SCL during the extinction period are displayed in figure 20.

The only significant effect to emerge from the analysis of NS-SCR frequency was a main effect of Repetition (approx $F(1,66)=4.12$, $p=.047$) reflecting the decline from the first measure to the second.

Heart rate during the extinction period revealed an interaction between Difficulty level and the Repetition factor (approx $F(5,62)=3.32$, $p=.01$), as well as a main effect of Repetition (approx $F(5,62)=3.06$, $p=.016$). Simple main effects for the interaction revealed that only the easy group showed a significant simple main effect of Repetition (easy group approx $F(5,29)=3.05$, unadjusted $p=.008$). However no linear trend appeared within the Repetition effect, implying that the difference was not due to differing rates of adaptation, see figure 21.

When raw scores were analysed there was also a significant interaction between Feedback and Difficulty ($F(2,66)=3.7$, $p=.03$). The simple main effect of Feedback approached significance only for the easy group ($F(2,33)=3.61$, unadjusted $p=.038$, Bonferroni critical $p=.025$). Multiple comparisons indicated that the negative feedback group had higher HR than the control group ($t(33)=2.44$, unadjusted $p=.020$) and tended to have higher HR than the positive feedback group ($t(33)=2.20$, unadjusted $p=.035$, Bonferroni critical $p=.025$).

Figure 21: Difficulty by Repetition interaction for Heart rate

While higher heart rate in the negative feedback group was predicted for the extinction period, it should be noted that the easy/negative feedback group had higher HR throughout the experiment. In previous analyses, it was those subjects performing the difficult task whose results were in line with predictions. As this interaction does not appear in the analysis of difference scores it is most probably due to pre-existing differences in HR, rather than the effects of the manipulation.

3.4.5 Summary. Firstly, all of the physiological measures increased above baseline during all of the task periods. There was no evidence for a depression of sweating as a result of the sentence verification task. The level of difficulty of the task also appears to have had little effect on the physiological measures. Only for heart rate during the extinction period did Difficulty exert an effect independent of Feedback condition, and the Difficulty by Repetition interaction obtained does not appear explicable.

While there were significant effects of Feedback on the physiological measures, these were weak. The PSI behaved as predicted during the first task period, the negative feedback group having higher sweat gland counts. During the first block of the second task period, however, both feedback groups showed higher PSIs than the control group. During the extinction period subjects performing the easy task showed greater sweating when receiving negative feedback, contrary to predictions. This interaction most probably reflects the existence of differences in pre-task activity. There was also a weak trend towards higher activity in the positive feedback group performing the difficult task. Analysis of difference scores revealed a main effect of Feedback only for the ratio of active to total

glands. This effect was similar to that found in the preceding block. Both feedback groups sweating more than the control group.

The two parameters of EDA showed little effect of the experimental manipulations. During the first block of task period two both showed a trend in the predicted direction, higher sweating in the negative feedback group. However, these trends did not reach statistical significance. During the extinction period only SCL revealed an effect of feedback, the positive feedback group failing to show adaptation over the course of the period.

During trials when feedback was given, heart rate was higher in subjects performing the easy task and receiving negative feedback than in other subjects performing the easy task. When difference scores were analysed, subjects in the difficult group were found to show higher HR when receiving positive feedback. During the extinction period, there was an interaction between feedback and difficulty level in the analysis of raw scores which seems similar to that described above, subjects tending to have higher HR in the easy task/negative feedback group. While higher heart rate was predicted for subjects previously receiving negative feedback, in previous analyses it was the analyses of change scores from subjects performing the difficult task which appeared to show the expected effect of feedback. It was predicted that the effects of feedback would be reversed in the extinction period. It seems likely that the the easy task/negative feedback group may have been atypical as regards heart rate, as well as the PSI.

Table 22: Between-subject correlations between
physiological measures

mean correlations, n=21

	PSI-A	SCL	NS-SCR rate
SCL	.509		
NS-SCR rate	.528	.550	
HR	.221	.110	.115

For all correlations the mean differs from zero, $p < .001$, one-tailed
Individual correlations over .195 are significant at $p < .05$, one-tailed

Table 23: Within-subject correlations between
physiological measures

mean correlations, n=72

	PSI-A	SCL	NS-SCR rate
SCL	.432		
NS-SCR rate	.545	.449	
HR	.305	.191	.294

For all correlations the mean differs from zero, $p < .001$, one tailed
Individual correlations over .369 are significant at $p < .05$, one-tailed

3.5 Comparisons Between Different Measures

The results described above provide support for an overall similarity between the three measures of sweating. All three increased during the task periods, and both the PSI and NS-SCRs returned to a point below the initial baseline in the following rest periods (see figs. 22-24). However, for SCL, both of the succeeding rest periods were above the initial rest period.

Both between-subject correlations between simultaneous measures for all four physiological variables (see table 22) and within-subject correlations between the variables for each individual subject (see table 23) were calculated. All of the correlations between measures of sweating are at a similar level. The PSI appears to correlate with both of the parameters of EDA at least as well as they correlate with each other. It is noticeable that the PSI also appears to show a small, but significant, relationship with HR.

There seems to be little relationship between the self-report measures and the physiological measures. The majority of the self-report measures differentiated the two levels of task difficulty. Whereas, the physiological measures failed to produce a single significant main effect of Difficulty. The self-report measures also responded to the feedback manipulation only after the extinction period, yet this is where the physiological measures showed the weakest effect.

Correlations were calculated between scores on the self-report scales and the various physiological measures. Of all the correlations between mean physiological scores during the first rest period and POMS scores obtained at the end of the period, only one was significant, a result which must be assumed to represent a type one error, given the number of correlations calculated.

Figure 22: Palmar Sweat Index during task periods + mean of rest periods.

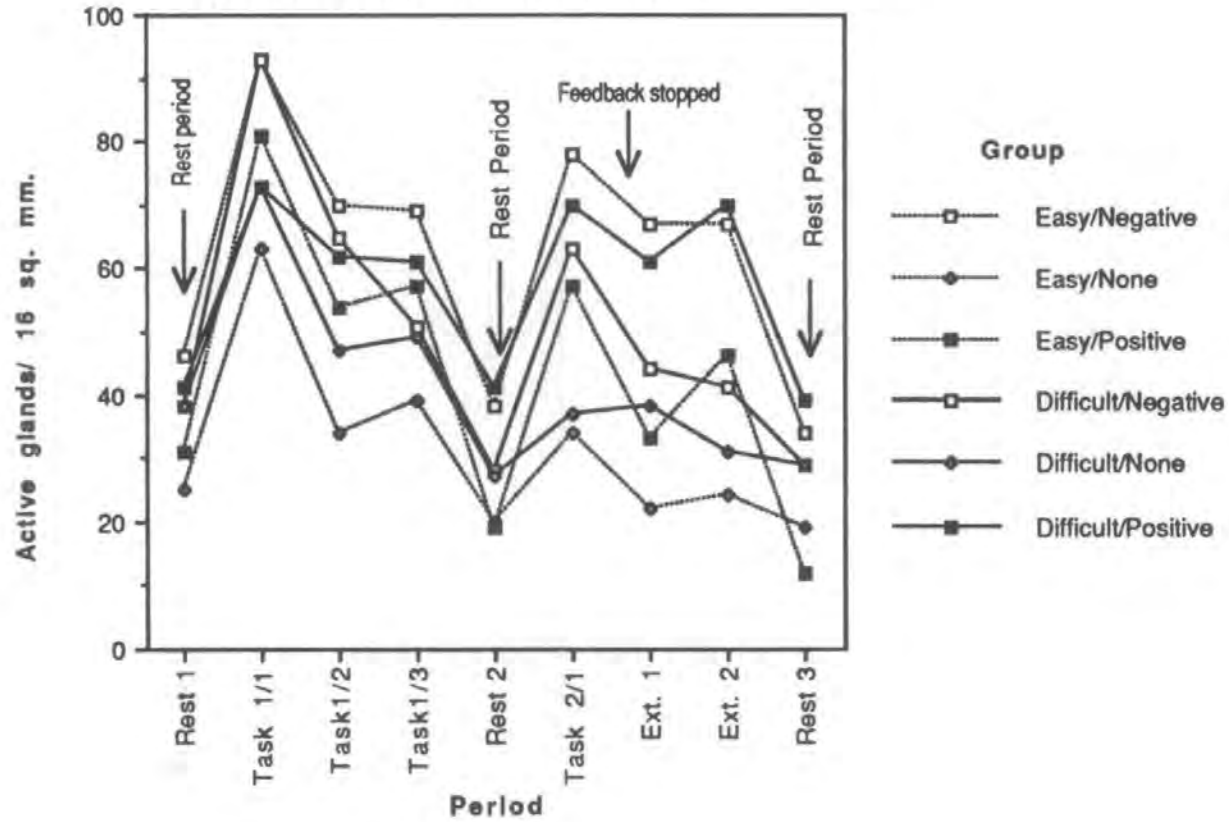


Figure 23: Skin Conductance Level during task periods + mean of rest periods

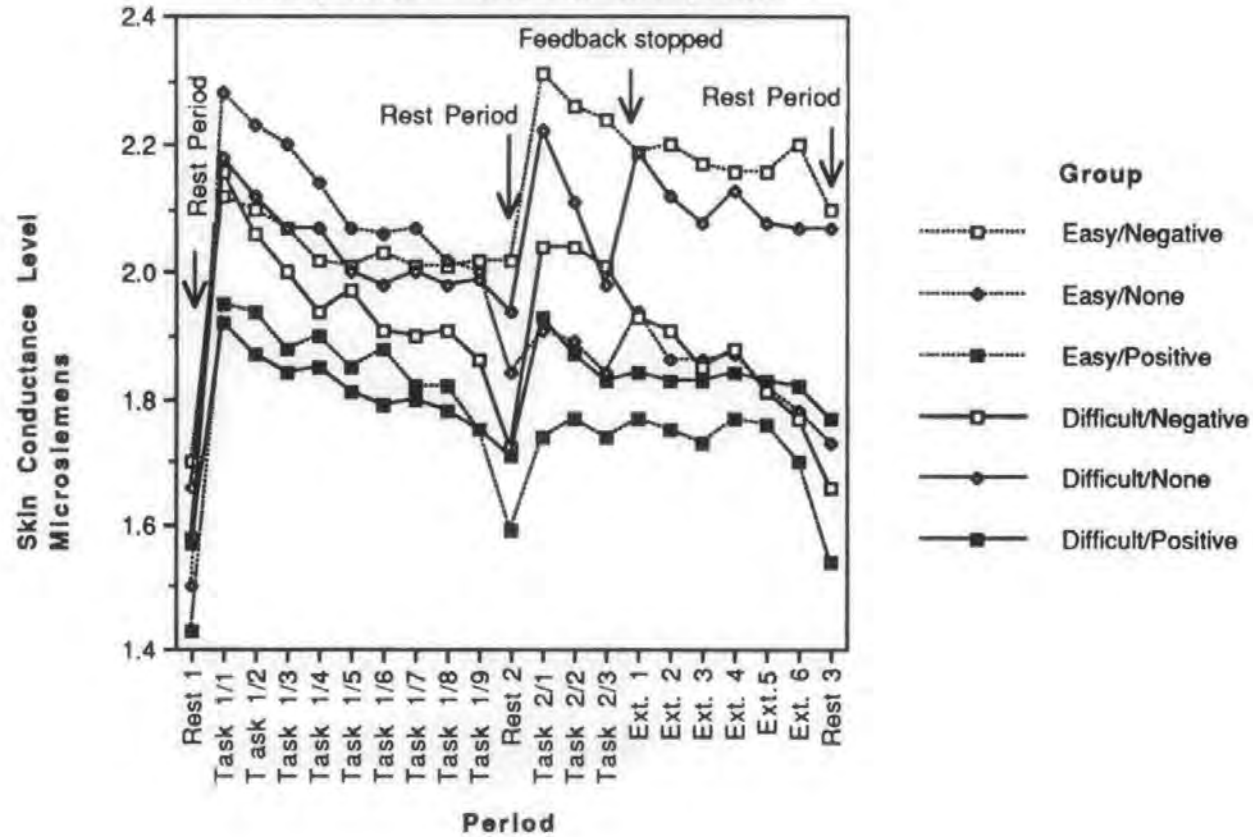
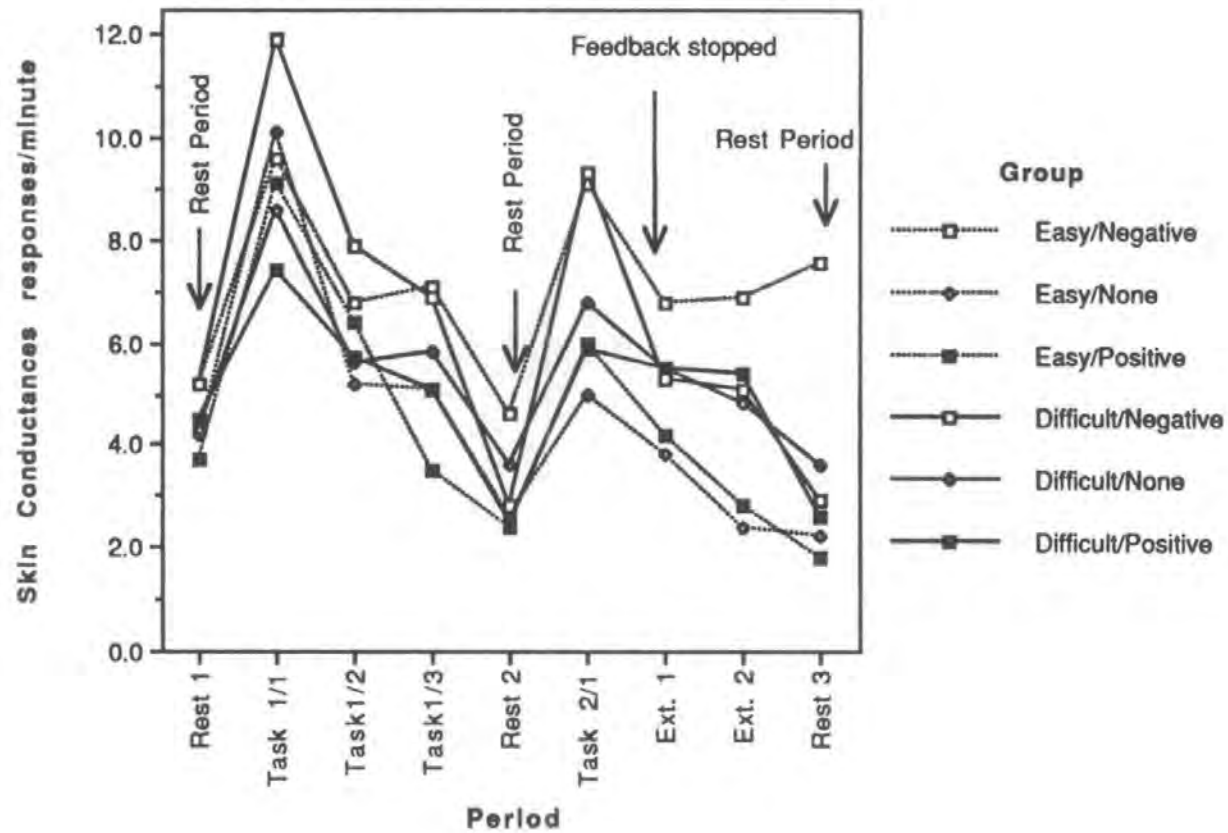


Figure 24: Skin conductance responses during task periods + mean of rest periods



Correlations between change scores for the self-report and physiological measures from each task period revealed only one significant relationship. For both task periods, SCL was significantly correlated with the change in reported vigour ($r=0.23$, $p=.05$ and $r=0.24$, $p=.044$, respectively, both two-tailed). Correlations between the self-report measures of "Anxiety" and "Motivation" administered during the task and physiological measures from the same block failed to produce more significant correlations than would be predicted by chance alone. These findings bear out the disparity between the results from the analyses of self-report measures and those from the analyses of physiological data.

3.6 The Effect of Temperature on Physiological Measures

When correlations were calculated between physiological measures and room or skin temperatures during the first rest period, several significant effects emerged, see tables 24 and 25. There was a positive relationship between SCR frequency and temperature. Mean levels during the first rest period and change scores for both task periods correlated significantly with skin temperature during the first rest period, and both change scores correlated significantly with initial room temperature.

Heart rate also seems to have been affected by temperature, higher initial temperatures being associated with lower heart rates. Mean heart rate during the first rest period correlated negatively with room temperature, whereas change scores for both task periods correlated negatively with skin temperature during the first rest period. The change in the PSI after the first task period also correlated significantly with skin temperature during the initial rest period.

Table 24: Correlations between room temperature during
the first rest period and physiological measures

Variable	Correlations with		
	mean levels in first rest period	change scores from first task period	Change scores from second task period
PSI-A	-.044	-.032	.204
SCL	.066	.063	.118
NS-SCRs	.172	.280*	.250*
HR	-.253*	-.044	-.157

* significant at $p < .05$, two tailed

Table 25: Correlations between skin temperature during
the first rest period and physiological measures

Variable	Correlations with		
	mean levels in first rest period	change scores from first task period	Change scores from second task period
PSI-A	-.023	.250*	.112
SCL	.179	.176	.019
NS-SCRs	.360**	.431***	.297*
HR	-.158	-.241*	-.406***

* significant at $p < .05$, two tailed

** significant at $p < .01$, two tailed

*** significant at $p < .001$, two tailed

3.7 Analysis of Other Questionnaires

The analysis of the life-events scale will be reported in chapter 10, where the validation of the scale is described.

3.7.1 Repression-sensitization, trait anxiety and physiological activity. Analysis of the two trait scales administered at the start of the experiment revealed that scores on the trait anxiety scale were positively correlated with nearly all of the baseline POMS scores except for vigour, which correlated negatively with trait anxiety (see table 26). The social desirability scale did not correlate significantly with any scale, although a negative correlation with baseline depression-dejection and a positive correlation with baseline vigour approached significance. Change scores for the POMS scales taken after each task period, however, were not predicted by trait scores. Only one correlation out of twenty-four was significant.

None of the mean resting scores during the first rest period for the physiological variables correlated with trait anxiety, however all of the change scores from the second task period for the measures of sweating correlated negatively with trait anxiety (see table 27).

The negative correlation between sweating during the second task period and trait anxiety is difficult to explain. A positive correlation might have been expected, given the likelihood that subjects high on trait anxiety might have experienced more task-induced anxiety. Analysis indicated that sweat gland activity during the second rest period did not correlate with trait anxiety. Therefore, the negative correlations with change scores do not seem to represent an effect of initial values. The social desirability scale was not significantly correlated with either baseline or change scores for the physiological variables.

Table 26: Correlations between trait anxiety and POMS scales
obtained after the first rest period

	Trait Anxiety
Tension-anxiety	.227
Depression-dejection	.540***
Anger-hostility	.206
Vigour	-.388***
Fatigue	.252*
Confusion-bewilderment	.458***

* significant at $p < .05$, two tailed

*** significant at $p < .001$, two tailed

Table 27: Correlations between trait anxiety and change scores
for physiological measures during the second task period

	Trait Anxiety
PSI-A	-.227***
BCL	-.413***
NS-SCRs	-.412***
HR	-.177

*** significant at $p < .001$, two tailed

Weinberger et al. (1979) used trait anxiety scores together with scores on the Social Desirability Scale to assign subjects to one of three groups. Subjects with low trait anxiety scores were categorised as either true low anxious or repressors, depending on their level of defensive responding. All high anxious subjects were assigned to the same group, defensive high anxious subjects being reported as relatively rare. They report evidence for weak differences in physiological activity between the groups, repressors appearing to show higher levels of activation than even the high-anxious subjects. A similar approach was attempted with the data from this study. Four groups were used, as a median split on each scale produced four similarly-sized groups. The four groups were "Low-Anxiety" (low anxiety/low defensiveness, $n=13$), "Repressors" (low anxiety/high defensiveness, $n=23$), "High Anxiety" (high anxiety/low defensiveness, $n=20$) and "Defensive high anxiety" (high anxiety/high defensiveness, $n=16$).

Use of both trait anxiety and repression scores together to produce four groups did not improve the relationship between trait anxiety and physiological measures. One-way ANOVAs were performed on baseline (Initial rest period) and change scores (task measures minus the mean of the preceding rest period). The effect of Group did not achieve significance in any analysis. The effects of anxiety/repression group on change scores for the PSI approached significance (task period 1 $F(3,68)=2.66$, $p=.055$; task period 2, $F(3,68)=2.34$, $p=.081$). The effects on NS-SCR frequency in the second task period also just missed significance ($F(3,68)=2.60$, $p=.059$). Only for NS-SCR frequency did any Newman-Keuls follow-up comparison reach significance. The low anxiety/low repression group had higher NS-SCR frequencies than the high-anxiety/high repression group.

It must be stressed that a division into four groups using a median split on both scales is a relatively crude approach and, while scores on both scales did not differ across conditions, the possible confounding effects of the experimental manipulation were not controlled for in this pilot analysis. However, there is no support here for the utility of repression-sensitization, as indexed by the social desirability scale, as a possible mediating variable in the self-report of trait-anxiety. This question will be addressed further in later studies.

3.7.2 Self-reported depression and physiological activity. Scores on the Beck depression inventory failed to correlate significantly with mean physiological scores in the first rest period. Of the change scores for each task period, only the increase in HR during the first task period correlated significantly (and negatively) with depression, a similar trend was apparent during the second task period (first task period $r = -0.28$, $p = .042$, second task period $r = -0.25$, $p = .066$, both two-tailed). This finding is consistent with the literature on clinical depression and heart rate (e.g. Albus et al, 1982; Kelly, 1980), although not all studies agree (e.g. Goldstein, 1965). However, it must be borne in mind that studies using clinical samples should not be expected to relate to findings from questionnaire data based on a full range of normal subjects. Clinical depression is also reported to be associated with reduced EDA. No such association was observed here.

3.8 Comparison of Different Statistical Treatments of the PSI

It was hoped that a comparison of the size of experimental effects on various transformations of the PSI might provide some

indication of the relative sensitivity of those transformations. Unfortunately, the effects of the feedback and difficulty manipulations on both the PSI and the other measures of sweat gland activity were weak. In addition, the evidence for possible differences in baseline between the groups confounds any interpretation of the size of between-subjects effects.

3.8.1 The number of active glands versus the proportion of glands active. The PSI was scored both as a simple count of the number of active glands visible and as the ratio of active glands to the total number of glands counted, active and inactive. Both of these methods of scoring revealed similar effects in the analysis of the effects of feedback. In practice, these measures correlate so highly as to be virtually identical. The correlation between mean values during the first rest period was .9826.

One comparison which can be made concerns the effect of the task itself on the PSI, irrespective of difficulty level or feedback condition. As was stated in Section 3.4, both the number of active glands and the ratio of active glands over total number of glands showed highly significant increases from the initial rest period to the first task period. Comparison of effect sizes (omega-squared, Dodd & Schultz, 1973) for this increase for the two measures revealed that the magnitude of effect was virtually identical for the two measures (Omega-squared=.203 for PSI-A and .193 for PSI-R).

A significant main effect of Feedback appeared, for the PSI only, during the first task period. Comparison of effect sizes for this effect implied that the number of active glands might be the most sensitive measure (PSI-A, omega-squared=.032; PSI-R omega-squared=.008). This effect was consistent with predictions.

However, no such effect appeared in the analyses of electrodermal measures. The comparison of effect sizes relies on the assumption that there is a real effect present. Given the weak effects of the between-subjects manipulations in the current experiment, this assumption may not be valid.

3.8.2 Compensating for possible differences in baseline activity.

In the analyses described above, difference scores were used in an attempt to control for possible group differences in baseline activity. The use of difference scores was effective in removing the Feedback x Difficulty interaction during the extinction period. As there is reason to believe that this interaction may have been due to differences in baseline activity, this provides support for the use of difference scores, at least where there is reason to suspect that pre-manipulation differences exist and a valid baseline is available. The use of difference scores also did not reveal a main effect of Feedback for task period one. While there was no evidence, from the PSI data, of differences between the groups during rest period one, such differences did appear for SCL. Thus, it is possible that this represents another demonstration of the effectiveness of difference scores in removing artifacts due to baseline differences. While the effect of Feedback in task period one was consistent with predictions, such an effect was not apparent for other measures of sweating. For this reason the alternative explanation, that difference scores reduce the sensitivity of the measure by adding extraneous variance, seems less plausible.

During the first block of task period two, difference scores revealed an effect of Feedback only for the PSI-R measure. This effect was consistent with predictions, the negative feedback group having

higher PSIs. In the analysis of raw scores both PSIs were above the control group.

For the PSI only, analysis of covariance was examined as a means of compensating for possible pre-existing group differences. Separate analyses were carried out for the first task period, the first block of the second task period and the extinction period. In each case, the mean level of sweat gland activity in the preceding rest period was used as a covariate. The regression of the covariate on PSI scores was always highly significant.

In every analysis a significant, or nearly significant, effect of Feedback emerged (First task period $F(2,65)=2.84$, $p=.066$; First block of second task $F(2,65)=6.37$, $p=.003$; Extinction period $F(2,65)=5.14$, $p=.008$). In the analysis of the extinction period this effect was modified by an interaction with Difficulty level ($F(2,65)=3.29$, $p=.044$). Follow-up analyses indicated that, during the first task period, only the negative feedback group had significantly higher PSIs than the control group. During the first block of the second task period, both feedback groups had higher PSI scores than the control group. Simple main effects analysis on the Difficulty by Feedback interaction during the extinction period revealed that the effect of Feedback was significant only for those subjects doing the "Easy" task. For those subjects, the negative feedback group sweated more than the control group. In the first task period there was also an effect of Repetition (approx. $F(2,65)=40.51$, $p<.001$), reflecting declining levels over the course of the period.

The conclusions from the analysis of covariance are very similar to those from the main analysis. While the use of difference scores removed several of the effects which were significant in the analysis of raw scores, using ANCOVA led to virtually identical conclusions.

ANCOVA seems to provide little advantage over the use of simpler procedures. Analysis of covariance did not remove the Difficulty by Feedback interaction during the extinction period, which was suspected of being due to inter-group differences in baseline.

There was no evidence of the effects of the Law of Initial Values, mean values during task periods correlated positively with values obtained during the preceding rest periods (all correlations $>.6$). The operation of the LIV would lead to negative correlations between baseline and response. Thus, there is no justification for the use of transformations to negate the effects of the LIV.

4 Discussion

This study had four main aims. These were as follows: Firstly the study was intended to examine the theory proposed by Fowles (1980). It was predicted that the positive and negative feedback conditions, would differentially increase heart rate and electrodermal activity, respectively. This effect was expected to reverse when feedback was unexpectedly terminated. Secondly, the inclusion of the cognitive task was intended to examine the response of the PSI to such a task. The task might be expected to lead to internally-directed attention, and so, following the suggestion put forward by Johnson & Dabbs (1967), might lead to a suppression of the PSI. Thirdly, the study provided an opportunity to compare the PSI and two parameters of electrodermal activity. Thus, the study allowed an examination of the concurrent validity of the PSI. Finally, by comparing different statistical treatments of the PSI, it was hoped that the study would provide evidence concerning the best means of scoring the index. These aims will be considered in turn.

4.1 The Effects of Feedback on Physiological Measures

The hypothesis concerning the effects of feedback has received limited support. There was some support from measures of sweat gland activity. However, HR consistently revealed an interaction between Feedback and Difficulty conditions.

During the first task period, the PSI behaved as predicted. During the second task period, however, the PSI revealed only a non-specific effect of Feedback, both feedback groups having higher PSIs than the control group. In the extinction period the PSI was higher in the easy/negative feedback group, whereas it was predicted that subjects previously receiving positive feedback would have higher sweat gland counts. Prior to the termination of feedback, both SCL and SCRs revealed weak effects of Feedback. Although the effect for SCL was apparent only in the analysis of change scores. During the extinction period, only SCL revealed effects consistent with predictions, the positive feedback group showing slower adaptation.

Throughout the experiment, heart rate tended to be higher in the easy/negative feedback group. On trials where feedback was given, analysis of change scores also revealed higher heart rate in the difficult/positive feedback group.

In general, the predictions concerning the effects of feedback have not received adequate support. There are a number of possible reasons why the feedback manipulation did not produce the predicted results. The task used in this experiment was very different to the serial reaction time task used by Fowles and his co-workers. In particular, the task used by Fowles involved considerable motor activity, with correspondingly high levels of physiological activity. For this reason the response criterion for SCRs chosen by Fowles was

unusually high, 0.2 micromhos, as opposed to 0.015 used in this experiment. In addition, all dependent variables were analysed using analysis of covariance, using the values obtained in a practice trial as a covariate, to statistically remove the effects of the task. In contrast, the task used in this experiment required much less motor activity and so had a smaller effect on physiological activity. Tranel (1983) obtained similar NS-SCR frequencies during the reaction time task to those obtained during task periods in this experiment. However, Tranel used a response criterion more than ten times larger. Had comparable response criteria been used, Tranel would have undoubtedly obtained much higher response rates. It seems unlikely that the low level of task-generated activity in this experiment could explain the absence of a clear effect of feedback. On the contrary, it would be expected that a task producing higher levels of activity might obscure the effects of feedback as a result of ceiling effects.

One possible factor which might explain the results obtained in this study is an interaction between the difficulty level of the task and the feedback condition. Obrist's (1976) work implies that tasks which are too easy might not lead to increased HR, due to a lack of motivation. However, such an effect did not consistently emerge in the studies undertaken by Fowles and his co-workers. The difficult task used in this experiment produced success rates of 47% during the first task period and 51% in the second, which should have led to sustained motivation. The easy task, however, led to much higher success rates, 92% in the first task period and 94% in the second and so might have failed to sustain motivation.

Analyses of both heart rate and the PSI produced evidence of interactions between feedback condition and difficulty level, which might represent the influence of success rates on the effectiveness of

feedback. When both raw and change scores were analysed, negative feedback led to higher HR in subjects performing the easy task. Subjects performing the difficult task showed higher HR in response to positive feedback when change scores were analysed. During the extinction period, both HR and the PSI revealed interactions between feedback condition and difficulty level, although these interactions were only apparent in the analysis of raw scores. In both cases, negative feedback led to higher levels of activity in subjects performing the easy task. For the PSI there was also a non-significant tendency for higher scores in the group receiving positive feedback on the difficult task.

Thus, the difficult task appears to have produced effects consistent with predictions only when paired with positive feedback. This combination produced tendencies toward higher HR on feedback trials and higher PSIs during the extinction period. In contrast, the easy task appeared to produce effects which were counter to those predicted when combined with negative feedback. The combination of the easy task and negative feedback was associated with increased heart rate throughout the experiment. Such an effect should only have appeared during the extinction period, yet during this period this group also had higher PSIs. The high success rates on the easy task could account for the absence of the predicted effect of feedback. However, success rates alone cannot account for effects opposite to those predicted.

Two possible explanations suggest themselves. Firstly the groups may have shown pre-existing differences in physiological activity. There was evidence for differences between the groups prior to any manipulation for SCL. One possible explanation for the interaction between Feedback and Difficulty is that similar group differences may

have existed for HR. It seems likely that the easy task/negative feedback group may have been atypical. It is less clear whether the difficult task/positive feedback group were also atypical. As this group only had higher HR during feedback trials, and tended to have higher PSIs in the extinction period the results for this group were in line with predictions.

While the combination of the difficult task with positive feedback led to some effects which were in line with predictions, the combination of the difficult task and negative feedback did not produce levels of physiological activity different from the no-feedback control. Before the results from the difficult task can be accepted as support for the predictions, it needs to be explained why these results were confined to only one of the feedback conditions.

An alternative explanation involves consideration of the meaning of the feedback provided. While it was assumed that the two feedback conditions were equal, but opposite, this may not be the case. It may be that the psychological effect of losing a sum of money is not equivalent to the effect of gaining the same amount. The meaning of the feedback may also interact with the difficulty of the task. It seems likely that failing a task which was objectively and subjectively "Easy" would have greater impact than success on the same task. Thus the negative feedback may have been more effective than positive feedback, when combined with the easier task, producing greater overall motivation and non-specific increases in physiological activity. A similar argument would suggest that negative feedback was less effective on the "difficult" task. Although this argument depends on the definition of "difficulty". Performance on the "difficult" task was close to chance level. However, as subjects performing the "difficult" task achieved approximately 50% success, they would have

received equal proportions of each type of feedback, and difficulty ratings for the difficult task were around the mid-point of the six point scale.

Fowles has systematically examined the effects of success rate on the response to feedback. While success rate has often been found to have no effect on HR response (Fowles, Fisher & Tranel, 1982). Where an effect has been observed, success rate has been positively related to the HR response (Tranel, 1983; Fisher, 1982). In this study, the combination of a lower success rate with monetary incentive appeared to lead to higher HR than a high success rate. Only when monetary penalties were administered was HR higher in the easier task. An attempt has been made to explain the interaction between difficulty and feedback in terms of the psychological significance of the feedback. Essentially, the argument is that less frequent feedback may have more motivational effect. However, this is the reverse of the effect observed by Fowles and his co-workers. Several aspects of the tasks used could explain this difference. In the current study, feedback was presented on a trial-by-trial basis, following performance on a demanding task. In Fowles' studies feedback was usually presented only after several responses, against a background of continuous motor activity. The feedback provided by Fowles and his co-workers may have been less salient than that used in this study. In some of Fowles' studies (e.g. Tranel, 1983) the rate of feedback was varied purely by altering the number of responses needed to gain the feedback, so that no "success" or "failure" was involved. Thus, in some of the studies undertaken in Fowles' laboratory, the feedback provided may have carried less intrinsic motivation than that provided in this study. For these reasons, the feedback provided in Fowles' studies may have needed higher success rates to maintain it's

motivational effect.

While the possibility of an interaction between feedback condition and perceived difficulty provides an alternative to an explanation in terms of pre-existing differences in physiological activity, the absence of such an interaction in any of the analyses of self-report measures of mood must cast doubt on such an explanation.

When feedback was given, mood was insensitive to feedback condition. Removal of feedback did lead to changes in mood, mood worsening when positive feedback was removed and improving when negative feedback was terminated. The absence of an effect of feedback condition on the self-report measures during the feedback blocks may be due to response bias. It is particularly noticeable that the mean Motivation score was 4, "Moderately motivated". In view of the fact that the experimenter sat next to the subject during the experiment (in order to take PSIs), this may just represent subject's desire to please the experimenter. However, the absence of a significant feedback effect on the more sophisticated POMS scales is harder to explain. Given that the theory explicitly predicts increased anxiety in the negative feedback group, the absence of any effect on self-report anxiety in the first task period is puzzling. It is noticeable that earlier work has failed to include self-report measures of anxiety or motivation (e.g Tranel 1983).

The changes in self-report measures in relation to the extinction period are broadly consistent with the theory and prove that, at least, subjects did notice the sudden termination of feedback, even if the physiological measures failed to reflect this awareness.

Physiological measures also did not seem to relate to measures of trait anxiety. Analysis of the Spielberger trait anxiety scale, together with the Marlowe-Crowne social desirability scale revealed

few significant correlations between self-report and physiological measures. There was a significant relationship between scores on the STAI and sweating during the second task period. Surprisingly, highly anxious subjects seemed to sweat less during the second task period. Consideration of both scales together seemed to add nothing to the prediction of levels of physiological activity. This question will be examined in more detail in later studies.

4.2 The Response to the Cognitive Task

All physiological measures showed a uniform increase during the task irrespective of difficulty level. There is no support here for the occasionally reported finding of a decrease in PSI scores during some types of task (e.g. Johnson & Dabbs 1967, Turpin, Takata & Tutton 1986). Future studies should examine other tasks.

The failure of skin conductance level to return to baseline after the task periods indicates that measures administered after the task might lead to different conclusions. After each task period, SCL would still be elevated, while the PSI, along with NS-SCR frequency, would show levels below those in the initial rest period (see figures 22-24). These effects are best interpreted as reflecting steady adaptation of the PSI and NS-SCR frequency, declining levels being observed within most of the periods.

As well as little or no overall adaptation the rate of adaptation of SCL appeared to vary from group to group. During the first rest period only the Easy/No feedback and Easy/Positive feedback groups showed significant adaptation over time. The failure of the Difficult groups to show adaptation during the first rest period might reflect anxiety about the complexity of the task they were to face. Had time permitted, it would have been better to provide the instructions after

the initial rest period. The failure of the Easy/Negative feedback group to adapt during rest period one is harder to explain. Examination of the raw data (see figure 23) indicated that the easy/negative feedback group appeared to show elevated skin conductance (and also heart rate) throughout the task and may have been atypical.

The increase in SCL over subsequent rest periods most probably represents the effect of epidermal hydration (e.g. see Bundy & Mangan, 1979). Unfortunately, the published formula for the electrode gel used (from Grey & Smith, 1984) contained an error which was not noted until after the experiment had been completed. The formula used gave a 0.5M solution, as opposed to the 0.05M solution claimed. More concentrated solutions of 3 or 4M do lead to elevated levels of SCL (Grey & Smith, 1984). Hygge & Hugdahl (1985) report that a 0.117M solution produced a higher response amplitude for the last response in a 75 minute experiment. This experiment lasted just under an hour, and it may be that the molarity of the solution used was partly responsible for the elevated levels of SCL found towards the end of the experiment. The hypertonic solution is unlikely to have influenced the NS-SCR frequency data and should not alter the conclusions regarding between-subjects effects involving SCL.

4.3 The Relationship Between the PSI and Electrodermal Measures

As regards the concurrent validity of the PSI, the sizable correlations with electrodermal measures indicate that the PSI does provide a valid measure of sweating. From the results reported here it is difficult to select one measure as preferable. On the whole, the PSI seemed to be more sensitive to the effects of feedback than the two parameters of EDA.

It has already been stressed that there was no evidence for a dissociation between the PSI and electrodermal measures of sweating. Furthermore, the observed differences between the PSI and SCL, with regard to their rates of adaptation, provide a plausible explanation for apparent dissociations in the literature.

4.4 Comparison of Different Treatments of the PSI

Examination of the two methods of scoring the PSI, a simple count of the number of active glands and the proportion of the number of glands present which were active, revealed little difference between the two measures. In view of the high correlation between the two there seems no reason to use the more complicated ratio measure, especially as this method is harder to score than the usual index.

The PSI data revealed no evidence of the operation of the Law of Initial Values. There was some indication that the use of difference scores might reduce the effects of differences in baseline, although possibly at the cost of reduced sensitivity. Had the LIV been in operation the use of difference scores would have had no effect on such differences. Controlling for possible baseline differences statistically, using analysis of covariance, produced virtually identical conclusions to the analysis of raw scores. There seems little reason to use the more complicated procedure. It should be noted that the baseline measures used in this study were obtained at rest in quiet conditions. Although levels of activity during the initial rest period were still moderately high. Where pre-task measures are obtained under less controlled conditions, levels of activity might be higher and the LIV more likely to apply.

Chapter 8

Experiment Two: Public-Speaking, Anxiety and the PSI

1 Introduction

The second experiment to be carried out was intended to examine a form of specific anxiety under field conditions. The aim of this experiment was to use the PSI as an alternative to electrodermal activity and to examine the effects of an anxiety manipulation with greater ecological validity than the feedback manipulation used in the last experiment.

It was decided to investigate public-speaking anxiety. This provides an ecologically-valid anxiety manipulation with considerable clinical relevance. There has been surprisingly little research on the psychophysiological correlates of public-speaking anxiety, and no clear picture emerges as to the role of physiological activity in this common form of anxiety. Research in the area of audience effects/ social facilitation (much of which has used the PSI, see chapter 3) indicates that the presence of others may lead to heightened levels of palmar sweating, although the evidence for effects on other presumed measures of arousal is less convincing (see Geen & Bushman, 1989 for a review of psychophysiological research into audience effects). However, this research most commonly involves a passive audience observing subjects performing a task which is not directly relevant to the audience. There has been far less research into the effects of speaking to an audience.

A study by Knight and Borden (1979) compared Heart Rate (HR),

Finger Pulse Volume and Skin Conductance for both socially-anxious (SA) and non-socially-anxious subjects, while anticipating and then giving a talk to a camera. Despite differences in subjective anxiety, they found few differences in physiological response between the two groups. Both showed increasing autonomic activity over the anticipation period, with a peak mid-talk. Only on FPV were the groups differentiated. SA subjects showed an inverse-U type curve of FPV over the anticipation period.

In contrast, a study by Beidel, Turner & Dancu (1985) reported evidence of greater cardiovascular responsivity in SA individuals while engaged in public speaking and while talking to a member of the opposite sex. Other studies, however have reported findings consistent with those of Knight & Borden (1979). McKinney, Gatchel & Paulus (1983) failed to find consistent differences in physiological responsivity (HR & EDA) between students reporting fear of speaking and those reporting no such fear, all showed increased activation in anticipation of a talk. A recent study by Puigcerver et al. (1987) also reports no differences in HR, FPV or EDA between SA and NSA subjects. Thus, while all studies reviewed so far report heightened levels of physiology in anticipation of speaking, or while actually speaking, the usual finding is that this activation is not confined to individuals reporting social anxiety. High and Low anxious individuals are usually found to show similar levels of autonomic activity in response to the threat of speaking.

Paul (1966) used a colorimetric sweat print technique, also known as the PSI, in a study examining the effectiveness of two treatments of public-speaking anxiety. His results are consistent with an interpretation of palmar sweating as an index of anxiety. He obtained sweat prints immediately prior to speaking from the same subjects at

two times, before and after a course of treatment. He found that desensitization produced a significantly larger decrease from pre- to post-treatment measures than a no-treatment control. Insight-orientated psychotherapy and an attention placebo produced intermediate reductions in pre-talk palmar sweating. Paul reports that PSIs correlated with two measures of self-reported anxiety and that the change in sweating from pre- to post-treatment correlated significantly with the change in observer-rated anxiety, measured using a behaviour checklist, during the talk. While his data do not allow the effect of the talk to be examined directly, the data do indicate that pre-talk sweating is related to anxiety.

A study by Giesen and McGlynn (1977) reports data on the effects of imagery on both HR and skin conductance level. On both physiological measures they found the group reporting public-speaking anxiety to show greater responsivity than the non-anxious group. However, this responsivity was not confined to fear-relevant imagery, the anxious group responded equally, if not more, to neutral imagery.

Lang et al., (1983) also investigated the effects of fear-relevant imagery. They compared both speech-phobic and snake-phobic subjects with regard to HR and SCL. Measures were taken both during actual exposure and imaginal exposure to both types of feared stimulus, i.e. while both types of subject were facing, or imagined facing, a snake and were giving, or imagined giving, a talk to an audience. During actual exposure, only skin conductance distinguished between the primary fear and the fear-irrelevant situation. Heart rate tended to show higher levels when speaking, due to the cardiovascular demands of the task, for both groups. Socially-anxious subjects showed little response to snake exposure, whereas snake-phobic subjects showed some anticipatory increase in SCL

prior to speaking as well as in response to snake exposure.

During imagery, similar patterns of response were seen, although the effects failed to reach significance. After training to increase the intensity of imagery, snake phobics produced significantly higher heart rate response to imagery of their feared stimulus. Lang et al. suggest that animal phobias involve a large avoidance component and corresponding tendency for heightened heart rate, in preparation for fight or flight. In contrast, they suggest that social phobias may involve little avoidance, centering more on passive coping with a feared stimulus. As EDA is associated with orienting, they suggest that EDA may be differentially sensitive to this sort of fear. This interpretation of the significance of EDA is compatible with Fowles' (1980) suggestion that EDA may provide an index of passive, as opposed to active avoidance.

The results cited above seem contradictory. Lang et al. claim that EDA may be sensitive specifically to anxiety experienced by socially-anxious subjects. However, other studies have not found any differences between SA and NSA individuals while speaking. Some of these differences may be due to differences in the subjects used. Lang et al. (1983), Biesen & McGlynn (1977) and McKinney, Gatchel and Paulus (1983) all selected subjects who specifically reported concerns about speaking. Two of these studies found differences between anxious and non-anxious subjects. The three other studies reviewed above selected subjects using measures of more general social anxiety, and only one study found clear differences between anxious and non-anxious subjects.

Perhaps, as Lang et al. suggest, the type of fear shown by subjects is a determinant of the physiological response shown. Even within the domain of social anxiety there may be sub-groups with

differing response profiles. The measure used both by Lang et al. and by Giesen & McGlynn, The Personal Report of Confidence as a Speaker (PRCS, Paul, 1966), would seem to be the most relevant to a public-speaking situation, and may tap a dimension of anxiety associated with differences in physiological responding. The current study will compare the physiological responses of subjects reporting different levels of anxiety on this scale.

In view of the large cardiovascular response produced by speaking, a measure of sweat gland activity such as the PSI seems to be the measure of choice for psychophysiological research into public-speaking anxiety. HR is unlikely to provide a sensitive measure of anxiety, given the large task-related response.

This experiment examined short-term changes in the PSI and state anxiety in relation to the experience of giving a public presentation. As well as a straight-forward examination of the effects of a common social stressor on self-report state anxiety and palmar sweating, the experiment also examined the contribution of both general and specific trait anxiety to the response to public speaking. The trait form of the State-Trait Anxiety Inventory (STAI, Spielberger, Gorsuch & Lushene, 1970) and the Marlowe-Crowne Social Desirability Scale (SDS, Crowne & Marlowe, 1964) were also administered to subjects. It was hoped that the simpler design of this study would allow a more detailed analysis of the relationship between these scales and physiological reactivity. In order to further extend the examination of trait vs state forms of anxiety a trait measure of specific anxiety, the brief form of the Personal Report of Confidence as a Speaker (Paul, 1966), was included in this study.

In this experiment each subject was used as their own control, subjects being run twice, once on an occasion when they were to give a

presentation and once when they were not speaking, but formed part of the audience. In view of the conflicting evidence for differences in physiological responses, the use of a within-subject design should provide a more powerful test of the hypothesis that higher trait anxiety scores are associated with larger physiological responses in response to public speaking.

The main hypotheses to be tested are that both palmar sweating and self-report state anxiety will be greater on occasions when a subject is presenting a talk than on occasions when that subject is not talking. For speakers, both measures are expected to increase up to the time of the talk and decline afterward. Palmar sweating might be expected to be slightly increased for control subjects during the talk, due to the effects of attention, although this would not be expected to be accompanied by increased STAI-S scores, nor would increased sweating be expected in the anticipation period. It is predicted that both high Trait anxiety scores and high PRCS scores will be associated with a greater response to the stress of presentation. It is expected that high SDS scores will be associated with lower STAI-T and PRCS but not lowered indices of state anxiety.

2 Method

2.1 Subjects

Nineteen subjects took part, all of whom were third-year psychology students, taking part in an option involving the giving of a presentation on a pre-selected topic. All subjects were volunteers and it was stressed that participation would have no effect upon subject's marks for the option. All subjects who were asked agreed to take part, although one subject was unable to attend for both sessions and was excluded from the experiment. The final group contained 3

males and 16 females.

2.2 Procedure

Each subject was tested twice, once on a day when they were to give a presentation, once on a day when they formed part of the audience. The order of the sessions was counterbalanced by randomisation. The dates on which subjects were tested in each condition were chosen randomly, with the only constraint that four subjects were tested on each day, two in each condition. Nine subjects gave their presentation before acting as a control, while ten acted as a control first. The mean period between presentation and control session was 4.8 weeks for subjects who presented first and 5.2 weeks for subjects who presented second. In both cases, the maximum period was 7 weeks and the minimum 3 weeks. On each of ten weekly sessions, data were collected from two speakers and two controls, each speaker being matched with one control. Due to unforeseen circumstances only one speaker was available in the 8th week (both controls being run simultaneously) and, to compensate, three speakers and one control took part in the last week (the control was run with the first speaker).

Each session began with all subjects for that week being asked to return to the room ten minutes early after a coffee break. This time was spent filling in a series of questionnaires. All subjects completed a questionnaire asking what they had drunk in the coffee break and whether they had smoked during the break, as well as the state form of the Spielberger State-Trait Anxiety Inventory (STAI-S) and the Personal Report of Confidence as a Speaker (PRCS). In addition, control subjects filled in the trait form of the STAI (STAI-T) and speakers filled in the Marlowe-Crowne Social Desirability

Scale (SDS). Subjects were given the PRCS on both occasions in order to assess the reliability of the scale. After completing the questionnaires a PSI was taken by the two experimenters, one for the control subjects and one administering the PSI to the speakers. Subjects were then asked to relax for five minutes. After this rest period another PSI was taken from each subject. Then the speaker who would go first was chosen by the toss of a coin.

After the audience had entered, the first speaker and control filled in the STAI-S and a PSI was taken from both speaker and control. The first speaker then began his or her talk. Each talk lasted fifteen minutes and a second PSI was taken from the speaker and the matched control half way through. A third PSI was taken from each member of the pair immediately after the talk finished and each was asked to complete another STAI-S describing how they felt during the talk. There then followed a short (around ten minutes) question session, followed by a final PSI. The procedure was then repeated for the second pair, starting from the point where the audience had entered.

2.3 Data Reduction and Analysis

As in experiment one, the PSI was analysed both as the number of active glands present (PSI-A) and as a ratio of the number of active glands divided by the total number of glands, active and inactive (PSI-R). In the analysis of the number of active glands three data points were missing (1.32%), four points were missing in the analysis of the proportion of glands active (1.75%). Missing values were replaced by values estimated on the basis of the regression equation for the other values. The analysis was repeated using only those subjects with complete data in order to examine the effects of the

replacement.

For brevity, only the analysis of the PSI-A, including estimated values, will be reported in detail. Other analyses will be discussed only where they present different conclusions.

There was very little evidence of skew in the distributions of the PSI data, out of twelve measurements only one revealed significant positive skew when the number of active glands was examined. For the ratio measure, two points revealed significant negative skew. No transformation was considered necessary to normalise the distribution of the data.

3 Results

3.1 Possible Confounding Variables

The data concerning subject's activities during the break preceding the experimental session were examined, in order to rule out possible differences between the two sessions. No subjects reported having smoked before either of their sessions. The numbers drinking tea or coffee during the break were also similar (7 subjects drank before speaking, 8 drank before their control session). Mean numbers of active sweat glands were compared for those subjects drinking and not drinking. Neither speakers nor audience members showed different levels of sweating as a result of the consumption of caffeine-containing beverages. Room temperature also did not correlate significantly with the mean number of active sweat glands recorded in either of the two sessions.

3.2 The Effects of Public Speaking on State Anxiety and Palmar Sweating

3.2.1 State Anxiety. State anxiety measures were analysed in a Condition (audience vs speaker) x Repetition (3 measures) MANOVA. Scores on the state anxiety scale of the STAI are presented in figure 25. The main effect of Condition was significant ($F(1,18)=79.70$, $p<.001$), subjects reported more anxiety at all times when speaking.

There was also a significant interaction between the Condition and Repetition factors (approx $F(2,17)=6.70$, $p=.007$). Orthogonal contrasts within the Repetition effect revealed that subjects reported themselves to have been more anxious immediately prior to the talk than at the start of the session or during the talk ($t(36)=2.69$, $p=.015$). The first measure and the mid-talk measure did not differ significantly. Contrasts within the interaction between Condition and time of measurement indicated that the difference between the groups lay in the peak in anxiety prior to the talk ($t(36)=3.38$, $p=.003$). Simple effects analysis indicated that only when subjects were speaking did they report significantly more anxiety before the talk ($t(36)=3.74$, unadjusted $p=.001$).

Thus, the experience of giving a presentation did lead to elevated levels of anxiety, with the highest levels being reported immediately prior to the talk, rather than during the talk.

The order of the two sessions did not appear to be related to the level of state anxiety reported.

3.2.2 The PSI. The Palmar Sweat Index was analysed in a Condition (audience vs speaker) x Repetition (6 measures) repeated-measures MANOVA. The Repetition factor was split into six orthogonal contrasts. These contrasts are listed in table 28.

Figure 25: Condition by repetition interaction for state anxiety

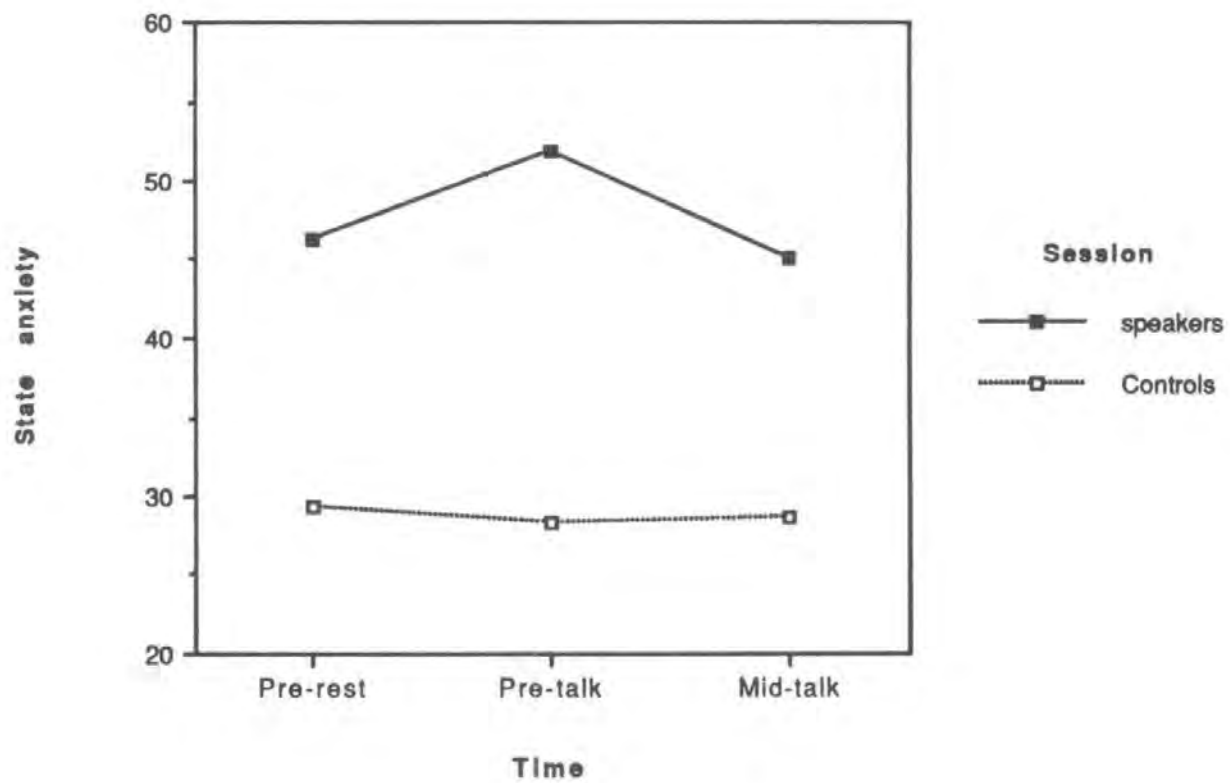


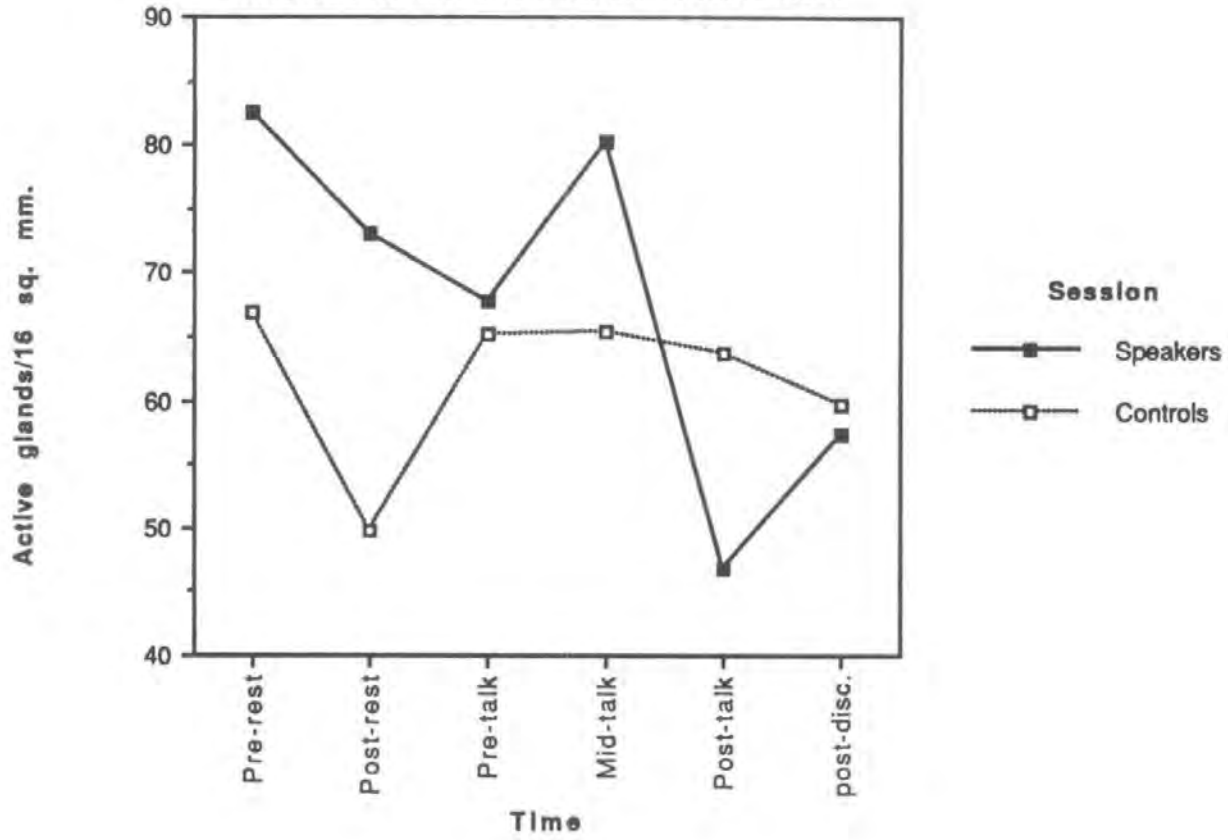
Table 28: A priori contrasts used in the analysis of PSI data

Measure	Contrast				
	1	2	3	4	5
Pre-rest	a	a	a		
Post-rest	a	a	b	a	
Pre-talk	a	a	b	b	
Mid-talk	b				
Post-talk	a	b			a
Post-discussion	a	b			b

Each contrast compares the mean of two measures or groups of measures, identified by different letters. Thus, contrast one compares levels of sweating during the talk with the mean level at all other times, contrast two compares levels of sweating prior to the talk to those after the talk etc.

The main effect of Condition was non-significant, indicating that overall levels of sweating did not differ significantly on the two occasions. There was, however, a significant Condition x Repetition interaction (approx $F(5,14)=3.01$, $p=.048$). Only two of the contrasts within the main effect of Repetition were significant. While mid-talk measures did not differ significantly from the mean of the other measures, measures taken after the talk were significantly lower than those obtained before ($t_{(90)}=2.90$, $p=.010$). For PSI-A only, the first measure taken, prior to the rest period, was significantly higher than the next two measures (PSI-A $t_{(90)}=2.13$, $p=.047$; PSI-R $t_{(90)}=1.75$, $p=.098$).

Figure 26: Condition by Repetition Interaction for the Palmar Sweat Index



The interaction between Condition and Repetition is displayed in figure 26. The most striking feature of the graph is the large drop in sweating after the talk, although an increase in sweating during the talk is also apparent.

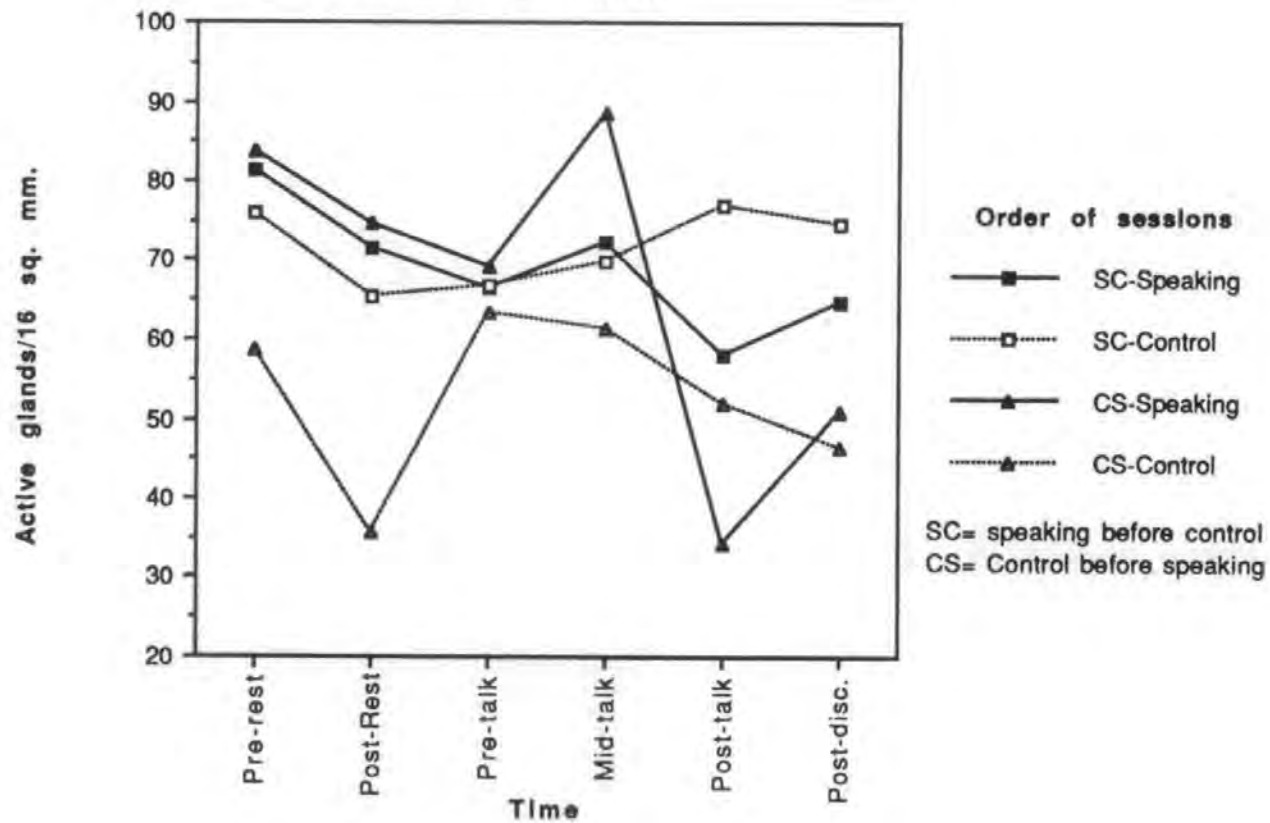
Examination of the interaction between the Condition factor and the contrasts within the Repetition factor indicated that the difference between the patterns of activity shown on the two occasions was in the change from pre-talk to post-talk measures ($t_{(90)}=2.43$, $p=.025$). Simple main effects analysis revealed that none of the contrasts within the audience condition were significant. When subjects were giving a presentation, however, the measures after the presentation were significantly below those obtained prior to the talk ($t_{(90)}=4.05$, unadjusted $p=.001$). A post hoc comparison of the measure obtained immediately prior to talking with that taken during the talk revealed that the apparent increase was non significant ($t_{(18)}<1$).

When only those subjects with no missing values were examined, the repetition effect was unchanged. However, neither the interaction between the Condition and Repetition effects nor any contrasts within this effect were significant. All of the missing data points were from occasions when subjects were giving a presentation. Examination of the mean values indicated that inclusion of the estimated data points did not significantly alter the means of any of the measures. Inclusion of the estimated values also did not significantly alter the variance of any of the measures. However, when the individual values were examined one of the estimated points was found to be an outlier, lying more than 1.96 standard deviations from the mean of the raw data. As this value was for the PSI taken in the middle of the talk and the estimated value was below the mean, actually being negative for the PSI-A, inclusion of this point would have served to slightly reduce

the difference between the two conditions. However, as a check, the analysis of estimated scores was repeated, excluding the subject with an extreme value. The Condition by Repetition interaction was significant in the analysis of the PSI-A measure (approx $F(5,13)=3.25$, $p=.040$) and approached significance for the PSI-R (approx $F(5,13)=2.76$, $p=.065$). This extreme value does not, therefore, explain the difference between the analyses of raw and estimated values. As can be seen from figure 26, when estimated values are excluded subjects still showed consistent differences between the two occasions. The difference between the two analyses is most probably due to the larger sample size of the analysis of the estimated data set. The increase in power resulting from a greater sample size serving to offset the large standard deviations which were found.

In order to examine the effects of the order in which subjects spoke on the PSI further, MANOVAs were undertaken including the order of the two sessions (speaking before audience or audience before speaking) as a between-subject factor. For the ratio measure alone, the order of the two sessions showed a weak relationship to sweat gland activity. The main effect of session order approached significance ($F(1,17)=3.62$, $p=.074$) while the interaction between the order of the two sessions and the Repetition factor just fell short of significance (approx $F(5,13)=2.92$, $p=.055$). Subjects who gave their presentation before their control session tended to sweat more on both occasions than those who spoke after having been assessed in the audience. This effect was greatest for the last two measures, both taken after the talk (see figure 27).

Figure 27: Order by Repetition interaction for the Palmar Sweat Index



One of the most striking features of the response of the PSI to the stress of speaking is the large decrease in palmar sweat gland activity which is apparent after the talk. While sweating increased during the talk, albeit non-significantly so, there appears to have been a "rebound" decrease afterwards. Thus, had the PSI been taken only after the talk, an apparent anhidrotic response would have been seen. In order to examine the relationship between this decrease and the preceding increase in sweating the correlation was calculated between the PSI taken during the talk, relative to the values obtained when subjects were in the audience, and the succeeding decrease, again expressed as the difference from values recorded at comparable times when subjects were in the audience. These two values correlated significantly ($r=.544$, $p=.030$, two-tailed). As this correlation is positive, subjects who showed larger increases during the talk appear to have shown smaller drops in sweating after the talk. This seems to indicate relative stability in the amount of sweating at the two times. If the post-talk decrease in the PSI represented some kind of exhaustion process, then the two values would be expected to correlate negatively, larger increases during the talk leading to greater fatigue of the sweat glands and lower, not higher, levels of activity after the talk. The correlation between absolute PSI scores at the two times for the speakers was also positive, although non-significant ($r=.399$).

In view of the significant effect of the talk on palmar sweating, it was possible to examine the sensitivity of the two means of scoring the PSI to this effect. For both PSI-A and PSI-R the effect size was calculated corresponding to the change over time when speaking. This revealed that the effect of the talk was greater for the number of active glands than for the ratio of active over total glands (PSI-A

omega squared=.286; PSI-R omega squared=.122).

This difference in effect sizes implies that the ratio measure may be less sensitive than the more commonly-used count of active glands. The gain in sensitivity due to compensation for differences in finger size and area scored may be insufficient to compensate for the added variance resulting from the inclusion of the number of inactive glands. It should be stressed that this comparison relies on the size of a within-subjects effect, results might be different were a between-subjects effect be examined.

3.3 The Relationship between Trait Anxiety, Social Desirability and the Response to Public Speaking

The Personal Report of Confidence as a Speaker was administered twice, once on each occasion, in order to rule out the possibility that scores on the scale might be influenced by situational factors associated with giving a talk.

Analysis revealed that mean scores on the two occasions did not differ significantly ($t(18)=1.37$, ns), although scores were slightly higher when subjects were expecting to speak ($\bar{X}=15.26$ vs 14.05). The two measures were highly correlated ($r=.889$, $p<.001$, one-tailed). Giving a presentation did not seem to have influenced the replies people gave on the PRCS. In succeeding analyses only the scores obtained on the occasion when subjects were speaking were used.

While correlations between scores on the SDS and scores on the two trait anxiety scales were negative, neither correlation reached significance (SDS with STAI-trait scale, $r=-.133$; SDS with PRCS, $r=-.245$). The correlation between the two anxiety scales was also non-significant ($r=.128$).

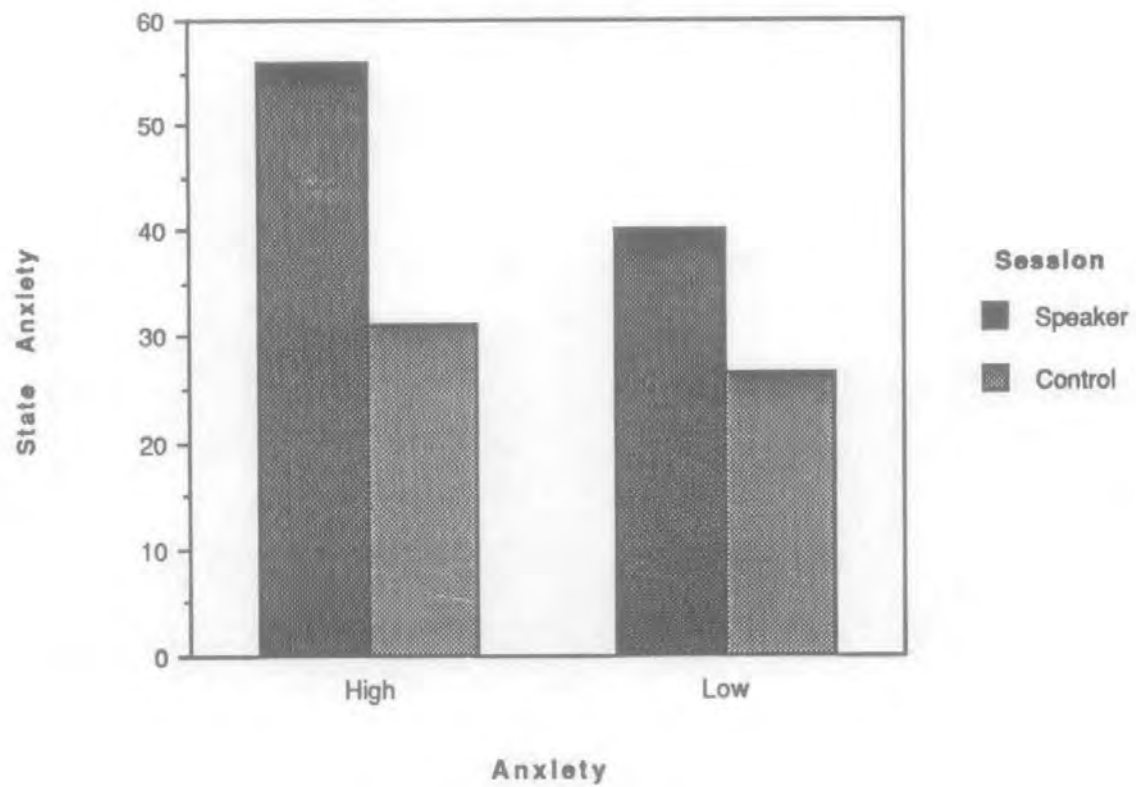
Each of the three trait scales were subjected to a median split

to produce two groups of nine subjects for each scale. For trait anxiety one of the three subjects scoring at the median (36) was randomly excluded, the others being counted as high-anxiety subjects in order to balance group sizes. Similarly, one of the two subjects scoring at the median of the SDS (14) was randomly excluded from the relevant analyses, the other subject being assigned to the repressor group. Only one subject scored at the median (15) on the PRCs, this subject was excluded from the relevant analyses.

For each of the scales, in turn, analyses were carried out comparing the PSI and state anxiety scores of subjects scoring above and below the median. For the PSI the effect of public speaking anxiety on the ratio measure approached significance ($F(1,16)=3.62$, $p=.075$). Surprisingly, subjects scoring above the median on this measure of trait anxiety tended to have lower sweat gland counts than those scoring below (mean values were .500 versus .606). While not significant, a similar trend was apparent in the data for the number of active glands (High anxiety group mean PSI=57.80, Low anxiety group mean=71.93). None of the other effects or interactions involving the trait measures was significant. An interaction between STAI trait anxiety and the repetition factor was of borderline significance for both PSI measures (PSI-A approx $F(5,12)=2.44$, $p=.095$; PSI-R approx $F(5,12)=2.67$, $p=.076$).

When levels of state anxiety formed the dependent variable the effect of public-speaking anxiety was highly significant ($F(1,16)=35.05$, $p<.001$). Scores on the PRCs also interacted with Condition ($F(1,16)=9.30$, $p=.008$). Subjects reporting high levels of public-speaking anxiety also reported more state anxiety (high anxiety group mean state anxiety=43.50, low anxiety group mean=33.30).

Figure 28: Public-speaking anxiety by condition interaction for state anxiety



The interaction with condition indicates that the two groups only differed significantly on the occasions when they were actually speaking ($F(1,16)=32.22$, unadjusted $p<.001$). The simple main effect of public speaking anxiety did not achieve significance when only measures taken from the audience were considered ($F(1,16)=4.26$, unadjusted $p=.056$). This interaction is displayed in figure 28. No other effects or interactions involving the trait scales were significant. For Trait anxiety, a triple interaction between trait anxiety, condition and the repetition factor fell short of significance (approx $F(2,15)=2.72$, $p=.098$).

Only the measure of public-speaking anxiety, the PRCS, appears to be clearly related to the response to the talk. As expected, subjects reporting high levels of anxiety about speaking also reported more state anxiety while talking. The indication that these subjects also appeared to show slightly lower levels of sweating is surprising. As this effect failed to reach acceptable levels of significance, for either of the means of scoring the PSI, it is difficult to draw any firm conclusions concerning this observation.

In an attempt to provide further information about the relationship between scores on the various trait questionnaires and the response to the situation of public-speaking, a series of regression analyses were undertaken. Initially, Scores on the three trait scales, state anxiety or the PSI as appropriate, together with the order in which subjects spoke on the day, the week in which they spoke and the order of the two sessions (speech before control or control before speech) were examined for their ability to predict scores on either the PSI-A or state anxiety obtained immediately before the talk. As mid-task state anxiety was assessed retrospectively it was felt that pre-talk measures might be more

reliable. Similar analyses were also carried out with regard to measures obtained during the talk. The results of these analyses are reported later.

For the PSI obtained prior to the talk, only one predictor emerged: Scores on the Marlowe-Crowne social desirability scale were predictive of higher levels of sweating prior to the talk, SDS scores accounting for 35% of the variance in PSI-A scores. Trait anxiety also correlated weakly with palmar sweating prior to the talk ($r = -.441$, $p = .058$, two-tailed). It should be noted that high scores on a measure of trait anxiety (the STAI trait scale) were associated with lowered sweat gland activity. A similar relationship between scores on the PRCS and palmar sweating was observed in the groupwise analysis reported above.

Two variables were found to significantly predict levels of state anxiety prior to the talk. Scores on the PRCS were highly related to self-reported anxiety, accounting for 60% of the variance in pre-talk state anxiety. The week in which subjects spoke made an additional contribution, taking the proportion of variance accounted for up to 70%. Subjects who spoke later in the term reported less anxiety prior to speaking.

The relationship between state anxiety and self-reported public-speaking anxiety was expected. The influence of week of speaking upon anxiety is also unsurprising. The relationship between the PSI and scores on the SDS was not expected, although the relationship seems explicable.

No measures were found to be adequate predictors of mid-talk levels of sweat gland activity. As for pre-talk anxiety, retrospectively-assessed state anxiety during the talk was strongly related to self-reported public-speaking anxiety. Scores on the PRCS

accounted for 42% of the variance in state anxiety scores. Trait anxiety also independently predicted levels of state anxiety during the talk, the two predictors together accounting for 56% of the variance in state anxiety.

As expected, these analyses indicate that self reported trait anxiety is predictive of higher levels of state anxiety in response to the stress of public-speaking. The relationship between trait anxiety and palmar sweating seems less clear. In both sets of analyses there were indications of an inverse relationship between reported anxiety on one or other of the two scales of trait anxiety and scores on the PSI. In the groupwise analysis, subjects reporting high levels of public-speaking anxiety showed a non-significant tendency to sweat less at all times. In the regression analysis, general trait anxiety scores were negatively correlated with sweating prior to the talk. The relationship between scores on the SDS and levels of sweating prior to the talk can most probably be explained as reflecting a higher motivation to present a favourable impression and, therefore, greater anxiety in response to the possible threat of public-speaking, in those subjects showing higher levels of socially-desirable responding.

4 Discussion

It was predicted that the talk would lead to elevated levels of anxiety, reflected in higher levels of state anxiety and in higher PSI scores. It was predicted that the response to the talk would be positively related to self-reported trait anxiety.

The first prediction was supported by the state anxiety data, but the PSI data were more complex than predicted. State anxiety was higher on occasions when subjects were to speak. Unexpectedly, the PSI failed to increase significantly during the talk. It is possible that

subjects may have felt sufficient anticipatory anxiety prior to the talk to mask any further increase on starting the presentation. This hypothesis is consistent with the decrease in sweating which is apparent after the talk. The fact that state anxiety was highest prior to the talk, rather than during the talk, also provides support for a large component of anticipatory anxiety. It should also be remembered that the mid-talk PSI was just that, being taken after subjects had been talking for approximately seven minutes. It is likely that some adaptation may have occurred during the initial few minutes of speaking. Had a PSI been taken during the earlier stages of the talk a larger response might well have been observed.

While the post-talk drop in the PSI could be viewed as recovery from anticipatory anxiety, the short duration of the decrease in the PSI makes an alternative explanation in terms of an exhaustion-like process also plausible.

The nature of this hypothetical rebound effect is rather mysterious. Post-talk levels of sweating correlated positively with mid-talk levels. If the increase during the talk was producing the post-talk dip, via some kind of exhaustion effect, then a negative correlation would be expected. Part of the dip may reflect delayed adaptation in the speakers. By the end of the experiment their initially high levels of sweat gland activity had declined to the levels observed when they were in the audience. Rapid adaptation alone does not seem to be an adequate explanation, though, as the post-talk dip produced levels of sweating below those observed in the audience.

The answer may lie in a better understanding of the mechanisms producing sweat gland activity. The time course of the sweat response is poorly defined. Skin conductance responses occur very rapidly, but at present it is unclear how rapidly the PSI changes. From the results

presented here it is apparent that the PSI can show large shifts in activity over a period of seven minutes or so. While the timing of the measures does not permit greater specification than that, it is tempting to conclude that the apparent reduction in sweating occurred only after the talk had finished. If that is the case, then the PSI may change very rapidly indeed.

Rapid increases in sweating are to be expected, neural control of sweat glands should allow rapid increases in sweat secretion, the mechanisms which might produce rapid decreases are less obvious. Once secretion has stopped droplets already produced need to be removed before the PSI can detect any change. Droplets might be removed by several processes, including diffusion out of the duct into the surrounding tissues, direct evaporation of droplets and relaxation of muscle tissue round the duct, allowing sweat to return into the duct. Some of these processes, singly or in combination, might allow very rapid removal of visible droplets from the mouth of the duct. The psychological significance of these processes is unclear. At present there is no evidence to indicate that these processes are under any degree of central control. Better understanding of the way these processes are regulated, and the way that their effectiveness is influenced by prior activity, might provide an explanation of the circumstances which produce rapid declines in sweating such as that observed here.

The second prediction to be examined was that the response to the talk would be related to levels of general trait anxiety and public-speaking anxiety. Only the increase in state anxiety produced by the talk showed the expected relationship to self-reported trait anxiety. Subjects expressing high levels of public-speaking anxiety were found to show greater state anxiety prior to the talk.

Trait anxiety did not consistently lead to higher levels of sweat gland activity. In fact, there were indications that higher levels of trait anxiety might be associated with lower scores on the PSI, although the relationship fell short of significance. While desynchrony between physiological and subjective measures is not a new finding, a negative relationship is less commonly found. One study which does report similar findings is that by McKinney, Gatchel & Paulus (1983), who also report non-significantly lower levels of skin conductance in high-anxious subjects in association with a talk. As the relationship was non-significant in either study, no conclusions can be drawn. The absence of higher levels of electrodermal activity in speech-anxious subjects replicates earlier findings (e.g. Puigcerver et al., 1987; Knight & Borden, 1979).

A recent study by Naveteur and Roy (1990) reports decreasing skin conductance response amplitude in high trait anxious subjects during a frustrating game. Low anxious subjects showed relatively constant amplitudes. They interpret this result as reflecting an inhibition of sweating by high levels of trait anxiety. State anxiety is assumed to lead to increased EDA. Such an explanation would be consistent with the weak evidence obtained here for a negative relationship between the PSI and trait anxiety. However, as Naveteur and Roy (1990) point out, other factors such as differences in task perception and coping strategies, may account for the difference in physiological activity between trait-anxious and non-anxious subjects. Interestingly, they suggest that Gray's (1982) Behavioural Inhibition System may also inhibit EDA. This is the opposite to the relationship proposed by Fowles (1980), although Fowles' experimental work has concentrated on the manipulation of state, rather than trait, anxiety. Clearly the distinction between trait and state anxiety is an important one.

Naveteur and Roy's proposal is worthy of further investigation, although until their results have been replicated it remains only an interesting suggestion.

The results of this study have a number of implications for the way in which the PSI should be used in future studies.

The PSI revealed a highly differentiated pattern of activity, levels of sweating revealed a series of changes over a relatively short time scale. The pattern of changes seems largely consistent with the activities undertaken by subjects at the time. On the control occasion, subjects showed decreasing levels of sweating while resting. While subjects expecting a talk did not show such a clear decrease, it would be expected that subjects might find it difficult to relax prior to a presentation. Levels were higher during the talk, albeit non-significantly so, most probably due to the high levels of anticipatory anxiety experienced. Part of the rationale for using the PSI to study public speaking anxiety was that measures of sweating may be less sensitive to the effects of the task itself than cardiovascular measures. If, as expected, the PSI is providing a, comparatively, pure measure of anxiety then it might be expected that this anxiety would be present before subjects actually began speaking. After the talk, levels of sweating declined rapidly. This sort of rapid, rebound-like decrease may explain the reports of an anhidrotic response in the literature. It seems clear that the PSI is a very responsive measure and may show dramatic changes over relatively short periods of time. The results of this study provide considerable evidence of the importance of obtaining psychophysiological measures during a task or stressor. Clearly, measures obtained immediately after a particular task may tell a very different story from measures taken during the task.

Comparison of the sensitivity of the two means of scoring the PSI implied that the count of the number of active glands might be more sensitive than the ratio of active glands over the total number of glands present. This conclusion must be tempered by the fact that the comparison in this study, and in experiment one, concerned a within-subjects manipulation. The ratio measure was expected to be more sensitive because it compensates for the effects of differences in gland density. In a within-subjects analysis, differences in gland density can only occur as a result of taking prints from different sites on the same finger. When measures come from the same subjects, then differences in finger size between subjects are already controlled for. Therefore, the ratio measure would be expected to be less useful in a within-subjects design than in a between-subjects design, where differences between subjects with regard to finger size might also inflate the error variance. Later studies will compare the sensitivity of these two techniques to between-subject effects.

The study has demonstrated that the PSI does allow the assessment of palmar sweating under field conditions and can be applied to ecologically-valid forms of stress. The next experiment to be reported examined another form of "real-life" stress under field conditions.

Chapter 9

Experiment Three: Examination Anxiety and the PSI

1 Introduction

As the last experiment demonstrated that the PSI could be fruitfully applied to the investigation of stressful events, the third experiment to be undertaken examined a more intense stressor. This study had two aims: Firstly, the study was intended to investigate the effects on the PSI of another ecologically valid form of anxiety. Secondly, the study allows the examination of the longitudinal effects of a stressful event on both the PSI and a variety of subjective measures. While experiment two examined changes over a short time period, experiment three investigated whether taking an examination produces longer-lasting changes in palmar sweating.

The experience of taking an exam has been found to produce effects on a wide variety of physiological measures, including neurotransmitter levels (e.g. Davis et al., 1985), endocrine measures (e.g. Herbert et al. 1986; Vassend, Halvorsen & Norman, 1987) and autonomic measures (e.g. Deffenbacher, 1986; Vassend, Halvorsen & Norman, 1987).

While there are comparatively few studies which have investigated the effects of examination anxiety on electrodermal activity, there is evidence to indicate that such anxiety leads to increases in both EDA (Holroyd et al., 1978; Hollandsworth et al. 1979) and other measures of sweat gland activity (Beam, 1955; Davis, 1957; Gladstone, 1953). However, the results from studies using colorimetric sweat prints are mixed. Gladstone (1953) carried out no less than seven experiments

examining levels of palmar sweating before, during or after exams in comparison to levels obtained in sessions during normal classes. Only two of these experiments observed significantly higher levels of sweating on the day of the exam. Both of the significant results came from experiments which had administered the sweat print in the middle of the exam. All of the other experiments administered the technique before or after the examination. A study by Winter, Ferreira and Ransom (1963) used a similar colorimetric technique, confusingly referred to as the Palmar Sweat Index, to examine palmar sweating just prior to an examination, as well as during laboratory manipulations of anxiety. While their laboratory manipulations were effective in increasing sweat production, the levels of sweating obtained on the day of the exam did not differ significantly from those obtained under non-anxious conditions, despite elevated levels of subjective anxiety on the day of the exam. Both Gladstone and Winter et al. report that their measures showed considerable consistency from day to day.

One study by Johnson and Dabbs (1967) used the PSI to examine levels of sweating prior to an classroom exam. This study found that pre- and post-exam PSIs did not differ significantly from those obtained prior to a regular statistics class, although all of these measures were significantly higher than those obtained at a later date while subjects were doing multiplication problems. The small sample size (n=12) must limit the conclusions which can be drawn from this study.

The study by Vassend et al. (1987) found that both blood pressure and serum prolactin levels were still elevated two weeks after an exam, despite a reduction in subjective measures of anxiety. While this finding is difficult to interpret due to the confounding effects of an imminent oral exam at the final time of testing, it seems to

imply that the physiological effects of an exam might be relatively long-lasting. As well as showing slow recovery after an exam, it can be assumed that physiological activation might begin some time before the exam, due to the occurrence of anticipatory anxiety.

Such a sustained increase in physiological activity might well have consequences for the long-term effects of this stressor. It is often assumed that the harmful effects of stress are mediated by the physiological response to stressors (Selye, 1976). If this is the case, then it follows that the response to stressful events must either be more intense or more prolonged than the response to non-stressful events. By taking measures over several weeks either side of an exam this experiment allowed the investigation of the time course of the physiological response to an exam.

This strategy also provides evidence concerning the temporal stability of the PSI. There is relatively little evidence concerning the test-retest reliability of the PSI. By taking repeated measures over a period of several weeks it was possible to examine how consistent individuals' levels of sweat gland activity were. Psychophysiological measures are most commonly applied as indices of psychological states. If the PSI provides such an index, then it is expected that levels of sweating will show considerable fluctuation over time. High degrees of consistency from one session to the next would imply that the PSI is more sensitive to trait factors. While such factors might include relatively stable psychological traits, such differences might also reflect stable physiological differences in sweat gland density or activity. The literature on electrodermal lability implies that stable patterns of electrodermal activity may exist (Bull & Gale, 1973; Schell, Dawson & Fillion, 1988), and that such patterns may be associated with differences in performance on a

variety of tasks (O'Gorman, 1988; Wilson & Graham, 1989). However, patterns of electrodermal activity do not appear to be related to conventional measures of personality (Hastrup & Katkin, 1976; O'Gorman, 1983). The temporal stability of the PSI and the psychological significance of different levels of tonic sweat gland activity are unknown. Studies using other measures of sweating, referred to above, indicate that the PSI might show relatively high test-retest reliability.

To provide indices of both reactivity and base level of sweating the PSI was taken twice, once at rest and once immediately after completing a one-minute digit-symbol substitution task. In order to allow simultaneous testing, subjects administered the PSI themselves, using a pad soaked in the solution. The studies reported by Gladstone (1953) indicate that measures taken during an exam might be more sensitive than those obtained before or after the exam. However, it was not possible to interrupt the exam to take the PSI. Measures on the day of the exam were taken in the same room as the exam, a certain amount of anticipatory anxiety should be present at the time of the first measure. It is possible that the measures taken after the exam might be depressed by the same sort of "rebound" effect that was observed in experiment two. The inclusion both of measures taken at several sessions temporally remote from the exam and of a control group was intended to maximise the sensitivity of the experiment to the relatively small increment in sweating which might be expected.

Data were collected over a seven-week period including a mock exam. The Profile Of Mood States and the Spielberger State Trait Anxiety Inventory, both used in experiment one, were also included in this study. In addition, subjects were given the Worry and Emotionality Questionnaire (Liebert & Morris, 1967). This scale taps

two dimensions of examination anxiety. Worry consists of cognitive preoccupation and is usually found to account for most of the detrimental effect of anxiety on test performance (see Deffenbacher, 1980; Morris et al, 1981). Emotionality consists largely of the awareness of emotional arousal and autonomic symptoms of anxiety, although emotionality is not generally found to correlate more highly with actual autonomic activity, than worry does (Morris & Liebert, 1970; Deffenbacher & Hazaleus, 1985). Emotionality is generally only found to be elevated close to the exam, whereas Worry is often elevated for some time before and after (Morris et al., 1981).

Subjects were also given the General Health Questionnaire (Goldberg, 1972) worded to assess symptoms over the last week. This scale provides a general index of psychological disorder. In addition the version used in this study (Goldberg, 1978) provides four subscales measuring Somatic Symptoms, Anxiety and Insomnia, Social Dysfunction and Severe Depression. This scale was included as an index of stress-related symptoms. Of particular interest is the time course of such symptoms. Work on life events scales implies that harmful effects may appear a long time after stressful events (Holmes & Masuda, 1974). It might be expected, however, that the effects of stress might be greatest at the time when stress is greatest, i.e. on the day of the exam or in the anticipation period immediately before. The study allows the simultaneous comparison of the time courses of the physiological and subjective effects of the exam.

It was expected that the exam would lead to elevated scores, relative to the control group, on the PSI and on self-report measures of mood disturbance and psychological disorder. Both physiological and subjective responses were expected to remain elevated for some time after the exam. It was expected that the PSI would show moderate

temporal stability.

2 Method

2.1 Subjects

19 first year psychology students formed the exam group, one subject dropped out of the experiment after the first session. All experimental subjects received credit for participation in partial fulfilment of a course requirement. The final exam group contained 16 females and 2 males. The control group consisted of 17 second year students who did not have an exam during the relevant period. All control subjects were paid £5 for participation. The control group comprised 14 females and 3 males.

2.2 Procedure

All subjects were tested five times. Testing sessions took place at the following times; two weeks before and one week before a mock exam at the end of the autumn term, in the week of the exam (with exam subjects being tested twice; immediately before and immediately after the exam), and one and six weeks after the exam (the final session being in the first week of the spring term).

All testing sessions followed the same format; Subjects were first given a set of questionnaires to complete, consisting of the state form of the State-Trait Anxiety Inventory (STAI-S), the Profile of Mood States (POMS) for their feelings at that moment and the General Health Questionnaire (GHQ) for the past week. The exam group were also given the Worry and Emotionality Questionnaire (WEQ). On the first session both groups were also given the trait form of the State-Trait Anxiety Inventory (STAI-T) and the Marlowe-Crowne Social Desirability Scale (SDS) to complete.

When subjects had finished the questionnaires they were asked to wait until all subjects had finished and then take one PSI. In order to allow convenient testing of a large sample, a method was devised that would allow the PSI to be self-administered. This was achieved by using a foam-rubber pad soaked in the solution, which subjects used to apply the solution to their finger. Two main problems arose with this technique. Firstly, the solvent used is highly volatile and tends to evaporate quickly. Using a lidded container reduces this problem, but the technique is still not suitable for long experiments. Secondly, the solvent used also reacts with some plastics, so that the container used needs to be carefully selected. For this experiment polythene containers originally intended for ice-cubes were used, together with separate lids.

All subjects were shown the technique before the first session and were given instructions, if requested, later. When dry, the print was rolled off the finger onto a piece of sticky-back plastic. The plastic was stapled, sticky side up, to a piece of cardboard clearly labelled with either "Rest" or "Task" as appropriate.

When all subjects had taken the first "Resting" print they were asked to carry out a digit-symbol substitution task, which they were told was "similar to those used in IQ tests". All subjects were given one minute to fill as many boxes as possible and then stopped and told immediately to take another print (the "task" print). The task used is presented in Appendix B. It was hoped that this procedure would allow an assessment of reactivity as well as base level of sweat gland activity. Although the problems of interpreting measures taken after, rather than during, a task have already been discussed.

2.3 Data Reduction and Analysis

All analyses of variance were carried out using SPSS* MANOVA procedure.

Because of the limitations of the system used to enable the PSI to be self-administered, the Palmar Sweat Index data in this study contained a high proportion of missing data (21%). In order to allow analysis, missing data points were estimated using a multiple regression approach on the basis of the other PSI measures (by the Genstat macro "MULTMISS"). The measures taken after the exam, which were only available for the exam group, were estimated separately on the basis of the pre-exam measures. This approach was necessary due to the higher rates of missing data in the exam group.

Due to the high rates of missing data, only the total number of active glands was used in the analysis, the alternative ratio measure producing even higher rates of missing data.

None of the PSI measures showed significant skew or kurtosis. No transformation was required to normalise the distribution of the PSI scores.

3 Results

3.1 Analysis of the PSI Data

3.1.1 The effects of the exam. The first analysis to be undertaken was a 2 x 2 x 5 MANOVA, with Group as a between-subjects factor and Task (pre vs post digit-symbol task measures) and Week as repeated-measures factors. The only significant effect to emerge from this analysis was a main effect of Task ($F(1,32)=6.13$, $p=.019$), measures taken after the digit symbol task being lower than those taken immediately before. Rather than a depression of sweating as a result of the task, this is probably best viewed as evidence that

adaptation was incomplete at the time of the first print. The possibility of a rebound effect similar to that seen in the last experiment also cannot be ruled out.

Because it was felt that the task might be increasing the error variance, rest and task PSIs were examined separately. Contrary to expectations, the analysis of the rest measures failed to reveal any significant effects. However the task data produced a borderline ($F(1,32)=3.91$, $p=.057$) main effect of Group. The exam group had higher scores after the task than did the control group (see figures 29 & 30). Thus, while measures of sweating at rest were not significantly affected by the exam, measures taken after the digit symbol task appear to have been more sensitive.

It was suspected that this effect might be secondary to differences in task performance. Inclusion of scores on the task as a covariate in the analysis of post-task PSIs produced only a relatively small reduction in the significance of the Group effect ($F(1,28)=3.55$, $p=.07$). Furthermore, the regression analysis carried out as part of the ANCOVA revealed that performance on the task was not significantly related to the level of sweat gland activity recorded after the task.

When scores on the digit-symbol task were analysed there was a Group by Week interaction (Approx. $F(4,26)=3.67$, $p=.017$) and a Week main effect (Approx. $F(4,26)=22.46$, $p<.001$) but no main effect of Group emerged. Analysis of simple main effects revealed that both groups showed changes in performance over the course of the experiment, see figure 31.

For the control group, performance improved significantly from the first week to the second ($t(56)=6.22$, $p<.001$) but performance on subsequent weeks did not differ significantly from the mean of preceding weeks.

Figure 29: Palmar Sweat Index:
Resting Measures

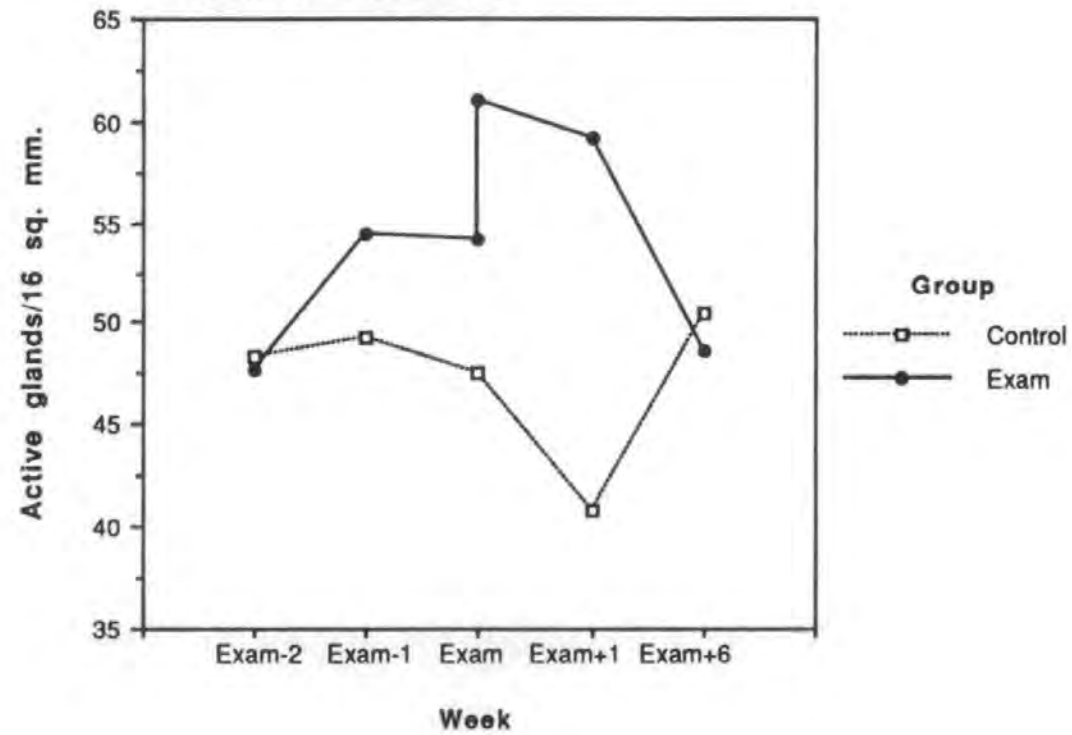


Figure 30: Palmar Sweat Index:
Post-task Measures

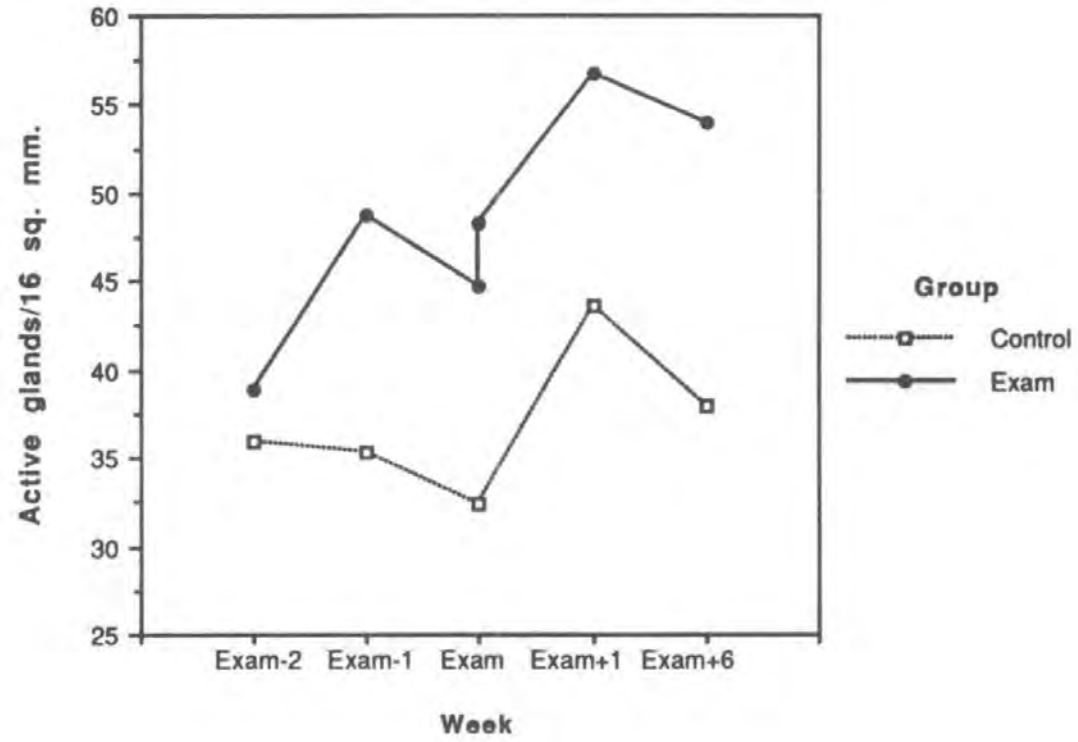
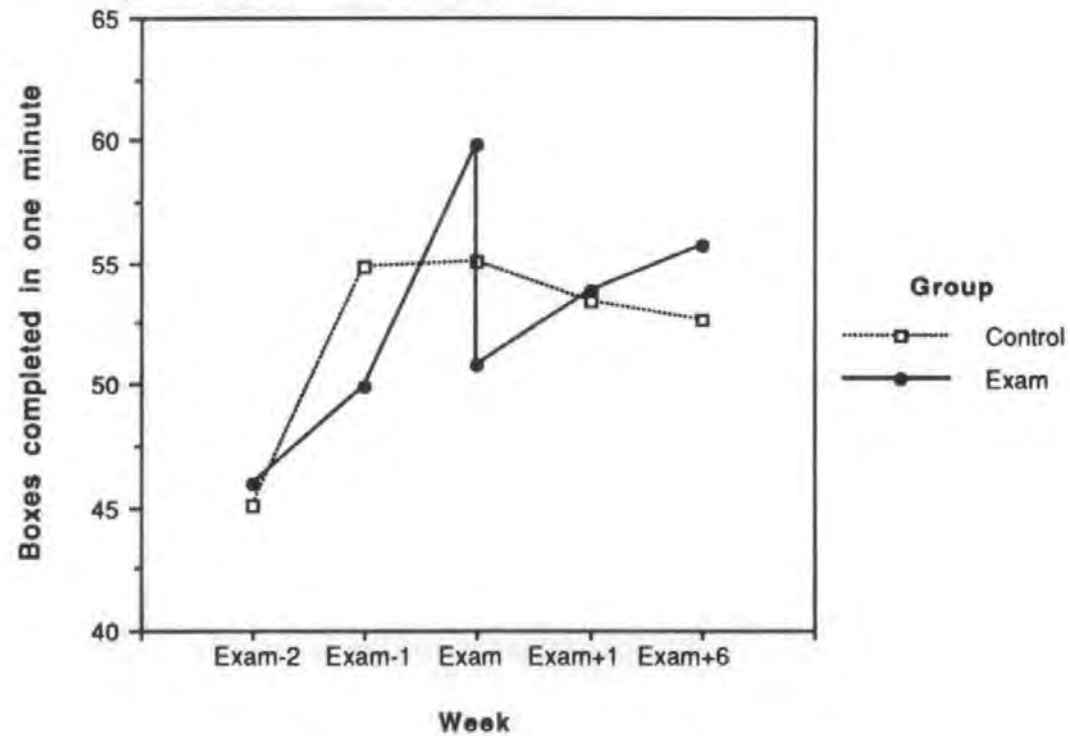


Figure 31: Group by Week interaction for digit-symbol task scores



For the exam group, on the contrary, performance on each subsequent week was significantly better than the mean of the preceding weeks, this effect only falling short of significance ($p=.067$) on the fourth session, one week after the exam, due to the higher scores obtained immediately before the exam. The exam group's better performance before the exam probably reflects the effects of arousal, it is harder to explain why they showed a continued gradual improvement rather than the larger initial improvement in performance shown by the control group.

The second investigation to be carried out compared the rest and task PSIs obtained immediately before the exam with those obtained immediately afterward (obviously for the exam group only). Despite the large decrease from pre- to post-exam apparent in the data (see figures 29 & 30) this effect failed to reach an acceptable level of significance ($F(1,16)=3.23$, $p=.091$). There were no significant effects involving the difference between rest and post-task PSIs.

The third measure was taken immediately before the exam. As this would be expected to be the point of greatest anxiety for the exam group it would be predicted that the difference between the groups would be greatest at this point. Examination of the data revealed that there was a fairly large difference between the mean scores of the two groups at the third measure, the exam group showing greater sweating. A further post-hoc ANOVA was performed on the measures from this point alone. This analysis failed to reveal any significant effects other than the decrease from before to after the digit-symbol task found in the first analysis ($F(1,32)=7.73$, $p=.009$). The amount of unexplained variance present in the data appears to be masking any effects of the exam.

3.1.2 Investigation of possible procedures for improving the sensitivity of the PSI. A number of analyses were then carried out in order to investigate whether, for future reference, any procedure could be used to reduce the amount of unexplained variance. These analyses focussed on two possible sources of variance which might mask the effects of the exam. The first analyses examined various means of removing the statistical effects of individual differences in baseline sweat gland activity. Following this, ANCOVA was used to examine whether controlling for changes in external temperature over the days of the study might reduce error variance. None of the approaches examined appeared to have promise as a means of increasing the sensitivity of the PSI to the effects of the exam.

The first approach to be investigated was the use of difference scores using the first measure (two weeks before the exam) as a baseline. There were no significant differences between the groups at this point. For each subject PSI scores obtained on the first week were subtracted from scores obtained on each of the succeeding weeks. This was done separately for resting and post-task measures. When these change scores were analysed, there were no significant effects, either when rest and post-task scores were analysed together, or for the two measures analysed separately. Predictably, rest and task measures did not differ when change scores were used.

A further attempt to control for individual differences in baseline was made. This analysis used analysis of covariance on rest and task scores separately, using scores two weeks before the exam as a covariate. Although the regression analyses for the covariates were significant (Resting measures $F(1,31)=10.78$, $p=.003$; Task measures $F(1,31)=13.15$, $p=.001$) the results of this analysis did not differ essentially from the earlier analyses: Rest PSIs appeared unaffected

by the manipulation, whereas post-task PSIs revealed only a weak ($F(1,31)=3.17$, $p=.085$) main effect of Group.

The effects of extraneous variables on sweating were then examined. Neither wet bulb temperatures nor dry bulb temperatures on each of the days of the study gave a significant regression on either of the two PSI measures when used as covariates. Only the analysis with wet bulb temperatures as covariates produced the borderline Group effect for post-task measures found in earlier analyses ($F(1,29)=3.78$, $p=.062$).

3.1.3 Examination of estimated data. In order to rule out the possibility of distortion by the procedure used to estimate missing values, the mean values of each of the PSI measures was compared before and after inclusion of the estimated values. None of the means had been changed significantly by the inclusion of the estimated values.

When individual estimated values were examined, seven were found to be extreme values, lying more than 1.96 standard deviations from the original mean value for the variable in question. Given the high rates of missing data in this study (81 estimated values) the number of extreme values observed is only slightly greater than might be expected by chance. These seven values appeared to be equally distributed across groups, four in the exam group, with two for one subject, and three in the control group. The extreme values also appeared to be equally distributed across times, three resting measures and four post-task measures had extreme estimates. The distribution of extreme estimates across sessions was as follows; week one-two task measures, week two-two resting and one task measure, week three-no extreme values, week four-one resting and one task measure, week five-no extreme values.

The analyses were repeated with the subjects who had extreme estimated values excluded. No significant effects involving the differences between the two groups emerged. The estimation procedure does not appear to have masked the effect of the exam. The results imply that the estimation procedure may even have exaggerated the difference between the groups. Although the analyses excluding estimated values had smaller sample sizes than the main analysis, and were, therefore, less powerful.

3.2 Analysis of Subjective Measures

Initially the two trait scales, as well as scores on all the state measures from the first session (two weeks before the exam), were analysed using t-tests to examine whether any baseline differences existed between the groups. Only one such difference was found, the exam group scored significantly lower on the Social Desirability Scale than the control group ($t(32)=3.00$, $p=.005$. Mean values, exam group 9.8, control group 14.8). Given the number of comparisons performed, this may represent a type one error.

All of the questionnaire measures included in the study were analysed using 2 x 5 ANOVAS (with Group as a between-subjects variable and Week of measurement as a repeated-measures factor). In addition, for the exam group only, the measures taken immediately before and immediately after the exam were compared.

Almost every scale revealed a significant main effect of Week. Only the GHQ Severe Depression and POMS Anger-Hostility scales did not produce effects of at least borderline significance. In addition, the vast majority of scales revealed significant interactions between Group and Week.

Table 29: Analysis of Self-Report Measures

Scale	Time main effect			Group by Time interaction			Group main effect		
	approx. F	df	p	approx. F	df	p	F	df	p
STAI									
State anxiety	10.70	4,27	<.001	9.50	4,27	<.001	<1	1,30	>.1
GHQ									
Anxiety and Insomnia	4.28	4,27	.008	5.20	4,27	.003	<1	1,30	>.1
Somatic Symptoms	2.80	4,27	.046	<1	4,27	>.1	<1	1,30	>.1
Social Dysfunction	4.57	4,27	.006	2.44	4,27	.071	1.70	1,30	>.1
POMS									
Tension-Anxiety	7.22	4,25	.001	6.76	4,25	.001	4.24	1,28	.049
Depression-Dejection	2.54	4,25	.065	3.48	4,25	.022	1.62	1,28	>.1
Vigour	3.78	4,26	.015	3.79	4,26	.015	<1	1,29	>.1
Fatigue	5.01	4,26	.004	<1	4,26	>.1	<1	1,29	>.1
Confusion-Bewilderment	8.82	4,26	<.001	8.70	4,26	<.001	2.03	1,29	>.1

Scales which revealed significant, or nearly significant, differences between the groups with regard to their profiles of subjective disturbance were; STAI state anxiety, GHQ Anxiety and Insomnia and Social Dysfunction scales, POMS Tension-Anxiety, Depression-Dejection, Vigour and Confusion-Bewilderment scales. Only the GHQ Somatic Symptoms and Severe Depression scales and the POMS Anger-Hostility and Fatigue scales did not produce significant Group by Week interactions. The POMS Tension-Anxiety scale also revealed a significant main effect of Group, the exam group tending to have higher scores at all times. Statistics for these analyses are presented in table 29. The Group by Week interactions are displayed in figures 32 to 38

Simple main effects for the interactions were examined and revealed similar patterns for all the scales. Only GHQ Anxiety and Insomnia scores varied over the course of the experiment within the control group, being lower six weeks after the exam than on the other sessions. All other scales did not vary significantly over time within the control group. The exam group, in contrast, reported increased disturbance in the week of the exam (defined as higher scores on every scale except POMS Vigour, POMS Vigour responding in the opposite direction to the other scales), with scores on the week after the exam dropping below the mean of the preceding weeks (all effects $p < .05$, except for GHQ Anxiety and Insomnia scale, pre-exam measure vs preceding measures $p = .079$). For STAI state anxiety and POMS Tension-Anxiety and Vigour scores, subjects in the exam group also reported less disturbance six weeks after the exam than in earlier weeks (all $p < .05$, similar trends for POMS Depression-Dejection and Confusion:-Bewilderment scores fell short of significance, $p = .077$ and $.082$ respectively).

Figure 32: Group by Week interaction for state anxiety

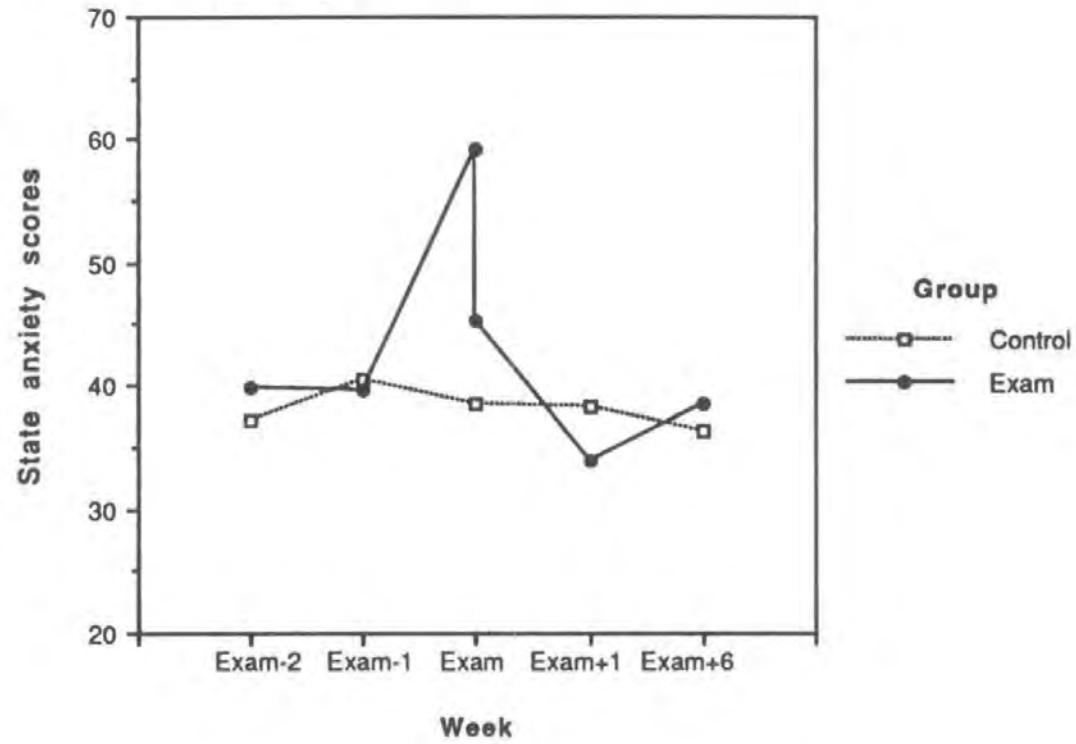


Figure 33: Group by Week interaction for GHQ Anxiety and insomnia scale

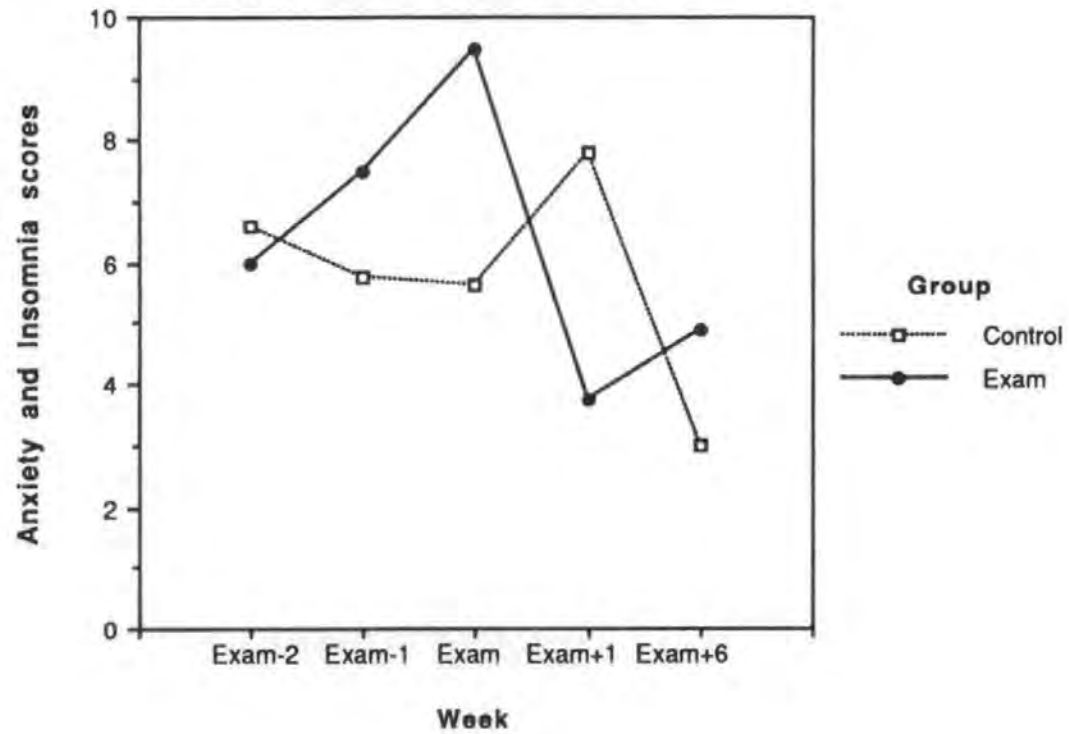


Figure 34: Group by Week interaction for GHQ Social Dysfunction scale

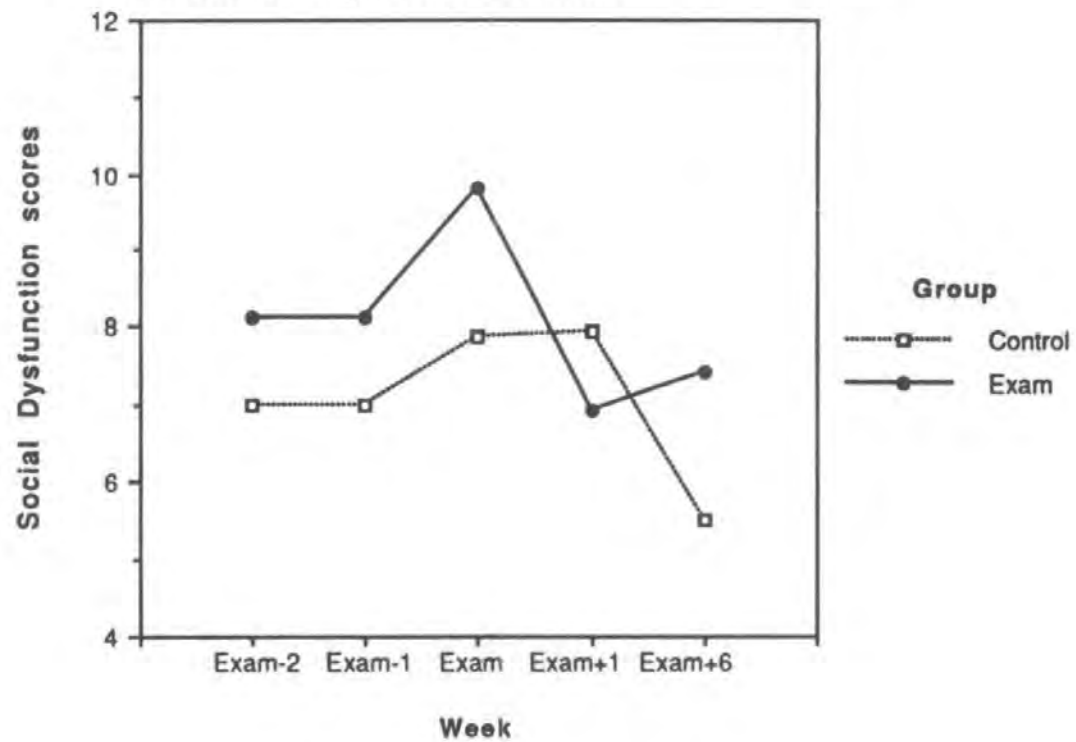


Figure 35: Group by week interaction for POMS Tension-Anxiety scale

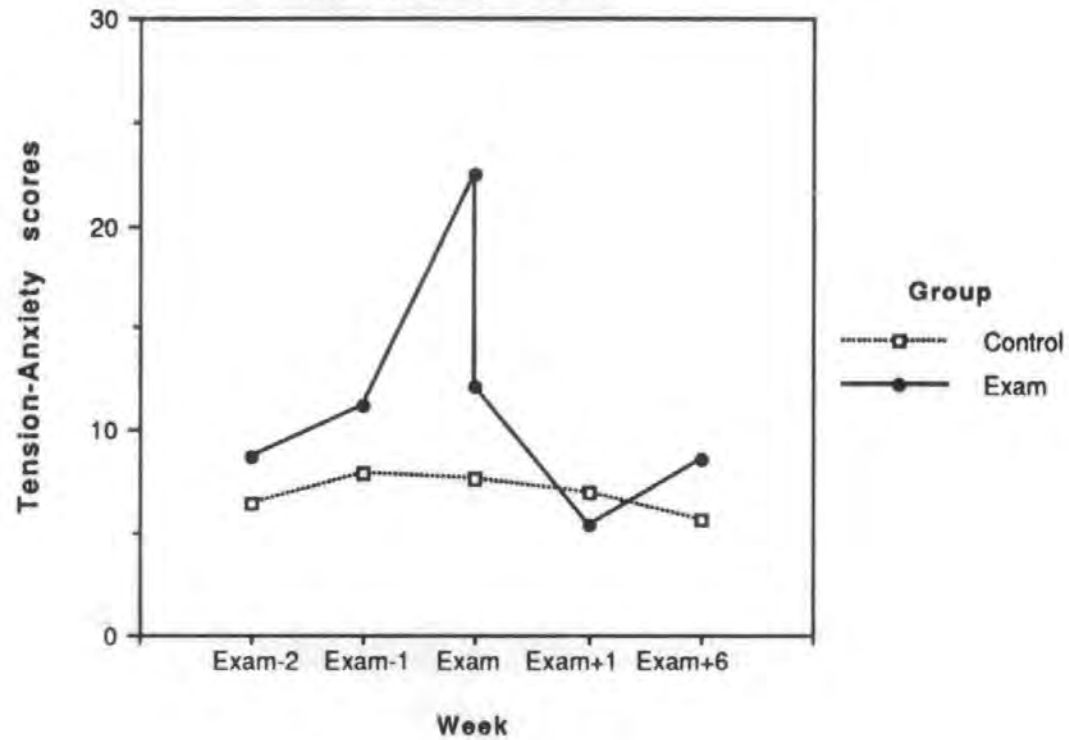


Figure 36: Group by Week interaction for POMS Depression-Dejection scores

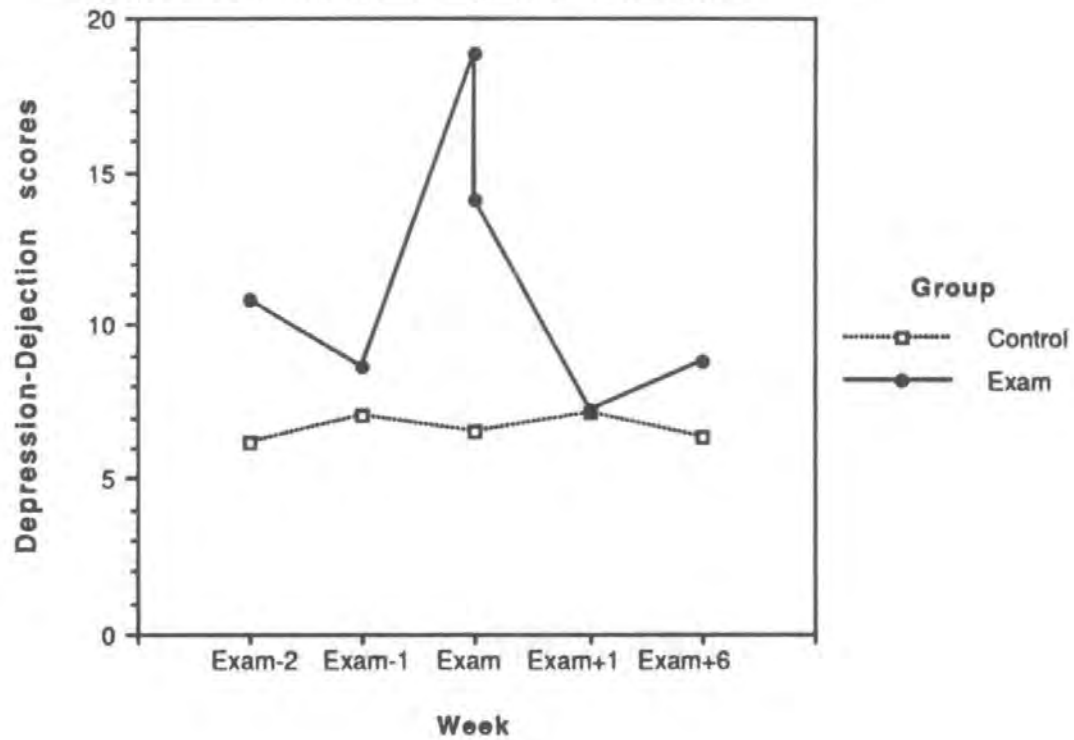


Figure 37: Group by Week interaction for POMS Vigour scores

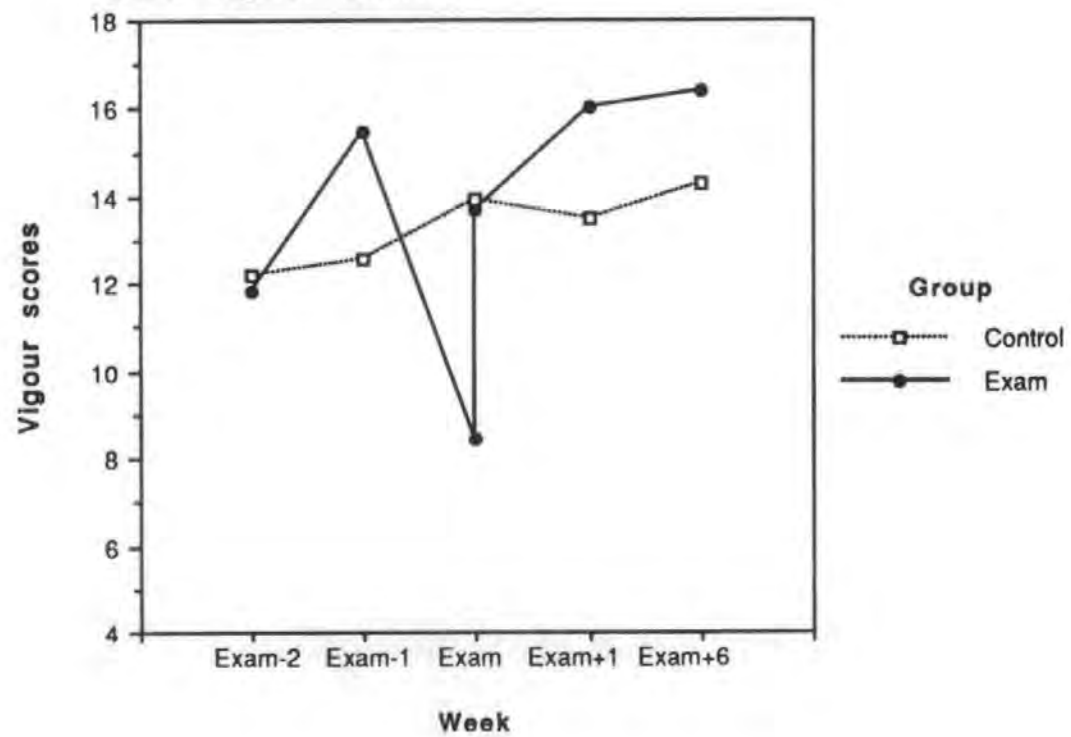
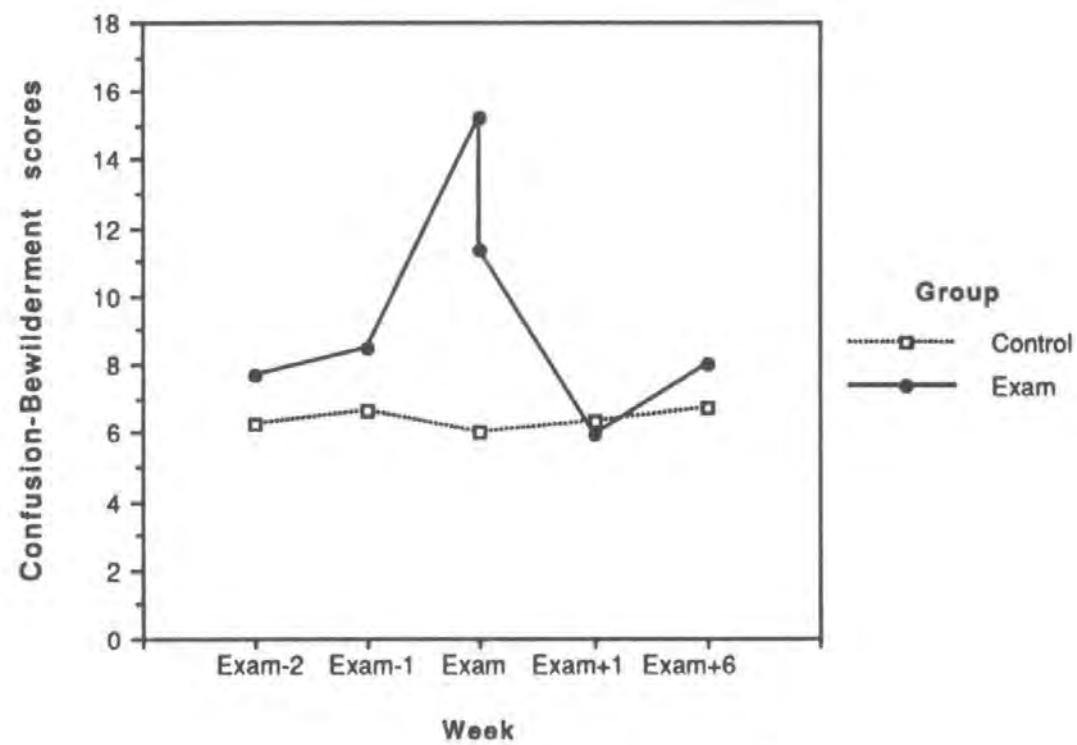


Figure 38: Group by Week interaction for POMS Confusion-Bewilderment scores



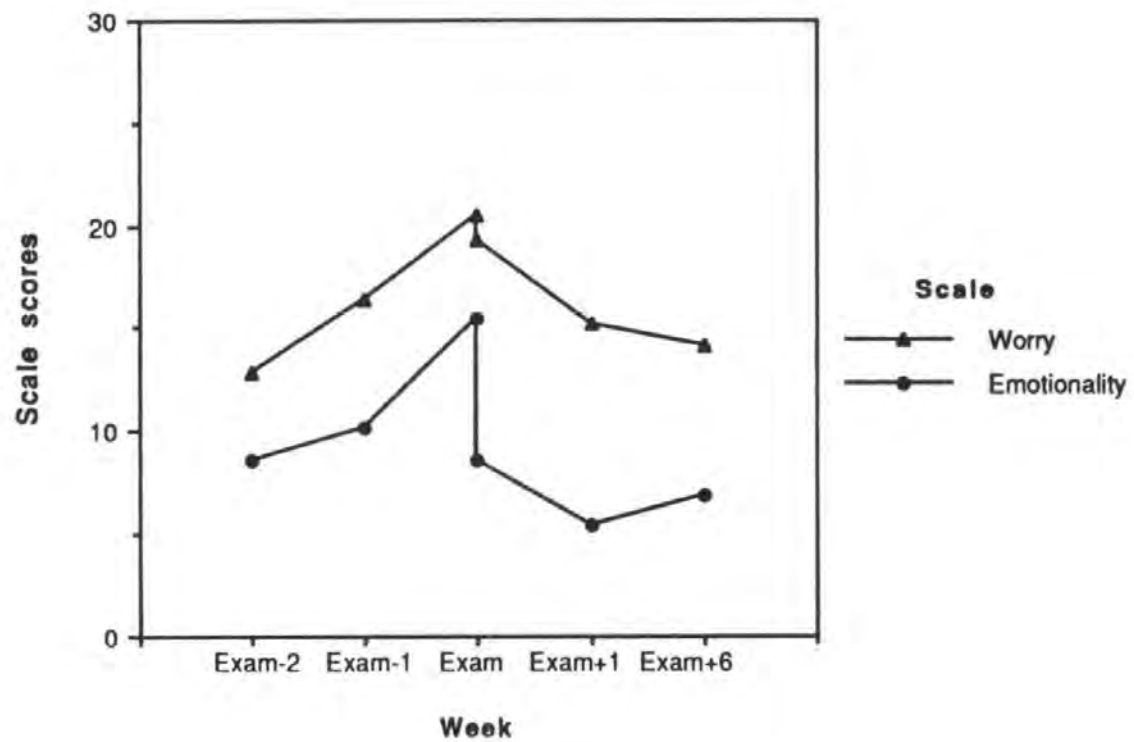
When measures taken immediately after the exam, for the exam group only, were compared with those taken immediately before it was found that state anxiety ($F(1,16)=12.54$, $p=.003$), POMS Tension-Anxiety ($F(1,16)=13.89$, $p=.002$) and POMS Confusion-Bewilderment ($F(1,16)=7.15$, $p=.017$) were all lower immediately after the exam than immediately before (see figures 32, 35 and 38). As in the analysis above, POMS vigour showed the opposite pattern ($F(1,16)=6.40$, $p=.022$), being higher after the exam than before (see figure 37).

Thus, the analysis revealed that the majority of the self-report measures were sensitive to the increased anxiety and other psychological effects of the exam. This is in contrast to the PSI, which showed very little response to the stress of the examination. The results imply that the manipulation was effective, the exam was a stressful experience, even if this stress was not reflected in significant changes in palmar sweating.

All of the measures which differentiated the groups appeared to show a maximal response at the time of the exam. Even the GHQ scales, which might be expected to tap symptoms which might not appear until some time after a stressful event, clearly peaked in the week of the exam.

One other self-report scale was included which is not covered above. This is the Worry and Emotionality Scale, which, because it taps feelings about a specific exam, was only given to the exam group. The usual finding with this scale is that Worry is elevated some time before the exam and remains elevated after the exam, whereas Emotionality peaks much more sharply and returns to normal soon after the exam.

Figure 39: Worry and Emotionality scores



Both scales varied significantly over the course of the experiment (Worry approx. $F(4,11)=15.37$, $p<.001$; Emotionality approx. $F(4,11)=14.59$, $p<.001$). Contrasts revealed that both measures increased consistently from two weeks before the exam to the measure taken immediately before the exam (week 2 vs week 1, Worry $t(56)=2.70$, $p=.017$; Emotionality $t(56)=2.38$, $p=.032$. Pre-exam vs weeks 1 & 2, Worry $t(56)=5.74$, $p<.001$; Emotionality $t(56)=4.31$, $p=.001$). Emotionality had returned to a point below the mean of the preceding weeks by one week after the exam ($t(56)=7.61$, $p<.001$). Both measures were below the mean of the preceding sessions six weeks after the exam (Worry $t(56)=2.35$, $p=.034$; Emotionality $t(56)=3.18$, $p=.007$). Worry and Emotionality scores are displayed in figure 39. Separate analyses revealed that Worry levels immediately after the exam did not differ from those immediately before, whereas Emotionality declined significantly from before to after the exam ($F(1,16)=12.18$, $p=.003$).

Both measures showed a peak at the time of the exam. As predicted, Emotionality declined faster after the exam than Worry. There is less evidence for a more gradual increase in Worry before the exam.

3.3 The Relationship Between Different Measures

3.3.1 Self-reported "stress" and the PSI. A number of analyses were carried out in order to examine the pattern of relationships between different variables. Firstly, the PSI data were analysed in order to determine whether there were any significant differences in palmar sweating between subjects in the exam group who reported differing levels of stress or anxiety.

The first measure to be examined was state anxiety. The exam group was split into two groups of eight subjects scoring above or

below the median of 58 on the STAI state anxiety scale administered immediately before the exam. These groups were compared on all the PSI measures, and a separate analysis was carried out on just the measures obtained immediately before the exam. For the analysis of the complete set of PSI data only one effect even approached significance, this was an interaction between high vs low anxiety scores and the difference between resting and post-task PSIs ($F(1,14)=3.84$, $p=.070$). Examination of mean scores indicated that only the group reporting lower levels of anxiety showed a large decrease from pre- to post-task (from 52 to 43 glands/16 sq. mm.), the group reporting higher levels of anxiety showed a much smaller decrease over the task (from 56 to 54 glands/16 sq. mm.). Once more, this seems to justify the inclusion of the digit-symbol task, but as this interaction only reached a significance level of .07 and there were no significant main effects of anxiety level or task no firm conclusions can be drawn. The analysis of the pre-exam measures alone also failed to reveal any significant main effects, although there were effects of borderline significance for both anxiety level ($F(1,14)=3.41$, $p=.086$) and rest vs task measures ($F(1,14)=3.78$, $p=.072$). High-anxiety subjects tended to have higher PSIs and scores tended to be lower after the digit-symbol task than before.

These analyses were repeated using the total score on the GHQ as an index of stress. The exam group again being divided into two groups of 8 subjects on the basis of a median split on the scores obtained immediately before the exam (median score=10). As with state anxiety, the complete analysis revealed a borderline Stress x Task interaction ($F(1,14)=3.94$, $p=.067$). This interaction also reflects a larger decrease for the group reporting fewer symptoms, the "high stress" group actually having slightly higher PSI scores after the task ("Low

stress" group changed from 60 pre-task to 49 post-task, "High stress" from 46 to 48 glands/16 sq. mm.). For the analysis of pre-exam measures, there was only a significant main effect of Task ($F(1,14)=6.59, p=.022$), scores being lower after the task.

While the results of these two analyses are indicative of a relationship between psychological and physiological responses to an exam, they imply that such a relationship is relatively weak and are far from conclusive.

3.3.2 Correlations between the PSI and other measures.

Correlations were computed between raw scores for all the variables measured immediately before the exam (see table 30). In addition, change scores were computed using the measure two weeks before as a baseline and correlations were also calculated between these change scores (see table 31).

Correlations were examined both for all subjects together and for each group separately. It was expected that correlations computed for the complete sample would be elevated due to the gross effects of the exam. While a failure to find such correlations between the PSI and self-report measures of anxiety would cast serious doubt on the validity of the PSI as an index of anxiety, such correlations are of limited practical significance. Of more interest would be significant correlations between measures within the exam group (physiological measures are generally not found to correlate with self report indices of anxiety in the absence of anxiety-provoking stimuli).

In the overall analysis of raw scores, only the post-task PSIs were found to correlate significantly with questionnaire measures. Post-task PSIs correlated positively with state anxiety and with POMS Tension-Anxiety, Anger-Hostility and Depression-Dejection scales.

Table 30: Correlations between pre-exam measures, both groups combined

	Resting PSI	Post-task PSI
State anxiety	.147	.395*
GHQ		
Somatic Symptoms	.063	.093
Anxiety & Insomnia	-.130	.027
Social Dysfunction	-.027	.044
Severe Depression	-.030	.244
POMS		
Tension-Anxiety	.164	.441*
Depression-Dejection	.148	.551**
Anger-Hostility	.279	.494*
Vigour	-.029	.046
Fatigue	.131	.282
Confusion-Bewilderment	.184	.373

* $p < .05$, two tailed

** $p < .01$, two tailed

NB due to missing data not all correlations are calculated on the same number of subjects.

Table 31: Correlations between change scores,
baseline to pre-exam, both groups combined

	Resting PSI	Post-task PSI
State anxiety	.451*	.103
GHQ		
Somatic Symptoms	.057	.554*
Anxiety & Insomnia	.235	-.384
Social Dysfunction	.253	-.231
Severe Depression	.395*	.011
PDMS		
Tension-Anxiety	.542**	.038
Depression-Dejection	.366	.122
Anger-Hostility	.398	-.447
Vigour	.002	.213
Fatigue	.280	.013
Confusion-Bewilderment	.436*	-.210

* $p < .05$, two-tailed

** $p < .01$, two-tailed

NB due to missing data not all correlations are calculated on the same number of subjects.

When change scores were considered, resting PSIs bore a stronger relationship to questionnaire measures. The change in resting PSI from two weeks before the exam to immediately pre-exam correlated to a moderate degree (about .4) with the change in state anxiety, GHQ Severe depression and POMS Tension-anxiety and Confusion-bewilderment scales. Change scores for post-task PSIs only correlated significantly with the change in the GHQ Somatic symptoms scale.

Thus, when both groups are considered together, the PSI does correlate significantly with differences in several questionnaire measures. Task measures appear to relate best to raw scores, implying that these measures give a better index of current mood than resting measures and may be less sensitive to individual differences in baseline. However, when change scores are used, rest measures appear to relate more strongly to self reported mood, implying that resting measures may be sensitive to longitudinal changes in mood when baseline differences are controlled for.

When within-group correlations are considered, the pattern in the exam group seems roughly similar (see tables 32 & 33). Raw PSI post-task scores correlated significantly with state anxiety, Emotionality and with POMS Tension-Anxiety, Depression-Dejection and Confusion-Bewilderment scales. When change scores were used rest scores correlated significantly only with GHQ Somatic Symptoms scores.

Change scores for post-task measures could only be calculated for four subjects. The correlations involving post-task PSIs are probably meaningless.

While physiological measures were not expected to relate to questionnaire measures within the control group, some significant relationships did emerge (see table 34).

Table 32: Correlations between pre-exam measures, exam group only

	Resting PSI	Post-task PSI
State anxiety	.207	.680*
WES		
Emotionality	.134	.693*
Worry	.078	.432
GHQ		
Somatic Symptoms	-.004	.160
Anxiety & Insomnia	-.435	-.093
Social Dysfunction	-.052	.135
Severe Depression	-.041	.465
POMS		
Tension-Anxiety	.107	.664*
Depression-Dejection	.179	.698*
Anger-Hostility	.349	.534
Vigour	-.241	.437
Fatigue	.258	.295
Confusion-Bewilderment	.163	.601*

* $p < .05$, two tailed

NB due to missing data not all correlations are calculated on the same number of subjects.

Table 33: Correlations between change scores,
baseline to pre-exam, exam group only

	Resting PSI	Post-task PSI
State anxiety	.381	.454
WES		
Emotionality	.011	.345
Worry	-.004	-.603
GHQ		
Somatic Symptoms	.583*	-.313
Anxiety & Insomnia	.112	-.233
Social Dysfunction	.217	.418
Severe Depression	.337	-.130
POMS		
Tension-Anxiety	.520	.358
Depression-Dejection	.218	-.122
Anger-Hostility	.319	-.934
Vigour	.135	.799
Fatigue	.235	-.797
Confusion-Bewilderment	.333	-.395

* $p < .05$, two-tailed

NB due to missing data not all correlations are calculated on the same number of subjects. Change scores for post-task PSIs were available for only four subjects.

Table 34: Correlations between change scores,
baseline to pre-exam, control group only

	Resting PSI	Post-task PSI
State anxiety	.256	.292
GHQ		
Somatic Symptoms	-.241	.657*
Anxiety & Insomnia	.020	-.212
Social Dysfunction	.248	-.230
Severe Depression	.622*	.066
POMS		
Tension-Anxiety	.280	.253
Depression-Dejection	.521	.304
Anger-Hostility	.560	-.099
Vigour	.151	-.172
Fatigue	.246	.272
Confusion-Bewilderment	.195	.165

* $p < .05$, two-tailed

NB due to missing data not all correlations are calculated on the same number of subjects.

None of the correlations involving raw scores achieved significance. However, there were significant correlations between change scores (see table 34). Change scores for resting measures correlated significantly with GHQ Severe Depression scores, whereas the change in post-task PSIs correlated only with GHQ Somatic Symptoms scores.

Within-subject correlations were also calculated between resting and post-task PSIs and State anxiety and GHQ total scores. The means of these correlations did not differ significantly from zero. Resting and post-task PSIs tended to correlate weakly (mean correlation = .23, mean value differs significantly from zero, $t_{(31)}=2.41$, $p<.05$).

3.3.3 Regression analyses. The next set of analyses to be carried out were a series of multiple regression analyses. These examined the relationship between various other variables and the PSI. Separately for measures from two weeks before the exam and for measures taken immediately before the exam, Trait Anxiety, Marlowe-Crowne scores, Sex, Group, wet and dry bulb temperatures and State Anxiety were entered into a stepwise regression procedure to determine whether resting PSIs were predicted by any of the variables. A similar analysis was carried out for post-task PSIs with resting PSIs and performance on the digit-symbol task included as possible predictors. The conclusions for measures from both time periods were essentially identical.

No variables gave significant prediction of resting PSIs. The only variable which significantly predicted post-task PSIs was the level of sweating prior to the task which accounted for 44% of the variance at the first session and 31% of the variance prior to the exam.

The second, and final, series of regression analyses were carried out using total scores on the GHQ as a dependent variable. These analyses attempted to determine the temporal relationship between physiological reactivity, state anxiety and stress-related symptoms. Work on life events implies that such symptoms as the GHQ attempts to measure may occur several weeks or even months after a stressful event. It was hypothesised that elevations in either physiological reactivity or state anxiety may serve as mediating variables between the stressful event and the later development of symptoms. Obviously, this hypothesis depends upon the validity of the GHQ as a measure of such symptoms. In view of the significant correlations between the GHQ and other measures claiming to tap current mood this validity is open to question. For example, 20 out of 24 correlation coefficients between pre-exam GHQ scores and pre-exam POMS scores are significant, with a mean correlation of .51, excluding the POMS Vigour scale, which correlates negatively with the GHQ scales.

In these analyses Group, Sex, Trait Anxiety, Marlowe-Crowne scores, both PSI measures and State Anxiety were entered into a stepwise multiple regression with GHQ scores as the dependent variable. Initially, this analysis was carried out using measures from either the first session (two weeks prior to the exam) or the session immediately before the exam. In both analyses State Anxiety was entered first, accounting for 51% of the variance in GHQ scores in the first session and 48% of the variance prior to the exam. No other variable predicted GHQ scores in the first week. Prior to the exam there was also a significant effect of Group, adding a further 6% to the total variance explained. Thus, it seems that the GHQ is highly related to current state anxiety. While high levels of state anxiety would be expected to lead to elevated levels of symptomatology, a

simpler explanation is that the scales may overlap to a large extent, and may just be measuring the same construct.

A second set of analyses were carried out using GHQ total scores from the last four sessions as dependent variables and with Trait Anxiety, Marlowe-Crowne scores, Group and State Anxiety and PSI scores from all the preceding weeks as predictors. It was hoped that this analysis would allow the temporal pattern of the relationship between the measures to be examined.

For measures one week before and immediately prior to the exam, as well as measures one week after the exam, current State Anxiety was the strongest predictor, accounting for 38%, 47% and 55% of the variance respectively. For measures taken a week after the exam, State Anxiety was the only predictor. For measures a week before the exam, State Anxiety in the preceding week also added to the prediction of GHQ total scores, adding 10% to the variance explained. However, in the analysis of GHQ scores obtained immediately prior to the exam resting PSI scores from the first week also correlated significantly with self-report psychopathology scores, the relationship, unexpectedly, being negative ($r = -.34$). Inclusion of resting PSIs from week one in the regression equation increased the proportion of the variance explained to 55%.

When scores from the last session, six weeks after the exam, were considered. State Anxiety scores on the day of the exam were the strongest predictor, although the effect was relatively weak, accounting for only 16% of the variance in GHQ scores. Once more, there was a significant negative relationship with resting PSI scores. When resting levels of sweat gland activity one week before the exam were entered into the equation, the proportion of the variance explained increased to 27%. While the total amount of variance

explained is very small, the fact that the relationship is significant over a gap of seven weeks is quite surprising. Of particular interest is the different temporal relationship for state anxiety and the PSI. It seems that self-report psychopathology is most strongly related to current state anxiety. Where a relationship appears between the PSI and GHQ scores, however, it is with levels of physiological activity some weeks before the occurrence of the symptoms reported.

Examination of the correlations between the GHQ subscales and the PSI and state anxiety reveals that this effect is largely due to the somatic symptoms subscale. In general, state anxiety correlates significantly with most of the GHQ scales and these correlations are comparable over all lags i.e. state anxiety tends to correlate significantly both with current GHQ scores and with GHQ scores up to eight weeks later. To some extent, this probably represents the effects of consistent response bias. The strongest relationships are with the Anxiety and Insomnia scale (12 out of 15 correlations significant) and with the Severe Depression scale (14 out of 15 correlations significant). The relationships between state anxiety and the Social Dysfunction and Somatic Symptoms scales appear weaker (4 and 5 significant correlations, respectively).

PSI scores, in contrast, tend not to correlate with GHQ scales. There are only three significant correlations between the other GHQ subscales and PSI scores. Which, given the ninety possible correlations, is slightly less than the number which would be expected by chance. All of these correlations are positive, and all involve measures taken in the same week, the week prior to the exam.

Figure 40: Correlations between GHQ Somatic symptoms scores from last session and other measures

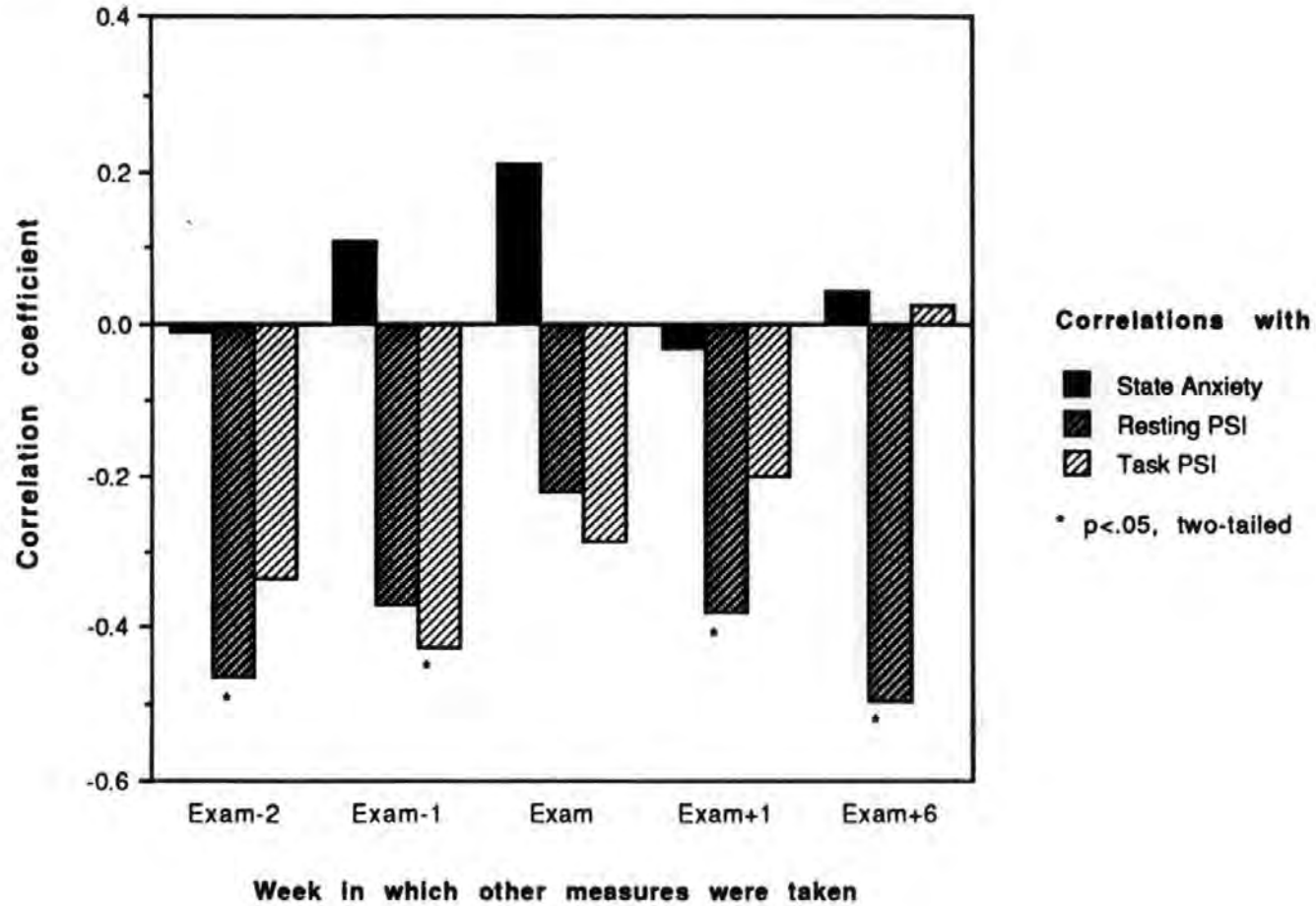


Figure 41: Correlations between GHQ Somatic symptoms scores from session one week after exam and other measures

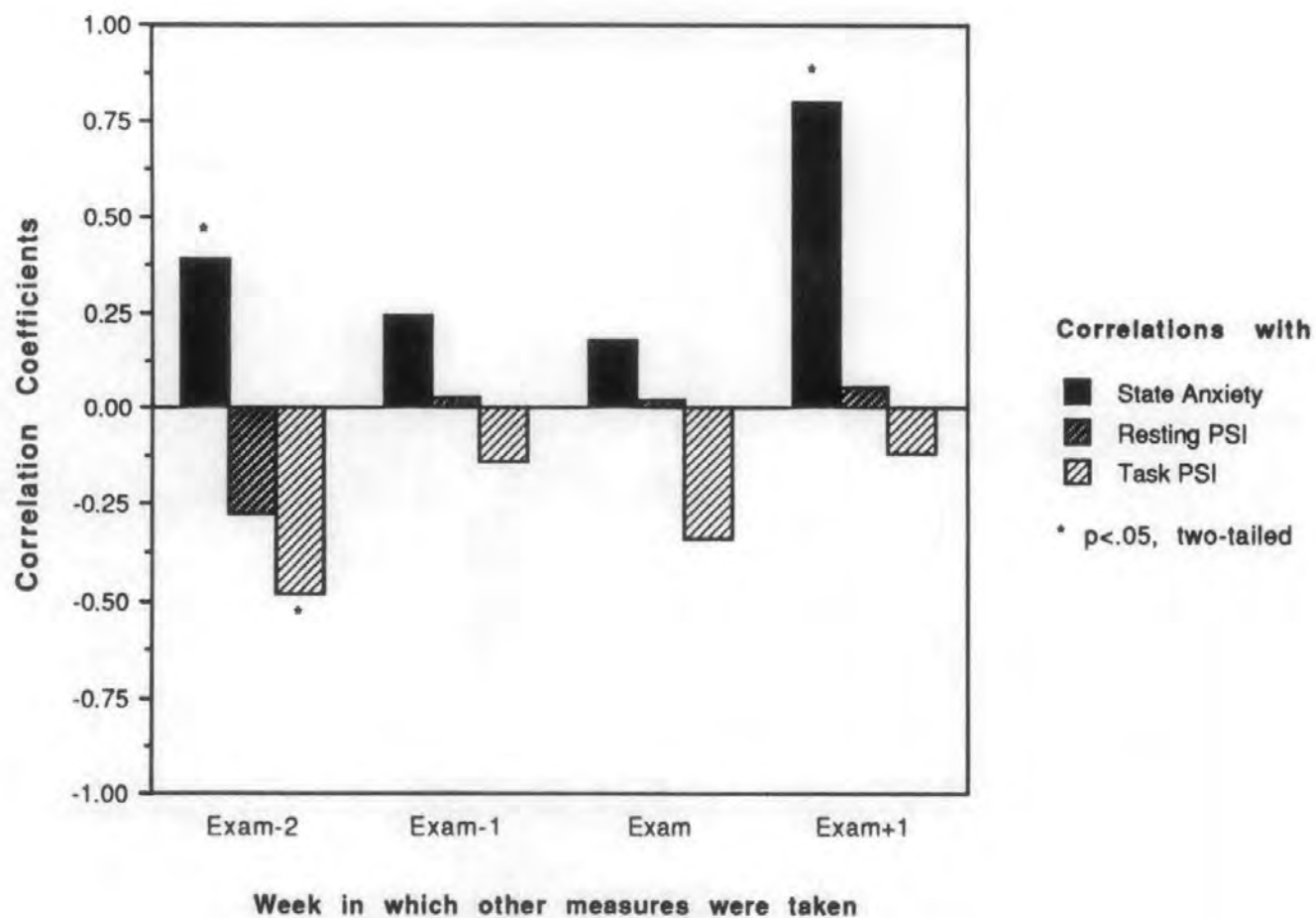


Figure 42: Correlations between GHQ Somatic symptom scores before the exam and other measures

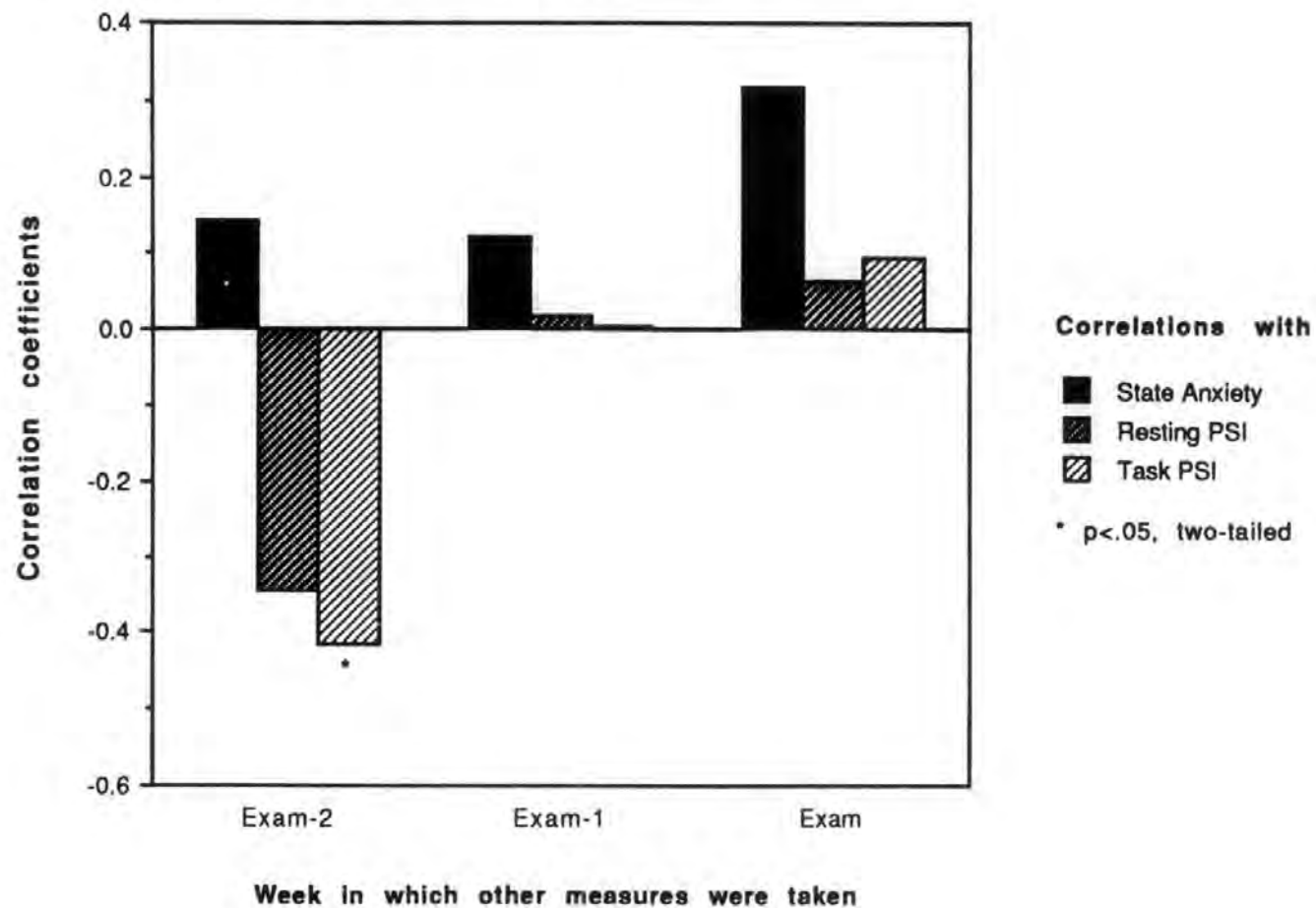


Figure 43: Correlations between GHQ Somatic symptom scores one week before the exam and other measures

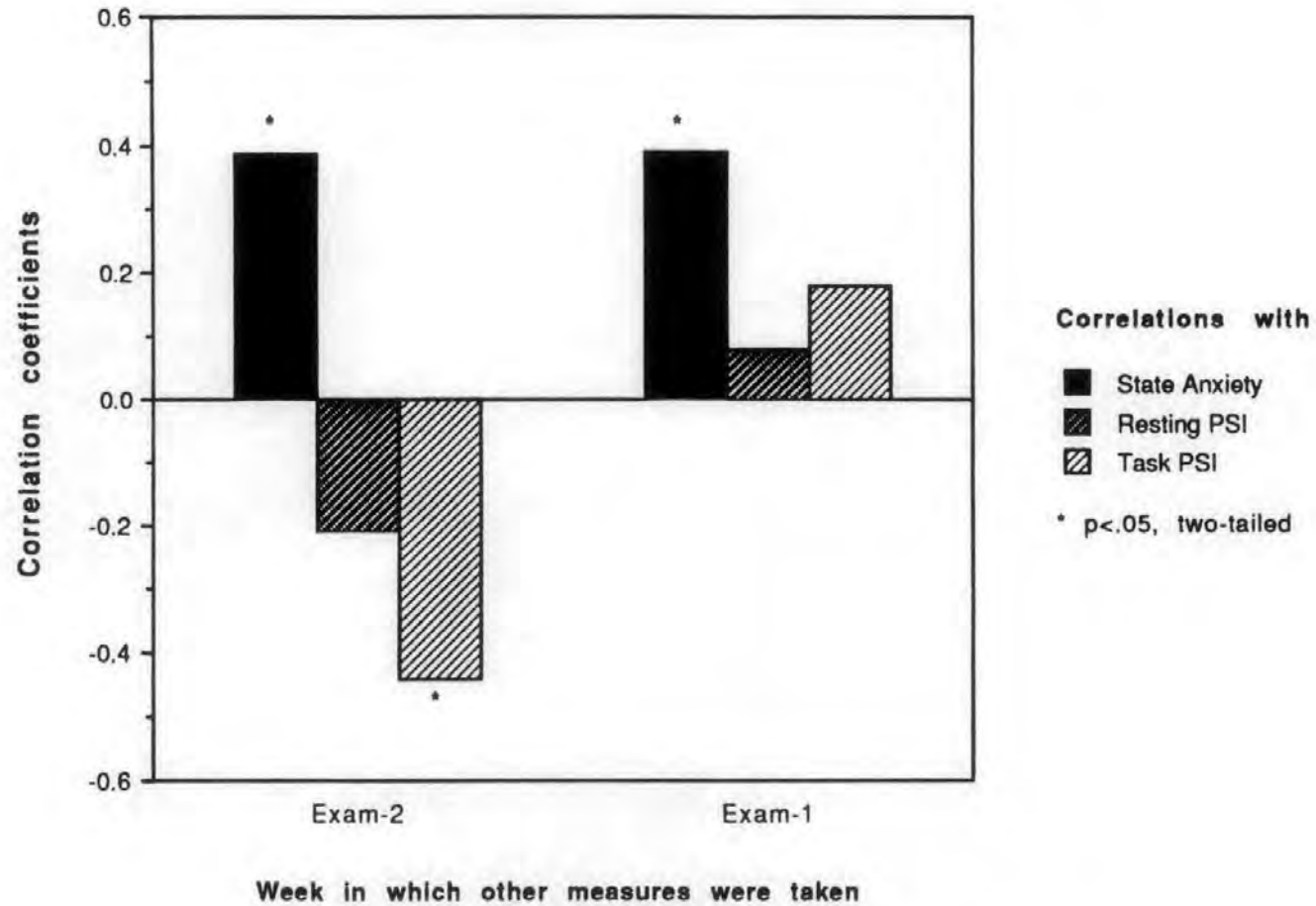
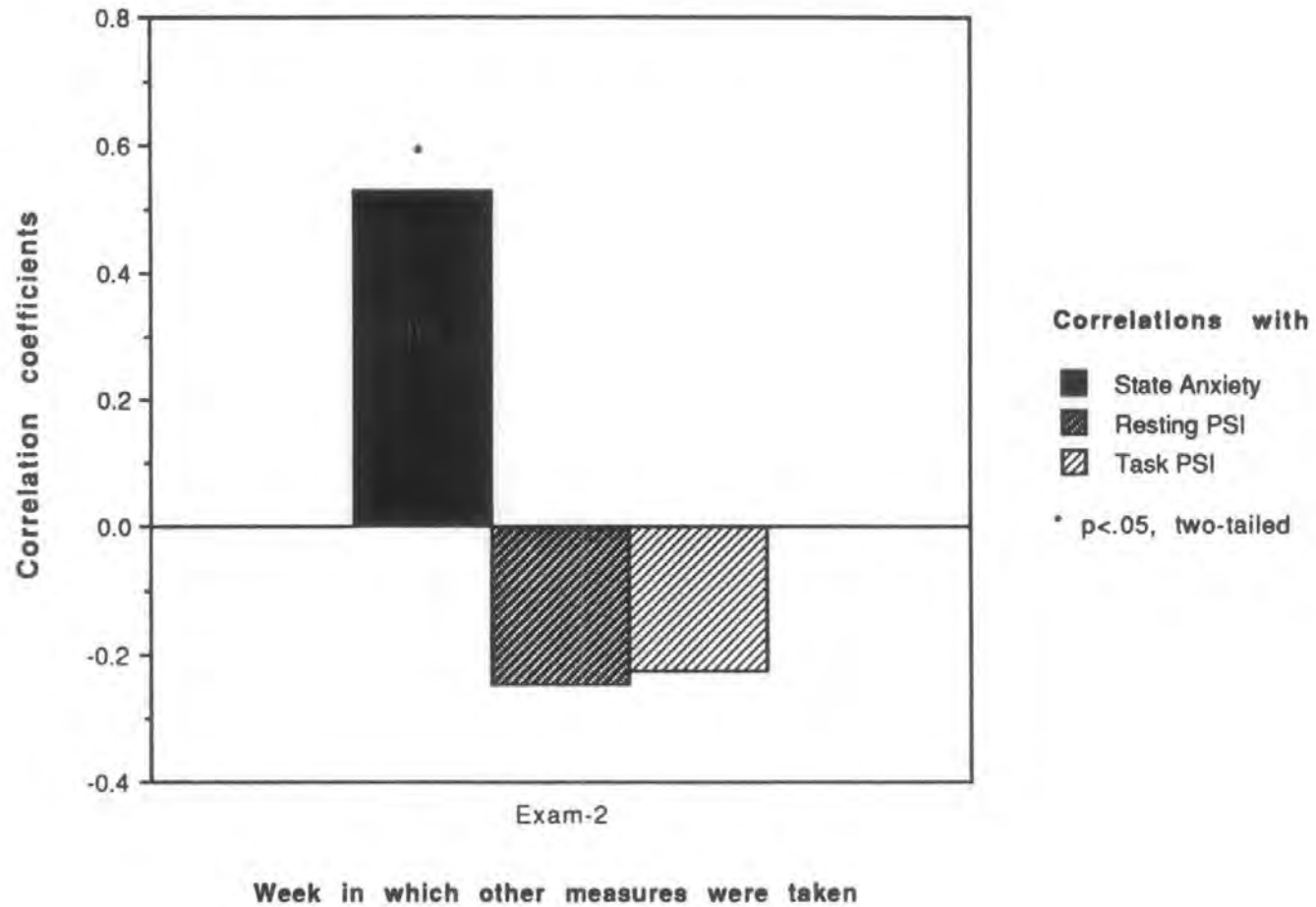


Figure 44: Correlations between GHQ Somatic symptom scores in the first week and other measures



However, scores on the Somatic Symptoms scale appear to correlate negatively with current and previous PSIs. Post-task PSIs obtained during the first week show significant negative correlations with GHQ somatic symptoms scores on each of the three succeeding weeks. In addition, Somatic symptom scores on the last week correlate significantly, and negatively, with three out of five resting PSIs and one of the post-task PSIs. Correlations involving the somatic symptoms scale are illustrated in figures 40 to 44.

While the relationship between state anxiety and somatic symptoms may be of little theoretical interest, the relationship between palmar sweating and self-reported somatic symptoms bears further examination. It is possible that this relationship may be artifactual, perhaps arising because of the difference between the two groups. This possibility seems unlikely however, while GHQ total scores did differ between the groups, neither resting PSIs nor the somatic symptoms subscale of the GHQ discriminated significantly between the groups, and inter-group differences on post-task PSIs never achieved significance. When correlations between GHQ subscale scores and state anxiety and PSIs are examined for each group separately the relationship between state anxiety and the GHQ was still apparent for both groups. The negative relationship between PSI scores and somatic symptoms was also apparent for both groups when post-task measures were examined, although only for the exam group did significant correlations between resting PSIs and scores on the Somatic Symptoms scale emerge.

Several explanations are possible, it may be that lower physiological activation is associated with lower coping effort and greater consequent disruption and distress. Alternatively, some third factor may be acting to produce both lower PSIs before the exam and

heightened symptoms later in some individuals. Few conclusions can be drawn on the basis of this study alone.

3.4 The Consistency of Levels of Sweat Gland Activity

Because this study provided longitudinal measures over several weeks, an attempt was made to determine the temporal stability of the PSI. For both resting and post-task measures, Kendall's coefficient of concordance was determined. This provides an index of the extent to which subjects maintained their overall ranking across all five measures. For both PSI measures, the coefficient was surprisingly large (resting measures $w=.507$, $p<.001$; post-task measures, $w=.548$, $p<.001$). As in the correlational analysis above, including both groups in the same analysis might lead to an inflated estimate. Examining both groups separately produced similar values (resting measures, exam group $w=.365$, $p=.023$; control group, $w=.641$, $p<.001$. Task measures, exam group, $w=.520$, $p<.001$; control group, $w=.553$, $p<.001$).

It seems that overall levels of palmar sweating show considerable stability, over the sort of time scale used in this study. In part, this is probably due to stable physiological factors such as finger size. It is also possible that stable psychological factors such as personality, as well as lifestyle factors such as caffeine consumption, stress levels etc. might also contribute to the consistency of PSI scores.

4 Discussion

Three main findings deserve consideration. Firstly, the effects of the examination on the PSI, and on the various subjective measures, will be discussed. This discussion will focus on possible explanations for the absence of clear effects of the exam on physiological

activity. Secondly, the conclusions regarding the relationships between the various measures will be examined. Finally, the apparent stability of PSI scores will be addressed.

The overall conclusion to be drawn from the analysis of the physiological measures is that the effects of the exam appear to be relatively weak, in comparison to the effects of individual differences and other sources of uncontrolled variance. The inclusion of the digit-symbol task is supported by the results, as measures after the task appear to be more sensitive than measures taken before. Three possible explanations exist for the apparent difference in sensitivity of pre- and post-task measures.

Firstly post-task measures may, in fact, be more sensitive than the "resting" measure. It may be that the task produced better standardisation and less uncontrolled variance than the "resting" measures, taken after subjects had spent ten minutes filling-in questionnaires. Alternatively, palmar sweating after the task may, as intended, be providing different information from the resting measure. An effect such as the stress-induced slowing of recovery after an IQ-type task found by Pardine & Napoli (1983), might explain these findings. Finally, the psychological effects of the task might determine the physiological response produced. The instructions to the task stressed that similar tasks are commonly used in IQ tests. It is quite likely that students anticipating an exam, or awaiting the results of an exam, would be more susceptible to evaluation anxiety.

The results also indicate that, within the exam group, students reporting greater anxiety or symptomatology tended to show a smaller decrease in sweating over the course of the task. This further implies that post-task measures may be more sensitive. However, this effect also failed to achieve acceptable levels of significance.

While the apparent differences in sensitivity between pre- and post-task measures are suggestive, they cannot be explained satisfactorily at present. Even when post-task measures are considered separately, the effect of the exam failed to reach conventional levels of significance. It seems that the use of the self-administration technique, and the relatively unconstrained conditions in this experiment may have obscured any effects of the exam.

Post-task measures were lower than the resting measures. While this may represent a rebound effect, similar to that observed in experiment two, it is more likely to represent the combined effects of rapid recovery and continued adaptation.

In many respects the results of this study are disappointing. There are no firm effects of the examination on palmar sweating despite very clear effects on a wide range of self-report measures. In some ways this resembles the results of experiment one, where task difficulty had the greatest effect on self report measures but did not seem to affect any of the physiological measures. This finding is not too surprising, given the amount of extraneous variance in field studies such as this. Factors such as room temperature, the effects of alcohol, caffeine and nicotine and extraneous influences such as illness, other stressful events and possible gender, and personality differences (including menstrual cycle effects) may all have served to introduce uncontrolled variance.

The results do not appear to provide any clues as to the best means of reducing the amount of unexplained variance in the PSI data. Neither of the two methods for accounting for individual differences in baseline appears to be satisfactory, indeed the use of change scores appears to reduce the sensitivity of the PSI. A similar effect was noted in experiment one. Neither external temperature nor

questionnaire measures accounted for a significant amount of the unexplained variance. The inclusion of dry bulb temperatures seemed to reduce the sensitivity. It would be expected that wet bulb temperatures would be superior as they take account of the effects of evaporation.

One aspect of the design of the study needs to be emphasised. The experiment took place over a period of eight weeks. The different sessions did not differ solely with regard to their temporal relationship to the exam. In addition to the examination, other events were happening during this period. In particular, the final set of measures were obtained after students returned from the Christmas vacations. It is possible that events happening outside the experiment might have influenced the results. The inclusion of a control group was intended to allow the effects of the exam to be isolated. It should be noted, however, that students in the control group were in a different year of the course to those in the exam group, and so had different timetables etc. This is probably the main shortcoming of the design, although it is difficult to see how the problem could be circumvented. Given that it is not possible to schedule exams solely for research purposes there is no obvious way of obtaining a more comparable control group. The problem of timing can be reduced by repeating the experiment using examinations at different times of the year. If the results were similar then that would provide reassurance that the original results were not unduly influenced by factors such as the effects of the Christmas vacation.

In addition, the technique used to estimate missing data was deliberately conservative, and may have acted to reduce differences between the groups, the regression equation being calculated on the basis of both groups' scores. However, comparison of scores for the

control group estimated by this method and those estimated from the control group's data alone revealed that the two sets of data did not differ significantly.

The method of self-administration used for the PSI was not very satisfactory. While methodological refinement might produce a more acceptable method, which would produce lower rates of missing data, for the remaining studies the traditional method of administration was used. The main problem with the method used in this study was the evaporation of the solution. Missing data rates were much higher for the post-task PSIs than for the initial resting PSIs, primarily because the solution had often dried up by the time subjects had completed the task.

Despite the apparent difference in sensitivity to the exam, the pattern of intercorrelations between the PSI and other measures does give support to the validity of the PSI as a component measure of anxiety. However, the results seem relatively non-specific; while the PSI did correlate with several scales measuring different forms of anxiety, correlations were on the same order of magnitude with scales supposedly measuring other constructs such as depression or anger. In practice, this finding is explained by the extensive pattern of intercorrelations found between the self-report measures. In all the correlational analyses carried out, state anxiety, trait anxiety and all of the GHQ and PDMS scales tended to be quite highly correlated (commonly above .5). Change scores tended to correlate negatively with trait anxiety, probably representing the effect of higher initial values.

The correlations between the PSI and subjective measures seem to indicate that post-task measures were a better index of current mood, a conclusion which is supported by the results of the main analysis of

the PSI data. However, the pattern of correlations also seems to imply that resting measures may be more sensitive to longitudinal change. Further research is necessary before any conclusions can be drawn concerning the nature of these relationships.

The relationship between the PSI and GHQ Somatic symptoms scores bears further examination in future studies. A negative relationship between palmar sweating and symptomatology was unexpected. It was assumed that, if a significant relationship emerged, it would be positive, both measures being assumed to increase in response to stress. It is possible that the negative relationship observed may reflect the way in which subjects deal with the stress of an exam. Higher levels of autonomic activity reflecting greater coping effort and, subsequently, better coping and fewer symptoms. However, this explanation involves several assumptions regarding the significance of both PSI scores and scores on the GHQ somatic symptoms scale. Both measures may reflect the influence of a wide variety of factors and, should not necessarily be taken at face value. Given the evidence for considerable stability in PSI scores, it would not be justified to attach too much significance to the temporal characteristics of the relationship. A full explanation of this finding must await a systematic replication of the result. The analysis carried out here is somewhat unsatisfactory, the possible effects of the exam, and the fact that measures were not taken at equivalent times, complicate the interpretation of the temporal aspects of the relationship.

The evidence for considerable consistency in PSI scores provides evidence for the existence of one type of external influence on the scores obtained in this study. Stable and relatively large individual differences in base level of activity seem to exist. What produces these differences is, as yet, unknown, although several possibilities

exist. Individual differences might reflect subject characteristics ("Response specificity", Lacey, Bateman & Van Lehn, 1953). Characteristics which might produce differences in palmar sweating include biological differences in characteristics such as finger size or sympathetic tone, and psychological characteristics such as personality. Such differences might also reflect stable environmental characteristics (some of which would be under personal control) such as adaptation to a particular level of heating, or the effects of nicotine or caffeine consumption. Finally, such stability might also reflect an interaction between the two, for example different individuals may consistently construe the testing situation in different ways, and so respond differently ("motivational specificity", Fahrenberg, 1986).

The results of the present study do not allow the reasons for this stability to be identified. Given the paucity of evidence for any relationship between sweat gland counts and the trait scales included in these studies, such differences seem unlikely to be due to stable personality traits. Had it been possible to examine the ratio of active glands to total glands in this study, it would have been possible to estimate the contribution of finger size and gland density to this effect. Such factors would not be expected to influence the ratio measure.

In summary, it seems that the attempt to apply the PSI under relatively uncontrolled conditions was too hasty. The next study to be undertaken involved a move back to the laboratory and extended the analysis of the effects of experienced stress on the PSI.

Chapter 10

Experiment Four: The Effects of Life Event Stress on Physiological Reactivity

1 Introduction

The last experiment demonstrated limits to the extent to which the PSI might be applied under field conditions. However, the results of experiment two demonstrate that the PSI may be of use in field experiments where conditions are better controlled. One possible rationale for the use of psychophysiological measures in field settings is that sympathetic activation may form part of the response to stress. Experiment three examined the effects of a single stressor on the PSI. The current experiment examined the relationship between a commonly-used index of general stress, self-reported life events, and a number of physiological measures.

Life event scales are widely used as an index of stress. Such scales are said to provide a convenient measure of "real-life stress", allowing the response to stress to be measured under controlled conditions, without sacrificing face validity. Such scales have been said to predict a variety of outcomes including psychiatric disorders (e.g. see Paykel & Dowlatshahi 1988) and physical illness (e.g. see Creed 1985). The present study examined the sensitivity of physiological measures to the cumulative effects of life-events. In addition, the study examined the relationship of the PSI to several parameters of electrodermal activity (EDA) and heart rate (HR).

Many models of the relationship between stress and ill health postulate that physiological responsivity may act as a mediating

variable between the two, the health consequences of stressful events occurring as a result of the physiological changes produced by the events. Such a view goes back to the work of Selye (e.g. 1976) on the General Adaptation Syndrome. While this sort of simplistic linear model has been, justly, criticised (e.g. Levine, 1986), many theorists still include psychophysiological responses as a mediating factor between stress and illness (e.g. Turpin & Lader, 1986). However, there has been little attempt to measure such responses directly. While studies have examined the physiological effects of specific, single stressors ranging from exams (see chapter nine) to nuclear accidents (e.g. Fleming et al. 1982), there has been almost no psychophysiological research using the life events approach. A small number of studies do, however, provide evidence for the importance of psychophysiological approaches to the study of life events.

A study by Pardine and Napoli (1983) reported a possible effect of the experience of life-events on physiological reactivity. These workers selected groups of subjects reporting high and low rates of recent life events respectively. These groups were found to differ with regard to their cardiovascular recovery rates after a stressful bogus intelligence test. The high stress group showed slower recovery of systolic blood pressure, and a tendency toward similarly slowed heart rate recovery, after the task. Responses during the task did not discriminate between the two groups.

Work examining electrodermal activity in schizophrenic subjects also indicates that the experience of stressful events might lead to heightened autonomic reactivity, although such individuals may be unusually susceptible to the effects of environmental stress. Studies by Tarrrier et al. (1978) and by Ventura, Dawson and Nuechterlein

(1986), reviewed in more detail in chapter four, both found heightened NS-SCR rates in subjects who had experienced life events. In the first study, individuals who had experienced a stressful event prior to a session did not show the usual response of reduced EDA following the entry of a relative. The same subjects did show such habituation on other sessions not preceded by stressful events.

A more recent study by Gannon et al. (1989) implies that physiological reactivity might also serve as an independent moderator of the effects of stressful events. A sample of students was given questionnaires assessing physical and psychological well-being, as well as a questionnaire assessing current levels of life stress, as indicated by the number of hassles (minor life events) experienced in the past month. Subjects then performed a stressful task consisting of mental arithmetic and anagram problems, while a number of psychophysiological measures were taken. They found that the stress measure predicted both scores on the Beck depression inventory and the number of physical symptoms reported. None of their physiological measures (Cardiovascular parameters, respiration rate and EMG) produced a significant main effect for either of the two dependent variables. However, for both cardiovascular and respiratory measures, response to the task and recovery after the task entered into significant interactions with experienced stress. For the majority of the physiological parameters this interaction was indicative of buffering. That is, subjects showing high physiological reactivity, or high levels during the recovery period, showed a stronger relationship between stress and the dependent variables.

The majority of these studies are correlational, as is all too common in the field of stress research. Thus, they are unable to rule out alternative explanations of the results obtained. However, by

including measures from more than one measurement domain, (questionnaires and psychophysiological recording) they are less vulnerable to some forms of confound than the majority of studies in this field. One persistent problem is the possibility of influence by stable response bias, due to personality factors such as "negative affectivity" (Watson & Pennebaker, 1989). Stress-illness correlations may just reflect a general tendency to report more negative experiences, rather than any causal relationship. The existence of a relationship involving directly measured physiological activity makes such contamination less likely, although other forms of confound can still occur. For example, negative affectivity is broadly equivalent to trait anxiety, which might also lead to elevated physiological activity under stressful conditions. The Tarrrier et al. (1978) study is superior to the other studies cited above, in that it was able to use each subject as their own control, thus ruling out the possibility of confounding by individual differences.

The fourth experiment to be carried out is intended to extend the findings of experiment three, which studied the longitudinal effects of a single stressful event, to the long-term effects of more general stress as measured by life events scales. It also forms a partial replication of the study carried out by Pardine & Napoli (1983). The experiment examines the effects of life events on a number of physiological measures. Both heart rate and measures of palmar sweating were examined during and after a stressful task. In addition, the effect of life event stress on habituation was also assessed. The study was undertaken before the study by Gannon et. al. (1989) was published, but a separate analysis examines whether the data obtained provides evidence for the sort of relationship they describe.

The concluding section of this chapter will also report the

analysis of the life events data obtained in experiment one. The life events scale used in this study was also given to subjects in the earlier experiment. That data was analysed, once weightings had been obtained for the items on the scale, to further examine the questions raised above.

Prior to description of the study itself, the selection and validation of the life event scale used will be described.

2 Validation of the Life Event Scale for Students

2.1 Introduction

The first step to be undertaken was to obtain a suitable Life Events scale. The scale to be used should provide a comprehensive list of events likely to be experienced by the population for whom the scale is intended. The events on the scale are usually weighted in terms of the supposed stressfulness of the event (see Paykel et al., 1971; Dohrenwend et al., 1978 for descriptions of the procedure). The weightings also need to be appropriate for the population to be used. Weightings are usually obtained by use of a panel of judges, who rate each event with regard to its stressfulness. This provides a weighting for each event based on the consensus as to the stressfulness of the average event of that type to the average individual. Grant et al. (1978) discuss various approaches to the scaling of life events.

The use of consensus weightings for events is the subject of some debate (e.g. Cleary, 1981). The most commonly used alternatives are to simply sum the number of events experienced or to use weightings of stressfulness for the specific event experienced, taking account of the context of the event. Additive weighted scores usually correlate

highly with a simple count of events (Skinner & Lei, 1980). This correlation is sufficiently high as to make the two approaches virtually identical in practice (Zimmerman, 1983). Where the techniques give different results, the use of weightings is to be preferred, as this method is likely to be more sensitive. While individual weightings might be expected to provide a more sensitive index of stressfulness, they are vulnerable to contamination by the outcome of the events, to the extent that they rely on subjective reports of stressfulness. Brown (e.g. Brown et al. 1973) has developed a widely-used life event methodology, which uses a panel of trained judges to rate various characteristics of events on the basis of contextual information obtained by interview. This technique has been used to investigate a number of disorders (e.g. see Brown & Harris, 1989) and Brown argues strongly that an interview-based approach is preferable to questionnaire-based measurement.

Other workers still favour the use of consensus weightings (e.g. Dohrenwend & Dohrenwend, 1981) and checklist-based measures are widely used. For this study a questionnaire measure of life events was chosen, as the use of interviews would have been prohibitively time-consuming. Brown's procedure can take up to half a day to complete and requires specific training.

While there is evidence for some generality of the weightings assigned to events, some events do differ in their perceived stressfulness to different populations (e.g. Dohrenwend et al., 1978). Such differences probably reflect the differing material circumstances of different groups, as well as differing cultural values. The weightings were thus obtained from the undergraduate population from which subjects were chosen.

While a number of Life events scales for student populations

exist (e.g. Costantini et al., 1974; Zitzow, 1984), these are generally aimed at American students, who appear to lead different life styles from the typical English student. For these reasons a life event scale originally developed for a Canadian population (Linden, 1984) was selected, as this scale appears to contain the sort of events typically experienced by English students.

The Life Events Scale for Students (LESS) was originally developed by asking a sample of 60 Canadian students to list recent events they had experienced which were typical of a student lifestyle and which were stressful (Linden, 1984). The scale contains 36 events such as "death of a parent", "Vacation alone or with friends" or "Failing a course".

In order to use this questionnaire, separate ratings of the stressfulness of the events were obtained for an English sample and a reliability study was carried out in order to ensure that subjects reporting of events was consistent.

2.2 Method

The 36 items from the scale were presented to a sample of 129 first year students (comprising 66 psychology and 63 combined honours students) and 62 second year psychology students at the start of term. Ratings were obtained from the second years at two different times, 35 gave ratings in the first week of term, while a further 27 second-years gave ratings at the first re-test one month later. All subjects were asked to rate the stressfulness of the events, in terms of the amount of adaptation they would require, for the average student. All ratings were to be in relation to event number one: "Death of a parent", which the original study had found to be the most stressful event. This event was given a rating of 100. In addition,

subjects were asked to indicate which of the events had happened to them over the last year and to indicate approximately when the event happened. As some of the events on the list are of a personal nature, subjects were not asked for their names. Rather, subjects were asked to put their sex, course and date of birth on the questionnaire. This allowed subject's later responses in the reliability test to be matched with their original responses, without the need to record subject's names.

In order to investigate the reliability of the questionnaire, subjects were asked again, one month after the first session, to list the events that had happened to them over the last year. Subjects were also re-tested six months after the first test. It was possible, therefore, to examine whether or not subjects reported the same events in a five month period when asked immediately after the period, one month after the period or six months after the end of the period.

2.3 Analysis of the Weightings Obtained

The overall weightings obtained are given in table 35. In order to test whether different years gave different weightings to events, for example because of the second years' greater experience as students, the ratings given were subjected to a MANOVA with Year (first versus second) and Event (weightings for 35 different events) as the independent variables. In addition, the data from the first year subjects was analysed separately, in order to ensure that subjects from the two different courses did not give different ratings.

The analysis of weightings given by different years revealed a significant main effect of Year ($F(1,181)=4.57$, $p=.034$). The interaction between Year and Event was non-significant.

In the analysis of data from first year students, the main

effect of Course was non significant, but the interaction between Course and Event was significant (approx. $F(34,85)=1.88$, $p=.010$). In both analyses the main effect of Event was significant, implying that different events were, as expected, given different weightings. These analyses imply that first years tended to rate all events as being less stressful than did second year students. Within the first year, combined honours and single honours students differed with regard to the profiles of the weightings they gave.

A follow-up analysis was undertaken comparing the two first year groups with regard to their weightings of individual events. Only one item differed between first year psychology and combined honours students (combined honours students rated a major argument with parents as more stressful, $F(1,84)=8.03$, $p=.005$), and, given the number of comparisons made, this one result must be suspected of being a type one error. Two other items fell short of significance ("Family get togethers", $F(1,84)=2.93$, $p=.09$; "Breakup with boy/girlfriend", $F(1,84)=2.97$, $p=.087$), both were rated as less stressful by combined honours students.

A similar analysis was undertaken on data from the two years. While the preceding analysis gave no evidence of differences between the profiles of the two years, it was expected that second years might give different weightings to some events as a function of their greater experience. Nine items were weighted differently by first and second year students. In every case second years rated the events as being more stressful.

Table 35: Weightings for events on the Life Event Scale for students

Event	First years			Second Years
	Single Hons.	Combined Hons.	Mean	Single Hons.
1) Major Personal Injury or illness	71	74	73	80
2) Major argument with parents	41	49	45	55
3) Beginning an undergraduate or graduate program at university or polytechnic	43	45	44	54
4) Moving away from home	48	39	44	50
5) Death of Parent	-	-	100	-
6) Getting an unjustified low mark on a test	37	32	34	39
7) Failing a number of courses	57	50	53	63
8) Minor violation of the law (e.g. speeding ticket)	22	22	22	27
9) Getting kicked out of college	70	62	66	73
10) Seeking psychological or psychiatric consultation	54	53	53	63
11) Vacation alone/with friends	14	16	15	18
12) Pregnancy (either yourself or being the father)	78	76	77	79
13) Minor car accident	40	41	41	46
14) Seriously thinking about dropping college	54	51	52	59
15) Getting your own car	22	18	20	24
16) Jail term (self)	81	76	79	83
17) Moving out of town with parents	41	43	42	48
18) Vacation with parents	24	30	27	27
19) Establishing new steady relationship with partner	33	33	33	38
20) Finding a part-time job	25	23	24	28
21) Sex difficulties with boy/girlfriend	50	46	48	48
22) Failing a course	55	48	52	56
23) Major change of health in close family member	66	68	67	69

Event	First years		Mean	Second Years	
	Single Hons.	Combined Hons.		Single Hons.	Hons.
24)Major car accident (Car wrecked, people injured)	79	75	77		77
25)Death of your best or very good friend	92	90	91		90
26)Family get-togethers	29	22	26		24
27)Breakup of parents marriage/Divorce	66	72	69		71
28)Losing a part-time job	30	26	28		36
29)Major and/or chronic financial problems	64	61	63		63
30)Major argument with boy/girlfriend	51	50	51		57
31)Parent losing a job	57	58	57		57
32)Switch in program within same college or university	39	34	36		40
33)Losing a good friend	59	54	56		60
34)Change of job	44	38	41		48
35)Breakup with boy/girlfriend	67	59	63		68
36)Minor financial problems	33	31	32		32

The pattern of events which were rated differently seems to be consistent. Some items represent second-year students greater involvement with their course ("Failing a number of courses", $F(1,147)=6.70$, $p=.01$; "getting kicked out of college", $F(1,147)=4.87$, $p=.029$; "Seriously thinking about dropping college", $F(1,147)=4.25$, $p=.041$) others may reflect the experiences of students ("Losing a part time job", $F(1,147)=7.15$, $p=.008$; "change of job", $F(1,147)=4.02$, $p=.047$; "beginning an undergraduate or graduate programme in university or polytechnic", $F(1,147)=6.87$, $p=.01$) others are less readily explained ("major personal injury or illness", $F(1,147)=6.95$, $p=.009$; "major argument with parents", $F(1,147)=8.80$, $p=.003$; "seeking psychological or psychiatric consultation", $F(1,147)=7.09$, $p=.008$, "Minor violation of the law" approached significance, $F(1,147)=2.97$, $p=.087$) although, all could be seen as representing second year students' greater perceived isolation from the support of their family.

The difference between the two groups of first year students appears inexplicable. As only one item separated the groups it was felt to be justified to use the average ratings for all first year students. It would be advisable to use different ratings for students from different years. Although, in the absence of a significant interaction between Year and Event, using either group's weightings would lead to similar conclusions, as long as the sample studied contained students from only one year. The difference between the years is in their mean weighting of events, their ranking of individual items was very similar. When using each year's own ratings, absolute scores would differ for the two years, but the ranking of subjects experiencing given events would be largely unchanged.

2.4 The Reliability of Life Event Reports

The reliability of life event scales can be assessed in two ways. Firstly the total scores obtained at different times, with regard to the same timespan, can be compared. The correlation between the total scores, in Life Change Units (LCUs), does not indicate whether the same events were reported. Identical scores could be obtained by reporting totally different events at the two times. While many studies have presented correlations between LCU scores as an index of the reliability of life event scales (see Zimmerman 1983 for a critical review of issues concerning the reliability of life event scores), a better approach is to examine the consistency in the events reported. Consistency can be expressed as the proportion of the total number of events reported which were reported on both occasions.

The major cause of inconsistency is likely to be forgetting. The number of events reported would be expected to fall off as the time between the event itself and the administration of the questionnaire increases. By comparing measures from three different times it is possible to estimate the extent of this fall off.

Subjects were asked to report the events which they had experienced over the past year at each of three times. The second occasion was approximately one month after the first and the third time was five months after the second. Thus, there was a period of five months which was reported on at each of the three occasions. At each time subjects were also asked to indicate when each event had happened, so that those events falling within the five month period can be identified.

Table 36: Correlations between life event scores for the same period
assessed at three different times

Delay between period rated and report of events	Zero	One month
One month	.661	
Six months	.614	.526

All correlations $p < .001$, one-tailed

Reliability data are presented in three forms. Firstly the correlations between the LCU scores obtained for those events falling within the five-month period are presented in table 36. All of the correlations are significant at $p < .001$ (one tailed). Therefore, there is reasonable stability in the life event scores.

A better indication of the reliability of the scale is the extent to which the same events were reported at different times. Two consistency figures are presented (tables 37 and 38). The first considers only those events that were reported as occurring in the same, or adjacent months, on both occasions. A more lenient estimate counts any report of the same event as reflecting consistency, even if the event was reported as happening in different months. A similar one month leeway was allowed. This means that if a given event was reported as falling in the five month period at one test, the subject was considered as being consistent if the same event was reported within one month either side of the period at the other time of testing.

Table 37: Consistency of life events reported in the same period
on two sessions, events reported in the same or adjacent months

Delay between first report and second.	Mean number of events reported		Consistency
	on one or both sessions		
	1st only/2nd only/Both		
One month	1.44/0.84/3.13		.612
Five months	1.68/0.47/2.18		.536
Six months	1.94/0.40/2.36		.537

Table 38: Consistency of life events reported in the same period
on two sessions, events reported in any month

Delay between first report and second.	Mean number of events reported		Consistency
	on one or both sessions		
	1st only/2nd only/Both		
One month	1.33/0.74/3.21		.631
Five months	1.59/0.39/2.27		.555
Six months	1.86/0.32/2.44		.555

The first estimate requires subjects to successfully recall events, but also requires the event to be accurately placed in time. The second estimate places fewer restrictions on memory, but may be subject to inflation by multiple occurrences of the same event.

It can be seen from tables 37 and 38 that all of the estimates of consistency are relatively high, lying between 50 and 65%. All are significantly different from zero (all $p < .001$, one tailed). As expected, insisting that events are reported in the same, or adjacent, months leads to slightly lower estimates of consistency. It should be noted that the overall figures are elevated slightly by the data from first year students, the majority of whom mentioned starting their degree at all three occasions.

For both measures the three estimates differed significantly, reflecting the expected fall off in recall with time ("same month" approx. $F(2,65)=6.65$, $p=.002$, "any month" approx. $F(1,65)=6.21$, $p=.003$). In both cases consistency was significantly greater over a one month interval than over five or six months ("same month" 1-2 vs 2-3, $t(66)=2.26$, $p=.027$; 1-2 vs 1-3, $t(66)=3.58$, $p=.001$. "Any month" 1-2 vs 2-3 $t(66)=2.30$, $p=.025$; 1-2 vs 1-3 $t(66)=3.51$, $p=.001$, all two-tailed tests). This provides evidence of a fall off in reporting of events. Further proof of such a fall off comes from examination of the number of events reported at each occasion. Tables 37 and 38 also present the number of events that were reported at both times as well as the number of events that were reported at only one occasion. In every case, significantly more events were reported only at the earlier session than were reported solely at the later session ("same month" 1-2 $t(125)=4.05$; 2-3 $t(85)=6.27$; 1-3 $t(77)=7.52$. "Any month" 1-2 $t(125)=4.07$; 2-3 $t(82)=6.27$; 1-3 $t(77)=7.52$. All $p < .001$, two-tailed).

2.5 Summary

The scale used seems appropriate to the sample it is intended to be used for and the weightings obtained seem plausible. While higher levels of reliability might be desirable, the values obtained are acceptable and consistent with the literature (see Zimmerman, 1983). While the analysis provides evidence for a decrease in the reporting of events over time, the scale of this fall off is relatively small. On average subjects report about .6 fewer events (13%) after a month and just over 1.5 fewer events (39%) after a six month period. Provided life event scores are obtained immediately prior to the experiment, the LESS should provide an acceptable measure of life event stress.

3 Life Event Stress and Physiological Reactivity

This experiment was intended to examine the cumulative effects of life events, as measured by questionnaire, on physiological activity. The study was a partial replication of a study carried out by Pardine & Napoli (1983). They selected samples who differed in terms of the number of stressful events which they had experienced over the previous 3 months. These groups were found to show different patterns of cardiovascular activity after a timed, IQ-type task. Low stress subjects showed declining levels of activity after the task, whereas high stress subjects failed to show such recovery. In this experiment, it was decided to use the digit-symbol task used in experiment three to examine differences in recovery between groups high, medium and low in experienced stress. In addition, it was predicted that differences in recovery might be paralleled by differences in habituation and subjects were also given an habituation series. As Pardine & Napoli

found effects for cardiovascular measures, heart rate was also recorded.

It was predicted that the experience of greater numbers of stressful events would be associated with greater physiological responsivity. This responsivity would result in larger electrodermal and cardiovascular responses to the task and slower recovery of those responses after the task. It was also predicted that life event stress might lead to larger skin conductance orienting responses, greater acceleration in the heart rate orienting response, and slower habituation of orienting responses.

The heart rate orienting response (HR-OR) is more complex than the skin conductance orienting response (SCR-OR), and is usually considered to consist of three overlapping components. The main distinction in the literature is between accelerative and decelerative components. The decelerative heart rate response can also be separated into primary and secondary components, discriminated by means of their latencies. Accelerative components may form part of the OR, but may also be produced as part of startle responses (Graham and Clifton, 1966). The two decelerative components both appear to be part of the OR. These components may be produced by different mechanisms, the early deceleration being a product of sub-cortical systems and the late component resulting from cortical processing (Graham & Jackson, 1970). Alternatively, the two components may be part of a single response, masked by the superimposed accelerative component. Turpin (1983) provides a discussion of the morphology of the HR-OR.

This design will also allow the comparison of PSI scores with various parameters of EDA not measured in experiment one. Response amplitude and habituation rate will be assessed from the habituation series. Habituation is of particular interest as several workers have

studied habituation behaviour in various clinical populations (e.g. Bernstein et al., 1982; Lader & wing, 1969).

The study also allowed the examination of the possible mediating role of physiological reactivity in the relationship between stress and ill health. Following the results of Gannon et al. (1989), it was predicted that life event scores would be predictive of psychological distress. This relationship was predicted to be stronger for those subjects showing higher electrodermal and cardiovascular reactivity to the digit-symbol substitution task.

4 Method

4.1 Subjects

The Life Event Scale for Students (LESS) was given to a sample of 87 first year students prior to a psychology lecture. This sample included some of the first year students included in the validation of the scale. The students were asked to calculate the number of events they had experienced over the last four months (this time period was chosen as it was the time since the start of term and so would be clearly defined in subjects' minds) and the total weighting of those events. All that was handed in were the number of events and the total stress score, the actual events which had happened to each student remained confidential. On the basis of their scores, letters were sent out to twenty subjects at each extreme of the distribution and twenty with moderate LCU scores, requesting them to take part in the experiment. 39 subjects took part, providing three groups of 13 subjects, who had experienced high, medium and low frequencies of life-events. As subjects were run over several weeks, for some subjects events will have occurred in between the original screening and collection of the data. In addition events may have moved out of

the four month window for some subjects. For these reasons the LESS was readministered to subjects who took part. Scores obtained immediately prior to participation determined the final assignment of subjects to groups.

The distributions of sex and handedness were as follows; The "Low" and "Medium" groups each contained 10 females and 3 males, the "High" group contained 11 females and 2 males. Both the "Low" And "High" groups contained 1 left-handed subject each. The "medium" group, however, contained 4 sinistral subjects.

All subjects were paid £1.25 for participation.

4.2 Apparatus

Electrodermal activity and heart rate were recorded continually throughout the experiment using the the same equipment as experiment one. The electrode gel used was purpose-made consisting of .05M NaCl in methyl cellulose.

A BBC model B microcomputer was used to administer a series of tones for the habituation test. The characteristics of the tones are given below.

4.3 Procedure

After informed consent was obtained, subjects were asked to wash their hands and then were seated in a soundproof room. The procedure was then explained and the electrodes were attached. Next, subjects were asked to complete the LESS, the Profile of Mood States (POMS) for the past week and the General Health Questionnaire (GHQ). The last two scales were intended to assess possible psychological effects of the differing amounts of stress experienced by the three groups.

After the questionnaires had been completed subjects were asked

to rest for four minutes while PSIs were taken bilaterally each minute. Then subjects were handed written instructions for the habituation series. Subjects were asked to sit quietly and ignore the tones. The instructions specifically asked subjects not to count the tones. After subjects had said they understood the instructions they were handed the headphones and the experimenter left the room.

The habituation series consisted of twelve 78 dB, 1000 Hz, 2-second tones with 40 ms onset and offset. The tone parameters were selected to produce orienting rather than startle or defensive responses. The tones were presented at an average interval of 40 seconds (maximum 60 seconds, minimum 20 seconds). The tones were generated by a computer, with inter-tone intervals being determined using one of two pseudo-random series, alternate subjects receiving different series.

After the habituation series the experimenter re-entered the room and took a PSI from both hands. Then subjects were given the digit-symbol task used in experiment one. A PSI was taken from the subject's non-preferred hand in the middle of the task. Finally there was a five minute rest period with PSIs taken bilaterally every minute.

After debriefing, subjects were asked to fill in the Trait form of the Spielberger State-Trait Anxiety Inventory and the Marlowe-Crowne Social Desirability Scale.

4.4 Data Reduction and Analysis

During rest periods and the digit-symbol task, skin conductance level (SCL), skin conductance response frequency (NS-SCRs) and heart rate (HR) were recorded at the same time as each PSI. Heart rate (HR) was recorded as the average of the rates calculated from five

successive inter-beat intervals. Skin Conductance response (SCR) frequency was measured as the number of responses exceeding a threshold of .015 micromhos in one minute centred on each PSI. The PSI was analysed both as a count of the number of active glands (PSI-A) and as the ratio of active over total glands (PSI-R). Only the analysis of the number of active glands will be reported in detail, although, where differences emerged, these will be discussed.

During the habituation series a skin conductance response was judged as present if a response of .015 micromhos or greater occurred within 1 to 4 seconds of stimulus onset. Heart rate responses (HR-OR) were defined as the deviation from pre-stimulus heart rate (averaged over five pre-stimulus beats) of each of the first eight beats after stimulus onset.

Prior to analysis, the distributions of the physiological variables were examined. All of the measures of sweat gland activity (PSI-A, PSI-R, NS-SCRs, SCL and SCR amplitude) were found to show significant positive skew. All of these variables were subjected to a square root transformation prior to analysis. A logarithmic transformation was also considered for SCL and SCR amplitude, but this was less effective in normalising the distribution of these variables.

As in earlier experiments, missing values for the physiological variables were replaced prior to the analysis by values estimated by the Genstat macro MULTMISS. The number of observations replaced was as follows PSI-A, 30 (3.7%); PSI-R, 33 (4.0%); SCL 2 (0.2%); NS-SCRs, 4 (0.5%); HR, 2 (0.5%).

Habituation measures were analysed as the mean values of blocks of three trials. Mean values could be obtained for all subjects so no estimation of missing values was necessary for these parameters. The number of missing values was as follows HR-OR 8 (0.2%). SCR amplitude

5 (0.5%).

The analysis of this study consisted initially of a series of comparisons between the three groups. Also studied were the effects of the two trait measures on the psychophysiological variables. A final series of analyses examined the relationship between different psychophysiological measures. As the study includes subjects over the full range of life events scores, it was felt to be justified to combine the three groups for the purpose of this last analysis.

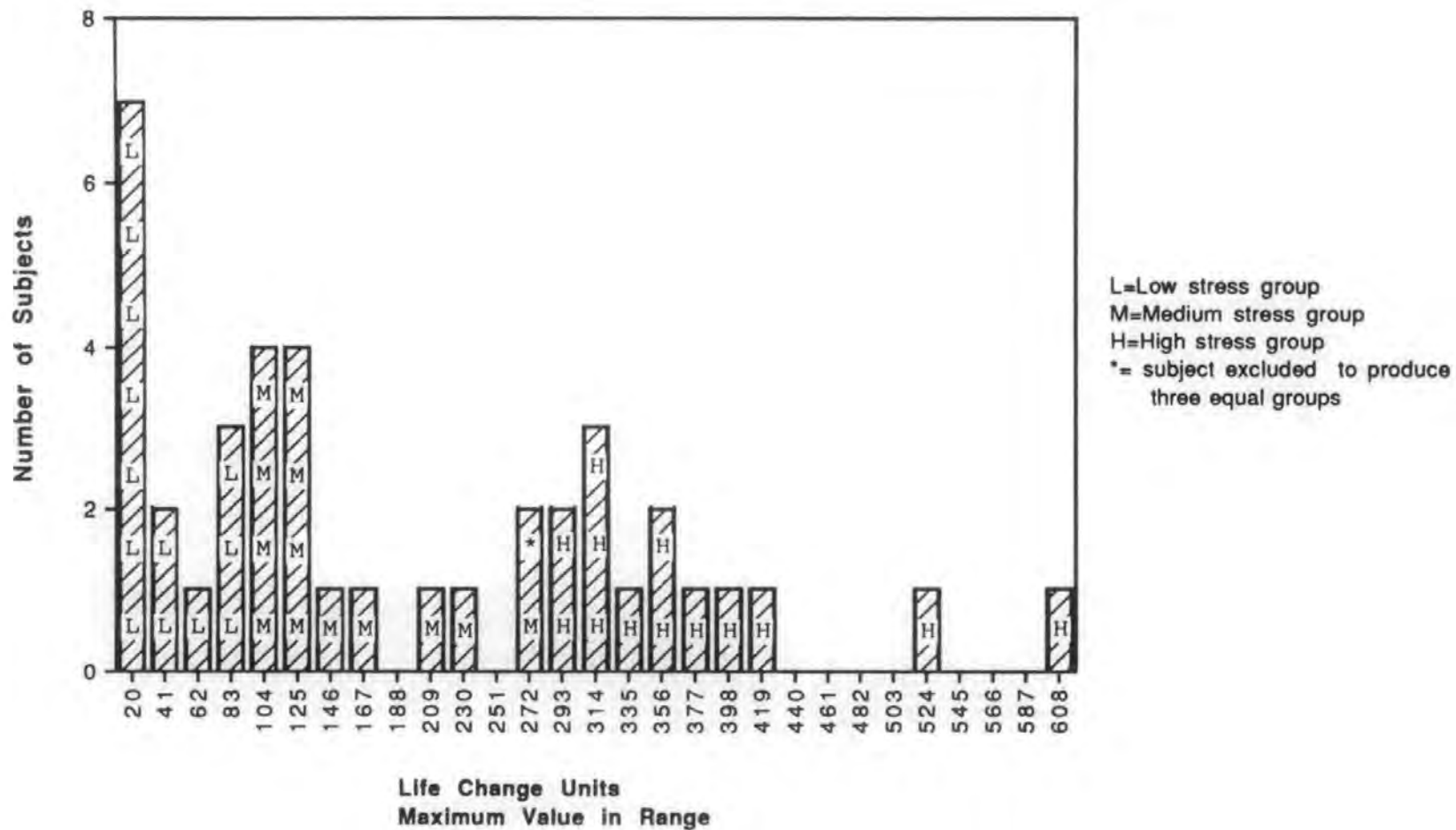
5 Results

5.1 Selection of the Groups

Figure 45 displays the distribution of LCU scores for the forty subjects who took part in the experiment. Subjects with scores below 83 were assigned to the "Low" stress group. Subjects with scores between 83 and 255 were assigned to the "Medium" group, and subjects with scores over 255 were assigned to the "High" stress group. One subject was excluded, on the basis of their LCU score (255), to provide three groups of 13 subjects each.

The distribution of the sexes was examined and found not to differ significantly across the groups. The groups also did not contain significantly different proportions of right- and left-handed subjects. The three groups showed similar levels of performance on the digit-symbol substitution task.

Figure 45: Life change scores



5.2 Analysis of the Questionnaire Measures

Analysis of the subjective measures supported the validity of the stress manipulation. The "high" group showed elevated levels of Severe Depression ($F(2,36)=6.68$, $p=.003$) and Anxiety & Insomnia ($F(2,36)=6.00$, $p=.006$) on the GHQ. The POMS Depression-Dejection scale was also higher in the "high" group ($F(2,27)=4.07$, $p=.029$). For all of these scales Fishers' LSD multiple comparison tests revealed that the "High" group reported significantly more disturbance than the "low" group. The "high" group also reported significantly more Severe Depression than the "medium" group. POMS Confusion-Bewilderment and GHQ Somatic Symptoms scales revealed similar trends which did not reach acceptable levels of significance ($F(2,27)=3.03$, $p=.065$ and $F(2,36)=2.72$, $p=.079$ respectively).

However, the "medium" group were higher in trait anxiety ($F(2,33)=5.02$, $p=.013$) and also in reported POMS Fatigue ($F(2,27)=3.53$, $p=.044$). Multiple comparisons tests indicated that the "medium" differed significantly from the "low" group on both questionnaires. This might reflect a meaningful difference, trait anxiety perhaps influencing life event experience through the differing lifestyles of anxious individuals. Alternatively the difference in trait anxiety might reflect a random difference between the groups, unrelated to the independent variable.

Mean scores on the questionnaire measures are displayed in table 39.

5.3 Analysis of the Physiological Measures

In order to ensure that estimated values had not distorted the results, analyses involving estimated values were repeated, excluding those subjects who originally had missing data. Unless these analyses

Table 39: Mean scores on the Questionnaire measures

Group	"Low"	"Medium"	"High"
Questionnaire			
Trait Anxiety	34.50	47.00	42.00
Social Desirability scale	12.00	11.64	11.54
GHQ			
Somatic Symptoms	4.92	8.54	8.00
Anxiety and Insomnia	2.77	5.31	8.77
Social Dysfunction	6.46	7.00	7.54
Severe Depression	0.00	1.30	4.31
POMS			
Tension-Anxiety	8.40	12.00	14.25
Depression-Dejection	6.10	10.75	17.92
Anger-Hostility	8.20	9.13	11.75
Vigour	14.20	11.88	13.92
Fatigue	5.50	11.63	9.58
Confusion-Bewilderment	6.30	11.63	12.50

produced different conclusions, only the results of the balanced analyses will be reported here.

While the distribution of left-handed subjects did not differ significantly across the three groups, there were more left-handers in the "medium" group. In order to rule out the possibility that this random difference might have confounded the results, those analyses revealing significant effects involving the hand of measurement were repeated, excluding sinistrals. Where this produced differing conclusions from the main analysis, this will be indicated.

5.3.1 The Initial rest period. Measures obtained during the initial rest period were subjected to MANOVAs with Group (3 levels) and Repetitions (4 levels) as factors. For the measures of sweat gland activity Hand was also a factor.

There were no significant effects or interactions in the analysis of HR. All of the measures of sweat gland activity revealed a significant main effect of Repetition, reflecting adaptation over the course of the rest period (PSI-A approx. $F(3,34)=6.43$, $p=.001$; SCL approx. $F(3,34)=32.83$, $p<.001$; NS-SCRs approx. $F(3,34)=5.20$, $p=.005$).

For skin conductance level there was also a significant main effect of Hand ($F(1,36)=37.95$, $p<.001$), indicating that subjects tended to have higher conductance in the right hand than in the left (means 1.17 and .95 microsiemens respectively). When left handed subjects were excluded the interaction between Group and Hand approached significance ($F(2,30)=3.00$, $p=.065$).

Both the PSI and NS-SCR frequency also revealed a triple interaction between Group, Hand and time of measurement (PSI-A approx. $F(6,70)=2.63$, $p=.023$; NS-SCRs approx $F(6,70)=2.69$, $p=.021$). These interactions are displayed in figures 46 and 47. For NS-SCR frequency

the interaction between the Repetition factor and Hand of measurement approached significance (approx. $F(3,34)=2.41$, $p=.084$).

Simple effects analysis of the PSI revealed that the effect of adaptation did not reach acceptable levels of significance for any combination of group or hand. Only for the low group did the change over the course of the rest period reach conventional levels of significance, without adjustment for the number of tests performed, and then only in the left hand. Faster adaptation in the low stress group would be consistent with predictions. Examination of figure 46 implies that the interaction is probably due to the slower adaptation shown by the "medium" group, especially in the right hand.

Follow-up analysis of the NS-SCR data revealed a more complicated pattern. Once again, no group showed changes in either hand when the bonferroni adjustment was employed to avoid inflated type one error rates. At conventional levels of significance, for the right hand, only the low group revealed a significant simple main effect of time. For the left hand however the other two groups were the only ones to show significant changes over the course of the period. Examination of figure 47 implies that the "Low" group showed rapid adaptation in the left hand, while the "Medium" group showed very little adaptation for right hand measures, revealing a pattern similar to that observed in the analysis of the PSI. In view of the absence of effects which reached an acceptable level of significance few conclusions can be drawn. Figures 46 and 47 indicate that there were few clear differences between the groups.

Figure 46: Group by Hand by Repetition interaction for the Palmar Sweat Index

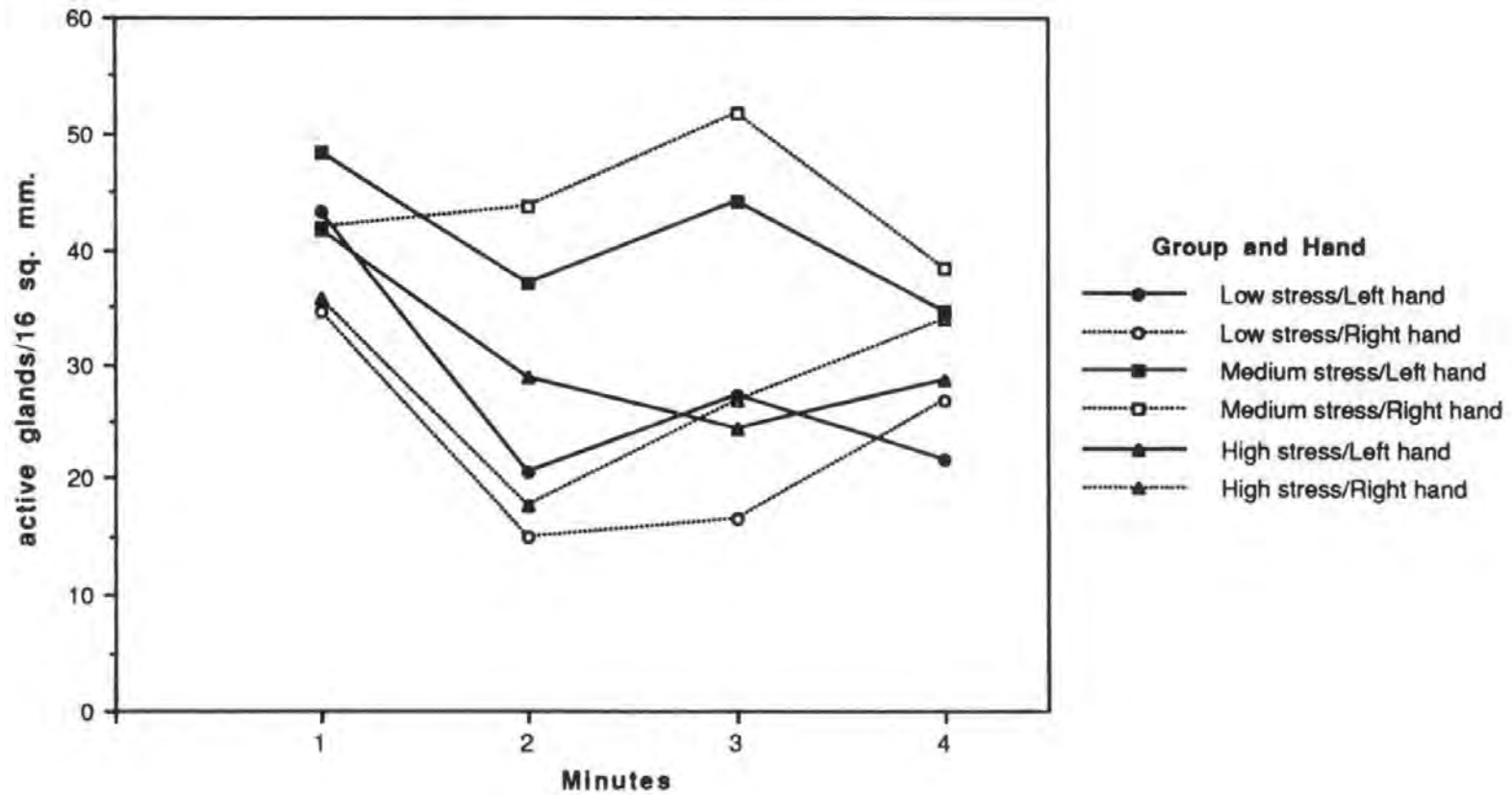
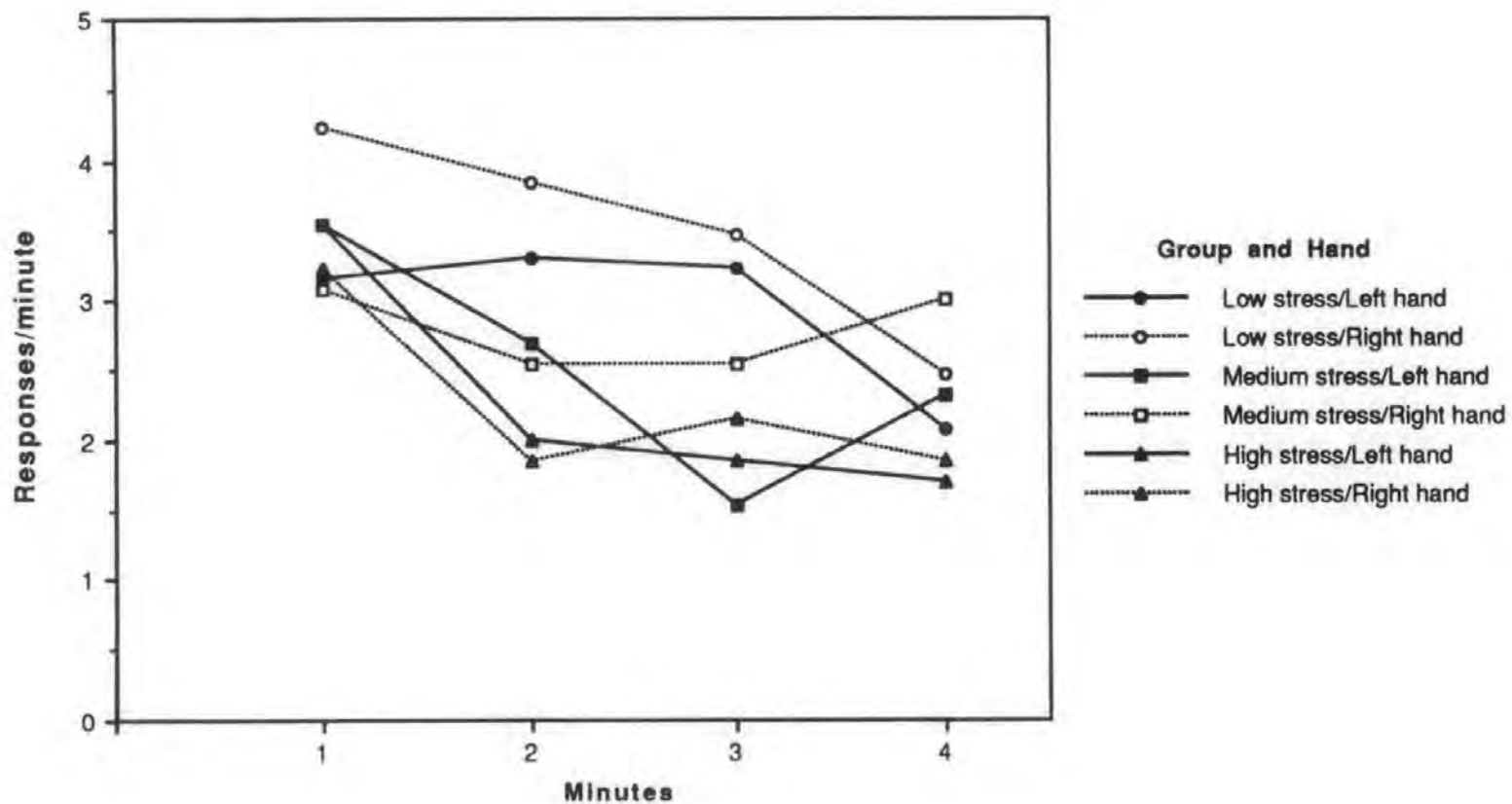


Figure 47: Group by Hand by Repetition interaction for non-specific response frequency



5.3.2 Habituation data. In order to perform statistical analyses, both heart rate orienting and SCR amplitude were analysed as the mean values of each of four blocks of three trials. Skin conductance data was analysed in a 3 (Groups) X 4 (Blocks) X 2 (Hands) MANOVA.

For SCR amplitude the effect of Block was significant (approx. $F(3,34)=28.39$, $p<.001$), indicating that habituation occurred. There was also a significant main effect of Hand ($F(1,36)=5.47$, $p=.025$), indicating that response amplitude was higher in the right hand (mean amplitude=.1248 microsiemens for the right hand and .1072 microsiemens for the left). Two effects involving the difference between the groups appeared. There was a significant Hand x Group interaction ($F(2,36)=3.60$, $p=.038$). The triple interaction involving Group, Block and Hand effect fell short of significance (approx. $F(6,70)=2.02$, $p=.074$). When sinistral subjects were excluded, however, this interaction achieved significance (approx. $F(6,58)=2.59$, $p=.045$). When only right-handers were studied the interaction between Block and Hand also approached significance (approx. $F(3,28)=2.60$, $p=.072$).

Simple main effects analysis for the interaction between Hand and Group indicated that only for the low group did the simple main effect of hand approach an acceptable level of significance ($F(1,12)=6.58$, unadjusted $p=.025$, Bonferroni critical $p=.017$). Figure 48 indicates that laterality appears to shift from larger right hand responses to greater left hand responses with increasing stress.

The borderline triple interaction does not appear explicable. Examination of the means (see figure 49) reveals similar rates of habituation for all groups and hands.

Figure 48: Group by Hand interaction for Skin Conductance Response amplitude

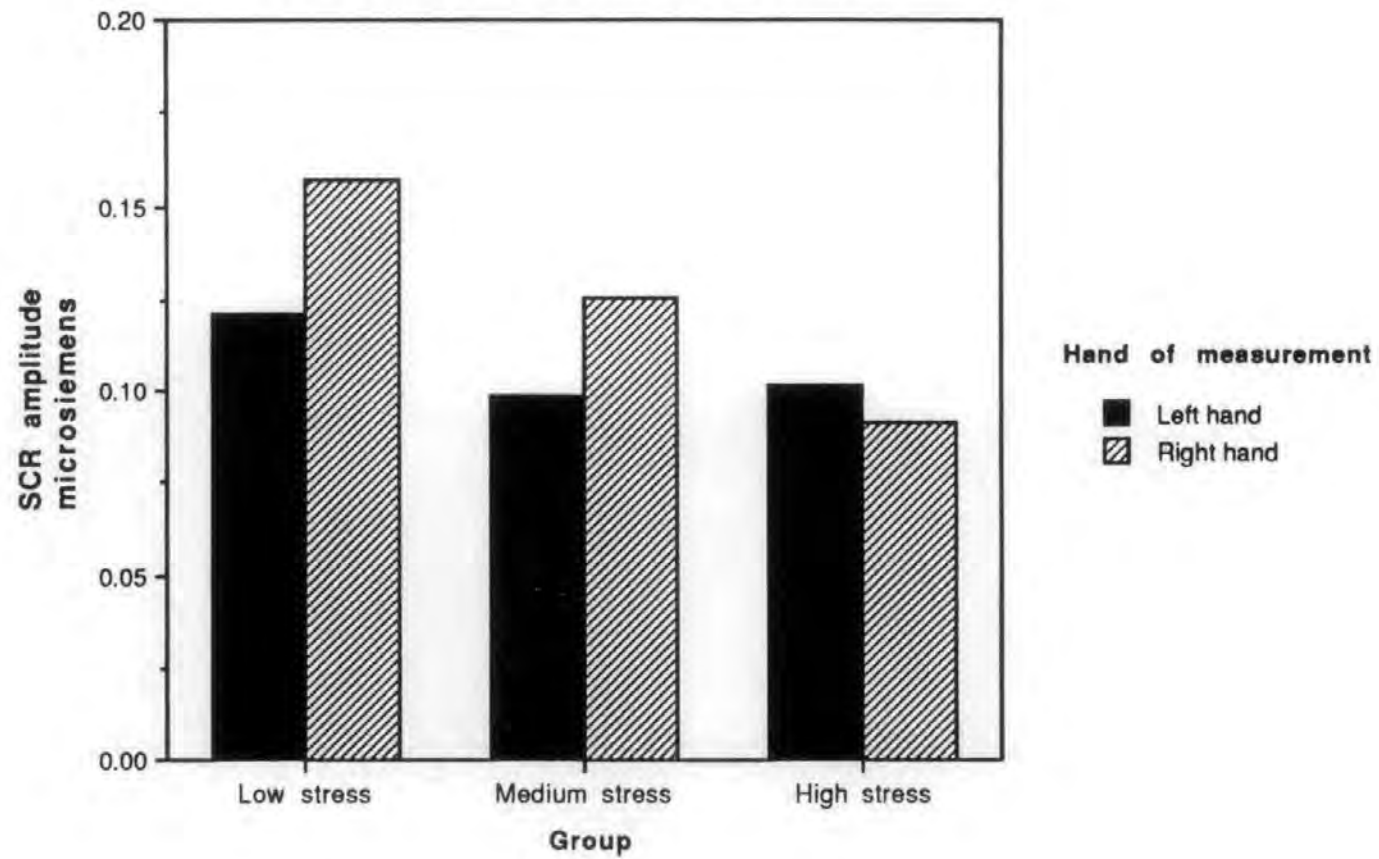
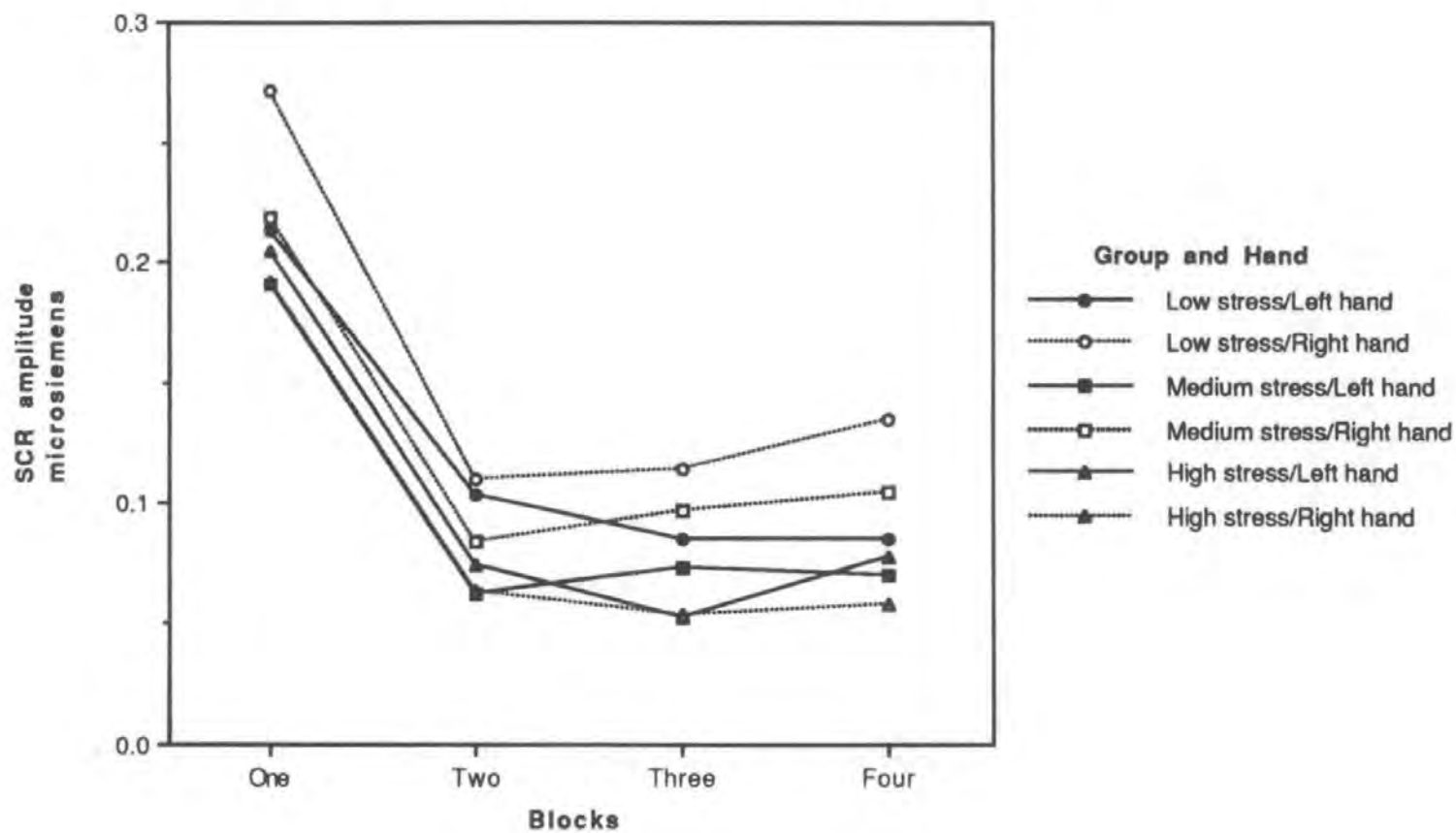


Figure 49: Group by Hand by Block interaction for Skin Conductance Response amplitude



The heart rate habituation data were analysed in a 3 (Groups) X 4 (Blocks) X 8 (Beats) MANOVA. This analysis revealed that the predominant Heart Rate response was deceleration, mean scores being significantly negative ($F(1,36)=4.21$, $p=.048$).

There was a significant effect of Beat (approx. $F(7,30)=4.54$, $p=.002$). Orthogonal polynomials within the Beats factor revealed significant linear ($t(30)=2.09$, $p=.043$) and cubic ($t(30)=2.30$, $p=.028$) trends, corresponding to the secondary deceleration apparent in the data (see figure 50), as well as a significant seventh-order trend ($t(30)=2.06$, $p=.047$). The Group X Beat interaction approached significance (approx $F(14,62)=1.72$, $p=.075$), reflecting differing response profiles for the three groups, with greater initial deceleration from the "Medium" group and the "low stress" group showing the largest secondary deceleration (see figure 51). There was also a borderline interaction between Group and Block (approx $F(6,70)=2.12$, $p=.061$) although this effect did not appear explicable, see figure 52.

There was no evidence of response habituation, neither the main effect of Block, nor the Block by Beat interaction, were significant.

Figure 50: Heart Rate Orienting Response

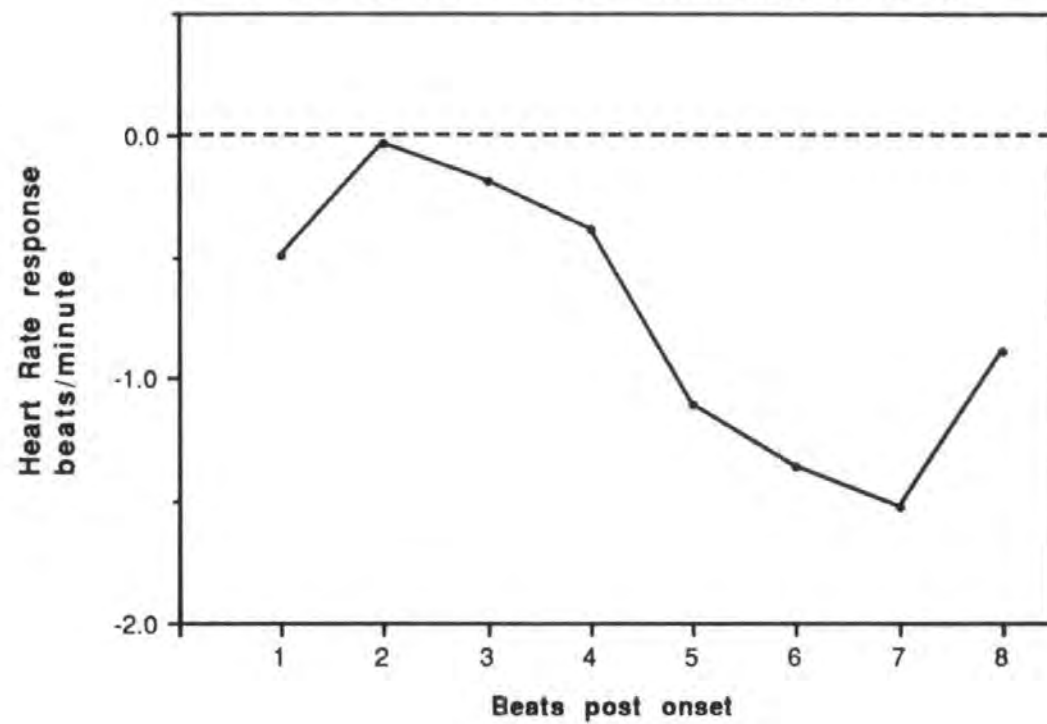


Figure 51: Borderline Group by Beat interaction for Heart Rate orienting response

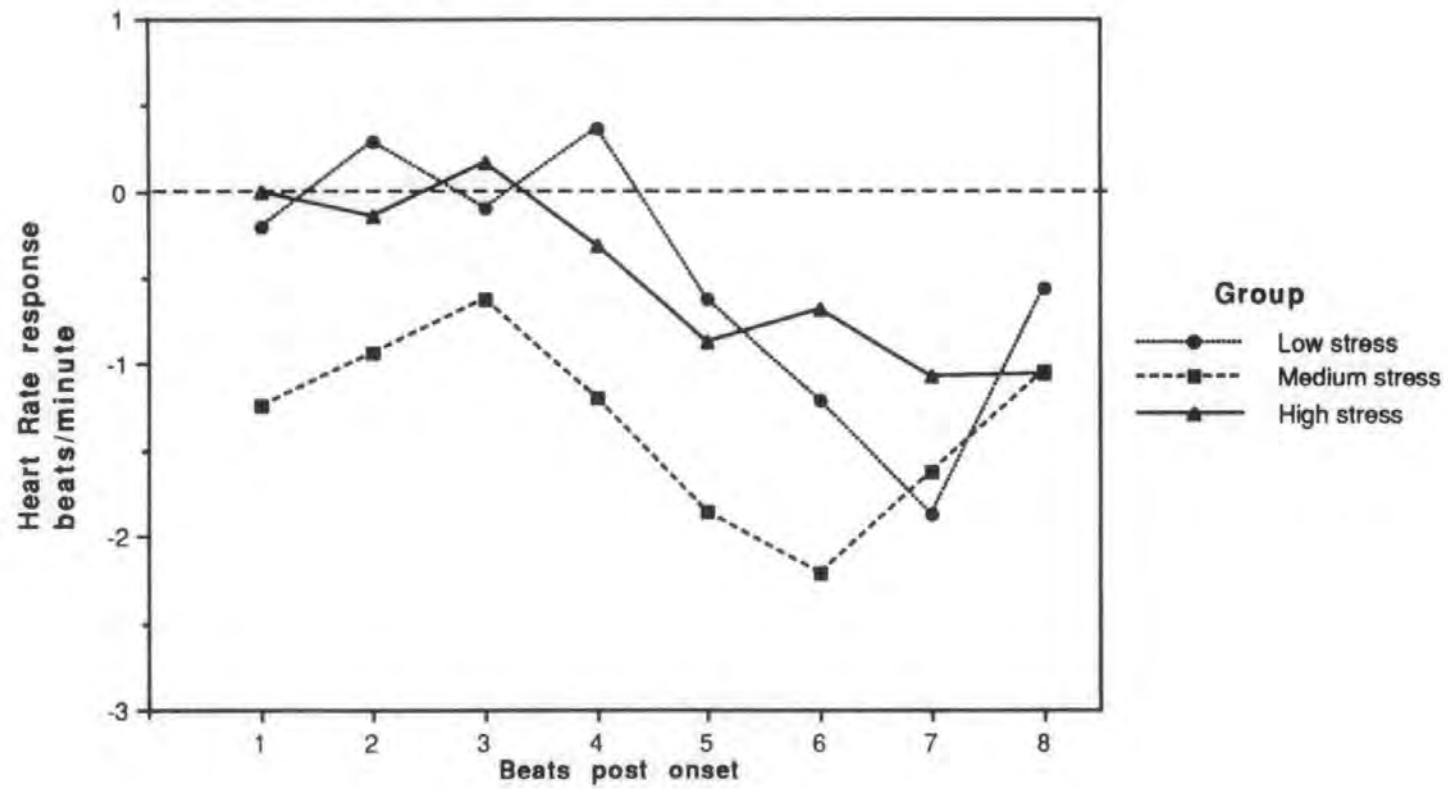
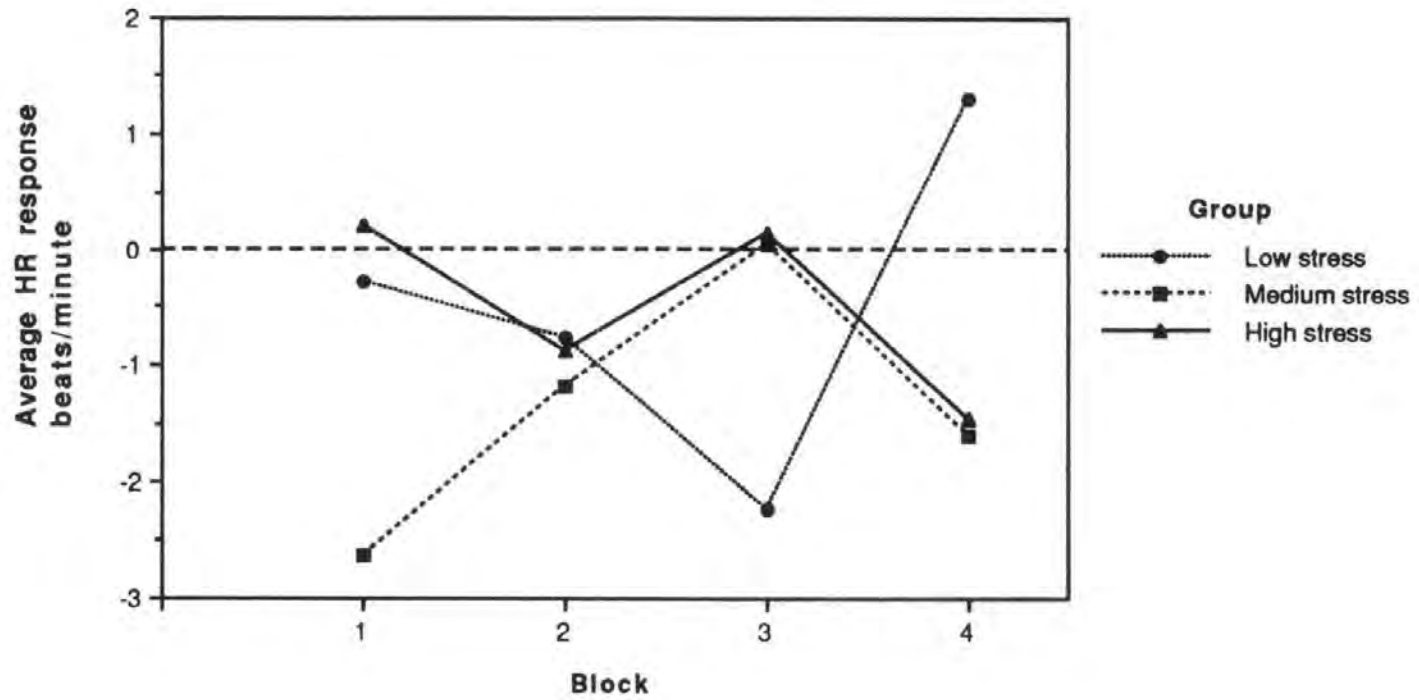


Figure 52: Borderline Group by Block interaction for the Heart Rate Orienting Response



In a further analysis of the heart rate habituation data, components of the heart rate response were extracted and analysed separately. Three components were extracted, corresponding to the primary and secondary decelerations and the primary acceleration. Figure 50 shows that all three components were, in fact, apparent in the data. For each subject, separate scores were calculated for the primary deceleration, defined as the lowest of the first two beats. Scores were also obtained for the primary acceleration, defined as the highest score of the second, third and fourth beats and for the secondary deceleration, taken as the minimum of the last four beats.

Each component was calculated as a change score from the prestimulus level, thus negative scores were possible. Each of these three components was analysed in a 3 (Groups) x 12 (Trials) MANOVA. None of these analyses revealed any significant effects. There were no differences between the groups with regard to these three parameters. Surprisingly, these analyses also failed to produce any significant effects involving the Trials factor, implying that none of the three components showed significant habituation.

The HR responses did not appear to be very reliable. Kendall's coefficient of concordance was calculated for each of the three components. None of the coefficients were significant, all being below .05. This is in contrast to the skin conductance responses to the tones. Both left and right hand responses showed significant consistency across time (left hand, Kendall's $W=.321$, right hand $W=.384$, both $p<.001$). These coefficients were significant despite the occurrence of habituation, which would serve to reduce the apparent consistency.

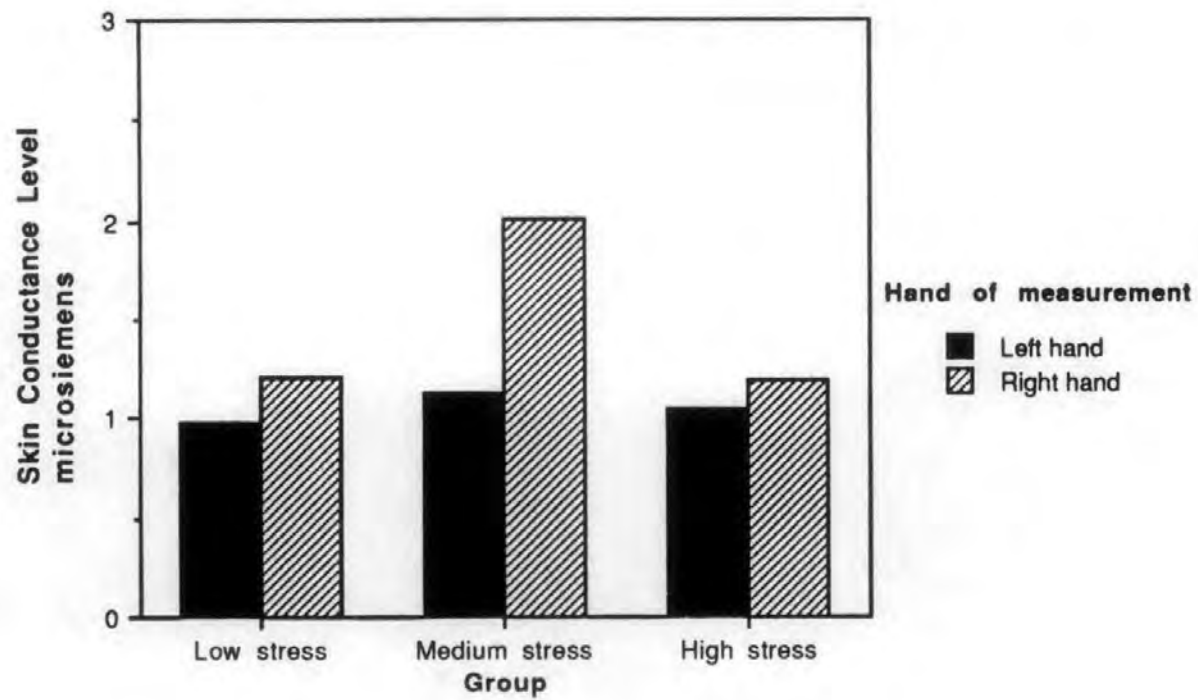
5.3.3 Analysis of pre-task measures. Before analysis of the measures taken during and after the task, pre-task measures were examined. Measures of sweat gland activity were subjected to a 2 (Groups) x 2 (Hands) MANOVA. Neither NS-SCR frequency nor heart rate revealed any difference between the groups at this point.

As in the initial rest period, SCL was significantly higher in the right hand ($F(1,36)=20.44, p<.001$). When two subjects with missing values were excluded the Group x Hand interaction for SCL just missed significance ($F(2,35)=3.16, p=.055$). This interaction was significant when left-handers were excluded from the analysis.

Only for the medium group did the simple main effect of hand achieve significance ($F(1,8)=17.88, \text{unadjusted } p=.003$). While non-significant in the main analysis, this interaction is worthy of note, as similar effects also emerged in later analyses. In contrast to skin conductance response amplitude, on which only the "Low" group showed a tendency toward lateral differences, SCL shows a tendency for greater lateralisation in the "Medium" group. The interaction is displayed in figure 53.

For the PSI, a borderline main effect of group appeared ($F(1,36)=5.89, p=.06$) this effect was significant in the analysis of the ratio measure ($F(1,36)=5.31, p=.01$). A Fisher's LSD test revealed that for both treatments of the PSI the "medium" group had significantly higher levels of sweat gland activity than the other two groups ("medium" vs "low" PSI-A $t(36)=3.19, p=.003$; PSI-R $t(36)=3.08, p=.004$. "Medium vs "high" PSI-A $t(36)=2.70, p=.011$; PSI-R $t(36)=2.47, p=.019$).

Figure 53: Borderline Group by Hand interaction for Skin Conductance Level



This difference may be due to the higher levels of trait anxiety shown by the "medium" group. It is possible that they may have been more anxious prior to the task. A later series of analyses will control for subject's levels of trait anxiety in order to examine this possibility.

For the number of active glands obtained from the PSI there was also a trend towards higher levels of sweating in the right hand prior to the task ($F(1,36)=3.62$, $p=.065$). This parallels the significant difference found for SCL.

5.3.4 The Physiological response to the task. In view of the evidence for differences in baseline activity on some measures prior to the task, data from the task were analysed both as raw scores and as change scores from the values obtained prior to the task. SCL and NS-SCR frequency were obtained from both hands during the task, the pre-task values from the appropriate hand being used as a baseline for the task measures. The PSI was only obtained from the non-preferred hand during the task, pre-task values for this hand forming the baseline for the difference scores.

For every variable, except the PSI, the difference scores differed significantly from zero, reflecting a significant increase in autonomic activation during the task. For the PSI, this increase just fell short of significance by a two-tailed test, but was significant at $p<.05$, one-tailed.

The main effect of Group did not achieve significance in any analysis. In the analysis of difference scores for NS-SCR frequency, the effect of Group approached significance ($F(2,36)=3.14$, $p=.055$). Further investigation revealed that the "medium" group had lower difference scores than the "low" group ($t(36)=2.38$, $p=.023$) and tended

to have lower scores than the "high" group ($t(36)=1.87$, $p=.07$). This effect was not apparent when the three subjects with estimated values were excluded. Examination of the means for the three groups revealed that the "medium" group had higher rates of NS-SCRs during the pre-task period, although the difference was not significant. Earlier analyses revealed significantly higher PSIs for this group, prior to the task. Furthermore, examination of the estimated values revealed that one subject, in the "medium" group had unusually high estimated values during the period prior to the task. Both of the estimated raw scores for this subject were significantly above the mean for those variables. Inclusion of the estimated values would only exaggerate the tendency for higher baseline levels in the "medium" group. The borderline effect of group apparent in the difference scores most probably represents the influence of a higher baseline level for the "medium" group, rather than any effect of the task itself.

For SCL, there was a weak trend towards an interaction between Group and Hand ($F(2,36)=2.458$, $p=.09$). When left-handers were excluded from the analysis this effect became significant ($F(2,30)=7.35$, $p=.003$). Further analysis indicated that the "Medium" and "High" groups showed significant differences between the hands, while the "Low" group did not ("Medium" $F(1,12)=11.76$, unadjusted $p=.005$; "High" $F(1,12)=11.36$, unadjusted $p=.006$). As this trend did not appear in the analysis of difference scores, it may represent a continuation of the differences which existed prior to the task, rather than an effect of the task itself.

For both NS-SCR frequency and SCL, there were significant differences between the two hands (NS-SCRs $F(1,36)=11.13$, $p=.002$; SCL $F(1,36)=23.80$, $p<.001$). This effect did not emerge in analyses of SCL when difference scores formed the dependent variable or when only

right-handed subjects were included. In all cases, EDA was greatest when recorded from the right hand. As subjects were engaged in writing during this period, it is likely that pre-existing differences may have been exaggerated by the effects of this activity.

The preceding analyses reveal few clear-cut differences between the groups. The task did not appear to produce differences between the groups. Those differences which did emerge appear to have existed prior to the task. Before the task, there was a tendency for higher PSI scores in the "Medium" group. A tendency for smaller increases in NS-SCR rate during the task probably also reflects higher pre-task activity for the medium group. At both times the "medium" group tended to show lateral differences in SCL. Only during the task, when subjects were writing, did lateral differences appear for the "High" group also.

5.3.5 Recovery after the task. Levels of physiological activity during the recovery period were also analysed both as raw scores and as change scores from the values obtained during the task. Mid-task measures were used as a "baseline" in order to provide an index of recovery which was independent of the size of the response to the task. These analyses produced very similar conclusions, only the analysis of raw scores will be presented in detail. Where the analysis of difference scores produced different results, these will be discussed. Because the PSI was only obtained from one hand during the task, these values, taken from the non-preferred hand, were used as the baseline for both right and left hand measures during the recovery period. As significant differences between the two hands emerged during the task, for those measures which were obtained bilaterally, the interpretation of any effects involving hand of measurement for

the PSI must be undertaken with caution.

Only NS-SCR frequency failed to show significant change over the recovery period (PSI-A approx $F(4,33)=3.16$, $p=.026$; SCL approx. $F(4,33)=29.29$, $p<.001$; HR approx $F(4,33)=5.06$, $p=.003$). In addition, the mean of the difference scores differed significantly from zero for every variable, indicating that values in the recovery period were below those during the task.

Exclusion of those subjects who had missing values in the recovery period (7 for PSI-A, 10 for PSI-R) abolished the effect of Repetition for both parameters of the PSI. When these subjects were excluded, the triple interaction between Group, Hand and Repetition was of borderline significance in the analysis of raw scores, for the ratio measure alone (approx. $F(8,48)=1.85$, $p=.09$).

Only heart rate revealed a significant effect involving Group. There was a significant interaction between the change over the recovery period and Group (approx. $F(8,68)=2.10$, $p=.048$). This effect fell short of significance when those subjects with estimated values were excluded (approx. $F(8,66)=1.98$, $p=.062$). Simple effects analysis revealed that only the "high" group showed a significant simple main effect of Repetition (approx. $F(4,9)=5.44$, unadjusted $p=.017$).

Examination of the mean scores for the groups (see figure 54) reveals that, rather than the expected decline in HR over the recovery period, HR tended to increase. There is no evidence of recovery occurring during the "recovery" period. It seems that Heart Rate recovery occurred very rapidly, and the changes over the course of the recovery period may reflect some other factor. Despite the significant simple main effect, the "high" group does not appear to show a larger increase than the other groups. Examination of polynomials within the effect of time confirmed this impression. There was no significant

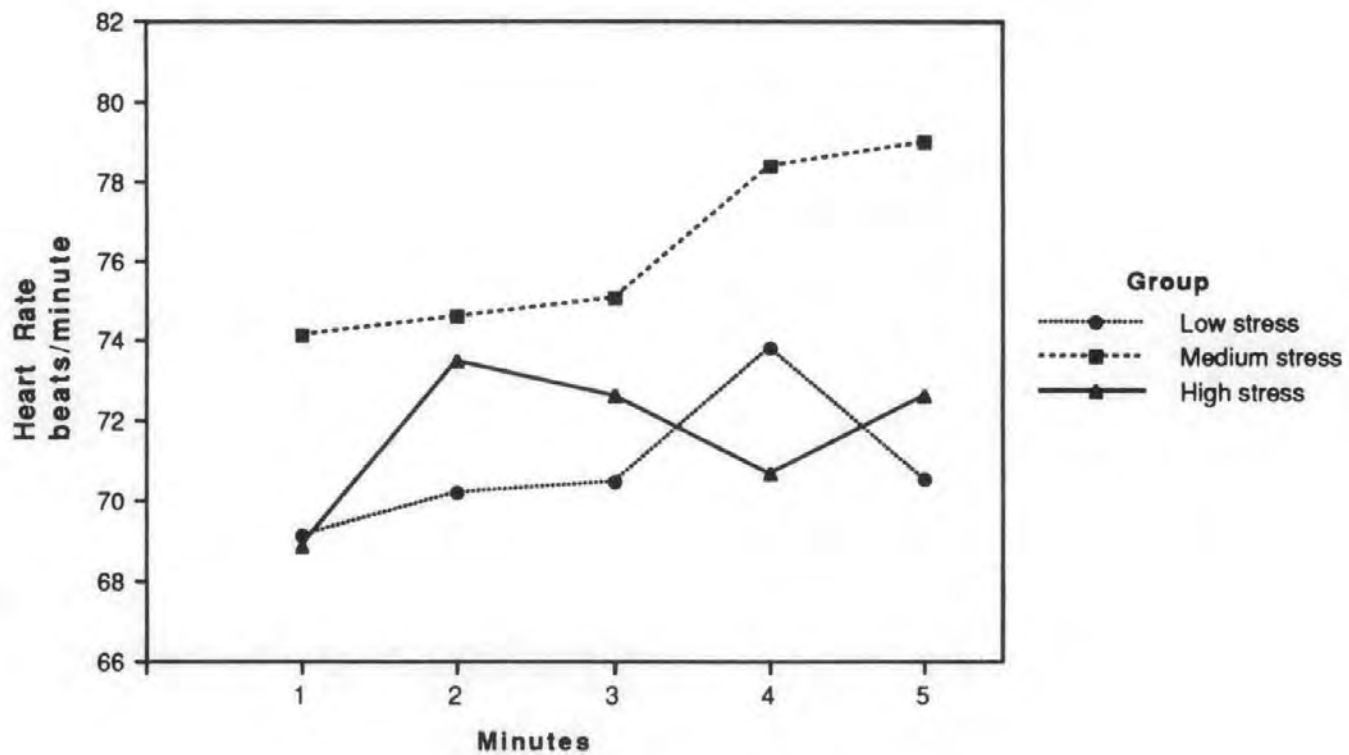
linear trend for the "high" group. Only the "medium" group revealed a significant linear trend ($t(48)=3.35$, unadjusted $p=.006$), reflecting the steady increase this group showed over the course of the recovery period.

For both of the parameters of EDA there were significant main effects of hand of measurement (SCL $F(1,36)=19.99$, $p<.001$; NS-SCRs $F(1,36)=7.01$, $p=.012$). Both measures were higher in the right hand, continuing the trend from earlier periods. The analysis of difference scores also revealed significant differences between the hands for these two parameters.

However, examination of the raw data revealed that difference scores were more negative for the right hand. i.e. although absolute levels of EDA were higher in the right hand, the right hand also showed greater recovery than the left hand. The higher tonic activity shown by the right hand also appears to be paralleled by greater phasic responsivity.

In a number of the analyses of measures of sweat gland activity, there were indications of an interaction between Hand and Repetition. Although never at an acceptable level of significance. For both PSI-R and NS-SCR frequency the interaction between Hand and Repetition approached significance in the analysis of raw scores ($p=.067$ and $.063$, respectively). This effect was also present, but of reduced significance, in the analysis of difference score for NS-SCR frequency ($p=.092$). This effect was not apparent for either measure when sinistrals were excluded from the analysis. For the PSI, exclusion of subjects with missing values also abolished the interaction. In the analysis of difference scores this interaction approached significance for skin conductance level ($p=.075$). When only right-handed subjects were considered there was also a weak Hand x Repetition interaction

Figure 54: Group by Repetition interaction for Heart Rate



for SCL ($p=.061$). These interactions do not appear interpretable and, as none of these effects achieved significance, little weight can be placed on them.

5.3.6 Summary of initial analyses. The analyses reported above did not replicate the findings of Pardine & Napoli (1983). The experience of high numbers of life events did not seem to delay physiological recovery after a stressful task. While there was an indication of differences between the groups with regard to their levels of heart rate during the recovery period these differences did not appear to be readily explicable. While the effects of the task were relatively disappointing, the habituation measures did give some indications of differences between the groups. There were some indications of weak differences between the groups with regard to their HR orienting, with the "low" group producing slightly larger secondary deceleration than the other groups. The major difference, however, was on skin conductance responding. There was an unexpected difference in skin conductance laterality. The low group showed a tendency toward right hand dominance. The other groups showed no significant difference between response amplitudes from the two hands, with the "high stress" group actually showing slightly larger responses in the left hand. The groups did not differ with regard to the habituation of Skin Conductance responding.

5.4 The contribution of trait anxiety to the results. The three groups used in the previous analysis had been found to differ with regard to their scores on the trait scale of the STAI. It is possible that the differences in physiological activity found might be secondary to differences in trait anxiety, possibly mediated by

subject's reactions to the experimental situation. For this reason The data were re-analysed using analysis of covariance to control for subject's levels of trait anxiety.

Each of the main analyses reported above was repeated including trait anxiety as a covariate. Results from these analyses will only be reported where these analyses produced different conclusions from the main analyses reported above. In none of the analyses did the regression of trait anxiety on the relevant physiological variable even approach significance. This indicates that trait anxiety was not an important determinant of physiological reactivity.

The analysis of data from the first rest period produced almost identical results to the original analysis. Only two differences emerged. The Hand x Repetition interaction for NS-SCR frequency, which just missed significance in the main analysis, was significant when trait anxiety was included as a covariate (approx. $F(3,31)=2.91$, $p=.05$). The main effect of Repetition for heart rate, while still not significant, was of borderline significance ($p=.083$) in this analysis.

The analysis of the habituation measures also produced very similar results. The only difference being that the borderline Group by Block interaction for HR did not appear.

Neither the initial rest period nor the habituation series, therefore, appear to have been unduly influenced by the inter-group difference in trait anxiety.

When measures taken before, during and after the task were examined several differences did emerge. In the main analysis the groups showed differing levels of palmar sweating, measured by the PSI prior to the task, with the "medium" group showing greater activity than the other two groups. This effect did not appear in the corresponding analysis of covariance, implying that this effect may

have been due to differences in trait anxiety.

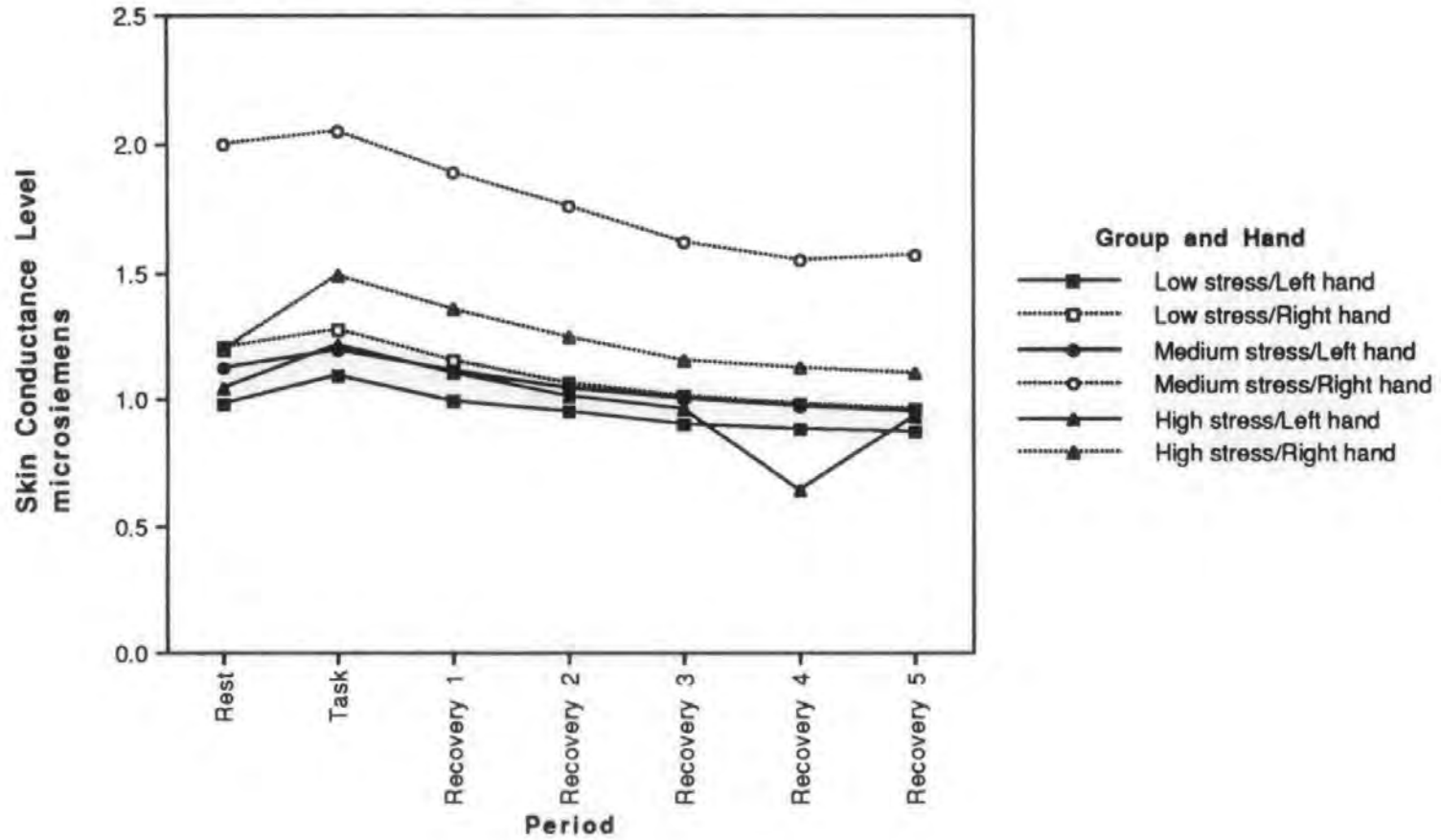
One other major difference to emerge was that both prior to the task, during the task, and during the recovery period, SCL revealed a significant Group x Hand interaction (pre-task $F(2,33)=3.91$, $p=.03$; mid-task $F(2,33)=4.48$, $p=.019$; Recovery $F(2,33)=3.85$, $p=.031$). In the original analysis non-significant trends in this direction had appeared in the analysis of pre-task and mid-task measures only. Subsidiary analyses, including only right-handed subjects, had produced similar interactions at these two times. This interaction is displayed in figure 55.

Simple main effects analysis indicated that the "low" group showed no significant laterality effect at any time. The "medium" group, in contrast, had significantly higher skin conductance in the right hand at all three times (pre-task $F(1,10)=14.24$, unadjusted $p=.004$; mid-task $F(1,10)=16.82$, unadjusted $p=.002$; recovery $F(1,10)=19.57$, $p=.001$). The high group also showed right hand dominance during the task and in the recovery period (task $F(1,12)=11.29$, unadjusted $p=.006$; recovery $F(1,12)=8.29$, unadjusted $p=.014$).

In the analysis of the recovery period the weak Group x Hand interaction for the PSI-R was replaced by an equally weak Group x Hand x Repetition interaction ($p=.083$). The Group x Repetition interaction for HR, which was significant in the main analysis, fell short of significance ($p=.053$) when trait anxiety was included as a covariate.

In general, these analyses produced very similar conclusions to the original analyses. Trait anxiety does not appear to mediate most of the physiological effects found. Only the pre-task differences in PSI scores are likely to be secondary to differences in trait anxiety.

Figure 55: Skin conductance level, before, during and after the task



The other important finding from these analyses is the apparent difference in SCL laterality between the groups. These findings seem to support the broad conclusions from the analysis of the habituation data, that there appear to be differences between the groups with regard to electrodermal laterality. Although the differences are in opposite directions for SCL and SCR amplitude. It is unclear at present what these differences mean. The interpretation of differences in electrodermal laterality is controversial (Hugdahl, 1984; Miossec et al., 1985). The interpretation of this finding is further complicated by the fact that significant differences, with regard to conductance level, only emerged in the analyses of covariance. However, more support is given to these findings by the fact that the exclusion of sinistral subjects from the main analysis also revealed similar results. As the medium group had both higher trait anxiety scores and more left-handers, the covariance analysis appears to have produced similar results to the analysis excluding left handers.

5.5 The Importance of Physiological Reactivity as a Mediator Between Stress and Illness

As the study had included subjects over the full range of life event experience, it was considered justified to combine the three groups in order to examine the relationship between the three classes of variables studied, life events, psychophysiological reactivity and psychopathology.

A recent study by Gannon et al. (1989) reports that physiological reactivity and recovery may act as mediators of the relationship between the experience of life event stress and the development of both physical and psychological disorder. They obtained reports of recent hassles (small life events and chronic stressors), from 50

subjects. These subjects also filled in the Beck Depression Inventory and a physical symptoms checklist. While subjects carried out a number of mental arithmetic and anagram problems a variety of cardiovascular measures as well as respiratory parameters and frontal EMG were recorded.

They found, as expected, that hassles frequency predicted the number of psychological and physical symptoms subjects reported. None of their physiological measures predicted illness. However, many of the physiological variables interacted with the experience of hassles in predicting illness. The majority of these interactions indicated that physiological reactivity served a buffering role. The relationship between stress and illness was stronger for subjects showing high levels of physiological reactivity, or slower recovery, than for less reactive subjects.

The analyses reported here will attempt to replicate the findings of the earlier study. As well as heart rate reactivity this study also includes electrodermal measures not used by Gannon et al. (1989), and measures of habituation.

Following the recommendations of Finney et al. (1984), prior to the analysis all of the variables used in the regression analyses were converted to deviation scores, by subtracting their mean. The interaction terms used were the product of the deviation scores for the two variables.

For simplicity, only electrodermal measures taken from the non-preferred hand were used. For all of the tonic measures the increase from baseline to task provided an index of reactivity. Following Gannon et al. (1989) recovery was assessed by taking the lowest score during the recovery period. Recovery scores were calculated as difference scores from the level obtained during the

task, this was felt to be a better estimate than the difference from a pre-task baseline, which Gannon et al. (1989) used. Also analysed were the amplitude of the SCR produced to the first tone and the total number of responses produced over the series of twelve tones. Heart rate orienting was taken from the response to the first tone. Three components were identified, the largest deceleration of the first two beats post-onset, the largest acceleration during the second, third and fourth beats, and the largest deceleration during the last four beats studied. As earlier analyses had failed to demonstrate habituation of the HR orienting response, no estimates of HR habituation were included.

Each of the physiological variables studied was used to form a regression equation, together with the score on the LESS and the interaction between the LESS and the relevant physiological variable. The total score on the GHQ formed the dependent variable.

As expected, life events significantly predicted the amount of distress reported on the GHQ. Only in one analysis, when initial SCR amplitude was included, was the main effect of LESS scores non-significant.

In contrast to the earlier study, these analyses did produce some significant main effects of physiological reactivity. The size of the increase in SCL associated with the task predicted levels of disturbance ($t_{(29)}=2.42$, $p=.022$). Both HR reactivity and recovery produced main effects which approached significance (reactivity $t_{(35)}=1.89$, $p=.067$; Recovery $t_{(35)}=1.83$, $p=.076$). A large increase during the task and a larger subsequent decrease were associated with greater disturbance. The first component of the HR orienting response also predicted disturbance ($t_{(34)}=2.23$, $p=.033$), greater deceleration being associated with greater disturbance.

While Gannon et al. (1989) reported that the majority of their physiological variables produced a significant interaction with life event scores, such interactions only appeared in this study for the two parameters of tonic heart rate (reactivity $t(35)=2.76$, $p=.009$; Recovery $t(35)=3.08$, $p=.004$). These interactions were explored by performing separate regressions of LESS scores on GHQ scores for those above and below the median on each of the two physiological parameters. Subjects showing high and low levels of physiological activity did not differ significantly with regard to their mean scores on either the LESS or the GHQ. The follow-up analyses indicated a pattern consistent with a buffering role for physiological reactivity. With regard to HR reactivity, the results replicated the findings of the earlier study; Only for high HR reactors did life events scores significantly predict GHQ scores ($t(19)=4.89$, $p<.001$). Figure 56 displays this interaction.

For recovery a similar pattern emerged, subjects showing greater recovery showed a relationship between life events and illness ($t(,16)=4.71$, $p<.001$), subjects showing less recovery did not. This interaction is portrayed in figure 57. This is contrary to the pattern found by Gannon et al. (1989), they found rapid recovery to be associated with a buffering-like effect.

The measure of recovery used in this study was the decrease from the task value, whereas Gannon et al. (1989) used a pre-task baseline. Both measures will be vulnerable to contamination due to the size of the task-induced increase. However, this increase might influence the two indices in different ways. In order to investigate this possibility the analyses of the tonic physiological measures were repeated using raw scores from the task and the lowest score during the recovery period, rather than the relevant difference scores.

Figure 56: Interaction between HR reactivity and life events in predicting GHQ scores

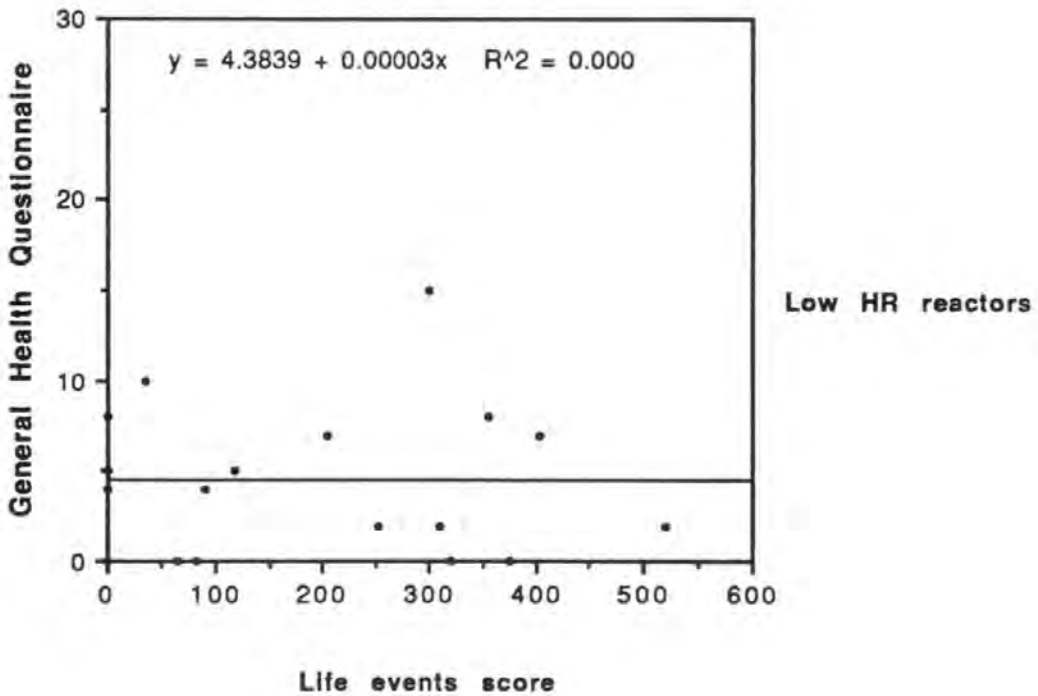
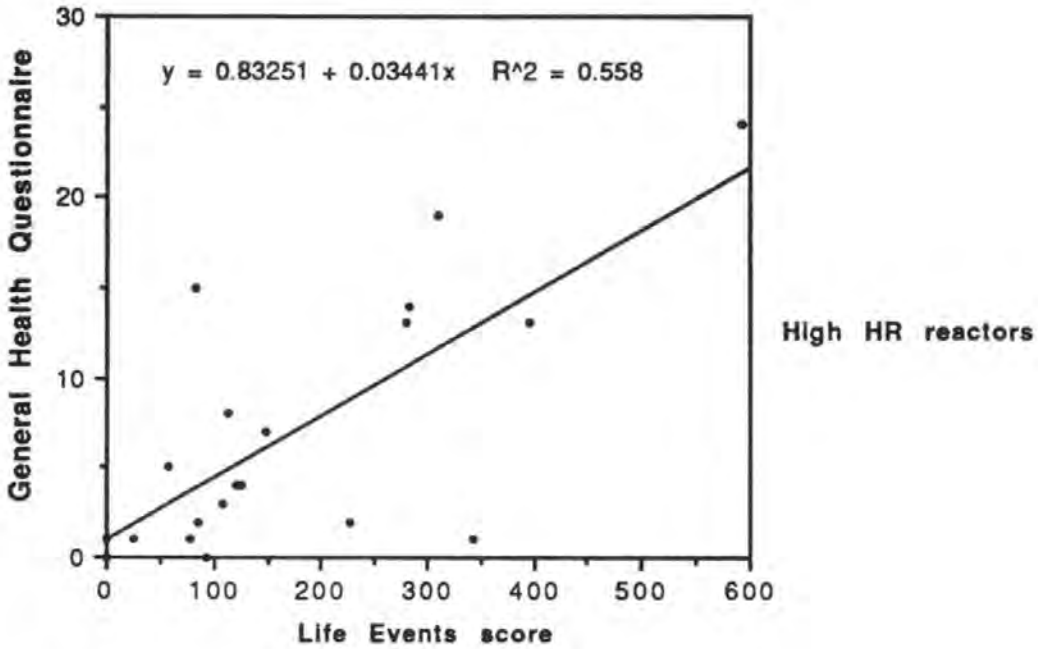
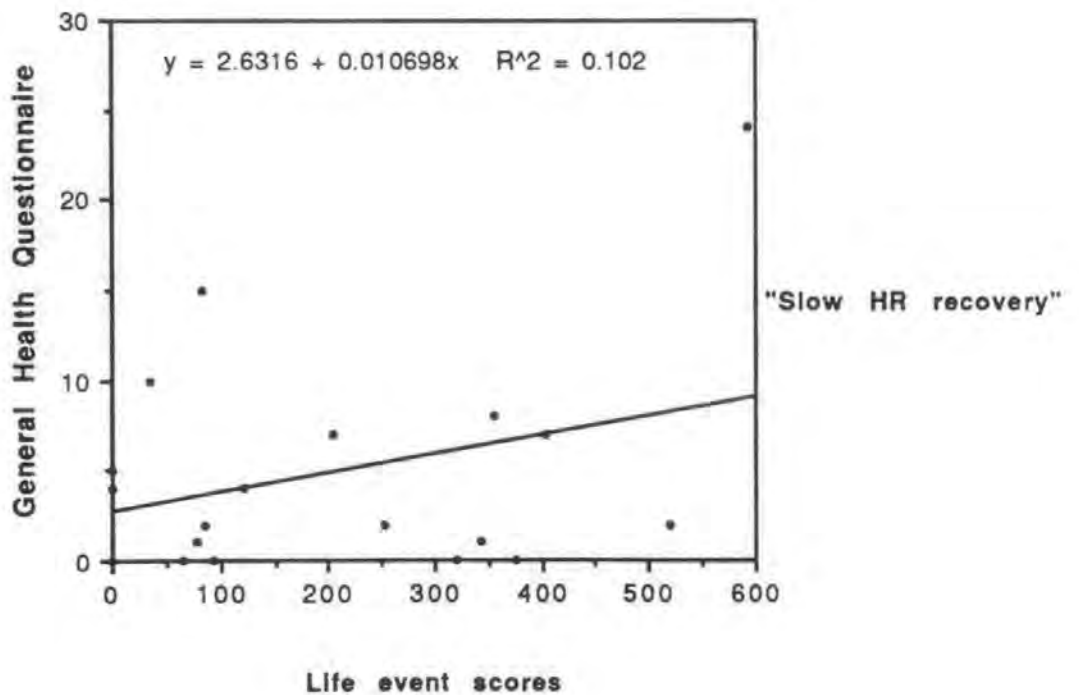
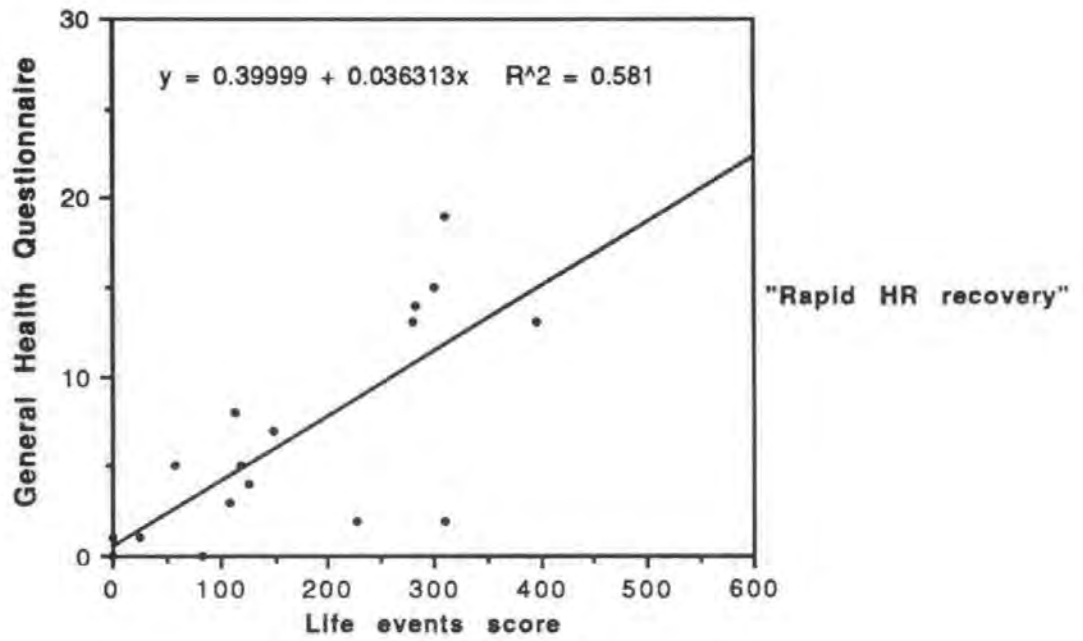


Figure 57: Interaction between "HR recovery" and life events in predicting GHQ scores



These analyses replicated the relationship between life event scores and illness. There were no main effects of physiological activity. Only one of the interactions between HR and LESS experience still appeared. The interaction between HR during the task and life event scores accounted for significant variance in GHQ scores ($t(35)=2.45, p=.020$).

Similar follow-up analyses were performed for this interaction. The pattern which emerged replicated the findings of the analysis of difference scores. For low-reactive subjects life event stress was only weakly related to disturbance ($t(17)=1.89, p=.077$). For highly reactive subjects there was a stronger link between reported stress and reported disturbance ($t(18)=2.24, p=.038$).

The absence of an interaction between HR recovery and LESS scores in these analyses can be explained quite simply. It seems that the interaction which occurred in the analysis of difference scores reflected the size of the initial increase during the task. Examination of the HR scores from the recovery period reveals that there was no apparent decrease over the course of the period. Rather, scores increased slightly. This implies that recovery was completed very rapidly, prior to the start of the recovery period. The "recovery" index used in the analysis of difference scores, therefore, was probably acting as a relatively pure measure of the size of the increase produced by the task. The analysis of raw scores removed the influence of the task and abolished the interaction. As Gannon et al. used a different task it is possible that recovery may have occurred more slowly and their recovery index may indeed have provided a better estimate of the speed of recovery.

The analysis replicated one of the findings of the earlier study. Heart rate reactivity does appear to mediate the relationship between

life event experience and psychological distress. The other measures included in this study did not appear to be involved in mediation of the effects of stress. Neither the measures of electrodermal activity, nor the habituation parameters interacted with the experience of life events.

Two physiological measures showed direct relationships with reported psychopathology. The size of the skin conductance response to the task predicted psychological distress. Greater reactivity being associated with higher GHQ scores. Greater initial HR deceleration to the habituation series was also associated with greater reported distress.

5.6 Relationships Between Different Measures

Finally, a set of analyses were undertaken examining the relationships between different measures. Of particular interest is the relationship between the PSI and measures of electrodermal habituation. Experiment one has already shown that the PSI does relate to other parameters of tonic EDA. The relationship between the PSI and parameters of phasic electrodermal activity has not yet been investigated.

Firstly, correlations were calculated between scores of the subscales of the POMS and GHQ and measures of physiological reactivity. Correlations were calculated with the mean levels of activity during the initial rest period, the digit-symbol task and the recovery period, as well as with initial SCR amplitude, the number of SCRs obtained during the habituation series and the three components of the HR orienting response. Correlations with measures of EDA were calculated using scores from the non-preferred hand. Very few of the correlations achieved significance. Given the number of correlations calculated, the number of significant results obtained is no more than would be predicted by chance.

Table 40: Correlations between mean levels of physiological activity
and temperature

		Room temperature	Skin temperature
	Rest period	.221	.166
PSI	Task	.157	.300*
	Recovery period	.277*	.096
	Rest period	.160	.309*
NS-SCRs	Task	.230	.292*
	Recovery period	.325*	.288*
	Rest period	.062	.178
SCL	Task	.089	.216
	Recovery period	.092	.185
	Rest Period	.241	-.002
HR	Task	.172	-.006
	Recovery period	.236	.111
	Initial SCR amplitude	.229	.301*
	Number of SCRs	.301*	.317*
	Primary HR deceleration	-.205	-.074
	Primary HR acceleration	.021	.225
	Secondary HR deceleration	-.465 ⁰	-.161

* $p < .05$, one-tailed

⁰ $p < .01$, two-tailed

The same physiological measures were also examined to see whether they were significantly related to life event scores. Of the seventeen correlations calculated, none were significant.

In order to examine the effects of temperature on the various physiological parameters correlations were calculated between room and skin temperature, measured at the start of the session, and each of the measures. Several of the parameters of EDA were significantly related to temperature, the only exception being SCL. Heart Rate was less responsive to temperature, only one significant correlation emerged. The size of the secondary deceleration to the orienting tones was proportional to room temperature. These correlations are displayed in table 40.

Correlations were also calculated between the physiological measures. All of the measures of tonic electrodermal activity showed high inter-correlations. These correlations were only slightly reduced when measures taken at different times were compared. This is further evidence for relative stability in the amount of EDA shown. Correlations between electrodermal measures are shown in table 41. As in experiment one, the PSI was the only measure of palmar sweating found to correlate with HR. Mean PSI scores during the initial rest period correlated significantly with HR at the same time and with HR during the task ($r=.306$ and $.347$ respectively, both $p<.05$, one-tailed).

Measures of tonic EDA were found to correlate with both amplitude and resistance to habituation of SCRs. Heart rate orienting, in contrast, seemed largely unrelated to tonic measures, whether EDA or HR. The only apparent relationship was a link between the secondary deceleratory component of the HR-OR and non-specific response rates.

Table 41: Correlations between different parameters of EDA

		PSI			SCL			NS-SCRs		Initial	Number
	Task	Recovery	Rest	Task	Recovery	Rest	Task	Recovery	SCRamp	of SCRs	
PSI	Rest	.400**	.682***	.514***	.435**	.475***	.757***	.235	.493***	.223	.582***
	Task		.393**	.190	.223	.180	.313*	.474**	.316*	.323*	.409**
	Rec.			.456**	.411**	.495***	.545***	.188	.654***	.251	.625***
SCL	Rest				.943***	.948***	.639***	.326*	.501***	.467***	.484***
	Task					.976***	.542***	.414**	.499***	.579***	.498***
	Rec.						.566***	.331*	.587***	.497***	.520***
NS-SCRs	Rest						.403**	.651***	.482***	.491***	
	Task							.464***	.437**	.330*	
Initial SCRamp	Rec.								.332*	.501***	
	Task									.456**	

* p<.05, one-tailed
 ** p<.01, one-tailed
 *** p<.001, one-tailed
 Rec. =recovery period

Higher NS-SCR rates during the task and the recovery period were associated with greater secondary deceleration ($r = -.396$ and $-.303$ respectively, both $p < .05$ one-tailed). HR orienting was related to skin conductance orienting. The acceleratory component of the HR-OR was significantly correlated with the amplitude of the SCR produced to the first tone ($r = .414$, $p = .004$, one-tailed). The initial deceleration from the HR-OR was significantly correlated with the two later components, in both cases greater initial deceleration was associated with smaller acceleration and greater secondary deceleration ($r = .453$ and $.693$ respectively, both $p < .01$, one-tailed).

In addition to comparison of mean scores on each of the measures of electrodermal activity, correlations were calculated between individual values at each of the points of measurement. Following the procedure used in the analysis of experiment one, these were expressed both as between-subject correlations, correlations being calculated between simultaneous measures for all subjects, and as within-subject correlations, one correlation being calculated for each subject comparing all of the measures taken in sequence. These correlations are displayed in tables 42 and 43. It is apparent that the PSI is more strongly related to NS-SCR frequency than to SCL.

Correlations were also calculated between measures obtained from the two hands. Previous analyses revealed significant differences between the two hands with regard to their levels of electrodermal activity. For this reason the degree of similarity between measures recorded from the two hands is of more than academic interest. Between- and within-subject correlations between the hands for each of the measures of sweat gland activity are displayed in tables 44 and 45.

Table 42: Between-subject correlations between
measures of sweat gland activity

Mean correlation between	
PSI and SCL	.414***
PSI and NS-SCR frequency	.614***
SCL and NS-SCR frequency	.544***

*** mean differs from zero, $p < .001$, one-tailed

Individual correlations over .275 are significant at $p < .05$, one-tailed

Table 43: Within-subject correlations between
measures of sweat gland activity

Mean correlation between	
PSI and SCL	.439***
PSI and NS-SCR frequency	.513***
SCL and NS-SCR frequency	.434***

*** mean differs significantly from zero, $p < .001$, one-tailed

Individual correlations over .521 are significant at $p < .05$, one-tailed

Table 44: Between-subject correlations between electrodermal measures
taken from different hands

Mean inter-hand correlation for

The PSI	.665***
NS-SCR frequency	.712***
SCL	.658***

*** mean differs from zero, $p < .001$, one-tailed

Individual correlations over .275 are significant at $p < .05$, one-tailed

Table 45: Within-subject correlations between electrodermal measures
taken from different hands

Mean inter-hand correlation for

The PSI	.555***
NS-SCR frequency	.773***
SCL	.815***

*** mean differs significantly from zero, $p < .001$, one-tailed

Individual correlations over .729 are significant at $p < .05$, one-tailed

These correlations are for the resting measures obtained before and after the task. As the task involved writing, PSI scores were only obtained from one hand during the task. It was also felt that the effects of movement might artificially reduce correlations involving the task. In practice, however, inclusion of task measures slightly elevates the correlations for SCL and NS-SCRs, due to the increased range of activity covered.

In order to clarify the relationship between the PSI and the other measures three regression analyses were carried out, examining the extent to which the other variables were independently related to the PSI.

For three periods, mean levels of SCL, mean NS-SCR frequencies and mean heart rates, as well as initial SCR amplitudes, total number of SCRs produced and the three components of the initial HR-OR were entered into a stepwise regression analysis, with mean scores on the PSI-A as the dependent variable.

In the analysis of the first rest period current NS-SCR frequency was the best predictor, accounting for 58% of the variance in PSI scores. The only other predictor was current HR, taking the proportion of the variance accounted for up to 66%.

When task measures were analysed, only the amplitude of the initial SCR was independently related to mid-task PSIs. SCR amplitude explained 27% of the variance in the PSI. While resting levels of palmar sweating appear to be closely related to other autonomic measures, it seems that the task produced more response specificity.

Levels of palmar sweating during the recovery period were strongly related to current rates of NS-SCRs. NS-SCR frequency accounted for 51% of the variance in PSI scores. Measures of electrodermal orienting also made an independent contribution to the

equation. The number of responses produced during the habituation series added 10% to the proportion of variance accounted for and initial SCR amplitude added another 5%. The three variables together accounted for 66% of the variance in PSI scores.

Because of the clinical interest in criteria such as electrodermal non-responding. The relationship between electrodermal responsivity and scores on the PSI was further examined. Given the evidence that the PSI does correlate with the number of responses produced during the habituation series, it might be possible to use the PSI to select groups corresponding to the groups of non-responders and/or non-habitators commonly investigated in clinical research into the psychophysiology of schizophrenia.

Figures 58 and 59 are scatterplots of the joint distributions of mean scores on the PSI taken during the two rest periods and the number of trials taken to reach a criterion of three successive non-responses. Both measures were calculated from scores for the non-preferred hand only.

It can be seen that for both of the resting PSI scores a cut-off point of 23 would identify all of the non-responders and fast-habitators (fast habitators being defined as subjects who responded on the first trial only). Non-habitators seem less consistent with regard to their PSI scores, although just over half of those who had not reached the criterion by the end of the series had PSI scores over 48.

As figure 60 shows, the levels of sweat gland activity during the task were less indicative of habituation rates. As the correlational analysis had indicated, the task appears to produce a PSI response which is much less reflective of general electrodermal responsivity than are resting measures.

Figure 58: Scatterplot of resting PSI scores against trials to habituation

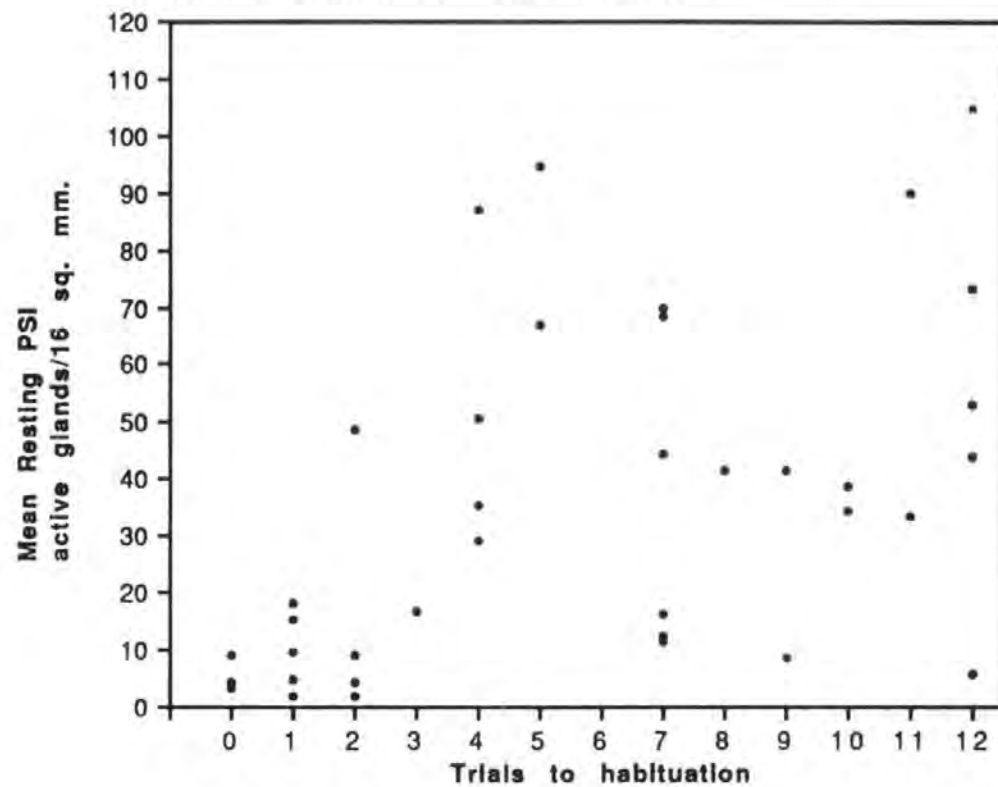


Figure 59: Scatterplot of PSIs during the recovery period against trials to habituation

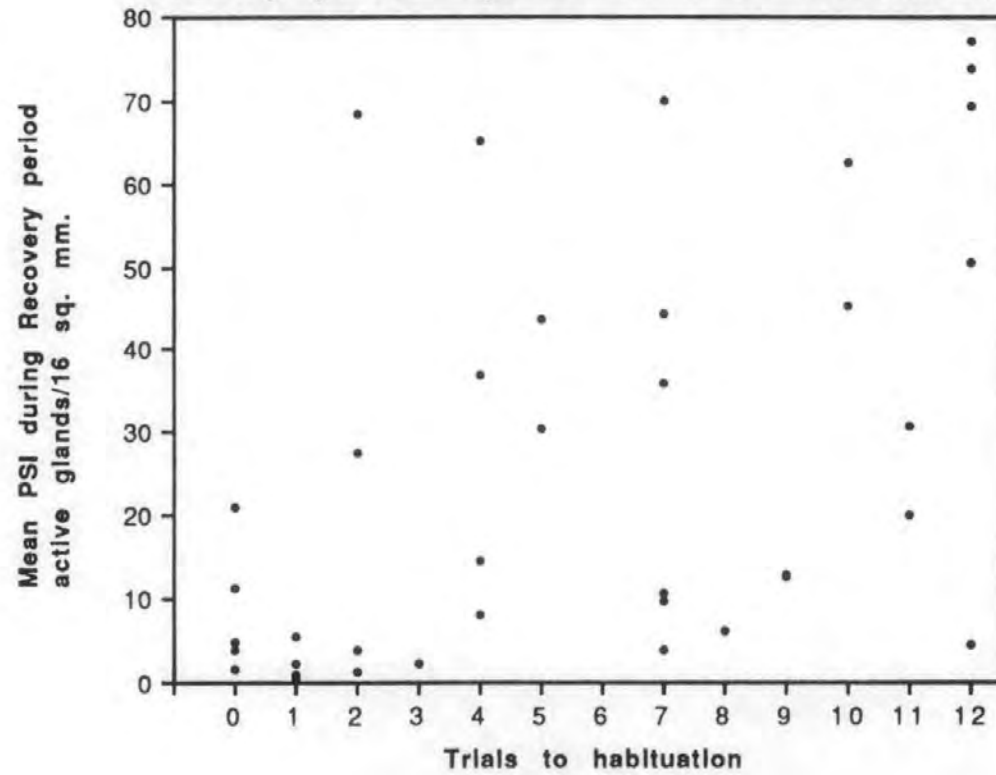
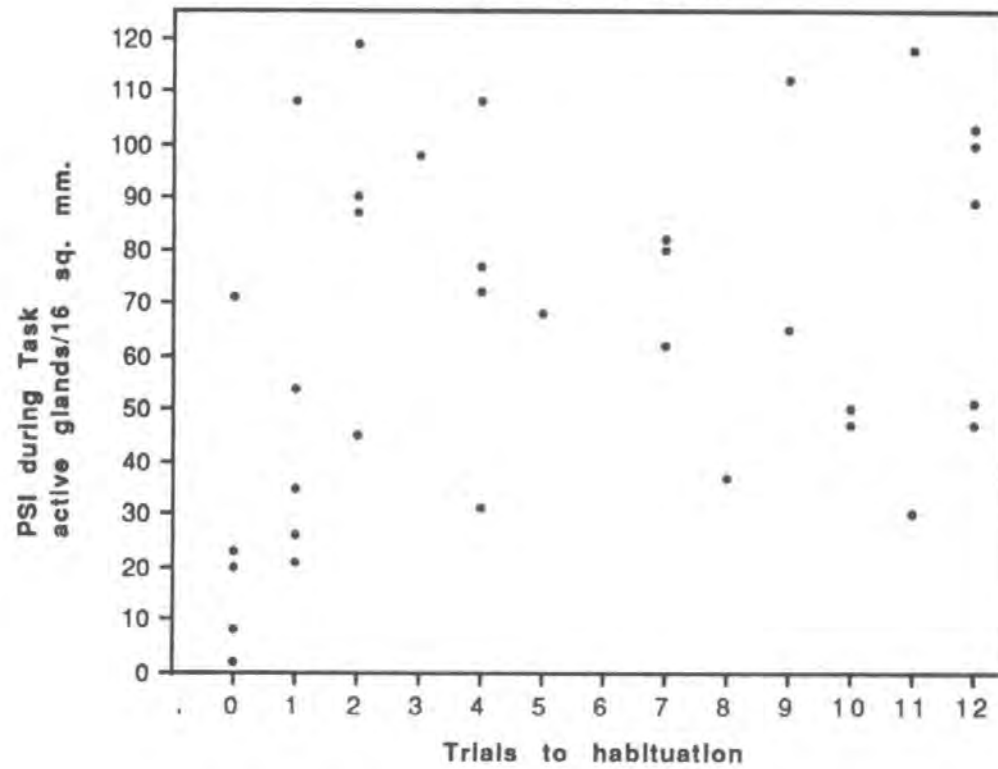


Figure 60: Scatterplot of mid-task PSIs against trials to habituation



The study provides support for the validity of the PSI as an alternative to measures of electrodermal activity. In particular, PSI scores in the last rest period were related to both current NS-SCR frequency and, independently, to resistance to habituation. This implies that the PSI may provide an index of electrodermal lability.

6 Summary of Results from Experiment Four

These results imply that self-reported, retrospective life-events seem to bear few associations with tonic physiological activity, but may be related to phasic responsivity.

The results seem to provide very little support for a difference in the rates of habituation of the three groups. The three groups did appear to differ with regard to the form of their heart rate responses to the tones. The tendency for greater deceleration in the "low" group is consistent with predictions. There was, however evidence for differences in electrodermal laterality between the groups.

The results indicating that heart rate reactivity may be a mediating factor between life event stress and psychological distress replicate earlier findings. The electrodermal measures studied, as well as aspects of habituation, did not seem to play any mediating role. There was evidence that skin conductance responsivity and heart rate orienting might be independently related to psychological disturbance. In common with most research in the life events field, this study was correlational in design. Clarification of the causal significance of the relationships observed must await further, prospective studies.

This study has provided further support for the use of the PSI as an alternative to electrodermal measures of sweat gland activity. The study replicated the findings of experiment one, that the PSI does

correlate highly with measures of tonic electrodermal activity. This study also demonstrates that scores on the PSI also predict levels of electrodermal responsivity in an orienting paradigm. Also apparent, was the weak relationship between the PSI and levels of heart rate found in experiment one.

7 Analysis of the Life Events Data From Experiment One

The Life Events Scale for Students was also completed by subjects in experiment one. This provides a larger data set with which to examine the relationships between life event stress, physiological reactivity and psychological disturbance. In addition, subjects in experiment one were asked to indicate when events had happened. This will allow a preliminary examination of the time course of any effects of stressful life events. While it is usual to summate the scores of events occurring at different times, there is some evidence to indicate that inclusion of the timing of events may strengthen the predictive power of life event scales. Surtees & Ingham (1980) found that a model including a fixed rate of decay of adversity provided a better fit than the usual summation model, when predicting levels of psychopathology.

Figure 61: The distribution of reported life events over time

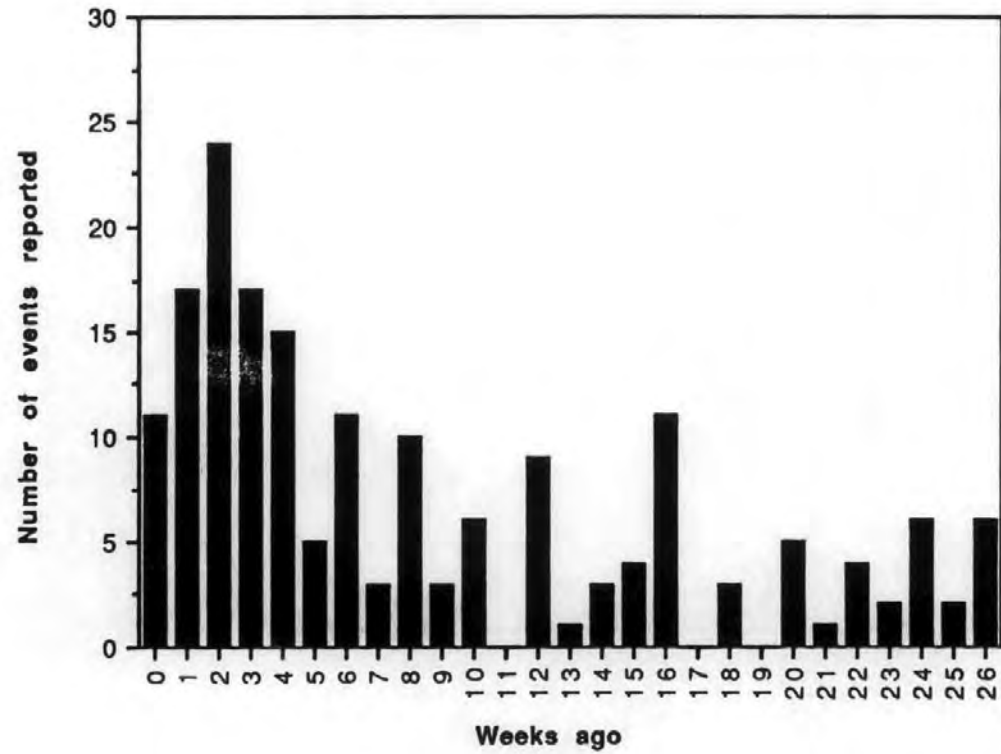
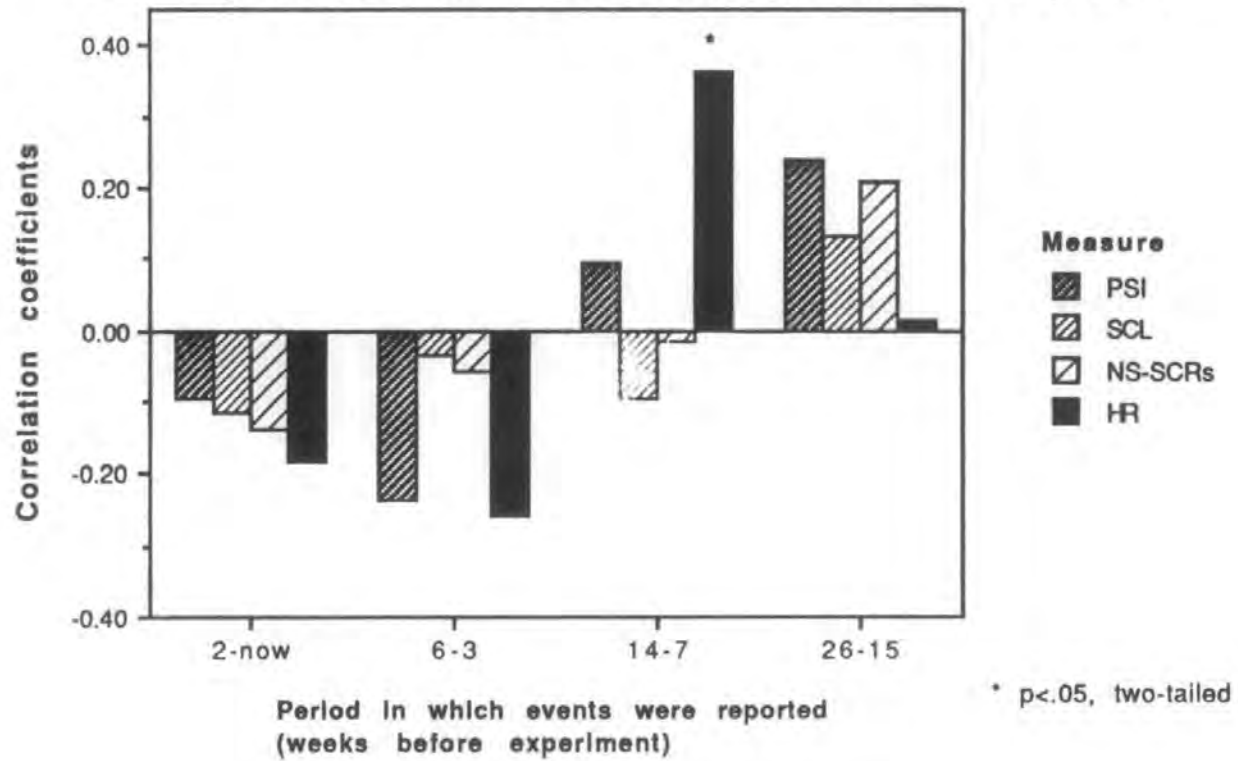


Figure 62: Correlations between life event scores and physiological measures during the first rest period



The distribution of life events is shown in figure 61. The number of events reported falls off with passing time, consistent with the effects of forgetting. The fall-off after the first month is particularly sharp, .8 fewer events (62%) being reported between five and eight weeks ago than were reported one to four weeks ago. Over later weeks the rate of forgetting is more moderate, averaging just under 1% per four week period.

For the purposes of the analysis, events were grouped into four time windows. These windows were not equal in length, rather they were chosen so as to include roughly equal numbers of events, and to ensure that each window contained a reasonable number of subjects who had experienced events. Roughly half of the 57 subjects who completed the LESS had experienced one or more events in each of the windows. Correlations were calculated between the cumulative life change scores in these four windows and levels of physiological activity during the initial rest period of experiment one.

Only one correlation was significant. Heart Rate during the rest period was positively related to life event scores for the period 7 to 14 weeks before the experiment. Surprisingly, correlations between HR and life events in the two earlier windows were negative, and the correlation between HR and events in the second window just missed significance ($p=.052$, two-tailed). A similar reversal in the direction of the correlations is also apparent for the electrodermal measures. Correlations between life event scores and the physiological variables are displayed in figure 62.

The number of correlations calculated, together with the lack of consistency in the relationship observed must raise the suspicion that the correlation between HR and life event scores may represent a type one error. There is, however, an alternative explanation. The

interpretation of these correlations needs to take account of the conditions of experiment one. While 57% of the subjects were run in two months, the experiment extended over six months. As the data includes measures collected over a relatively wide time span, these correlations may be elevated by chance temporal associations. Correlations between physiological activity and events falling in a narrow window might represent the temporal relationship between events in the student calendar, such as exams or vacations and external factors such as meteorological changes.

Further correlations were calculated between scores on the Profile Of Mood States, taken after the initial rest period, the Beck Depression Inventory and life events. None of the correlations between the POMS scales and Life event scores were significant. The Beck Depression Inventory correlated only with events falling in the most recent time period, covering the preceding two weeks ($r=.324$, $p=.016$, two-tailed). This correlation is in the predicted direction, and seems consistent with the other correlations between the BDI and life event scores, which were smaller (around .17) but all positive. However, no relationship emerged between the POMS Depression-dejection scale and life events. Once again, in view of the large number of correlations calculated little confidence can be placed in the one significant result observed.

Correlations were also calculated between life events scores and the mean levels of physiological activity during the first task period and during the following rest period. These analyses, however, are potentially confounded by the effects of the task. An analysis of the cumulative scores for the last six weeks, preparatory to the analysis reported below, revealed a significant interaction between condition and feedback.

Table 46: Life events scores for the groups of experiment one

		Task	
		Easy	Difficult
	Negative	40.11	62.71
Feedback	None	136.60	49.00
	Positive	57.91	62.64

Life Event scores (Life change units) for the preceding six weeks

As can be seen from table 46, subjects in the easy task/no feedback group had higher average life event scores than other subjects. As the combination of an easy task with no feedback is arguably the least stressful group, this confound is unlikely to produce a positive correlation between life change scores and experienced stress. Negative associations may be suspect however.

Levels of heart rate during the task and in the following rest period showed a significant relationship with events 7 to 14 weeks ago (HR during the task $r=.261$, $p=.05$; Resting HR $r=.359$, $p=.006$, both two-tailed). When data from the second rest period were examined, the negative relationship between HR and life events in the second window, covering the period 3 to 6 weeks before the experiment was also significant ($r=-.409$, $p=.002$, two-tailed). A non-significant trend in this direction was also observed in the previous analysis.

To summarise, the correlations reveal little stability with regard to the relationship between life events and physiological reactivity. Only for HR did a significant relationship emerge and there was evidence of a change in the direction of the relationship between the two around 6 weeks after events occurred. The unstable

nature of these relationships, and the very small number of significant correlations obtained, must lead to the suspicion that they are due to external factors, or represent type one errors, rather than reflecting any causal relationship.

A final series of regression analyses were undertaken to examine the possible mediating effects of physiological reactivity on the stress-illness relationship. Scores on the Beck Depression Inventory formed the dependent variable for these analyses. As in the comparable analyses of the data from experiment four, the highest level during the task and the lowest level during the recovery period were used as indices of reactivity and recovery for each of the physiological measures. These indices were calculated as difference scores from the mean value of the preceding period.

These analyses revealed only a weak relationship between stress (the life event scores for the past six weeks) and illness. Only in one analysis (including heart rate recovery) did the main effect of stress approach significance ($t(51)=1.77$, $p=.083$). Unexpectedly, none of the interactions between stress and physiological responsivity were significant.

Out of the physiological variables only one gave any indication of a significant main effect. The relationship between heart rate reactivity and depression just missed significance ($t(51)=2.00$, $p=.051$). The relationship was negative, smaller HR increases being associated with greater depression. This might be expected given the negative relationship with life event scores noted in earlier analyses.

The use of a smaller time period for event sampling might have obscured the relationship between events and the other variables studied. By studying events which fell within a short period of time,

single events are granted greater importance. This might cause the results to be distorted by chance temporal relationships. The analysis of the life events data from experiment four studied life event scores obtained from a four month period, so that the presence or absence of a single event would be less likely to influence the results.

In order to investigate this possibility, the regression analyses were repeated using cumulative life event scores from the total period studied (six months). This made little difference to the conclusions obtained. The majority of the analyses still did not indicate that life events were predictive of depression. Only two analyses produced such an indication. When the increase in NS-SCR frequency due to the task was included, stress was predictive of BDI scores ($t(51)=2.15$, $p=.036$). When HR recovery was included there was also a trend in the same direction ($t(51)=1.91$, $p=.063$).

When events were sampled over a longer time period the negative relationship between HR reactivity and depression was significant ($t(51)=2.25$, $p=.029$). For both the PSI and NS-SCR rates there were indications of a relationship between recovery rates and depression (PSI-A, $t(51)=1.75$, $p=.086$; NS-SCRs, $t(51)=1.82$, $p=.075$). In both cases, smaller decreases in activity after the task were associated with greater reported depression.

In summary, the conclusions of this analysis are rather different from those from the analysis of experiment four. In that experiment there was evidence for a buffering role of cardiovascular reactivity but only weak evidence for a direct effect of life event stress on physiological reactivity. This analysis, in contrast, did not reveal the expected interaction between life events and heart rate reactivity in predicting levels of depression. There was, however some weak evidence of differences in tonic physiological activity in association

with differences in life events experienced.

8 Discussion

The research reported in this chapter had three main aims. Firstly, the research was intended to form a partial replication of the study by Pardine & Napoli (1983), examining the effects of life events on physiological activity. The discussion will review the evidence obtained on this point and consider possible explanations for the findings. Secondly, subsidiary analyses examined whether electrodermal or cardiovascular reactivity acted as mediators of the stress-illness relationship. The conclusions from these analyses will be presented. Finally the study examined the relationship between the PSI and various parameters of electrodermal activity. The possible implications for the use of the PSI as an alternative to EDA will be considered.

8.1 Life Events and Physiological Activity

The analyses of physiological variables revealed few straightforward differences in physiological reactivity between groups differing with regard to life event scores. There were indications on several measures of electrodermal activity that the groups might differ with regard to some aspect of electrodermal laterality. Triple interactions between Group, Time and Hand of measurement, which occurred for both the PSI and NS-SCR frequency during the initial rest period, were not explicable. However, there were clear indications of differences in skin conductance between the groups in the later stages of the experiment. The "Low" group showed larger SCR amplitudes in the right hand, whereas the two groups reporting higher life event frequencies responded similarly in both hands. These differences were

paralleled by apparent differences in baseline SCL. Several analyses gave indications of differences in SCL between the groups subsequent to the habituation series. These analyses indicated that the "Medium" group, and to a lesser extent the "High" group, showed greater lateralisation.

In general, HR did not discriminate between the groups, while there were indications of some differences in both habituation and recovery, these did not appear readily explicable. The task used in this experiment does not appear to have produced sufficient HR response. HR recovery appears to have been completed more rapidly than expected, with the consequence that the measure of HR recovery used does not appear to adequately reflect recovery.

The habituation data appear to reveal weak differences between the groups. On skin conductance measures there were no apparent differences in response amplitude or habituation, but a difference in laterality did emerge. The tendency toward reduced right hand dominance with increased stress was unexpected. This might be explained in terms of the levels of depression reported by the "high" group. There is some evidence (reviewed in chapter four) to indicate that clinical depression is associated with higher levels of EDA in the left hand. However, explanation of the current findings in terms of such an effect requires a string of tenuous assumptions. The evidence from clinical studies is far from conclusive, and it must be questioned whether clinical depression bears any relationship to the levels of depression found in this study. Furthermore, differences in SCL appeared to be in the opposite direction, with the "low" group showing reduced right hand dominance. This shows an apparent dissociation between tonic and phasic activity with regard to the laterality of EDA. It is possible that this might represent an effect

of the law of initial values, higher levels of baseline activity being associated with lower responsivity.

The presence of an interaction between stress and hand of measurement for SCR amplitude, and the indications of such an effect for skin conductance level, may have implications for research using skin conductance measures. Had SCL been assessed unilaterally this effect would not have been observed. Such an interaction seems to imply, however, that the findings from studies using unilateral measurement could depend upon which hand was studied. These effects seemed to be largely confined to skin conductance measures. This seems to imply a partial dissociation between skin conductance measures and other parameters of EDA. While differing patterns of laterality might be explained by passive properties such as epidermal thickness. The interaction with experienced stress seems to support a functional difference between conductance-based and other parameters of EDA.

Measures of heart rate orienting were indicative of some differences between the groups. Unfortunately these differences failed to achieve acceptable levels of significance. There was an indication of larger decelerative responses in the "low" group. This finding is in the predicted direction, as it would be expected that the groups experiencing higher levels of stress might show a greater tendency towards defensive rather than orienting responses, with a greater tendency towards accelerative rather than decelerative responses. There was also an indication that the groups might differ with regard to some aspect of their habituation, although the nature of this difference was unclear, and it, too, failed to reach significance.

The study did not provide evidence for the habituation of the HR response to the tones. Only skin conductance responses were shown to diminish with repeated presentation. Other workers have claimed that

the decelerative component of the HR response may not show habituation (Barry, 1987; Vossel & Zimmer, 1989), although such claims are strongly contested (Siddle & Turpin, 1987; Simons, 1989; Turpin, 1989b). The procedure used in this study to identify separate components of the HR-OR is not ideal. The low temporal stability of the components chosen reflects the limitations of the procedure used. While low reliability might explain the absence of any evidence of habituation in the analysis of separate components of the HR-OR, habituation also failed to appear in the analysis of beat-by-beat HR. In the absence of any clear evidence of habituation it is not too surprising that no significant inter-group differences in habituation were found.

The analysis of the life events data from experiment one produced a number of differences from the similar analyses of experiment four. Some significant relationships were found between physiological activity and the experience of life events. Events occurring several weeks before the experiment were predictive of higher heart rate. When recent events were studied, life event stress appeared to be predictive of lower physiological activity. The unstable nature of the relationship observed may indicate that the few significant correlations found are, in fact, type one errors. In addition, the examination of life events falling within a narrow window may lead to artifactual relationships being observed due to chance temporal associations.

Set against this evidence that the results might be confounded is the larger sample size used in the second investigation. The concentration on more recent events might also strengthen the relationship between life events and any physiological response. Although this increase in sensitivity might be at the cost of an

increase in vulnerability to spurious associations.

The apparent change in the direction of the relationship between events and physiological activity with increasing time since the event might also explain why no effect is seen if events are summed over too long a time period.

The life event scale used seems to show acceptable external validity. As expected, higher rates of life events were associated with higher levels of reported psychological disturbance. Less predictably, the two extreme groups showed lower levels of trait anxiety. While this may well be due to random selection, it is possible that trait anxiety may be linked to life event experience in some way.

Three possible pathways suggest themselves. Firstly, trait anxiety may play a causal role in the occurrence of stressful life events. The experience of certain events may be partly determined by individual's lifestyles, which, in turn, may be influenced by personality factors. Specifically, high levels of trait anxiety may predispose individuals to experience moderate levels of stress. Perhaps trait anxious individuals avoid situations likely to produce severe stress, thereby experiencing fewer major events. However, the higher levels of state anxiety experienced by individuals high on trait anxiety may be disruptive, causing higher rates of more minor events.

Another possible explanation for the association between moderate levels of life events and higher trait anxiety is that trait anxiety might influence the reporting of life events. Watson & Pennebaker (1989) suggest that reported correlations between ill health and life events may be partly due to negative affectivity. Individuals scoring highly on this trait, closely related to trait anxiety, being more

likely to attend to negative events and experiences. Subjects may therefore report both high levels of stress and poorer health because of response bias. If, as they suggest, trait anxious individuals are more likely to report stressful events, then this might well produce moderate scores on the LESS. It seems likely that selective recall is more likely to affect the report of more minor events, such as arguments, than the reporting of major events such as car crashes or bereavement. Major events depend to a lesser extent on interpretation than minor events, and are also less likely to be forgotten or over-looked. The result of this sort of distortion, therefore, might be to move highly trait anxious subjects into the moderate range of life event scores, rather than to produce very high scores.

Alternatively, life event stress may influence individuals' levels of reported trait anxiety. High levels of life events were found to produce high levels of depression on both the GHQ and the POMS, as well as higher GHQ Anxiety and insomnia scores. However, moderate levels of life events might also have psychological consequences. The relatively severe stress experienced by the "high" group might lead to some degree of "giving up" and consequent depression. The less severe stress experienced by the "medium" group is more likely to be within an individual's ability to cope. However, the effort of coping with moderate events might produce more subtle psychological effects, particularly on scales such as the STAI trait scale which assess enduring patterns of behaviour.

For these reasons, it would be unjustified to assume that trait anxiety is, necessarily, just a confounding variable to be controlled for. The relationship between the experience of life event stress and the physiological and psychological consequences of the stress is inevitably complex and many factors are likely to mediate the

relationship.

8.2 Physiological Activity as a Mediator Between Stress and Distress

The expected interaction between heart rate reactivity and life events emerged. The study successfully replicated the findings of Gannon et al. (1989). Similar relationships did not emerge for the measures of electrodermal activity. For reasons discussed above, an interaction between HR recovery and life events was not found.

The size of the skin conductance response to the task did appear to independently predict levels of psychological distress. While EDA did not enter into the sort of interaction described by Gannon et al., it seems that EDA may be directly related to reported distress. As skin conductance measures were obtained only from the non-preferred hand in this analysis, it is possible that this relationship may be secondary to the inter-group differences in laterality noted in some earlier analyses. However, it should be noted that such a difference did not emerge in the analysis of difference scores, which were used in the regression analysis. Furthermore, the direction of the difference would need to be opposite to that noted in the tonic measures. In the analysis of SCL the "Low" group showed less right hand dominance, which might lead one to expect a negative relationship between left hand levels and disturbance. The relationship found here, in contrast, was for greater left hand reactivity to be associated with greater disturbance.

The size of the initial HR deceleration was also related to reported distress. It is unclear why such a relationship should appear for the primary deceleration and not for the secondary deceleration, as both components are thought to form part of the OR (Graham & Clifton, 1966).

When a similar analysis was attempted on the data from experiment one, the conclusions were different. Life events were not significantly related to reported depression. Furthermore, no interactions between physiological reactivity and life events emerged.

There were a number of differences between the data from experiment one and that from experiment four which might explain the different results. One of the main differences is the nature of the task used. The manipulations of feedback and task difficulty in experiment one confound the interpretation of task-induced increases as pure measures of reactivity. Whereas all subjects in experiment four undertook the same task, this was not the case in experiment one. This increase in variance unaccounted for is probably sufficient to explain the absence of any buffering effect in the regression analyses. The uneven distribution of life events across the feedback and difficulty conditions of experiment one might also have distorted the results obtained. The absence of a relationship between life events and psychopathology in experiment one may be a result of the different measures used in the two analyses. The analysis of experiment four used the total score from the GHQ as an index of psychopathology, whereas this analysis used the BDI. Life events may be primarily related to one of the other types of psychopathology measured by the GHQ.

B.3 The Relationship Between the PSI and EDA

Further support was provided for the use of the PSI as an alternative to electrodermal measures. The PSI correlated acceptably with both SCL and NS-SCR rates. Evidence was also produced for a relationship between resting scores on the PSI and indices of phasic responsivity. The PSI seems likely to correlate with indices of

electrodermal lability, as it correlates independently with both of the components of this construct.

It may be possible to use the PSI to select electrodermally non-responsive subjects in clinical trials. Evidence will be produced concerning this possibility in a later chapter.

As in experiment one, a weak relationship was found between the PSI and heart rate. Similar correlations did not emerge for the parameters of EDA studied. Such a relationship might be expected given the involvement of sympathetic activation in contributing to the activity of both physiological systems. It is still unclear why the relationship appears stronger for the PSI than for electrodermal measures.

B.4 Conclusion

Experiment four provided further support for the use of the PSI as an alternative to electrodermal measures of sweat gland activity. There is rather less evidence for an effect of life event stress on physiological reactivity. This result, while disappointing, may clarify the results of experiment three. The failure of that study to demonstrate significant effects of examination stress on the PSI might be due to the relatively weak nature of the effects themselves, rather than the methodological short-comings of the study.

The evidence for a potential buffering role of HR reactivity is of great interest and worthy of further investigation. In order to clarify the relationship it would be necessary to undertake a prospective investigation, assessing reactivity prior to the experience of stress.

Chapter 11

Experiment Five: The Effects of the Presence of an Experimenter on Physiological Activity

1 Introduction

Previous studies provided some support for the use of the PSI as an alternative to electrodermal activity. When taken simultaneously, the two measures correlate highly. However, the PSI may not be interchangeable with skin conductance measurement. The PSI requires the experimenter to interact with the subject to a limited extent. Electrodermal activity, in contrast, can be assessed while the subject is alone. Work on audience effects, some of which has used the PSI (e.g. Cohen, 1979), indicates that the presence of the experimenter might lead to elevated levels of sweat gland activity.

Studies which have examined the effects of an audience on the PSI were reviewed in chapter three. Several studies found increased levels of palmar sweating in the presence of an audience, particularly when the audience was described as evaluating a subject's performance. It seems likely that subjects in an experiment will suspect that their performance is being evaluated when the experimenter is in the same room. Thus it is possible that the use of the PSI might lead to an increase in arousal or anxiety, with a corresponding increase in the values of autonomic activity recorded.

Surprisingly little research has examined the effects of an audience on measures of electrodermal activity. Several studies have found no effect of an audience on the skin conductance level of subjects working on cognitive tasks (Borden, Hendrick & Walter, 1976; Geen, 1979; Henchy & Glass, 1968). The study by Geen (1979) did find

increased SCR frequency in subjects working in the presence of an experimenter, but only for those subjects who had experienced failure on a prior task. Those subjects who showed increased EDA in the presence of the experimenter were, therefore, those most likely to be anxious about their performance and to be worried about possible evaluation.

Work on public-speaking anxiety, reviewed in chapter eight, indicates that giving a talk to an audience leads to increased activation on a number of measures. A study by McKinney, Gatchel & Paulus (1983) found that differences in the size of the audience had no effect on the size of the response to speaking, implying that it is the task, rather than the audience, which is primarily involved in producing increased activation. However, this study's findings are confounded by the absence of a true no-audience condition, all subjects being observed by the experimenter.

A recent study by Cacioppo et al. (1990) examined the effects of observation on subjects not performing a task. Subjects were ostensibly waiting while the experimenter calibrated equipment prior to an experiment. Half of their subjects believed the experimenter could see them, half believed they were unobserved. Tonic levels of physiological activity were unaffected by observation. However, the skin conductance response to an innocuous tone was larger in those subjects who believed that they were being observed. Cacioppo et al. interpret their results in terms of an increase in reactivity, rather than arousal, as a result of observation. Their findings lead them to conclude that increased reactivity is a function of the increased potential for punitive outcomes from the situation. The effect of observation by a stranger is to increase the possibility of negative outcomes, such as embarrassment. This is consistent with the

literature using the PSI, which seems to indicate that it is evaluation apprehension rather than mere presence which is necessary for increased palmar sweating to occur.

This study suggests that the presence of the experimenter might lead to a larger response to a stressful task, but that levels of activity at rest might be insensitive to the experimenter's presence. If it is reactivity, rather than tonic arousal, which is increased by observation, then skin conductance response frequency might be a more sensitive measure than skin conductance level. This is consistent with the literature examining the effects of an audience on electrodermal measures. Only one study examined skin conductance response frequency (Geen, 1979), and that study did find an effect of an audience, although only in conditions where evaluation apprehension was likely to be elicited.

Work conducted within a different framework implies that, under some circumstances the presence of others might lead to reduced EDA. Schachter (1959) noted that people who are afraid show an increased desire for affiliation. He suggested that the presence of others might be capable of reducing fear. Several studies which have examined the effects of companions on physiological measures presumably related to fear, including EDA, have shown that the effect of a companion is critically dependent on the situation. Several studies indicate that only when the situation involves potential embarrassment does social presence lead to increased EDA (Buck & Parke, 1979; Glass, Gordon & Henchy, 1970; Friedman, 1981). Studies which have used shock to induce fear have found that the presence of a companion reduced EDA (Kissel, 1965; Friedman, 1981), consistent with Schachter's proposal. For a more detailed review of this literature, and of work conducted within the framework of social facilitation theory see Geen and Bushman (1989).

While there is some, limited, support for an association between the presence of an audience and increased sweating from studies using the PSI, studies using electrodermal activity have largely failed to indicate such a relationship. The literature does not support the claim that social presence invariably leads to increased sympathetic activation, at least when electrodermal measures are studied. An alternative explanation for audience effects on arousal is that arousal occurs not through the effects of 'mere presence' but as a result of evaluation apprehension (Cottrell et al. 1968). This explanation is consistent with work on the effects of an audience on both EDA and the PSI, and with the conclusions from work on companionship as a fear-reducing mechanism. Several studies indicate that the presence of another may lead to raised EDA when embarrassment is likely. Only when fear occurs in response to physical threat does the presence of a companion seem to reduce physiological activation.

In the majority of experiments the main source of anxiety is likely to be the potential for embarrassment rather than physical threat. For this reason, the presence of an experimenter is more likely to produce increased EDA than the less commonly observed reduction in EDA. It must also be doubted whether the presence of another would reduce fear of physical threat when the other was perceived as being responsible for the threat, as the experimenter would be.

Koehler, Weber & Voegelé (1990), suggest that taking the PSI might, itself, lead to elevated levels of sweat gland activity. They administered the PSI to subjects as part of a study examining the responses to laboratory stressors. Even though subjects had spent thirty minutes in the laboratory, with electrodes attached, PSIs taken during the first ten minutes were significantly higher than those taken in the next nine minutes. This effect was primarily due to high

levels of sweat gland activity on the first two prints taken. A similar decrease was also apparent for SCL and systolic blood pressure, but not for HR, NS-SCRs or diastolic blood pressure. They suggest that the initial few prints may show elevated levels of activity due to the novelty of the PSI procedure. They claim that the changes over the first few measures are unlikely to be due to adaptation, as subjects had already had considerable opportunity to acclimatise to the experimental situation. They recommend rejecting the first two sweat prints, in order to avoid artificially high baseline measures.

Experiment five was undertaken to investigate the effect of the experimenter's presence, and the administration of the PSI, on the reactivity of both electrodermal activity and palmar sweat gland counts. There is some, inconsistent, evidence that the presence of the experimenter might lead to elevated levels of sweat gland activity. It is possible that this effect might be greater when sweat gland counts or phasic aspects of EDA are studied than when skin conductance level is examined. Subjects were given a task to perform, in order to allow reactivity to be assessed.

Sweat gland activity was recorded continuously using a microscope. By adjusting a light source near the finger active sweat glands can be visualised by the light reflected from the droplets of sweat they produce. The palmar sweat index also provides a count of the density of these droplets, using a plastic impression of the finger tip. Thus, video recording of sweat gland activity should provide an alternative to the PSI, which can be obtained in the absence of an experimenter.

The technique used for recording sweat gland activity is somewhat cumbersome. It is also vulnerable to loss of data due to small

movements of the subject's finger, which can cause the area under the microscope to move out of focus or prevent the light from reflecting from the sweat droplets. However, this technique does have some advantages. The video record can be scored at intervals of one twenty-fourth of a second. The technique is therefore able to track very rapid changes in the height of the sweat in the sweat duct. The technique should provide a better idea of the time course of changes in sweat gland activity than is available from the PSI. Experiment two demonstrated that the PSI can show large changes in activity over periods of several minutes. The present experiment will examine if the PSI also changes significantly over much shorter time scales.

The ability to detect rapid changes in sweat gland activity was used to provide a comparison between the video technique and phasic skin conductance measures. Subjects were presented with a tone during the initial acclimatisation period. The responses of the two measures to this tone were compared. A normal orienting response should be apparent on the skin conductance record. Whether such a clear-cut response would be apparent on the video record was unclear. An increase in the height of the columns of sweat in the sweat ducts could cause changes in skin conductance without producing visible droplets at the skin surface. There is also the possibility of another mechanism, such as the membrane response proposed by Edelberg (1972a, see also Fowles, 1974) which might contribute to skin conductance responding.

In order to allow the effects of the experimenter's presence to be assessed subjects were asked to carry out the same digit-symbol substitution task used in experiments two and four twice. Subjects were asked to perform the task once while the experimenter was present, and taking the PSI, and once when alone, with the order of

the conditions being counterbalanced across subjects. Skin Conductance Level was recorded continuously during both periods, as was sweat gland activity. Skin Conductance Response frequency was also calculated during the task and associated rest periods.

If, as social facilitation theory predicts (Zajonc, 1965), the presence of the experimenter does lead to increased arousal, all measures should be higher when the experimenter is present than when the subject is alone. If, as Cacioppo et al. (1990) suggest, reactivity is increased by the presence of another person, then only the response to the task will be greater while the experimenter is present, levels during the rest period should be unaffected by the manipulation.

2 Method

2.1 Subjects

Twenty-four subjects were run in all. Four were excluded because of unacceptable levels of missing data. Thus, data from twenty subjects (3 males, 17 females) were analysed. All subjects were volunteers, and received credit towards a course requirement for participation.

2.2 Apparatus

The subject's non-preferred hand was placed on a purpose-made rest and secured by a strap across the middle of the fingers. Skin conductance was recorded from electrodes on the index and middle fingers, while sweat gland activity was recorded from the tip of the middle finger.

Skin conductance was recorded continuously during the experiment, using the same equipment used in earlier experiments. The electrode

gel used was purpose made consisting of .05M NaCl in a Methyl cellulose base.

Sweat gland activity was recorded continuously by video recording. An Olympus model B071 microscope was positioned over the finger, giving 10X magnification. A video camera recorded the view through the microscope. Once the microscope was focused on the end of the finger, a fibre-optic light source was adjusted until the light was visible reflecting off the droplets of sweat on the finger. The light source did not produce any heat.

For scoring the videotapes were replayed on a monitor. The total linear magnification of the images scored was between 32.5X and 45X.

2.3 Procedure

Subjects were asked to wash their hands prior to taking part in the experiment. Once informed consent had been obtained the equipment was set up. Sudorific activity was recorded continuously, throughout the experiment, using both skin conductance techniques and by direct video recording of sweat gland activity using a microscope.

Initially, subjects spent five minutes resting on their own. Two minutes into this period a two-second, 80dB, 1000 Hz tone was presented via loudspeakers. The tone was pre-recorded on a cassette tape.

The output from the video camera was visible on a monitor in the experimenters cubicle. If necessary, the microscope was re-focused after each of the rest periods.

After the first rest period subjects performed a timed digit-symbol substitution task, intended to produce a stress-related autonomic response. This task was identical to that used in experiments two and four. The task was administered twice, once while

the male experimenter was seated next to the subject and once while the subject was alone. The order of the two conditions was balanced across subjects. The subjects had one minute to fill in as many boxes as possible. Each task was followed by a five minute rest period. In the experimenter present condition the palmar sweat index was obtained at one-minute intervals, from the subject's preferred hand, during this rest period. No PSI was taken during the task as both of the subject's hands were fully occupied.

Prior to the first task each subject was asked to read the instructions on the clipboard in front of them. If the subject was alone this was done using the intercom. If the subject's first task was to be with the experimenter present, the experimenter entered and asked the subject to read the instructions personally.

2.4 Data Reduction and Analysis

Both the number of sweat glands active and skin conductance level were recorded at the same points in time. A template was used to assess the number of active glands visible in an area four millimeters square from the videos. The template was calibrated against a grid placed under the microscope at the start of each experimental session. Thus, the values obtained from this measure should be comparable to those obtained using the palmar sweat index.

Ten readings were taken of the response to the tone. The first was obtained two seconds prior to the onset of the tone. Subsequent values were recorded at one second intervals.

One measure was taken in the middle of each task period. Measures were also taken at one minute intervals in each of the post-task rest periods. These measures started thirty seconds into the rest period and, when the experimenter was present, were taken at the same time as

the PSI.

Skin conductance response frequency was also calculated during each of the tasks and during the rest periods after the task. The number of responses exceeding a criterion of .015 micromhos in one minute were scored, giving one measure for the task period and five measures from each rest period. Where the PSI was taken, each minute was centred on the corresponding PSI.

Both electrodermal measures were transformed prior to analysis to reduce the skewness of the distribution. Skin conductance data were subjected to a logarithmic transformation, while a square root transformation was used for NS-SCR frequency.

3 Results

3.1 Reliability of the video technique

The videos of the response to the tone were scored twice by the same person, to provide an estimate of the reliability of the novel method of measuring sweat gland activity. The two rating sessions were separated by a period of several months. The overall correlation between the ratings from these two occasions was .869 ($p < .001$, one-tailed). This demonstrates that the technique does show acceptable reliability. The analysis of the orienting response data is presented in section 3.3 below.

3.2 The Effects of the Presence of an Experimenter on Palmar Sweating

Initially, the data from the two tasks, and associated rest periods, were analysed to examine whether taking the PSI did lead to elevated levels of skin conductance. Skin conductance level, non-specific response frequency and sweat gland count data were subjected to 2 (experimenter present vs experimenter absent) x 2

(order of the conditions) x 6 (repeated measures) MANOVAs. Order of the conditions was a between subjects factor, ten subjects receiving each of the two possible orders.

For skin conductance level, none of the effects or interactions involving the presence of the experimenter or the order of the conditions was significant. The main effect of Repetition was significant (approx. $F(5,14)=8.92$, $p=.001$). An a priori comparison revealed that levels during the task were higher than those obtained during the following rest period ($t(90)=5.58$, $p<.001$), see figure 63. The difference between the two orders of presentation, which is apparent in the raw data did not approach significance.

Findings were similar for NS-SCR frequency, only the effect of Repetition was significant (approx. $F(5,14)=4.28$, $p=.014$). Responses were more frequent during the task than during the following rest periods ($t(90)=3.83$, $p=.001$). See figure 64.

A similar main effect emerged in the analysis of the video data (approx. $F(5,14)=5.28$, $p=.006$). Once again, levels during the task were above those during the rest period ($t(90)=5.20$, $p<.001$). However, there was also an interaction between Condition and Order of presentation ($F(1,18)=5.86$, $p=.026$). This interaction is displayed in figure 65. Simple effects analysis revealed that neither of the two orders of presentation lead to a significant difference between measures taken in the experimenter's presence and those taken while subjects were alone. Examination of figure 65 indicates that subjects appeared to show higher levels of sweat gland activity during their second task, irrespective of the experimenter's presence.

Figure 63: Skin Conductance Level when subjects are alone and when the experimenter is present

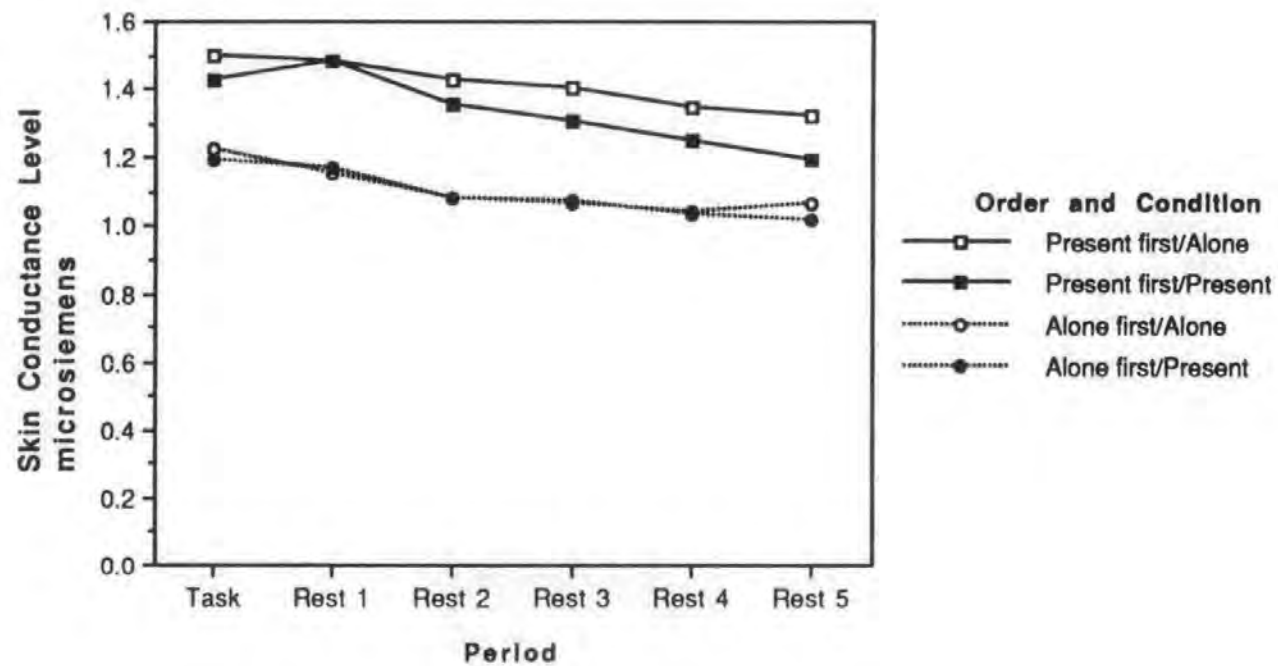


Figure 64: Non-Specific Skin Conductance Response frequency when subjects are alone and when the experimenter is present

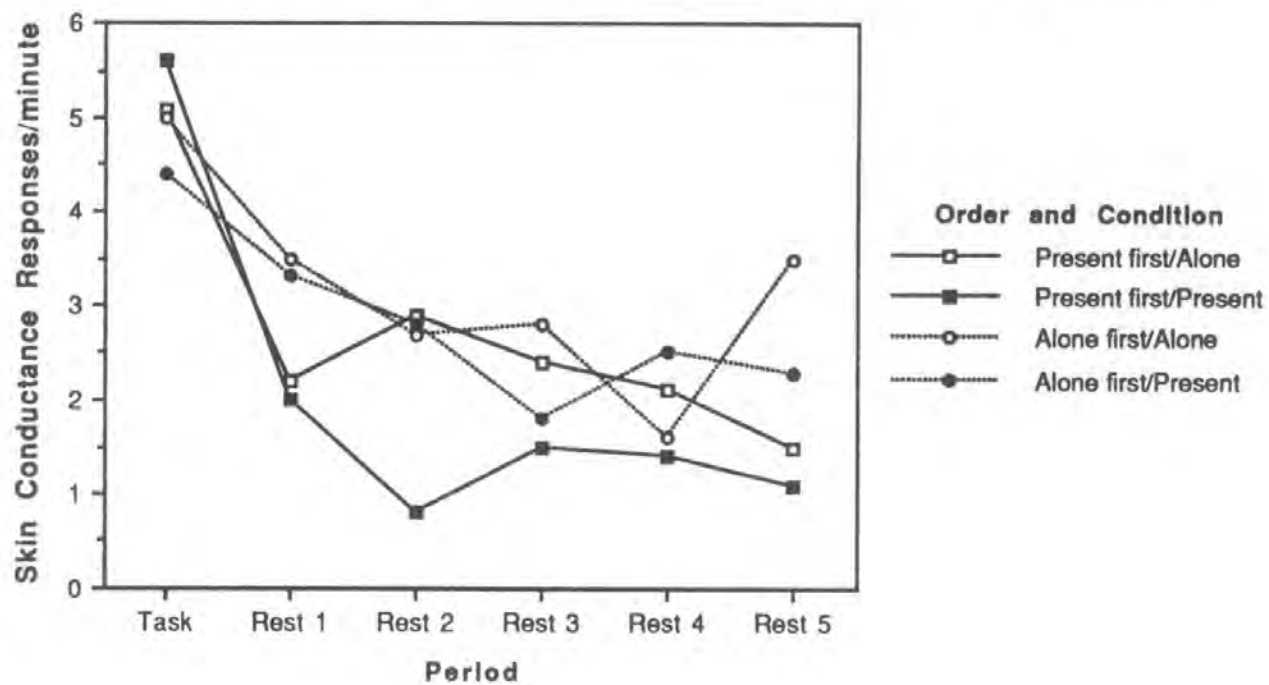
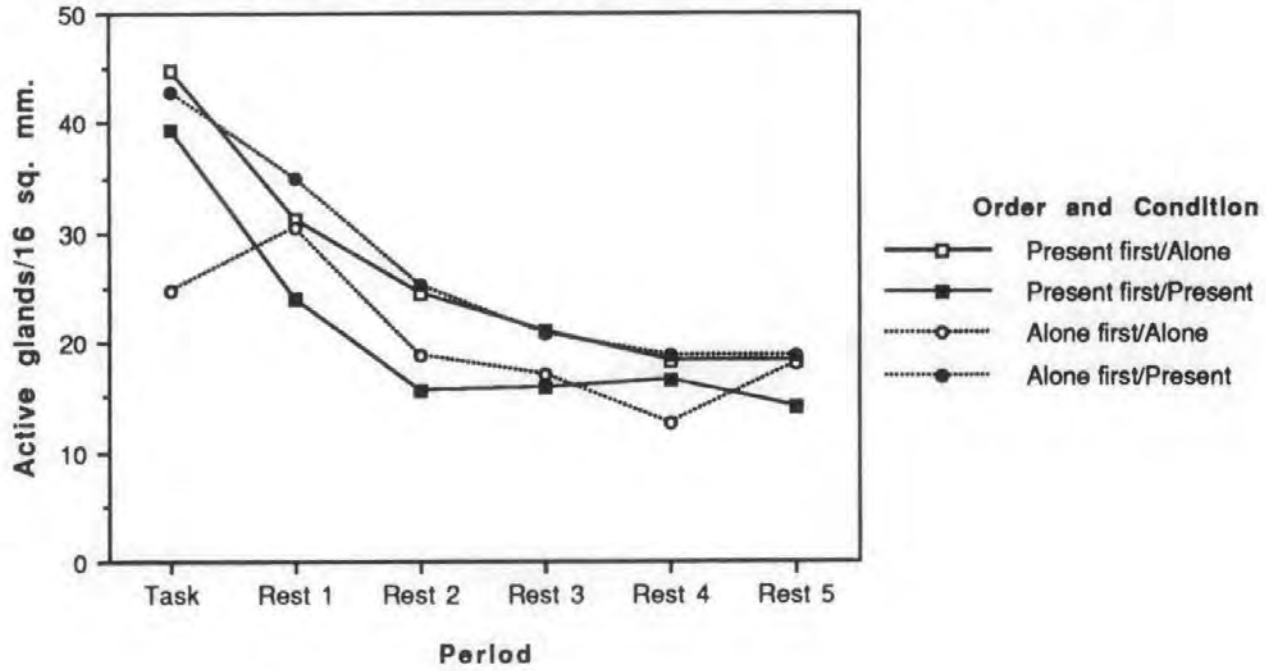


Figure 65: Video technique, Condition by Order interaction

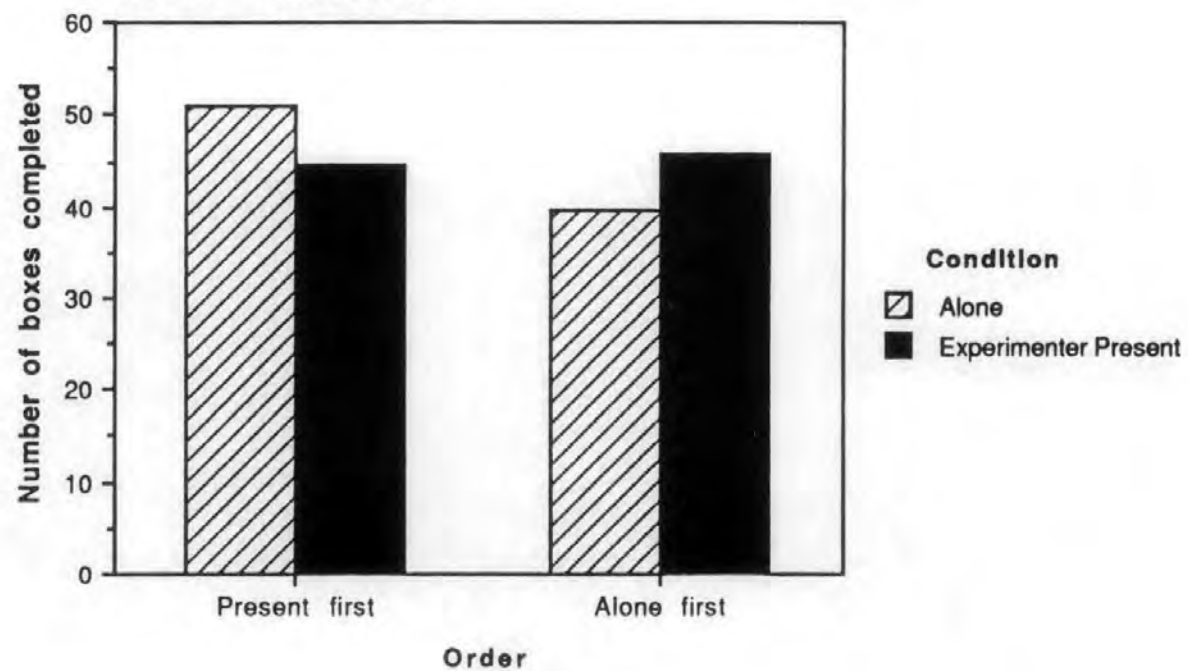


Performance on the digit-symbol task was also analysed in a 2 (presence of experimenter) x 2 (order of conditions) ANOVA. The expected interaction between Order and Condition appeared ($F(1,18)=13.77, p=.002$). As figure 66 indicates, subjects showed a clear practice effect, performing better on the second task. However there was also a trend towards a main effect of Order ($F(1,18)=3.77, p=.068$). The simple main effect of order was only significant for the measures taken when the subjects were alone ($F(1,18)=12.76, \text{unadjusted } p=.002$). When the experimenter was present, performance on the task seems to have been less susceptible to practice effects. This can probably be explained due to the effects of greater motivation when the experimenter is present.

The five PSIs taken during the rest period were also examined for order effects. None were found. The only significant effect was a main effect of Repetition (approx. $F(4,14)=3.54, p=.034$) reflecting decreasing levels over time.

Because of the evidence for differences in task performance between some of the conditions, the analyses of the physiological measures were repeated, including performance on the two tasks as covariates. None of the analyses revealed a significant regression of task performance on Electrodermal activity. Only in the analyses of the video technique, the PSI and NS-SCR frequency did the regression of task performance approach significance in any part of the analysis ($p=.074, .060$ and $.082$ respectively in the analysis of between subject terms for the video technique and the PSI and in the analysis of within-subject terms for NS-SCR frequency).

Figure 66: Digit-symbol task, Condition by Order interaction



All of the analyses revealed a significant main effect of Repetition. None of the analyses revealed any other significant main effects. However, there were weak interactions involving the order of the conditions. In the analysis of skin conductance level the interaction between Order and Repetition approached significance (approx. $F(5,14)=2.43$, $p=.087$). For the video technique the interaction between Order and Condition, significant in the main analysis, was non-significant when scores were adjusted for task performance ($F(1,17)=3.06$, $p=.099$). A similar interaction approached significance in the covariance analysis of NS-SCR frequency ($F(1,17)=3.68$, $p=.072$).

These analyses do not change the conclusions regarding the effects of taking the PSI. The only new effect involving the two conditions was the borderline interaction for NS-SCR frequency. Examination of figure 64 indicates that the interaction most probably represents the low levels of activity shown during administration of the PSI by the group for whom that was their first condition. This effect is in the opposite direction to that predicted.

The presence of the experimenter, and the taking of five PSIs during a rest period, did not affect levels of skin conductance, response frequency or palmar sweat gland activity. There was some evidence for differences in performance on the task. The presence of the experimenter appeared to lead to a reduced practice effect. Differing performance was not reflected in different levels of sweat gland activity however.

There was no evidence for a decrease in sweating during the task. Both electrodermal activity and sweat gland counts revealed increased sweating during the task, although the difference was fairly small for both measures. The digit-symbol task used does not seem to be

particularly successful at producing sympathetic activation.

3.3 Comparison of the Three Measures.

Despite the small number of PSIs taken, the PSI did appear to correlate within-subjects with both electrodermal activity and the number of active sweat glands observed directly (see table 47). The PSI also tended to correlate between-subjects with the video technique and with NS-SCR frequency (see table 48). Surprisingly, between-subject correlations between skin conductance level and the two sweat gland counts tended to be small and negative. Because of the consistency of the correlations, the small negative correlation between SCL and the video technique would achieve significance if a two-tailed test was used. NS-SCR frequency tended to correlate positively with both SCL and the two sweat gland counts.

A characteristic orienting response was apparent in the Skin Conductance data obtained after the tone (see figure 67). The video data revealed a similar response with a latency of around 2 seconds. However, figure 67 shows that there was also an increase in sweating simultaneous with the onset of the tone.

Orienting data were analysed as difference scores using the mean of the initial three measures as a baseline. Sweat gland count data from two subjects was excluded from the analysis as the videos were indistinct and could not be scored.

Both sets of sweat gland counts were analysed in separate repeated measures MANOVAs. For both variables the "constant" term was significant, indicating that values did tend to be higher after the tone (Video $F(1,17)=9.37$, $p=.007$; SCR $F(1,19)=6.45$, $p=.020$).

Figure 67: The response to the tone, measured by both Skin Conductance and the video technique

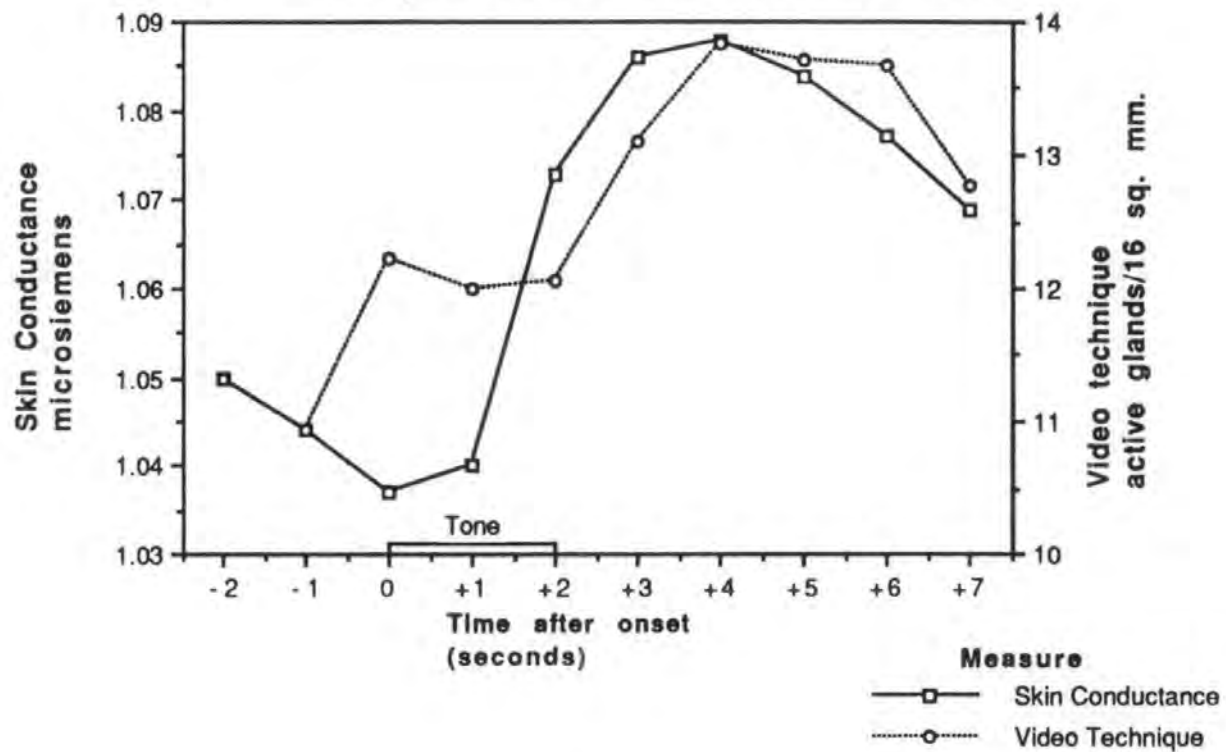


Table 47: Mean within-subject correlations

Measures	Mean correlation
SCL-NS-SCRs	.515***
SCL-PSI	.528***
SCL-Video technique	.337**
NS-SCRs-PSI	.345**
NS-SCRs-video technique	.328**
PSI-Video technique	.216*

* $p < .05$, one-tailed

** $p < .01$, one-tailed

*** $p < .001$, one-tailed

Each value averaged over twenty subjects, correlations including NS-SCR frequency could only be calculated for seventeen subjects, as three subjects produced no responses during the rest period. Correlations calculated from five points per subject. Probabilities presented test the hypothesis that the mean value for each correlation is greater than zero. Individual correlations of .805 or greater are significant.

Table 48: Mean between subjects correlations for resting measures

Measures	Mean correlation
SCL-NS-SCRs	.337*
SCL-PSI	-.141
SCL-Video technique	-.161
NS-SCRs-PSI	.355*
NS-SCRs-Video technique	.421***
PSI-Video technique	.425**

* $p < .05$ one-tailed

** $p < .01$, one-tailed

*** $p < .001$, one-tailed

Each value is the average of five correlations. Correlations calculated from twenty subjects. Probability values test the hypothesis that the mean of each correlation is greater than zero. For individual correlations a value of .378 is significant.

The main effect of time was non-significant for the video technique, and analysis of orthogonal polynomials revealed no significant trends for this measure. The absolute size of the response was very small and there was considerable inter-individual variation, both in base level of activity and response characteristics. For skin conductance also, the main effect of time was non significant. However, contrasts indicated that the skin conductance response contained significant quadratic ($t_{(114)}=3.50$, $p=.002$) and cubic ($t_{(114)}=2.85$, $p=.010$) trends, there was also a weak linear trend ($t_{(114)}=1.79$, $p=.089$).

Because it was felt that the increase in sweat gland activity occurring simultaneously with the onset of the tone might represent a response to the start of the tape, which produced a slight click about two seconds before the tone, a post hoc analysis of the three baseline measures was carried out for the video data. The overall change across these three measures was non-significant (approx. $F_{(2,16)}=2.21$, $p=.142$). However, contrasts revealed that the third measure, at the onset of the tone, differed from the mean of the preceding two measures at a level which approached significance ($t_{(16)}=2.21$, $p=.060$).

The tendency for sizable within-subject correlations and small between subject correlations was apparent for these measures also (within-subjects mean correlation=.327; between-subjects mean correlation= .045).

4 Discussion

Two issues require discussion. Firstly, the conclusions to be drawn regarding the physiological effects of taking the PSI will be examined. Secondly, the evidence regarding the time course of the PSI

response will be discussed.

The results indicate that, under these circumstances, the procedure necessary to obtain the PSI has little effect upon the values of sweat gland activity obtained. While the video technique did reveal an interaction between presence of the experimenter and order of presentation, neither of the two possible orders of presentation produced a significant difference between measures taken when the subject was alone and those obtained when the experimenter was present. The interaction appears to reflect a pure order effect, the second condition produced higher sweat gland counts, irrespective of which condition it was. This is surprising, the usual finding is that levels of activation decline over time. This trend is apparent within the rest periods (see figure 65). It is puzzling that sweat gland activity should then increase between the end of the first rest period and the start of the second task period to a level above that in the preceding task period.

While no experiment can be considered immune to experimenter effects, and the nature of such effects may be dependent upon characteristics such as the sex of subject and experimenter and the social setting, these results indicate that the PSI does not appear to be especially likely to induce such effects. Obviously, the possibility remains that under some other set of circumstances the PSI might be a reactive measure, producing changes in the behaviour it is attempting to record. However, it would be impossible to completely rule out the possibility. What this study has shown is that the PSI can be administered without changing the level of electrodermal activity observed.

Koehler, Webber and Voegele (1990) reached different conclusions. Even though subjects had been sitting in the laboratory for 30

minutes, they observed large initial decreases in the PSI, and in SCL and systolic blood pressure, during the first few minutes of an experiment. They interpret these changes as reflecting the effects of taking the PSI. The novelty of the procedure, they suggest, leads to elevated levels of physiological activation. Once subjects get used to the procedure this effect declines. As all subjects were administered the PSI the effect cannot be unambiguously attributed to the Palmar Sweat Index, rather than some other aspect of the experimental procedure. However, Koehler et al. recommend that the first two Palmar Sweat prints should be discarded to remove the possibility of this effect.

While experiment five included an initial adaptation period, the PSI was not administered until the first task. Therefore, the PSI was a novel procedure for subjects, and the effect Koehler et al. describe should have been apparent in the PSI data. Taking the PSI, therefore, should have lead to elevated levels of EDA when the PSI was taken. No such effect was observed.

One possibility which needs to be considered, is that the experimental setting, itself may be arousing (Gale & Baker, 1981). Therefore, there may be little scope for further effects due to the presence of the experimenter and the administration of the PSI. A number of explanations have been suggested for the increased arousal believed to produce social facilitation. These include evaluation apprehension (Cottrell et al. 1968), distraction (Baron 1986) and increased self-awareness (Duval & Wicklund 1972), although increased arousal may only result from increased self-awareness when subjects expend greater effort as a result of the increased monitoring of performance. These effects may already be present in the experimental setting. Clearly, taking part in an experiment may lead to evaluation

apprehension. The experimental setting may also provide sources of distraction, although this may be less of a problem inside a soundproof cubicle. Psychophysiological experimentation may be more likely to induce boredom than over-arousal! Taking part in a psychology experiment, particularly where physiological reactions are being measured, might also lead to increased self-awareness.

If these factors are active, then the experimental setting might already lead to the effects normally attributed to the presence of an audience, masking the effects of any additional manipulation. If this is the case, then stronger effects of the experimenter's presence might be expected when research is carried out in more naturalistic settings. However, while field studies might be less likely to lead to evaluation apprehension or increased self awareness, they may provide greater distraction. Field studies typically also provide fewer opportunities for control over environmental factors such as temperature. If, as seems to be the case in this experiment, any effects of the presence of the experimenter are relatively weak, they may be masked by the higher levels of extraneous variance in field studies.

By providing a long acclimatisation period prior to recording, Koehler, Webber and Voegelé (1990) may have allowed much of the arousal produced by participation in an experiment and the attachment of electrodes to dissipate. With this background arousal removed, the small effect of administering the PSI became apparent. The shorter acclimatisation period included in this experiment may have been insufficient to allow all of the anxiety experienced by subjects to dissipate.

In summary, the experiment does not provide any reason to expect higher levels of sweat gland activity as a result of administering the

Palmar Sweat Index. However, there may be circumstances where the PSI does lead to elevated sweat gland activity. Such an effect would be more likely when the presence of the experimenter is a source of evaluation apprehension, for example where subjects are likely to be embarrassed. It can be suggested that effects are also more likely to be observed where levels of background sweat gland activity are low. The experiment does demonstrate that the PSI does not produce effects over and above those produced by skin conductance assessment, in combination with the general experimental setting. Future experiments should provide the opportunity for subjects to get used to the procedure of administering the PSI, just as experiments routinely include adaptation periods when other physiological measures are used.

The video technique gave some evidence for a similar orienting response to that observed with skin conductance measures. The response, however, appeared to be much weaker and subject to more variability. Examination of the raw data indicated that a rise in sweat gland activity was apparent as the tone started. It is not known whether this represents random variation or a response to the start of the tape. As no such response was apparent on the skin conductance record, the former explanation seems more likely.

The orienting response data demonstrate that measures of sweat gland activity can change as rapidly as skin conductance parameters. The orienting response from the video technique appeared three seconds after the tone, and had reached its maximum amplitude by four seconds after the onset of the tone. The response had declined considerably by the last measurement, only seven seconds after onset. Measures such as the PSI tap both phasic and tonic responses. This demonstrates, once again, the need to ensure that the PSI is administered at an appropriate time. If activity can change over a period of a few

seconds then measures taken after a manipulation, or in between blocks of a task, may not reflect the levels of activity occurring during the task.

There was no evidence for a decrease in sweating during the task. Once again, no evidence has emerged of an anhidrotic response. The video technique also supported the evidence from skin conductance measurement that there was no sudden drop in sweating after the task. After the task both measures showed a gradual decline consistent with recovery and/or adaptation.

The use of the video technique was based on the assumption that it was equivalent to the PSI. The correlations between the two measures support this assumption. The two measures clearly did correlate, even when a very small number of values were compared. It needs to be stressed that the video technique offers few advantages over existing measures. It doesn't offer the portability and ease of use of the PSI, and is more restrictive and cumbersome than skin conductance measurement. However, the ability to record very rapid changes in sweat gland activity may be of use in future research.

In contrast to previous studies, SCL revealed a weak negative correlation with both the PSI and the video technique when between-subject correlations were examined. A dissociation between skin conductance and sweat gland counts, when individual differences are examined, can be explained as being due to stable individual differences in factors such as epidermal thickness and finger size, which might affect the two types of measure in different ways. Within-subject correlations would be more sensitive to phasic factors such as changes in autonomic activation, which should produce similar changes in both types of index.

Preceding chapters have attempted to demonstrate that the PSI is

suitable for use in a clinical setting. The following chapter will briefly review a number of studies which have used the PSI in such settings.

Chapter 12

The Utility of the PSI as an Applied Measure

1 Introduction

This chapter will briefly review a number of studies carried out in collaboration with other workers. These studies are intended to provide an illustration of the utility of the Palmar Sweat Index. The research described demonstrates that the PSI can be successfully applied in a clinical setting.

Three studies will be described, the first examines sweat gland activity in schizophrenic subjects. The study attempts to replicate previous findings, obtained using electrodermal measures, of abnormal levels of activity in schizophrenic subjects, and of relationships between electrodermal activity and symptomatology within the schizophrenic group.

The second study examines the relationship between sweat gland activity and vulnerability to depression. There is considerable evidence indicating that reduced electrodermal activity may be a marker for depression. The study described examines levels of palmar sweating in pairs of twins either concordant or discordant for depression.

The final study to be reviewed used the PSI as an index of anxiety as part of a programme of relaxation training. Psychophysiological techniques are already used in behaviour therapy, although their use is limited. The PSI could extend that use, both by removing the need for expensive equipment, and by allowing measurement to take place in field settings and so extending the range of behaviours capable of being studied.

As these studies are presented primarily to illustrate the utility of the PSI, they will be presented in less detail than were the experiments which form part of this investigation. The first two studies each represent preliminary results from continuing programmes of research.

2 Study One

2.1 Introduction

The first study was undertaken in collaboration with M. Romer at the Max-Planck Institute, Munich and by Dr K. Hahlweg at the University of Braunschweig. The study examines levels of sweat gland activity in a group of schizophrenic subjects. There is a considerable body of research, reviewed in chapter four, which indicates that schizophrenic subjects may show abnormal levels of electrodermal activity. The most common finding is the presence of a large subgroup (typically around 40%) who are electrodermally non-responsive (Ohman, 1980), although some workers also report finding a hyper-responsive subgroup.

Within the schizophrenic population differences in electrodermal activity have been found to correlate with symptomatology, and to be predictive of outcome (e.g. Alm et al., 1984; Ohman et al., 1989).

The type of large scale study needed to examine such differences is difficult to conduct using electrodermal measures. The portability and simplicity of the PSI makes it ideal for use in such a study.

It was predicted that the schizophrenic sample would contain a sizable sub-group showing low levels of palmar sweating. Within the schizophrenic group it was predicted that levels of palmar sweating would be predictive of symptomatology, assessed by the Brief Psychiatric Rating Scale (BPRS; Overall & Gorham, 1962). Following the

results reported by Dawson, Nuechterlein & Schell (1988), it was expected that higher levels of palmar sweating would be associated with higher scores on the Excitement, Activation, Hostile Suspiciousness and Thought Disturbance factors of the BPRS.

2.2 Method

The PSI was obtained in a study that examined performance on the Continuous Performance Test in different psychiatric groups. Data from 57 schizophrenic, 46 Bulimic and 71 "normal" subjects were collected before and after the task. Psychiatric groups were selected on the basis of ICD-9 diagnoses. In addition, psychiatric subjects were rated on the Brief Psychiatric Rating Scale. As well as the 18 subscales of the BPRS, scores on 5 higher order factors (Activation, Anergia, Anxious Depression, Hostile Suspiciousness and Thinking Disturbance) were calculated (Lukoff, Nuechterlein & Ventura, 1986).

Prior to collection of the PSI data, experimenters were given written instructions concerning the procedure for administering the PSI (see appendix C). The experimenter who would be administering the PSI took a number of pilot prints, which were examined by the current author to ensure adequate print quality. All prints were scored by the current author.

Sweat gland counts were analysed both in terms of the number of active glands present (PSI-A) and as a ratio of the number of active glands to the total number of glands (PSI-R). As the PSI data showed significant positive skew, data were subjected to a square root transformation before analysis. As results were essentially the same for both the number of active glands and for the ratio of active over total glands, only the results of the analysis of the number of active glands will be reported here.

2.3 Results

Two diagnostic groups were available. These were, a group of 57 subjects with schizophrenia (ICD-9 codes 295, 295.1, 295.2, 295.3, 295.5 & 295.6) and a group of 46 bulimics (ICD-9 code 307.5), who acted as a psychiatric control group. It was also possible to identify a group of 26 subjects with some form of paranoia, some of whom were also counted in the schizophrenic group (ICD-9 codes 295.3, 297 & 297.2).

Each of these groups in turn was compared with the control group (n=71) in a 2 (group) x2 (PSI measure) MANOVA. None of the groups showed a significant difference from the control group. In addition there was no main effect or interaction involving the Task effect, indicating that the PSI taken after the Continuous Performance Test did not differ significantly from the resting measure. There was also no evidence of homogeneity of variance in any of the analyses, implying that the distribution of PSI scores was comparatively normal in each of the diagnostic groups. Thus, this analysis does not confirm previous findings of abnormal levels of electrodermal activity in schizophrenic subjects.

Within the schizophrenic and bulimic groups correlations were computed separately between the two PSI measures and scores on the BPRS. Both the original eighteen subscales of the BPRS and the five higher-order factors investigated by Dawson, Nuechterlein & Schell (1988) were used. These correlations are presented in tables 49 and 50.

Table 49: Correlations between palmar sweating and BPRS scores

Scale	Schizophrenic sample		Bulimic sample	
	"Resting"	"Task"	"Resting"	"Task"
	PSI	PSI	PSI	PSI
Somatic Concern	-.148	-.011	-.011	.031
Anxiety (Psychic)	-.237	-.023	-.451**	-.194
Emotional Withdrawal	.089	.022	-.309*	.076
Disorganisation	.114	.008	-.054	-.048
Guilt Feelings	-.001	.058	-.220	-.016
Tension	-.095	.034	-.252	.070
Mannerisms & Posturing	.111	.119	-.057	.143
Grandiosity	.073	.095	-.129	.229
Depressive Mood	-.313*	.024	-.235	.114
Hostility	.417**	.307*	.121	.243
Suspiciousness	.165	.141	.126	.071
Hallucinations	.090	.298*	-	-
Motor Retardation	-.073	-.014	.096	.097
Uncooperativeness	.213	.074	-.050	.281
Unusual Thought Content	.190	.208	.153	.623***
Blunted Affect	.064	-.100	-.158	.246
Agitation	-.011	-.036	-.105	.267
Disorientation	.031	.001	-	-

* $p < .05$, two-tailed

** $p < .01$, two-tailed

*** $p < .001$, two-tailed

Correlations involving two scales could not be calculated for the bulimic group, as there was no variation in their scores.

Table 50: Correlations between palmar sweating and BPRS factors

Factor	Schizophrenic sample		Bulimic sample	
	"Resting"	"Task"	"Resting"	"Task"
	PSI	PSI	PSI	PSI
Anxiety-Depression	-.252*	.020	-.334*	-.026
Anergia	.038	-.032	-.232	.185
Thought Disturbance	.175	.254*	-.009	.446**
Activation	.013	.065	-.223	.194
Hostile-Suspiciousness	.343**	.226*	.062	.291*

* $p < .05$, one-tailed

** $p < .01$, one-tailed

*** $p < .001$, one-tailed

NB as no specific predictions were made for the Anxious-Depression factor, a two-tailed test might be more appropriate, in which case only the correlation with resting PSIs for the bulimic group achieves significance

Several correlations were significant, or approached significance, for both groups. The first PSI correlated negatively with the Psychic Anxiety scale of the BPRS. Not surprisingly the same measure correlated negatively with the Anxious Depression factor, which includes the Psychic Anxiety scale. For both groups, the second PSI measure also correlated positively with the Thinking Disturbance factor of the BPRS and with the Hostile Suspiciousness factor (although, as no relationship was predicted for the bulimic group, this correlation falls short of significance if a two-tailed test is

used). The Hostile Suspiciousness factor also correlated with the first PSI, for the schizophrenic group only.

Several other scales correlated with the PSI measures for one group alone. Within the schizophrenic group higher scores on the first PSI were correlated with lower Depressive Mood and higher Hostility ratings and the second PSI correlated positively with the Hostility and Hallucinations scales. In the bulimic group the first PSI correlated negatively with the Emotional Withdrawal scale and the second PSI correlated positively with the Unusual Thought Content scale. When the PSI-R was studied, one other correlation achieved significance, for the Bulimic group higher sweating was associated with exaggerated self-esteem ($r=.302$).

Despite differences in the exact patterns of correlations in the two groups, there are several similarities. In both groups lower sweating, especially at the start of the session, appears to be associated with a depressed and anxious pattern of symptomatology, whereas higher levels of sweating, particularly after the CPT, are associated with a more hostile pattern and more florid symptomatology.

The strongest relationships reported by Dawson, Nuechterlein & Schell (1988) were with the Activation and Hostile Suspiciousness factors. A link between Hostile Suspiciousness and PSI scores emerged in this analysis. However, no relationship with the Activation factor was found. Furthermore, there was evidence of a negative relationship with the Anxious-Depression factor, which didn't appear in the earlier study. Dawson, Nuechterlein & Schell used a sample of schizophrenics with a recent onset of the disorder. As the current sample included many subjects with a much longer duration of illness a separate analysis was performed to investigate whether this had contributed to the difference between these findings and those of Dawson et al.. The

schizophrenic sample was divided into those with a length of illness of two years or less (n=15, "recent-onset" cases) and those with a longer duration of illness (n=43, "chronic" cases). Correlations were computed within each group between the PSI and the BPRS, see tables 51 and 52.

Only one correlation reached significance for both groups. Hostility correlated positively with the first PSI. Levels of sweating after the task were also predictive of higher Hostility for the chronic group. The Hostile Suspiciousness factor correlated positively with the first PSI for the recent onset group and with the second PSI for the chronic group.

Table 51: Correlations between palmar sweating and BPRS factors for "Recent onset" and "chronic" schizophrenics

Factor	"Recent onset"		"Chronic"	
	"Resting"	"Task"	"Resting"	"Task"
	PSI	PSI	PSI	PSI
Anxiety-Depression	-.614**	-.016	-.196	.036
Anergia	.106	.228	.043	-.086
Thought Disturbance	.072	.362	.217	.231
Activation	.460*	.308	-.146	.014
Hostile-Suspiciousness	.677**	-.037	.242	.292*

* p<.05, one-tailed

** p<.01, one-tailed

Table 52: Correlations between palmar sweating and BPRS scores
for "recent onset" and "chronic" schizophrenics

Scale	"Recent onset"		"Chronic"	
	"Resting"	"Task"	"Resting"	"Task"
	PSI	PSI	PSI	PSI
Somatic Concern	-.635*	.177	.010	-.033
Anxiety (Psychic)	-.182	.031	-.295	-.032
Emotional Withdrawal	.062	.155	.097	-.010
Disorganisation	.473	.393	.020	-.064
Guilt Feelings	.056	-.235	-.052	.180
Tension	-.204	-.108	-.069	.059
Mannerisms & Posturing	.431	.438	.002	.051
Grandiosity	-.188	-.442	.140	.166
Depressive Mood	-.622*	-.045	-.238	.050
Hostility	.549*	-.185	.446**	.375*
Suspiciousness	.225	-.176	.137	.232
Hallucinations	.034	.506	.101	.243
Motor Retardation	-.163	.347	-.022	-.075
Uncooperativeness	.799***	.171	-.042	.041
Unusual Thought Content	-.055	.169	.285	.216
Blunted Affect	.126	.009	.066	-.139
Agitation	.622*	.192	-.334*	-.117
Disorientation	.236	.249	-.098	-.073

* $p < .05$, two-tailed

** $p < .01$, two-tailed

*** $p < .001$, two-tailed

One correlation was of opposite sign for the two groups. The first PSI was related to higher levels of Agitation in the recent-onset group but was correlated with reduced Agitation scores in the chronic group.

For the recent-onset group alone, higher sweating at the start of the session was associated with lower Somatic Concern, less Depressive Mood, higher Uncooperativeness, lower scores on the Anxious Depression factor and higher scores on the Activation factor.

In an attempt to identify subgroups differing in terms of physiological reactivity, subjects scoring less than 23 on the first PSI were labelled hypo-responsive. In experiment four, levels of resting sweat gland activity below this criterion had distinguished all subjects found to be electrodermally non-responsive as well as all those who responded to a tone on only one trial. An attempt was made, therefore, to select a group of hyper-responsive subjects. The lower criterion used to select hypo-responsive subjects corresponded roughly to the 31st percentile of the distribution of normal subjects. For this reason an upper criterion of 50 was chosen, corresponding to the 69th percentile. It was harder to choose a criterion for hyper-responsivity on the basis of data from experiment four. Subjects who were hyper-responsive electrodermally in that study had shown considerable variation in their PSI scores. Overall levels of sweating in the previous study were also slightly lower than those observed in the current study. However, the criterion chosen would have identified the majority of the non-habituators in the earlier study.

Chi-square analyses revealed that the proportions of subjects falling into the three groups did not differ significantly between schizophrenic, bulimic and control samples. There is still no indication, therefore, of the presence of schizophrenic subgroups with

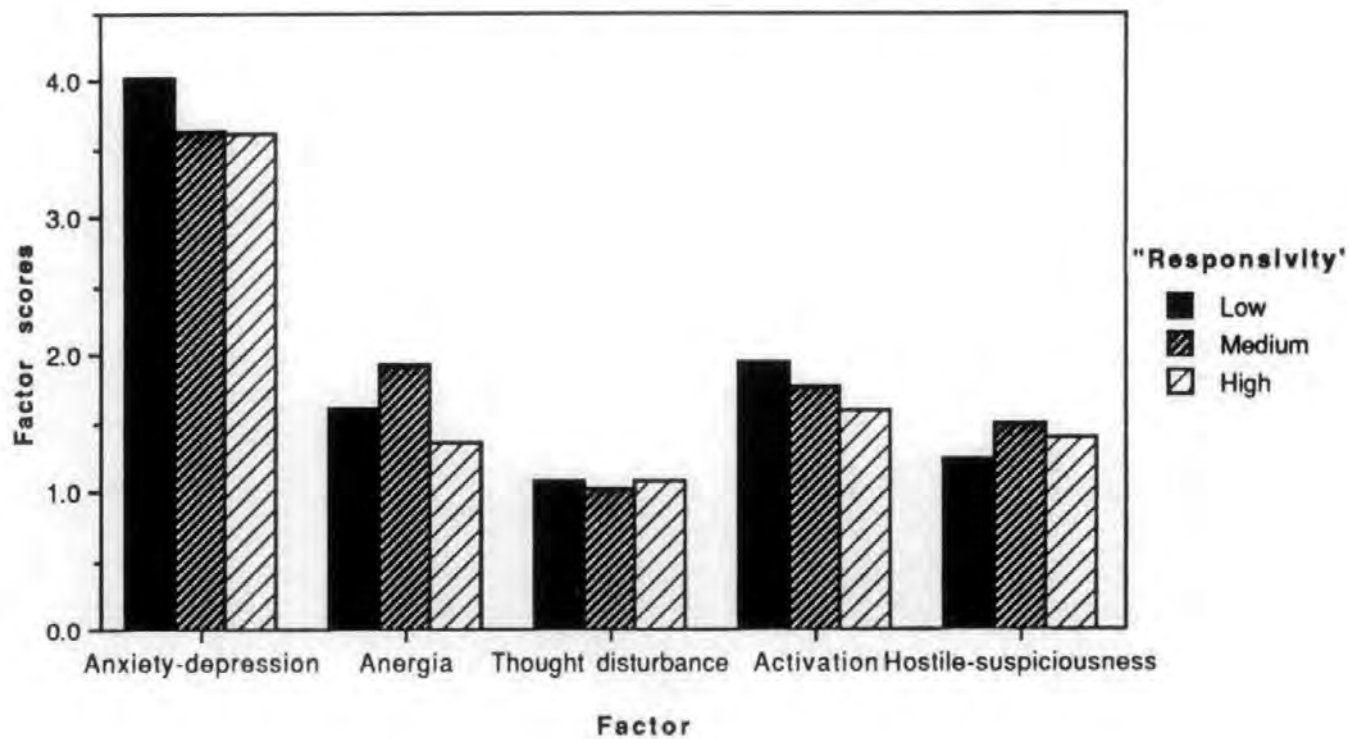
extreme levels of sweat gland activity.

Separate profile analyses were performed for the schizophrenic and bulimic groups comparing the low, medium and high responsive groups in terms of their ratings on the BPRS scales. Separate analyses were also performed using the five BPRS factors as dependent variables. When the schizophrenic sample was analysed, neither individual BPRS items nor the five higher-order factors revealed any significant effects involving the Responsivity factor. In both analyses the "Constant" term was significant, indicating that the group showed significant symptomatology, and the difference between scales or factors was significant, indicating that some symptoms were more prevalent than others.

The analysis of the bulimic group revealed a significant interaction between Responsivity and the profile of scores on the five factors (approx. $F(8,82)=2.20$, $p=.036$). However, simple main effects analysis revealed that no single scale differed significantly across the three groups. Even when conventional levels of significance were used, without the bonferroni adjustment, only one factor revealed a difference which approached significance, the most responsive group appeared to show lower levels of Anergia than the other groups ($F(2,42)=3.06$, unadjusted $p=.057$). The profiles of the three groups on the five factors are displayed in figure 68. As in the analysis of schizophrenic subjects, the "constant" effect was significant in both analyses, as was the difference between different items.

The two diagnostic groups were also examined for possible differences in age, length of illness and sex distribution between the sub-groups showing different levels of sweat gland activity.

Figure 68: Profiles on the BPRS for groups defined by differing levels of palmar sweating, bulimic sample only



The only finding which approached significance was a tendency, in the schizophrenic subjects, for the three groups to differ with regard to age ($p=.056$) the hypo-responsive group being slightly older than the other groups. A decrease in sweating with increasing age has been shown by other studies (e.g. Catania et al. 1980). In order to rule out the possibility that this age difference might be masking differences in symptomatology, an analysis of covariance was performed on the data from the schizophrenic sample with the five BPRS factors as dependent variables and age as the covariate. The conclusions from the analysis were unchanged.

2.3 Discussion

The commonly-reported presence of a large hypo-responsive group within the schizophrenic population was not confirmed using the PSI. The, less commonly reported, hyper-aroused group was also not detected. The physiological data analysed in this study were from resting subjects, although one measure was taken immediately after a task. The hypo- and hyper-responsive subgroups identified in previous research are most commonly defined in terms of habituation measures. The lack of evidence for such groups in this study may simply be due to the use of measures of tonic activity rather than phasic responsivity.

The PSI did appear to be predictive of current symptomatology. However, similar relationships were present for the bulimic group as well as the schizophrenic group, implying that the relationship may not be specific to schizophrenia.

The division into recent onset and more chronic cases provides a partial explanation for the differences between the results of the analysis of the whole schizophrenic sample and the findings described

by Dawson et al. (1988). They found significant relationships with the Agitation (or Excitement) scale of the BPRS and with the Activation, Hostile Suspiciousness and Thought Disturbance factors. In this study, the correlation with Agitation was positive for the recent-onset group, replicating the finding of Dawson et al., but was negative for the chronic group, which explains the absence of a significant correlation when the two groups are combined. The Activation factor was also correlated with the PSI only within the recent-onset group. The Hostile Suspiciousness factor was related to sweating in both groups. The relationship with Thought Disturbance reported by Dawson et al. and found in the overall analysis was not significant for either group alone. The relationship with the Anxious depression factor found in our earlier analyses was found to be present for the recent-onset group. It is not clear why Dawson et al. did not find such a relationship.

There was little evidence to indicate that the PSI might identify schizophrenic sub-groups with differing symptom profiles. Only for the bulimic sample did groups selected on the basis of palmar sweating show different scores on the BPRS.

The study demonstrates that the PSI may allow the extension of prior research from laboratory to clinical settings. Future research will examine the prognostic significance of levels of palmar sweating. As well as discriminating sub-groups with different symptom profiles and prognoses, the PSI might also be useful as part of an early signs monitoring program. A number of studies have been undertaken in recent years searching for prodromal signs of schizophrenic relapse (e.g. Birchwood et al. 1989). There is reason to believe that changes in sweat gland activity may be such a sign.

Changes in electrodermal activity, associated with social stress

from relatives high on expressed emotion (EE), have been reported to be predictive of relapse in remitted schizophrenics. Studies by Tarrrier and his co-workers, using schizophrenic subjects, (Tarrrier et al, 1978; Tarrrier et al, 1979) found that the number of spontaneous skin conductance responses during interaction with a relative was highly related to the relative's EE status. Furthermore, these studies also found larger responses to the entry of a relative in subjects who had recently experienced a stressful life event. With the exception of a small number of replicating studies (Sturgeon et al., 1981, 1984; Ventura et al., 1986; Tarrrier, 1989) these findings have received little research attention.

If the PSI is similarly sensitive, then the measure may be of great significance, as the assessment of a relatives expressed emotion status is both time consuming and intrusive, requiring data from a long interview between relative and patient to be rated by a trained observer. The studies using electrodermal activity imply that the same information could be obtained using a simple physiological measure, such as the PSI.

3 Study Two

3.1 Introduction

The second study was carried out in collaboration with Randy Katz, Joan Rutherford & Peter McGuffin at the Institute of Psychiatry. This study is an investigation into the genetic basis of depression. The study also includes an investigation of the role of life events in triggering depression, but this data is not yet available. The PSI was obtained from a large sample of twins, either concordant or discordant for depression.

There is a large body of research examining the relationship between electrodermal activity and depression (see chapter four for a detailed review). Several early studies implied that sweat gland activity may be of use in the discrimination of subcategories of depression. In general, patients described as neurotic, non-endogenous or agitated depressives were found to show levels of electrodermal activity and responsivity above those of controls, while psychotic, endogenous or retarded depressives were generally found to be below normal in terms of electrodermal activity. Recently, most attention has focused on the occurrence of reduced sweating in individuals with severe depression (e.g. see the review by Henriques & Davidson, 1989). These differences appear to occur both in acutely ill subjects and in subjects in remission (Dawson et al., 1977; Storrie et al., 1981; Iacono et al., 1983, 1984), so that it is possible that such differences could serve as markers for a vulnerability factor.

As well as evidence for reduced overall activity in depressed subjects there are also persistent reports of asymmetries in the electrodermal activity of depressed subjects, with depressed subjects showing higher left hand than right hand activity (e.g. Gruzelier & Venables, 1974). Such differences are usually interpreted in terms of differences in hemispheric activation, although the relationship between electrodermal laterality and cerebral laterality is not well understood (Hugdahl, 1984).

Results from other studies also seem to imply that, as well as a measure of stable individual differences in the vulnerability to depression, electrodermal activity might also provide an index of the severity of depression. Subjects showing MMPI scores indicating more severe depression, whether patients or normal subjects, have been found to show lower skin conductance levels and responsivity. This

could imply that electrodermal measures may be sensitive to the state of depression and could provide an indicator both of the onset of depression and of its severity. Further investigation is needed to determine whether an individual's sweat gland activity does change when the severity of his depression alters. While markers might be expected to show either state or trait properties, but not both, it is possible that markers may provide a stable index of vulnerability and also change with current status. Dawson and Nuechterlein (1986), while presenting a vulnerability model of schizophrenia, introduce the idea of mediating vulnerability markers. These are trait characteristics which indicate the presence of vulnerability for a disorder in individuals who are currently well, while also becoming more abnormal during episodes of illness.

One study has already used the PSI to investigate depression. This study was carried out by Bagg and Crookes (1966) who found that depressed patients showed higher sweat gland counts after recovery than when depressed. This result seems to support the findings reported earlier that the severity of depression is associated with reduced sweating and provides evidence that this relationship does occur within, as well as between, subjects. This implies that the PSI may indeed be comparable with the electrodermal measures of sweat gland activity used in the majority of studies. Surprisingly Bagg and Crookes found few differences between "neurotic" and "endogenous" depressives. However, they do not say what criteria were used to make the division into these two groups and it may be that their diagnostic criteria were sufficiently different from those used in other studies to prevent a direct comparison.

The current study examines bilateral sweat gland activity from a group of twins with a history of depression. In addition, data is also

available from the co-twins of probands, including twins both concordant and discordant for depression. The study compares subjects diagnosed as neurotically depressed with those with a diagnosis of psychotic depression. In addition, pairs concordant for depression will be compared with those discordant for the disorder. It is likely that concordant pairs will possess a greater vulnerability than those discordant for the disorder. If, as predicted this vulnerability is associated with lowered electrodermal activity, then it might be expected that discordant pairs will show higher PSIs than concordant pairs. The PSI was recorded from both hands in this study, allowing the possible occurrence of laterality effects to be examined. Prior research implies that depression should be associated with higher levels of sweating in the left hand.

3.2 Method

The PSI was obtained from subjects in their own homes. Measures were taken from each hand at three different times. Measures were taken at rest, immediately after performing the digit-symbol substitution task used in prior studies, and again at rest. It was hoped that this would provide an index of reactivity as well as of resting levels of palmar sweat gland activity.

The technique used was demonstrated to the experimenters who would be administering the PSI prior to the study, and each was given written instructions covering the technique (see appendix C). All of the prints were scored by the current author.

As well as PSI data, each subject was given a lifetime diagnosis on the basis of an interview and psychiatric history, using the criteria of the Present State Examination (PSE). Data on medication status and whether or not subjects smoked or drank coffee during the

session was also available.

The PSI was analysed both as a count of the number of active glands (PSI-A) and as the ratio of active glands to the total number of glands present (PSI-R). Since the two analyses gave very similar results, only the analysis of the number of active glands will be reported. Because the number of active glands was positively skewed, these data were subjected to a square root transformation prior to analysis.

Because of the high rates of missing data encountered (12% for PSI-A, 16% for PSI-R) missing data points were estimated using the GENSTAT macro MULTMISS prior to analysis. In order to ensure that this procedure had not distorted the results, analyses were repeated excluding those subjects with missing data. As in previous chapters, only where there were differences from the main analyses will the results of this analysis be reported.

3.3 Results

The first analysis to be carried out was a comparison of the three sizable groups of subjects the data provides; normals (n=17), endogenous depressives (n=41) and neurotic depressives (n=38), with time of print (rest 1, task and rest 2) and hand as within subject factors. All three groups were analysed together in a 3 (Group) x 2 (Hand) x 3 (Repetition) MANOVA. Linear contrasts were chosen within the group factor to allow the well subjects to be compared to the depressed subjects, and the two depressed samples to be compared with each other.

None of the analyses revealed any effect or interaction involving the Group factor, or the contrasts within this factor. There was no evidence that current levels of sweating were related to a history of

depression. None of the analyses revealed a difference between the overall levels of activity in the two hands. The analyses of the number of active glands did reveal an interaction between Hand and time of measurement (approx. $F(2,59)=3.25$, $p=.046$). There was also a significant main effect of Repetition (approx. $F(2,59)=3.75$, $p=.029$). Simple effects analysis revealed that only the left hand showed significant variation over time. Surprisingly, the measure taken after the digit-symbol substitution task was not significantly higher than the other measures. The first measure was, however, significantly higher than the last.

As the groups used above had included subjects who were receiving medication and had included a small number of left-handed subjects who might be expected to show atypical laterality, the analyses above were repeated excluding these subjects. These analyses also did not reveal any significant effects involving diagnostic group.

The three groups were compared with regard to a number of variables which might confound the above analysis. Diagnosis was unrelated to subject's age, sex and handedness. The depressed groups were not significantly more likely to be taking medication, although no details were available concerning the type of medication being taken, which almost certainly did differ between depressed and well subjects. There were no differences between the groups with regard to the mean temperature on the day of testing, or with regard to the number of subjects drinking coffee or tea during the session. However, there was a tendency ($p=.051$) for differing levels of smoking in the groups. Individuals with a diagnosis of endogenous depression were more likely to smoke than subjects with neurotic depression or well subjects (35% of well subjects, 27% of neurotic depressives and 54% of endogenous depressives smoked during the testing session).

In order to rule out the possibility that differences in levels of soaking may have masked underlying differences in electrodermal activity, the previous analyses were repeated including the occurrence of smoking during the testing session as a covariate. None of these analyses revealed any significant differences between the groups. Furthermore, the regression of soaking on the PSI failed to reach significance in any analysis, indicating that the effect of smoking on palmar sweating was small.

Of all of the variables studied, only age and drug status appeared to be related to palmar sweating. Both resting prints taken from the right hand correlated significantly with age (Rest 1 $r = -.189$, $p = .032$; Rest 2 $r = -.273$, $p = .004$, both one-tailed). As in the previous study, PSI scores declined with age. When a MANOVA was carried out to compare subjects taking medication with drug-free subjects a significant Drug by Hand by Repetition interaction emerged (approx. $F(2,48) = 3.72$, $p = .031$). This interaction is displayed in figure 69.

Thus, the conclusion to be drawn on the basis of the analyses undertaken so far is that there appears to be no effect of a diagnosis of depression on the PSI, in contrast to the findings of Bagg & Crookes (1966), who found a clear depression of PSI scores in depressed subjects. One point which must be borne in mind is that the normal subjects used in this study were all twins of depressed individuals. Most of the evidence from work with EDA implies that lowered sweating is a trait marker for depression, probably associated with the genetic predisposition to depression. It may well be the case that PSIs from non-depressed twins are not significantly different from those from their depressed siblings because the normal group contains a sizable number of individuals who carry the genetic vulnerability factor for depression and, as a result, have depressed sweat gland activity.

Figure 69: Drug by Hand by Time interaction for the PSI

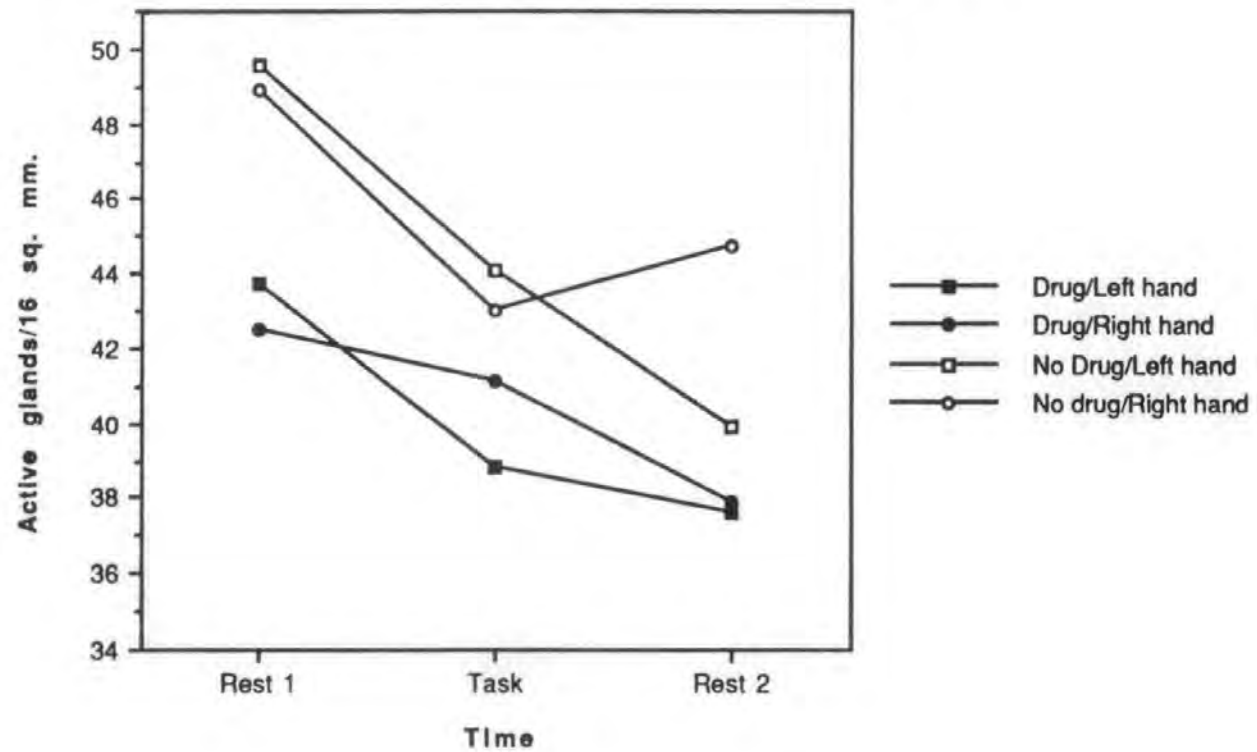


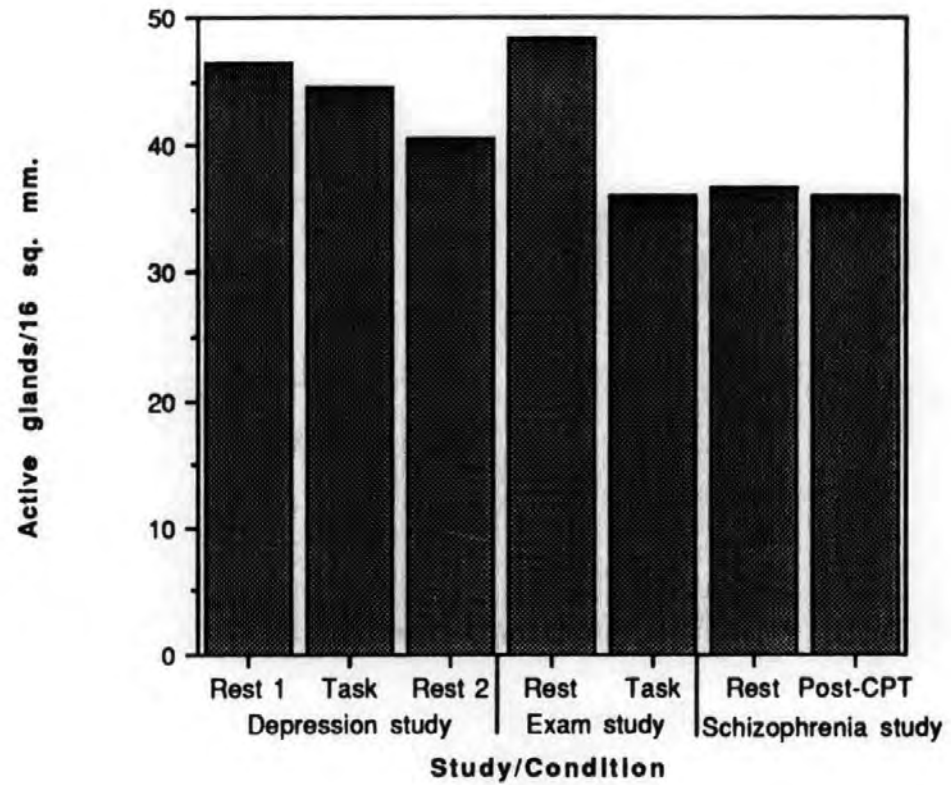
Figure 70 compares PSI scores obtained from well subjects in this study with values obtained from control groups in two previous studies. The scores obtained in this study do not appear to be abnormally low, despite the much lower average age of the control group from experiment three. Such comparisons are limited, however, by the differences in conditions between this study and previous investigations. Further analysis was undertaken to examine the extent to which genetic factors might be affecting the PSI.

Correlations were examined between sweat gland counts from members of those pairs of twins for whom data was available (45 pairs). For each of the three times of measurement, correlations were calculated between the mean level of sweat gland activity in both hands for probands and co-twins. Correlations were also calculated between laterality indices (Left-right/left+right) from each twin. Neither overall levels of activity nor the laterality indices correlated significantly between twins.

The correlations were calculated separately for monozygotic (23 pairs) and dizygotic twins (23 and 17 pairs respectively, information on zygosity was not available for 5 pairs). None of the correlations were significant, there did not appear to be a stronger relationship between the PSIs of monozygotic twins than dizygotic.

Correlations were also calculated separately for pairs concordant for affective disorder and for discordant pairs. Pairs were counted as concordant if both the proband and the co-twin had received a diagnosis of depression or mania. Pairs in which the co-twin had no psychiatric disorder were counted as discordant. Eleven pairs were discordant and twenty-five were concordant, diagnostic data was unavailable for nine co-twins. Once again, none of the correlations were significant. Concordant twins seemed no more similar with regard to sweat gland activity than did discordant twins.

Figure 70: Comparison of control group PSI scores from three studies



In an attempt to examine whether the predisposition to depression had any effect on palmar sweating, sweat gland data were compared for probands from concordant and discordant pairs. The presence of affective disorder in a subject's twin might provide a crude index of the strength of the predisposition to affective disorder, whether genetic or environmental. If this predisposition is associated with reduced sweating, it might be expected that probands from concordant pairs might show lower sweat gland activity than those from discordant pairs. This proved not to be the case. There were no significant effects in this analysis, not even the hand by time interaction found in earlier analyses. In only one analysis did a significant effect involving concordance emerge. When the PSI-R was analysed, excluding subjects with missing data, a concordance by time interaction emerged (approx. $F(2,19)=4.17$, $p=.031$). Initially, subjects from discordant pairs showed much higher levels of palmar sweating than concordant probands. Subjects with well co-twins showed a decrease from rest to after the task, whereas subjects with a co-twin who also had an affective disorder showed an increase. Thus, the two groups' scores converged after the task, and remained similar at the time of the final PSI (see figure 71). Higher PSI scores in discordant twins were predicted. However, this analysis involved small group sizes (7 discordant, 15 concordant), and so its results may not be representative.

Probands from concordant pairs did not differ significantly from those from discordant pairs with regard to age, handedness, temperature during testing etc.

Figure 71: Concordance by Time interaction for PSI-R

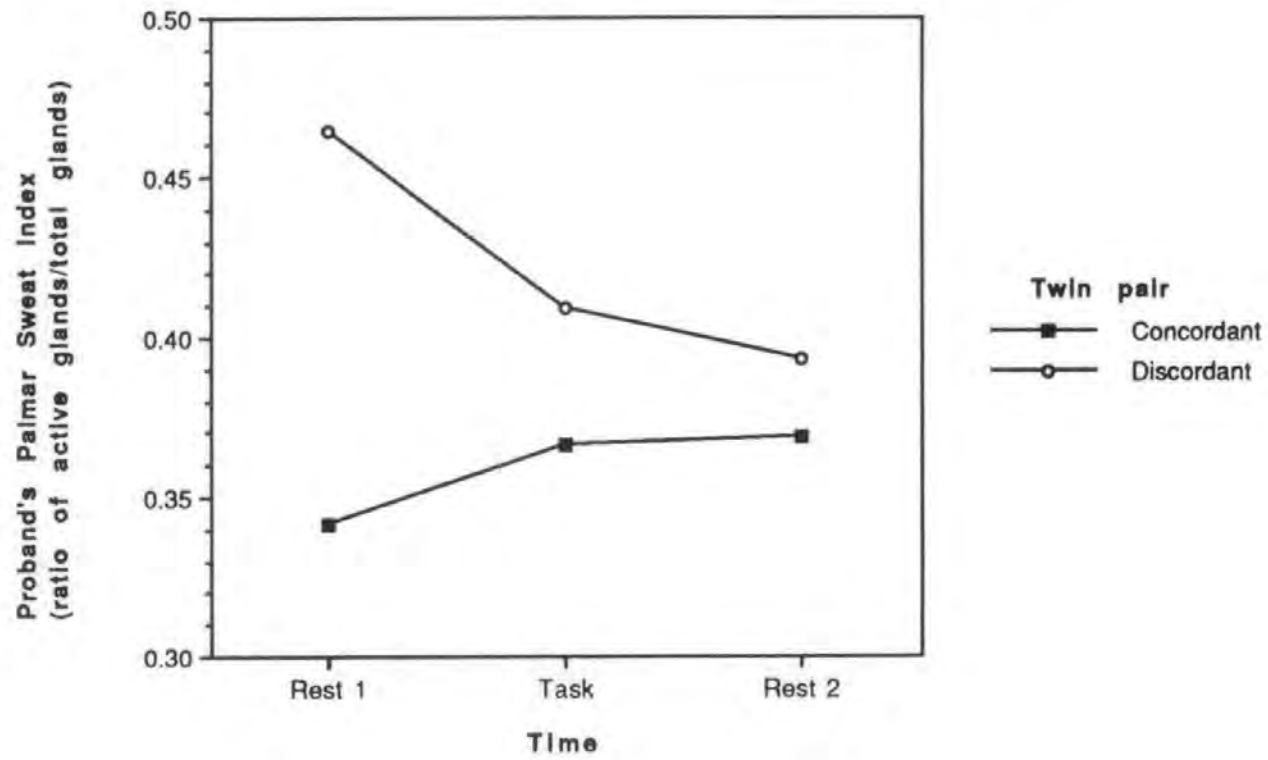


Table 53: Correlations between Palmar Sweat Indices
taken at different times

		Rest 1	Task
Correlation between	Task	.586***	
mean levels of activity	Rest 2	.607***	.551***
Correlation between	Task	.063	
laterality indices	Rest 2	.304**	.190*

* $p < .05$, one-tailed

** $p < .01$, one-tailed

*** $p < .001$, one-tailed

Overall levels of activity showed considerable stability within-subjects. Subjects tended to show similar laterality during the two resting measures, but laterality at rest was, at best, weakly related to laterality after the task, see table 53.

Correlations were calculated between left and right hand PSIs. Between-subject correlations were all quite large. The task appeared to produce lower inter-hand consistency than the resting measures (Rest 1 and Rest 2, inter-hand correlations .597 and .598 respectively, Task correlation .437, all $p < .001$, one-tailed).

3.4 Discussion

The main conclusion to be drawn from this study is that there are no overall differences between depressed and non-depressed twins in terms of the Palmar Sweat Index. In view of the ubiquity of the finding of lowered EDA in depressed individuals, several points would bear further examination. The rate of depression in cotwins of depressed probands was very high, it might reasonably be assumed that a sizeable proportion of the "well" group also carried a risk factor for depression, whether genetic or environmental. The inclusion of an unrelated control group would have allowed this possibility to be examined.

There is also the question of whether the conditions of the test were equivalent. The first "resting" measure followed a diagnostic interview. Such an interview might be expected to be more meaningful to a depressed individual than to one with no history of depression. It might be that the testing conditions were seen as more stressful by subjects who had had a psychiatric illness than those who had not.

In addition, the lack of any quantitative data relating to severity of depression make comparisons between different diagnostic sub-groups difficult. While previous studies have found lower sweating in endogenous or retarded groups of depressives than in agitated or neurotic groups, it is possible that our groups may have differed in the severity of their depression and that such a difference might mask meaningful differences between diagnostic subgroups. It is hoped to obtain such data in the near future. Knowledge of current status at the time of testing would also allow investigation of the possibility that lowered EDA may be a state marker for depression, rather than a trait vulnerability marker.

There was no evidence of consistent lateral differences in the

PSI. In experiment four, where bilateral measures were also taken, both the PSI and measures of EDA revealed higher activity in the right hand. A shift towards greater left-hand dominance has often been reported in depressed subjects. However, this explanation cannot be accepted without considerable reservations. Firstly, laterality was unrelated to diagnosis. Non-depressed subjects also failed to show higher levels in the right hand. Secondly, the PSI showed only weak laterality in experiment four, lateral differences emerging in only one of three rest periods. It is possible that the PSI is less sensitive to lateral differences than measures of EDA.

Neither overall levels of activity nor laterality correlated significantly between twins. There is no evidence from this study that genetic, or common environmental, factors influence the PSI.

The results of the study are somewhat disappointing. There was no evidence for a difference in the PSI between subjects with a history of depression and those without. The PSI also did not seem to discriminate between different subtypes of depression. However, the absence of a true control group in this experiment limits the strength of these conclusions. The mean levels of sweat gland activity observed in this experiment (42 glands /16 sq. mm.) do not seem abnormally low, when compared to those found in earlier studies (30 glands/ 16 sq. mm. for the normal control group in the previous study). Such comparisons are not valid however, given the differences in the populations used and the conditions of measurement.

It is hoped to extend this study by including data on psychiatric diagnosis at the time of testing and by examining the contribution of life events experienced prior to testing, to examine the response to stressful events of those with and without a history of depression.

4 Study Three

4.1 Introduction

The final study to be described used the PSI as an index of anxiety as part of a programme of behaviour therapy. The study was undertaken by John Ormrod in Gloucester. The PSI was used to compare three different forms of therapy with alcoholic subjects. It was predicted that both relaxation training and anxiety management training would lead to successful reductions in anxiety, and corresponding reductions in the PSI. Health education sessions were used as a control condition.

The PSI was used in group training sessions, as an index of the effectiveness of the programme. Techniques such as anxiety management or relaxation training can be taught successfully to large groups, providing an efficient use of psychologist's time. However, evaluation is normally restricted to subjective or behavioural indices of anxiety. Traditional psychophysiological measures require considerable time and expertise to administer, negating the practical advantages of group training. Because the PSI can be self-administered, it may be possible to use it to obtain a physiological index of anxiety with no more effort than is required to obtain self-report measures of subjective anxiety.

4.2 Method

The PSI was obtained from thirty-six subjects, both before and after sessions. Each subject attended six sessions in total. The PSI was self-administered, each subject taking their own PSI, using a bottle of solution and selotape, rather than the method of self-administration used in experiment three.

All palmar sweat prints were scored by the same person. For ethical reasons it was considered desirable to keep all prints at the same site, to guarantee confidentiality. This was necessary to allay any fears subjects may have had about being "fingerprinted". For this reason, prints were scored by the experimenter who supervised the training sessions. The rater was given written instructions for the administration of the PSI, see appendix C. The technique for administering the PSI, as well as the procedure used for scoring, was demonstrated by the current author. A random sample of the prints were independently scored by the current author, the correlation between the two ratings was .79, demonstrating acceptable reliability of scoring.

Thirteen subjects took part in an anxiety management programme, Eleven received relaxation training and twelve received a health education session. Half of the subjects in each group were supervised by an occupational therapist, half by a clinical psychologist trainee.

Because of the method of administration of the PSI, this study had high rates of missing data due to prints being illegible (124 prints, or 29%). Five subjects missed one session each, producing further missing data. As in previous analyses, missing data points were replaced by values estimated using the GENSTAT macro MULTMISS prior to analysis. Because of the high levels of missing data it was not possible to analyse the data excluding the estimated values. Only the number of active glands present were scored.

4.3 Results

The PSI data was analysed in a 3 (Group) x 6 (Session) x 2 (pre vs post session) MANOVA. Two significant effects emerged. There was a

significant effect of time of measurement, post session PSIs being lower than pre-session PSIs ($F(1,33)=66.58, p<.001$). There was also a significant interaction between time of measurement and Session (approx. $F(5,29)=3.71, p=.01$). This interaction is displayed in figure 72. The reduction in the PSI following each session seems to be greater with increased experience. Simple effects analysis indicated that the decrease from pre to post-session was significant, after adjustment for multiple comparisons, only for the last three sessions. It is apparent from the raw data, plotted in figure 72, that the last session did not produce a decrease in sweating when estimated values were excluded.

There was also a weak interaction between Group and Time ($F(2,33)=2.80, p=.075$). Surprisingly, this interaction reflects weaker reductions in sweating after anxiety management than after relaxation training or health education, see figure 73. Simple main effects of Time reached the Bonferroni critical value only for the Relaxation and Health education groups.

As well as the PSI data, an adjective checklist was administered to subjects before and after each session, providing subjective reports of "stress" and "arousal". This scale was a shortened version of the Stress and Arousal Checklist developed by MacKay et al. (1978). For both scales there was an effect of Session, although only "stress" revealed a clear decrease over time. No other effects emerged in the analysis of the "arousal" scale. For the "stress" scale there was also a significant difference between pre and post-treatment measures and an interaction between Time and Session. While a Time by Session interaction also emerged for the PSI, these interactions are different. For "stress", the difference between pre- and post-session measures decreased over time. The opposite was the case for the PSI.

Figure 72: Time by Session interaction for the PSI

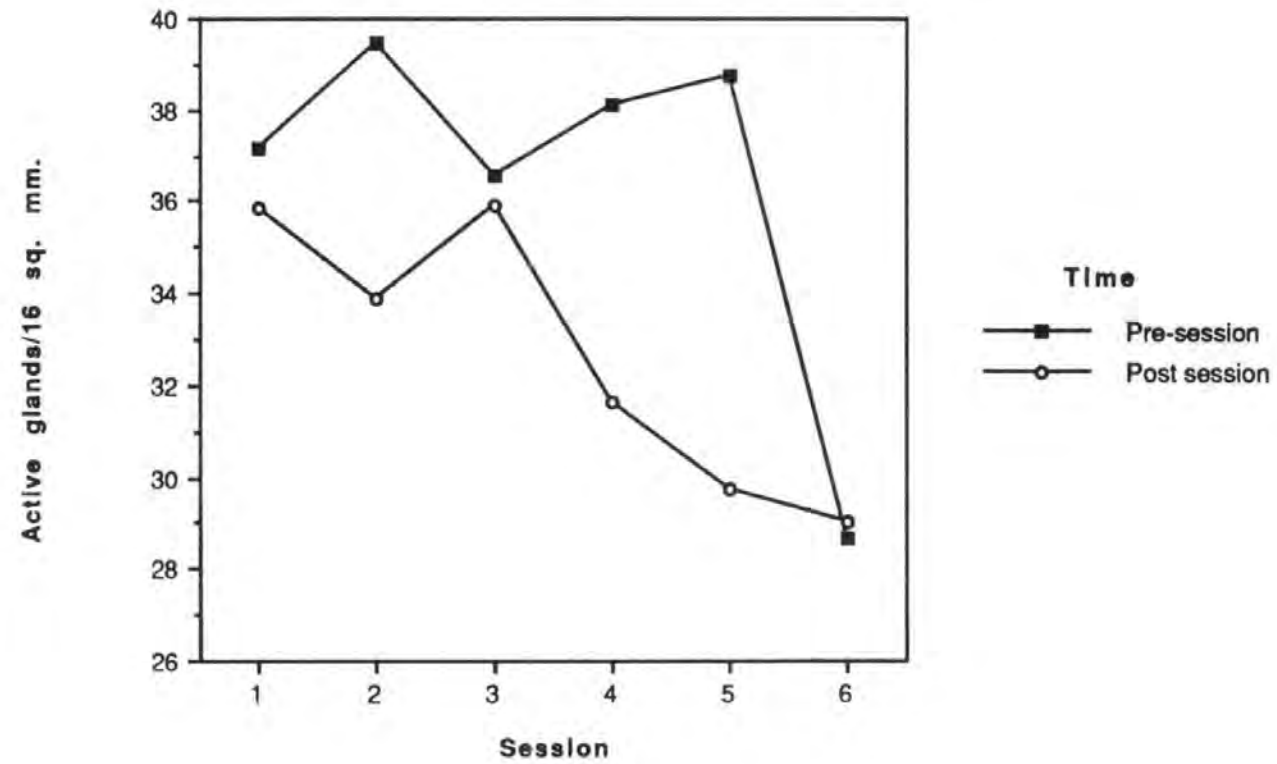
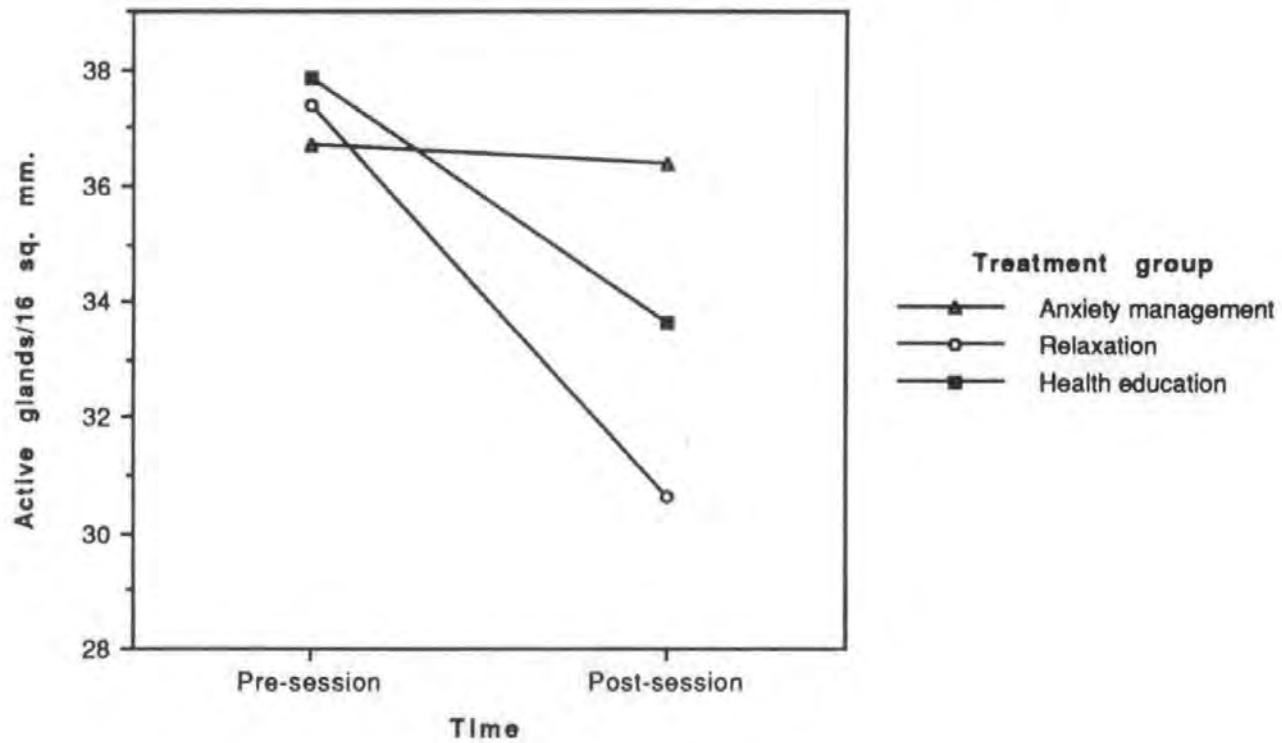


Figure 73: Borderline Group by Time interaction for the PSI



There was also a significant interaction between Condition and Session for the "stress" scale, with the anxiety management group producing a greater decrease across sessions than the health education group.

The Spielberger State-Trait Anxiety Inventory (Spielberger, Gorsuch & Lushene, 1977) was also administered to subjects before and after the course of treatment as an outcome measure. Both state and trait anxiety showed greater reductions after anxiety management than after health education. Anxiety management also produced significantly greater reductions in state anxiety than did relaxation training. The analyses of the subjective measures are described further by Ormrod (1988).

4.4 Discussion

Overall, the PSI indicated that all of the treatments lead to reduced levels of sweating. Furthermore, this effect increased with practice, later sessions producing larger decreases than earlier sessions. This change is consistent with predictions. However such an effect might represent non-specific factors such as adaptation or the placebo effect, rather than a direct effect of behaviour therapy on anxiety.

The results from this analysis fail to bear out the prediction that health education would be less effective in reducing sympathetic activation than the other treatments. Indeed, there is evidence to indicate that anxiety management may have been slightly less effective in producing immediate reductions in sweat gland activity than the other two treatments. The lack of a significant difference between the treatments might be due to the presence of a placebo effect. However, the borderline difference which did emerge is explicable in terms of

the nature of the treatments. Whereas relaxation training should have direct effects on anxiety, and health education may reduce anxiety by distraction, anxiety management focuses attention on the likelihood of experiencing anxiety. Anxiety management may, therefore, produce short-term increases in anxiety, which may be what the PSI is indicating. However, if the training is successful, these short-term increases may lead to better long-term management of anxiety.

There is an apparent dissociation between the results of the analysis of the PSI and the analysis of self-report measures. The self-report measures partially confirmed predictions, the health education control was least effective in reducing self-reported "stress" and anxiety. The PSI, in contrast, implied that the change from before to after sessions might be less for anxiety management than for the other treatments. However, the PSI revealed a difference in within-session changes, while self-report measures indicated that the groups differed with regard to their changes across sessions. The two changes may represent different processes. It is possible that the greater physiological arousal shown during anxiety management may be instrumental in producing greater subsequent reductions in self-reported stress and anxiety.

Foa & Kozak (1986) suggest that activation of fear schemata may be central to the reduction of fear. They further suggest that one way such activation may be observed is by increases in physiological arousal. While this theory is primarily addressed towards fear reduction by exposure, the smaller average decrease over a session shown by the anxiety management group may represent a similar process. Interestingly, studies examining desensitization have, on occasions, also failed to demonstrate across-sessions habituation of physiological responding in subjects reporting successful treatment of

subjective anxiety (Kozak, Foa & Steketee, 1988; Sartory, Rachman & Grey, 1982).

5 Summary

As the studies described here were intended to demonstrate the use of the PSI in a clinical setting, the discussion will not dwell on the results of the individual studies. Instead, this section will attempt to highlight the general conclusions which follow from these studies and to link the studies described here to the findings of the experiments which form the bulk of the thesis.

In general, the studies discussed demonstrate that the PSI can be used in an applied setting. The results of study one, in particular, demonstrate that the PSI can be used as an alternative to electrodermal measures. Study one did not replicate the finding of hypo- or hyper-responsive subgroups within the schizophrenic sample. However, hypo-responsivity is usually defined in terms of electrodermal non-responding. While the PSI was found to correlate with electrodermal habituation in experiment four, no direct measures of orienting were examined in this study. Only measures of tonic activity were obtained, this may be why subgroups were not identified.

In the schizophrenia study, the PSI was related to symptomatology, and the relationships obtained showed some similarities to those obtained in a study using skin conductance measures. This demonstrates that it is possible to generalise between these two types of measurement. Previous experiments have shown that the PSI does correlate highly with various parameters of EDA. The two measures have also been shown to respond in a similar fashion to various experimental manipulations. The study described here provides further evidence that the two measures covary.

The second study, examining vulnerability to depression, failed to replicate previous findings, obtained using both electrodermal measures and the PSI. There are a number of problems with the design of this study. The most obvious problem is the lack of a true control group, all of the well subjects being the co-twins of depressed probands. Even were such a group available, the situation would not be identical for the two groups. The PSI was obtained during a long session including a diagnostic interview. This interview would have very different implications for subjects with a history of depression and those without. For these reasons it is difficult to draw firm conclusions concerning the best explanation for the negative results of this study.

There was no evidence from this study for a genetic influence on palmar sweating. Twins did not show any similarity in their levels of palmar sweating. Correlations between PSIs taken from different hands were all moderate, but significant, providing some support for the reliability of the PSI.

The final study described in this section examined the use of the PSI as an outcome marker in behaviour therapy. The PSI did reveal the predicted pattern of change, both within and across sessions. However, the absence of a clear difference between different treatment groups does not allow the effects of non-specific factors to be separated from treatment effects. There was a non-significant trend in a direction counter to predictions. This trend seems explicable in terms of the content of the treatment and, if replicated, would be consistent with the literature on treatment of anxiety by exposure.

Two of the studies produced quite high rates of missing data (12% in study two, 29% in study three). However, the quality of the prints obtained in the first study compared favourably with those obtained in

earlier experiments, only 3.8% being illegible. It seems that poor print quality is not an inevitable consequence of using experimenters less experienced in taking the PSI. The high rates of missing data obtained in the final study were a consequence of using a method of self-administration. Experiment three, which also used a self-administered PSI, had similarly high rates of missing data (21%). It is possible that this problem might be alleviated by development of alternative means of administering the PSI. In particular, some means of reducing the evaporation of the solution needs to be found. Missing data in experiment two was often due to the solution having dried out before a print could be taken. Procedural factors, such as the taking of more prints, could also reduce the problems caused by missing data.

Studies one and two, provide further confirmation that sweat gland counts taken after a task may not reveal elevated levels of activity. Earlier studies have shown that the digit-symbol task used in study two does not appear to produce large or sustained increases in sweating. From the results of study one, it appears that the continuous performance test also does not lead to lasting increases in sweat gland activity.

In summary, two out of the three studies described provided some support for the predictions made. The results of study one also provide a partial replication of results previously observed using electrodermal measures.

The second study, which produced largely negative findings, suffers from some methodological shortcomings, which limit the confidence which can be placed in the results. In all three studies, there were features of the design which were not ideal, this is inevitable in studies intended to address questions additional to those examined here.

The three studies, taken together, demonstrate the suitability of the PSI for applied research. They demonstrate that the PSI can be administered successfully by researchers with only limited familiarity with the measure. The studies also provide examples of three areas, out of many, where the PSI could make an important contribution to clinical research.

Chapter 13

Discussion

1 Introduction

The research described was undertaken with the aim of demonstrating that the Palmar Sweat Index could be used as an alternative to electrodermal activity. A number of experiments have been described, each, in part, addressing a different topic from the others. The discussion will concentrate on drawing together the common themes from these experiments and showing how, together, they answer the questions identified at the beginning of this investigation.

Four main questions were set out at the start of the thesis. these were

- 1) Can the PSI be measured reliably?
- 2) Is the PSI a valid alternative to electrodermal activity?
- 3) How does the PSI respond to psychological stress?
- 4) Does the PSI provide a valid index of anxiety?

These questions will be addressed in turn.

2 The Reliability of the PSI

Three aspects of the reliability of the PSI have been directly assessed, these are the inter-rater reliability of the scoring of the prints, the temporal stability of sweat gland counts, and the reliability of prints taken from different hands, or from different parts of the same finger.

In addition to direct assessment of the reliability of the PSI, most of the studies described have included some consideration of the contribution of methodological factors to the reliability of the index. These have included comparison of different statistical

treatments of PSI data, and examination of the effects of possible extraneous influences, such as temperature. These issues will also be discussed in this section.

2.1 Inter-Rater Reliability

The data presented in chapter six demonstrate that palmar sweat prints can be scored reliably. The reliability coefficients obtained are comparable to those in the literature. For example, Koehler, Weber & Voegele (1990) report a mean inter-rater reliability of .87, as compared to an overall reliability of .86 for the PSI-A and .89 for PSI-R in this study. Other studies, reviewed in chapter three, report reliability coefficients ranging from .87 to .99.

The results of these analyses imply that the part of the finger chosen for scoring does not influence the level of activity observed. Neither identifying the area scored for the second rater, nor the calculation of the proportion of glands active, lead to increased reliability. If activity varied greatly at different points on the finger, then scoring at the same location should have lead to higher estimates of reliability. If the total number of glands differed for different parts of the finger then both identifying the area scored and the use of the ratio measure should have produced higher reliability scores.

It is known that sweat gland density and activity do vary between different parts of the body (see Kuno (1956) pp63-75). It should be stressed that, even where the area to be scored was not identified for the second rater, both raters attempted to score an area as close as possible to the central whorl. In practice, therefore, the areas scored would be very similar for both raters. The procedure for administering the PSI should be as standardised as possible, including

taking prints from the same part of the finger on all subjects. What these results imply is that, within this constraint, local variations in gland density or reactivity seem unlikely to inflate the error variance of the measure. Were prints to be taken from widely separated areas of the finger, variation in activity between sites is only to be expected.

Automated scoring using an image analysis system also gave support for the objectivity and reliability of visual scoring. The preliminary analysis carried out did not provide support for the use of automated scoring in preference to visual scoring, as a means of increasing reliability. However, the use of image analysis warrants further investigation. In particular the calculation of derived parameters, such as average gland size, or the area covered by active glands, may provide improved sensitivity. A systematic investigation of the procedure used to process the image and extract features might also lead to improvements in sensitivity.

2.2 The Temporal Stability of the PSI

It is neither necessary nor expected that the PSI should show high test-retest reliability. Skin conductance can change in less than a second. The video technique used in experiment five demonstrates that sweat gland counts may be similarly reactive. However, the data presented do provide considerable evidence that the PSI does show consistency across different times and conditions. The most striking evidence comes from experiment three, where subjects' relative levels of activity were stable over a period of several weeks.

In experiment four, all of the measures of electrodermal activity showed evidence for stability. Measures taken at one point tended to correlate significantly with measures taken at other times. For

example, the correlation between mean scores in the initial rest period and scores in the recovery period was .68 for the PSI, for NS-SCRs the comparable correlation was .65, and for SCL it was .95.

Such stability has been demonstrated before (e.g. Schell, Dawson & Filion, 1988). The evidence does not indicate that the PSI shows greater stability than other electrodermal measures. However, the apparent stability of measures of sweat gland activity has implications for the way in which such measures are used. Where the focus is on pre-existing individual differences, such as in research examining putative psychophysiological markers, then it is a pre-requisite assumption that stable individual differences exist. At the very least, similar levels of activity should be observed when measures are taken under similar conditions.

Where research is examining the effects of experimental manipulations, high levels of stability may be more problematic. Stable individual differences will inflate the error variance in such studies and may mask the effects of experimental manipulations. When within-subject manipulations are used, individual differences may be controlled for statistically by the use of change scores, ANCOVA etc. The relative effectiveness of such procedures will depend upon the nature of the individual differences present. Factors to be considered include whether individuals differ in activity or responsivity, and whether the Law of Initial Values is in operation. The effectiveness of different strategies for controlling for individual differences in PSI scores will be considered in a later section. Where manipulations are between-subjects, pre-existing individual differences can only increase the background noise, against which experimental effects must be detected. For this reason the usual practice in psychophysiological research is to include baseline measures and to compare response

profiles, rather than absolute levels of activity. Such safeguards are clearly as important for research using the PSI as for research using electrodermal measures.

2.3 Inter-Hand Consistency of the PSI

One other type of consistency which does have implications for the reliability of the PSI is the degree to which the PSI is stable across different hands or fingers within a hand. If PSIs taken from different hands are not well correlated then the interpretation of the PSI is cast into doubt. Data concerning this point are available from experiment four. In this experiment both the PSI and EDA were obtained bilaterally.

When correlations between measures from different hands were examined, the PSI was found to be slightly less consistent than the two parameters of EDA studied. Between subjects all three measures showed similar, high correlations between measures taken from the two hands. However, when within-subject correlations were examined, the PSI was found to be less consistent across hands than the other two measures. Why this should be so is not clear. The correlations excluded the mid-task measure, so the variation across time was relatively small in comparison to individual differences. This might explain why within-subject correlations were smaller than between-subject correlations, but does not explain why this should only occur for the PSI. Within-subject correlations tended to be higher than between-subject correlations for SCL and NS-SCR frequency. Furthermore, inclusion of the task measure did not produce higher correlations for the two parameters of EDA.

The collaborative study examining sweat gland activity in depression found slightly lower between-subject correlations between

PSIs taken from the two hands. Lower inter-hand correlations might have been expected in this study, one of the reasons for studying depression was that depression has been linked to abnormalities in sweat gland activity, possibly due to some peripheral abnormality (Bernstein et al., 1988). There have been persistent reports of abnormal lateralisation of EDA in depressed individuals (e.g. Gruzelier & Venables, 1974). For this reason, lower than normal inter-hand consistency of sweat gland activity might be expected in subjects at risk for depression.

The only conclusion that can be drawn from these observations is that, while levels of palmar sweating in the two hands do correlate significantly, the PSI may show lower consistency between hands than do the measures of EDA studied. There seems no obvious reason why this should be so. Before more specific conclusions can be drawn, further research is needed to replicate this finding. If the finding can be replicated, it becomes necessary to explain why the inter-hand consistency of the PSI might differ from that of EDA. The lower inter-hand consistency of the PSI may be due to a lower overall reliability. Alternatively, the PSI may be more sensitive to factors acting unilaterally.

The significance of lateral differences in electrodermal activity is unknown. While such differences have been linked to differences in hemispheric activation (e.g. LaCroix & Compere, 1979), there is at present insufficient evidence to allow interpretation of lateral differences (Hugdahl, 1984; Miossec et al., 1985). This provides a strong argument for bilateral assessment of the PSI. If the PSI is sensitive to lateral differences then, until the nature of such differences is known, unilateral recording involves a risk of missing the activity of most interest.

2.4 The Effect of Statistical Treatments on Reliability

In most of the experiments described, several different statistical procedures were used prior to the analysis of the PSI. By comparing the results of these analyses it is possible to gain some idea of the relative effects of the differing transformations.

2.4.1 The ratio of active glands to total glands. In most of the studies, the PSI was calculated both as the number of active glands present (PSI-A) and as the ratio of active glands over total glands (PSI-R). There are a priori reasons to expect the second measure to be more reliable than a simple count of the number of active glands.

However, the comparisons of the two measures did not meet this expectation. The two scoring methods were compared in experiments one, two and four. The two techniques gave very similar results in experiments one and two. In experiment four there were some differences in the results for the two sets of analyses, but there seems little consistency in the pattern of differences. Prior to the task a main effect of group, which was significant when the number of active glands was considered, was of borderline significance when the ratio of active to total glands was considered. At the same time, however, a main effect of hand, which approached significance for PSI-A did not appear at all for PSI-R. After the task the reverse was the case, a borderline effect for PSI-R was non-significant for PSI-A.

Both scores were also calculated in the study examining palmar sweating in schizophrenia, reported in the last chapter. No differences emerged between schizophrenic and control subjects for either measure. The correlations between scores on the PSI-A and BPRS factors were very similar to those between PSI-R scores and

symptomatology.

Comparison of effect sizes, which should give a better estimate of the sensitivity of the two measures, gives some indication that a simple count of the number of active glands may be more sensitive. In experiment one the size of the effect of the task was virtually identical for both measures. However the number of active glands was more sensitive to the between-subjects effect of feedback. The effect of feedback was predicted, but was not significant for any measure other than the PSI. Therefore, use of this effect as a criterion provides only weak support for the number of active glands as the preferred measure. In experiment two speaking produced a larger effect for the number of active glands than for the ratio of active to total glands.

None of these comparisons provides conclusive support for either measure. The comparison of effect sizes implies that the number of active glands may be a more sensitive measure, however this relies, in part, on the assumption that the feedback manipulation in experiment one was effective. This may not be so, the effect observed for the PSI was not apparent in other measures of Electrodermal Activity.

At present, there seems little reason to use the more complicated ratio measure in preference to the original method of scoring the PSI. The high correlations observed between the two scores (.98 in experiment one) mean that the two measures should be virtually identical. The analyses indicate that the advantages of controlling for finger size and gland density do not outweigh the extra variance added by counting the total number of glands present in addition to the number of glands active. Weisenberg et al. (1976) also report that the two measures can be used interchangeably on the basis of their study.

The problem of missing data, to be discussed in detail later, favours the use of the simpler index. In all of the studies described, the number of prints which could not be scored was higher for the ratio measure. Counting the total number of glands is subjectively harder than counting only those glands active. Where prints are very dark, the dark spots corresponding to inactive glands may not be visible, even though the holes produced by active glands are clearly visible.

2.4.2 Baseline differences and the PSI. Experiments one and three considered possible ways of controlling for differences in baseline activity. In experiment one there was an indication that the groups differed with regard to their levels of electrodermal activity at rest. There was no evidence for initial differences between the groups in experiment three. There was also evidence for pre-task differences in experiment four, but no significant group differences emerged in any analysis of the PSI. Therefore there were no grounds for a comparison between different statistical treatments of the PSI.

In experiment one and in experiment three the "baseline" measure correlated positively with the response studied. If the Law of Initial Values was acting, these correlations would be expected to be negative. Thus, the data provide no evidence for the action of the LIV. Therefore, any confounding effect of these baseline differences is likely to appear as a continuation of pre-task differences into task periods. Rather than higher baselines leading to smaller responses, as the LIV would predict.

The conditions of experiments one and three were very different. In experiment one, the baseline measure was obtained immediately prior to the task, in experiment three the "baseline" measure was taken two

weeks before the exam, and may therefore have been subject to the effects of anticipatory anxiety. Despite these differences the analyses produced similar conclusions. In both experiments the use of change scores, subtracting baseline scores from the measures of interest, led to reductions in the number of significant effects observed. The use of ANCOVA, including baseline measures as a covariate, did not change the conclusions of any analysis.

Where there may have been differences in baseline levels of activity, in experiment one, the use of change scores seemed to remove the effects which might have been due to such differences. However the analysis of experiment three suggests an alternative explanation. Rather than statistical control of individual differences the use of change scores may reduce the power of the test.

It is difficult to draw conclusions on the basis of these results. Clearly future studies should test for the possible confounding of between-group comparisons by individual differences. Where there is evidence for such differences, the use of change scores is likely to provide the best means of removing the effects of such differences. Where there is no evidence to suggest that such differences are present there does not seem to be any justification for the use of change scores as a matter of course.

Johnson & Lubin (1972) recommend the use of change scores when the LIV is not in effect. When the effects of the LIV are apparent, then they recommend the use of Lacey's (1956) autonomic lability score, equivalent to the use of ANCOVA (Benjamin, 1963). While the research described evaluated only two of the very large number of transformations that have been suggested for use with electrodermal activity (e.g. Edelberg, 1972a, pp. 398-399; Giesen & McGlynn (1977)), the use of change scores also appears appropriate for the PSI.

The choice of statistical transformations should be guided by common sense. Prior to choosing a transformation, the data should be examined for evidence of the LIV or of baseline differences. While no effect of the LIV was found in this study, under other conditions responsivity might be inversely related to baseline activity, in which case the use of ANCOVA might be more appropriate.

2.5 The Problem of Missing Data

2.5.1 Missing data and the PSI. In several of the studies, particularly those involving self administration of the PSI, the technique produced unacceptably high levels of missing data. As mentioned earlier, computing the number of active glands as a proportion of the total number of glands present lead to higher rates of missing data. However, even when the number of active glands was used, the percentage of prints which could not be scored ranged from just over one percent (experiment two) to 29 percent (the final collaborative study).

Both of the studies where subjects administered the PSI themselves had rates of missing data over twenty percent. One other study, the depression study, where the PSI was taken by another worker, had a missing data rate of twelve percent. In all of the other studies less than four percent of the prints could not be scored. For comparison, in experiments one and four, none of the other psychophysiological variables had rates of missing data in excess of one percent.

The technique used for self administration led to problems with evaporation of solvent. If this technique was to be used in future it might be possible to improve the technique, either by using airtight

containers or by not transferring the solution into the containers until immediately before it was to be used.

The level of experience and training of administrators may influence the quality of the prints obtained. In one of the two studies where the PSI was taken by workers in a different laboratory, the number of prints which could not be scored was high. However, all of the prints in the first study of chapter twelve, and half of those taken in experiment two, were taken by someone other than the current author, and the quality of the prints obtained in these studies was good.

When the PSI is taken carefully by an experienced person it is possible to reliably obtain usable prints. The number of prints which cannot be scored does seem to be slightly higher than the number of points missing when traditional psychophysiological measures are recorded using the polygraph. Where missing data is likely to cause problems it may be possible to compensate by taking more than one measure at a time and averaging the results. The taking of redundant measures is one factor which contributes to the low rates of missing data when traditional psychophysiological measures are used. The polygraph gives a continuous record. This means that, where no data is available at a given point, it may be possible to score an adjacent point.

2.5.2 The estimation of missing values. In the majority of the experiments, missing data was replaced by estimated values. This is a good point to examine the effectiveness of this strategy. In general, there were few differences between the results of analyses excluding subjects with missing values and those where missing data points were replaced by estimates. Examination of those situations where there

were differences does not clearly favour either approach.

In experiment one, the effect of feedback on the PSI appeared to be weaker when missing values were replaced. In the first task period the effect of feedback was significant for PSI-R when subjects with missing values were excluded but of borderline significance when estimates were used to replace missing values. In the extinction period, the estimation procedure abolished the main effect of feedback in the analysis of the change in PSI-A. In both cases the effect of feedback was significant in other analyses of the PSI, but not in the analyses of electrodermal measures.

The use of estimated values also weakened the interaction between difficulty, feedback and time of measurement for SCL in the first rest period of experiment one. This interaction was not significant for any other measure. Although there were indications of stable differences between the groups at other times.

The results of experiment one imply that the inclusion of estimated values might lead to a less sensitive analysis. The effect of feedback was predicted on a priori grounds. The estimation procedure takes no account of groups, and so is conservative with regard to between-subject factors.

In experiment two, only the analysis involving estimated values revealed the predicted interaction between session (speaking versus audience) and time. Analyses reported in chapter eight indicated that the difference was not due solely to the presence of extreme values in the estimated data. In this within-subjects analysis the use of estimated values appears to increase the power of the test.

Both approaches were also used in experiment four. Several effects, were significant when subjects with missing data were excluded, but non-significant (or of borderline significance) when

estimated values were used. A Group x Time x Hand interaction in the first rest period for PSI-R was weakened by the inclusion of estimated values, this effect was significant for PSI-A and NS-SCR frequency. A borderline Group x Hand interaction for SCL prior to the task appeared only when subjects with missing values were excluded. After the task a borderline hand by time interaction for PSI-R, which was apparent for NS-SCRs as well, was replaced by a borderline triple interaction including group, when subjects with missing values were dropped.

The interpretation of these differences is difficult. None of these effects was predicted, although most were present for more than one measure. All but one involved between-subject factors, this reinforces the impression that the estimation procedure may be conservative, where between-subject factors are involved. Two factors were only apparent in the analysis of estimated data. One was the effect of time during the recovery period for both PSI-A and PSI-R, again it seems that the estimation procedure may be more sensitive to within-subject factors.

Finally, a main effect of group was significant for NS-SCRs during the task, when change scores were used. This effect appears to be due to the presence of pre-task differences, confounded by an extreme estimated point in the pre-task baseline. In other experiments, some of the estimated points appeared to be extreme, although there was little evidence that outlying points had distorted the results.

It is impossible to make firm recommendations on the basis of the evidence available. On theoretical grounds, the estimation procedure should increase the power of analyses. This increase in power should result from the use of larger samples and balanced designs. On the other hand, the estimation procedure does not consider group

membership, and so is somewhat conservative with regard to between subject factors. The gain from inclusion of estimated values would be expected to be greater when within-subject factors are considered. The data are broadly consistent with this interpretation. Within-subject effects, such as the Week x Time interaction in experiment two, may be more likely to achieve significance when estimated values are included. When analyses involve between-subject factors, however, effects generally appear weaker when estimated values are included, the blurring of group differences appears to outweigh the gain in power.

The best strategy must be to avoid missing data wherever possible. The strategies discussed above will increase the likelihood of achieving this goal. Where data is lost, the estimation procedure provides an acceptable, if not ideal, alternative to dropping large numbers of subjects. Where missing data rates are high, as was the case in experiment three, replacing missing data may be the only option. With several measures per subject, excluding all subjects with missing data may not leave enough subjects to allow the data to be analysed.

2.6 Possible Confounding Variables

In a number of studies, the effect of variables such as room temperature, smoking etc. was examined. If such extraneous influences do alter subjects' levels of sweat gland activity, then failure to control for the presence of these factors will limit the reliability of the PSI.

2.6.1 Extraneous factors. Room temperature was calculated in all of the experiments. Experiments one and four also included assessment

of subject's skin temperature. In none of the experiments was there a significant correlation between room temperature and levels of activity recorded with the PSI. In both experiment one and experiment four there was a relationship between levels of skin temperature and the size of the PSI response during the tasks used in those experiments.

In some of the studies, other variables were considered. In experiment two, and in the depression study in chapter twelve, data was obtained on whether subjects had drunk tea or coffee. Subjects who had recently consumed caffeine-containing beverages were not found to show differing levels of sweat gland activity from those who had not. In the collaborative study subjects were also allowed to smoke during the session. There was no evidence that smoking influenced the PSI.

2.6.2 Subject characteristics. The literature indicates that palmar sweating may vary with age. Older subjects being reported to have lower levels of sweating (e.g. Catania et al., 1980). There are also reports indicating that there may be sex differences in sweat gland activity (e.g. Weisenberg et al., 1976).

In two of the collaborative studies, there were indications of a decrease in palmar sweating with increasing age. Such a result is consistent with the literature. These studies did not reveal any association between sex of subjects and levels of palmar sweating.

Only one of the main studies, experiment one, provided sufficient male subjects to allow investigation of possible sex differences. In experiments two to five, the proportion of subjects who were male was around 20% or less. The number of male subjects did not reach double figures in any of the last four experiments. Male and female subjects did not differ in experiment one, neither in resting levels of

activity, nor in the size of the response to the task.

2.6.3 Implications for the use of the PSI. Only two of the variables studied have been found to influence the PSI. Higher skin temperature was associated with larger numbers of sweat gland counts. Age was also found to influence the PSI, with older subjects having fewer active sweat glands.

The effect of temperature on the PSI appears to be fairly small. Whether under the controlled conditions of a soundproof room, or in field settings, room temperature did not influence palmar sweating. Obviously, temperatures outside the range studied, such as might be encountered out of doors, almost certainly would influence the PSI. Even in field studies, temperature should be held constant within the normal range wherever possible. While this was not apparent in the data studied, room temperature might influence the PSI via an effect on skin temperature. Steps can be taken to standardise room temperatures, controlling skin temperature is much harder. In future studies it would be a good idea to record skin temperature, where this is practical.

The effect of age on palmar sweating will only cause problems where selection of subjects is not possible. Otherwise, subjects in different groups can be matched with regard to age. Where it is not possible to select subjects, analysis of covariance might provide a method of statistically removing the effects of age on palmar sweating. Although interpretation of the results can be difficult, if inter-group age differences are not solely due to random selection.

There was no evidence for a sex difference in palmar sweating. This does not really challenge previous reports of sex differences. Because of the sex distribution of psychology undergraduates, it was

only possible to investigate possible sex differences in three studies. Thus, the range of tasks studied was limited. Where such differences have emerged they have generally occurred as differences in responsivity to stressful situations (e.g. Kleinknecht & Bernstein, 1978). The literature implies that reported sex differences may be due to differences in appraisal or coping strategies, rather than any physiological difference. Had it been possible to examine the response of the sexes to the exam, or to public speaking, differences might have been found.

Specification of the sex of subjects is a minimum requirement for psychological research. While the research described implies that sex differences in physiological activity are not inevitable, there is sufficient evidence in the literature that such effects can occur to justify further steps to control possible confounding by sex differences. Where practical considerations allow, this can be done either by restricting experiments to subjects of a single sex, or by inclusion of the sex of subjects as a factor in the analysis of experiments.

3 The PSI as an Alternative to Electrodermal Activity

3.1 Introduction

If the PSI is to be used as an alternative to electrodermal activity, for use in those settings where measurement of EDA is not practical, then the two measures should be closely related. This relationship should be reflected in high correlations between the two measures, when both are recorded together. The literature reviewed in chapter three consistently reports moderate correlations between the PSI and SCL, most being in the range .4 to .7. There are few reports in the literature concerning the relationship between the PSI and

other parameters of EDA.

As well as showing significant correlations, the two measures should respond similarly to experimental manipulations. Studies such as that reported by Turpin, Takata and Tutton (1986), which appear to show a dissociation between the PSI and parameters of EDA cast doubt upon the validity of the PSI.

3.2 Correlations Between the PSI and EDA

3.2.1 The PSI and skin conductance. Experiments two, four and five included joint measurement of the PSI and various parameters of electrodermal activity. In all of these experiments, correlations between the PSI and skin conductance level or response frequency were comparable to those observed between the two parameters of EDA. The correlations obtained in experiment five were fairly small, but this is only to be expected considering the small number of subjects in this study, and the fact that the PSI and measures of EDA were taken from different hands. Within- and between-subjects correlations from these studies are summarised in table 54.

Data collected in experiment four indicates that resting levels of sweat gland activity are predictive of skin conductance orienting, subjects with high PSI scores tending to show larger SCRs and slower habituation.

Clearly, the PSI does correlate with electrodermal activity. The index seems to be most closely related to NS-SCR frequency, correlations between these two measures being higher than those between the PSI and SCL. NS-SCR frequency, like the PSI, is also commonly found to correlate positively with resistance to habituation (e.g. Schell, Dawson & Fillion, 1988).

Table 54: Within- and between-subjects correlations between
the Palmar Sweat Index and electrodermal activity

Measures	Study	Between-subjects		Within-subjects	
		Mean	N	Mean	N
PSI/SCL	1	.509	21	.432	72
	4	.414	10	.439	39
	5	-.141	5	.528	20
PSI/NS-SCRs	1	.528	21	.545	72
	4	.614	10	.513	39
	5	.355	5	.345	20
SCL/NS-SCRs	1	.550	21	.449	72
	4	.544	10	.434	39
	5	.337	5	.515	20

NB each value given is the average of a number of individual correlations. The columns headed "N" give the number of these correlations.

The observed correlations between the PSI and SCL are comparable to those reported in the literature. The majority of previous studies report correlations ranging between .4 and .7 (e.g. Venables & Martin, 1967; Voegele & Steptoe, 1986). Table 54 indicates that all three of the tonic measures correlate on the order of .40-.50, with the correlation between the PSI and NS-SCR frequency being slightly higher than that between the PSI and SCL.

On theoretical grounds, it might be expected that within-subjects correlations would be slightly higher than between-subjects correlations. Between-subjects correlations might be reduced by the effects of stable peripheral factors such as finger size, gland density and epidermal thickness. Only the data from experiment 5 gave any indication of differences in the magnitude of the two types of correlation. In the last experiment measures were taken from different hands, which would further reduce between-subjects correlations.

3.2.2 Implications of the gel used in experiment one. In experiment one the gel used for skin conductance measurement was too concentrated, .5M rather than the desired .05M. This is a convenient point to consider what effects the use of a hypertonic electrode gel may have had. The literature indicates that hypertonic gels of 3M concentration lead to elevated levels of skin conductance being recorded (Grey & Smith (1984). A less concentrated gel of .117M was not found to alter EDA, except at the end of a 75 minute experiment, where more concentrated gels led to a larger SCR amplitude (Hygge & Hugdahl, 1985).

The correct gel was used in experiment four, allowing comparison of the two studies. Mean levels of SCL recorded during the initial rest period were higher in experiment one (1.573 vs .993 microsiemens, $p < .001$). As subjects were given the task instructions prior to the

rest period in experiment one, the difference may be due to anticipatory anxiety, although higher observed SCL would be predicted to result from the use of a hypertonic gel.

In experiment one, SCL increased slightly, but significantly over the course of the experiment ($p < .001$). In contrast, in experiment four SCL decreased over time ($p = .019$). Experiment one lasted just under an hour, experiment four lasted about 45 minutes. Elevated EDA toward the end of a long experiment is consistent with the effects of a hypertonic gel. However, experiment one involved a stressful task, whereas subjects in experiment four spent most of the experiment resting. These differences, together with the effects of epidermal hydration (Bundy & Mangan, 1979) might be sufficient to explain this difference between the studies.

In summary, the differences between the EDA observed in the two studies are consistent with an effect of the hypertonic gel used in experiment one. However, procedural differences between two studies also provide an adequate explanation for the differences observed.

If the use of a hypertonic gel in experiment one did, in fact, cause the higher overall levels of SCL observed in that experiment, then this would not have altered any of the conclusions produced. However, if the gel was also responsible for the elevation of SCL over the course of the experiment, then such a change could alter the conclusions drawn from the results. If this was the case then the within-subject correlations between SCL and the other measures would be expected to be lower in experiment one than in experiment four. Examination of these correlations reveals that this is not the case. The two sets of correlations are virtually identical (see table 54). There seems to be no reason to suspect that the use of a hypertonic gel in experiment one lead to any distortion of the results.

3.2.3 The PSI and Heart Rate. Surprisingly, the PSI appears to be more closely related to tonic heart rate than does EDA. Only the PSI correlated significantly with heart rate in both experiment one and experiment four. To the extent that both measures are indicative of sympathetic activation, a weak correlation between measures of sweating and heart rate is to be expected. It is not clear why the relationship is stronger for the PSI than for measures of EDA.

3.3 The Response of the Two Measures to Experimental Manipulations

The main reason for suspecting there might be a dissociation between the Palmar Sweat Index and electrodermal activity, is the evidence, reviewed in chapter 3, for an anhidrotic response from the PSI (e.g. Harrison, Mackinnon & Monk-Jones, 1962). In general, electrodermal activity is considered to increase in response to stress. Later reports indicate that two of the stressors which have been linked to the anhidrotic response appear to produce similar effects on both EDA and the PSI (Voegele & Steptoe, 1986; Johnston & Johnston, 1974). However, other studies have shown apparent decreases in the PSI using other stressors (e.g. Martens & Landers, 1970).

Furthermore, the proposal by Johnson & Dabbs (1967), that the PSI may be responsive to the direction of attention, warrants consideration. Studies reviewed in chapter 3 include several reports of decreased palmar sweating in association with a variety of tasks (e.g. Carver & Scheier, 1981), including one study apparently showing increased EDA in response to the same task (Turpin, Takata & Tutton, 1986).

The relationship between the PSI and experienced stress will be considered in detail later. This section will consider the direct

evidence from studies recording both the PSI and EDA simultaneously.

The tasks used had similar effects on the PSI and on EDA; both increased during the tasks. There was no evidence that either the sentence verification task used in experiment one, or the digit-symbol substitution task used in experiments four and five produced an anhidrotic response in either measure of sweat gland activity.

The digit-symbol substitution task used in the last three experiments did not appear to be particularly effective in producing increased autonomic activation. While studies including measures during the task revealed increased activity, this activity declined almost immediately after the task. In experiment three, where the PSI was only taken after the task, these measures were found to be below the pre-task baseline. Without the evidence from other studies, of an increase during the task, these findings might also have been interpreted as showing an anhidrotic response from the PSI.

The evidence from several of the studies, that the PSI can show rapid changes in activity, provides a partial explanation of some of the studies reviewed in chapter three, which appear to show an anhidrotic response. Several of these studies administered the PSI after a task (e.g. Cohen, 1978; Turpin, Takata & Tutton, 1986; but see Carver & Scheier, 1981). Very rapid recovery of the PSI response, superimposed on gradual adaptation, would lead to post-task levels being below a pre-task baseline.

Because EDA can be recorded continuously, studies using skin conductance measures usually take readings during whatever task is being used. Thus, the apparent dissociation between the PSI and EDA may be partly explained by a tendency for researchers to take the two measures at different times. This tendency would be compounded by any difference in the rate of adaptation of the two measures. In

experiment one, the PSI and NS-SCR rate showed declining levels of activity over time, while SCL tended to increase over the course of the experiment. The failure of SCL to show adaptation may be a result of the use of an hypertonic electrode gel. However, similar patterns have been reported in other studies, and have lead to reports of dissociations between SCL and NS-SCR frequency (see Bundy & Mangan, 1979). Apparent dissociations between the PSI and SCL might result from similar differences in the rate of adaptation of the two measures.

The PSI and electrodermal activity revealed similar responses to the two cognitive tasks investigated. There are other similarities between the results obtained using the two measures.

In experiment one there were indications that both the PSI and measures of EDA responded similarly to the feedback manipulation. The negative feedback group showed indications of higher activation when feedback was given. However, this effect did not reach acceptable levels of significance for the two parameters of EDA. The PSI and SCL also responded similarly during the extinction period, showing an interaction between task difficulty and feedback condition.

There were some similarities between the results obtained using the PSI and NS-SCR frequency in experiment four. Both showed similar interactions involving hand and time of measurement during the rest periods, although these interactions were not explicable. Both the PSI and NS-SCR frequency gave indications that the "Medium stress" group had higher levels of sweat gland activity prior to the task.

In experiment four, one difference emerged between the PSI and EDA. Both Skin Conductance Level and non specific response frequency showed consistent lateral differences, being higher in the right hand, no such differences emerged for the PSI. This is surprising given the

evidence from this experiment indicating that electrodermal activity is more consistent across hands than the PSI.

In experiment five, direct video recording of sweat gland activity revealed an order effect, which was not present for the two parameters of electrodermal activity. All three measures increased during the task used and showed similar recovery afterwards.

The collaborative studies reported in chapter twelve, also provide evidence to indicate that the PSI, does behave similarly to electrodermal measures. The studies reported did not replicate earlier findings of differences in EDA between depressed or schizophrenic individuals and controls. However, the first study did demonstrate relationships between the PSI and scores on the BPRS, within the schizophrenic group, which are similar to those previously reported using electrodermal measures.

In summary, there was little evidence for any dissociation between the PSI and electrodermal activity. The only area where differences between the two measures did seem to emerge, concerned the lateral differences observed in experiment four. Both parameters of tonic EDA showed higher levels of activity in the right hand. No consistent lateral differences emerged for the PSI. The significance of this finding is unclear. No anhidrotic response was observed when the PSI was obtained during a stressor. The digit-symbol task appeared to produce a short-lived response, so that measures obtained immediately afterward revealed levels of activity at or below the pre-task baseline. Only in one study, experiment two, was there any indication that the PSI might show an inhibitory response. This response followed a high level of sweating during the task. As EDA was not recorded in this study, it is unknown whether a similar pattern would have been observed using skin conductance measures. The small

number of studies which have obtained electrodermal measures during public speaking (see chapter 8) only report data for the period while subjects were speaking.

3.4 The Effect of Taking the PSI

The final point considered, was the extent to which the PSI produces effects additional to those produced by recording skin conductance activity. Experiment five produced no evidence that the presence of the experimenter led to changes in EDA. Activity recorded while the experimenter was present did not differ from that while the experimenter was absent.

For obvious reasons, it was not possible to compare the PSI with a true no observation control condition. All that could be done was to search for additional effects of the PSI, above those produced by the procedure needed to record EDA. It is not claimed that administering the PSI has no effects on subject's psychological or physiological state. All that is required is that the PSI produces similar effects to those produced by traditional psychophysiological recording techniques. The results of experiment five imply that this is so.

This conclusion, however, rests on the assumption that the effects of recording the PSI are additive to those of recording skin conductance. If this is not the case, then the PSI may not be interchangeable with skin conductance measures. One way in which this might occur is if the PSI has less effect on subjects than EDA. For example, if the anxiety induced by being in a soundproof room and having electrodes attached is greater than that produced by having the PSI taken from a fingertip, then the response to the traditional psychophysiological procedures might have masked the response to the PSI in experiment five. However, under normal conditions, where only

one measure would be used, the use of the PSI would lead to lower levels of observed activation than the use of skin conductance measures.

The social facilitation literature implies that the presence of the experimenter in the same room is likely to lead to greater, rather than lesser, sympathetic activation. Social facilitation research using the PSI is reviewed in chapter three. However, the possibility remains that taking the PSI on it's own may lead to effects not observed when the PSI is administered together with skin conductance recording. All that can be concluded is that taking the PSI does not inevitably lead to an alteration in sweat gland activity.

3.5 Summary

The research described provides support for the criterion-related validity of the PSI with regard to electrodermal measures. The PSI correlates well with several parameters of electrodermal activity. While the correlations obtained are of moderate size, they are comparable to those observed between different parameters of EDA. Furthermore, in three experiments, the two types of measure were affected in similar ways by experimental manipulations. The rapid recovery of the PSI response provides a partial explanation of apparent contradictions in the literature concerning the PSI.

One difference which was observed concerns laterality. Electrodermal activity was found to show higher activity in the right hand than in the left, the PSI did not. The existence of, and interpretation of, differences between the hands, with regard to the PSI, is a topic in need of further investigation.

Experiment five has shown that administering the PSI does not automatically lead to increased electrodermal activity.

4 The Construct Validity of the PSI as an Index of Stress or Anxiety

4.1 Introduction

The majority of the studies reviewed in chapter three used the PSI as an index of the related constructs of stress or anxiety. The program of research has examined the effects of several manipulations of these constructs in an attempt to clarify the relationship between the PSI and stress or anxiety.

The first three studies were intended to examine the effects of specific manipulations of anxiety. These included two field studies examining ecologically-valid anxiety manipulations, and a laboratory study using a more limited definition of anxiety. All of the studies reported included psychological stressors, in the form of various demanding tasks. In addition the two field studies examined the PSI response to "real-life" stress. Experiment four investigated the relationship between the experience of stressful life events and physiological activity.

The literature review presented in chapter three presented a range of evidence consistent with a positive relationship between the PSI and several forms of anxiety, including fears of surgery and dental treatment and evaluation apprehension. Evidence regarding the relationship between the PSI and stress is more mixed. The literature reviewed in chapter three contains evidence that some forms of stress may lead to a reduction in the PSI. Such reductions are not usually reported with electrodermal measures, although this is probably due to differences in the conditions studied using the two measures (Voegele & Steptoe, 1986). By studying a range of different situations it was hoped to provide a clearer definition of the response of the PSI to experienced stress.

The term stress has no single, universally-accepted definition, it may be used to refer to objective features of the environment, the psychological or physiological response to particular situations or to the subjective process of appraisal linking the two. Even within one of these domains, there is little agreement as to what constitutes stress. Stress may be used to refer to any unpleasant or undesirable stimulus, or stress may be used interchangeably with anxiety, being defined as the threat of negative consequences in the future. Alternatively, stress may be used to refer to any situation involving an increased workload, whether physical or mental. The studies undertaken used a variety of different manipulations in order to attempt to determine in more detail what features of the environment are associated with increased levels of palmar sweating. Prior to general discussion concerning the psychological correlates of increased palmar sweating, the individual studies will be reviewed to determine what conclusions they produce concerning the relationship between the PSI and experienced stress.

4.2 Review of Individual Studies

4.2.1 Experiment one. In experiment one the PSI was found to increase while subjects were carrying out a complex sentence verification task. As well as requiring considerable processing capacity, this task also exposed subjects to the threat of failure. Task difficulty alone was not found to influence physiological activity. The difficult task made greater cognitive demands than the easier task, and also carried a greater risk of failure. The absence of a clear physiological discrimination between the two levels of difficulty implies that palmar sweating may be insensitive to these characteristics. At most, there may be a threshold, for example, tasks

requiring more than a certain amount of processing capacity may produce a response, but with no further increase in sweating for tasks above this level. Task difficulty did interact with feedback in predicting the response to the task. This seems to occur because the difficulty of the task alters the amount of each type of feedback received.

There was some support for the predictions made concerning the effects of feedback on the physiological measures. The PSI was higher in those subjects receiving negative feedback than in those receiving no feedback or positive feedback during the first task period. Support for the predictions from other measures was weak. Heart rate revealed persistent interactions between task difficulty and feedback condition. While the analysis of change scores revealed higher HR in the group receiving positive feedback on the difficult task, which is partially consistent with predictions, the combination of the easier task and negative feedback also led to higher HR on feedback trials. The extinction manipulation had few effects on any of the physiological measures.

Experiment one provided evidence for a dissociation between subjective measures and physiological measures. The feedback manipulation had little effect on self-report measures of anxiety, or on measures of other moods. Self-report measures also failed to correlate with physiological measures. While the manipulation checks administered during the task were comparatively crude, the PSI also failed to correlate with the more sophisticated scales on the POMS.

Desynchrony between subjective and physiological indices of anxiety has been observed many times (e.g. Rachman & Hodgson, 1974). However, the desynchrony observed here is more than just a failure to correlate significantly. The two sets of measures responded most to

different aspects of the experimental manipulation, implying that subjective and physiological measures were tapping different dimensions. The self-report measures were sensitive both to the difference between the two levels of difficulty and to the effects of the extinction period. Physiological measures revealed no clear response to either. Balanced against this is equivocal support from the physiological measures that feedback had the predicted effects. There seems to be little evidence to support the claim that the PSI is acting as an index of anxiety.

Despite some suggestive effects, there is insufficient support for the predictions made concerning the effects of feedback on physiological measures. The results do not provide adequate support for the predictions based on Fowles' proposals concerning the motivational significance of physiological measures.

The experiment included a number of factors which have not been included in Fowles' own research on the three arousal model. Despite Gray's linkage of the Behavioural Inhibition System to anxiety, work in Fowles' laboratory has not included subjective measures of motivation. Only one of their studies has examined the effects of monetary penalties (Perkins, 1982). The inclusion of these factors seems to complicate the results observed. The sentence verification task used in this study is also very different from the serial reaction time task used by Fowles. The use of a different task may be responsible for the differences between the results reported here and those Fowles has obtained. It is suggested that the HR results in this study may reflect the increased motivational effect of less frequent feedback. While Obrist's work (1976) indicates that intermediate levels of success produce the largest physiological response, Fowles' work shows increasing HR with higher success rates (e.g. Tranel,

1983). It is likely that the effects of success rate may vary depending on the nature of the task studied.

4.2.2 Experiment two. Giving a presentation was found to lead to a distinctive pattern of activity including elevated PSI scores prior to the talk and a sharp drop in sweating immediately afterward.

Public-speaking imposes a cognitive load, giving a talk requires sustained attention and makes demands on working memory. Speaking also requires some physical effort, requiring control over respiration and producing cardiovascular effects which are independent of fear (Lang et al, 1983). In addition, the talk produced elevated levels of anxiety. However, self-reported trait anxiety was not associated with higher levels of sweating, rather high trait anxiety tended to be associated with lower PSI scores. State anxiety also did not correlate with the PSI.

In this study the PSI was influenced in a way consistent with an effect of anxiety on the PSI, but the PSI was relatively independent of self-reported anxiety. The apparent dissociation between the PSI and self-reported trait anxiety is consistent with reports in the literature. Several of the studies reviewed in chapter eight, did not observe physiological differences between subjects reporting different levels of public speaking anxiety. Although two studies report contradictory results (Paul, 1966; Beidel, Turner & Dancu, 1985). Previous research has generally failed to examine the period after speaking. It is not known whether the suppression of sweating apparent after the talk would also appear if electrodermal measures had been taken.

The occurrence of elevated sweating prior to the talk is consistent with an association between the PSI and anxiety. The drop

after the talk is harder to explain. It may be due to the physical demands of the talk. Prior research using physical stressors (e.g. Harrison & Mackinnon, 1963; Turpin, Takata & Tutton, 1986) has reported evidence for decreased sweating after the stressor. When measures are taken during physical stress, however, an increase in sweating may be found (Johnston & Johnston, 1974). The literature on the anhidrotic response, reviewed in chapter three, implicates the hormonal response to stress in the occurrence of reduced sweating. Such an explanation is inadequate to explain the apparent depression of sweating occurring after the talk. The depression of sweating was only apparent on a single measure. Any hormonal response to the stress of speaking would have occurred during the talk, or in the anticipation period, and so should also have influenced the PSI taken during the talk.

Higher levels of sweating during the talk, were predictive of higher levels after the talk. This implies that the depression of sweat gland activity is not due to exhaustion of the sweat glands. Whether the drop in PSI scores represents some kind of reflexive inhibition of sweating or is due to psychological effects, such as the temporary blocking of anxiety by relief at having completed the talk, is unclear. In experiment three levels of sweating after an exam gave no indication of a suppression of sweating, although measures were taken some fifteen minutes after the exam and there may still have been anxiety about performance during the exam.

4.2.3 Experiment three. The results of experiment three are disappointing, the examination had only weak effects on the PSI. The exam would be expected to produce high levels of anxiety, and this was found to be the case when subjective measure of anxiety were examined.

Levels of sweating after the digit-symbol task were below those obtained immediately before the task. This might represent an anhidrotic response. However, such a response was not found using the same task in experiments four and five. In experiment four the PSI increased during the task and then decreased significantly afterward. Video recording of sweat glands in experiment five also revealed higher levels of activity during the task. The apparent suppression of sweating in experiment three is probably due to the absence of a true adaptation period in experiment three, coupled with rapid recovery after the task.

The digit-symbol task involves a cognitive load. An attempt was also made to arouse evaluation apprehension, by stressing the similarity of the task to those used in IQ tests. Neither of these properties appears to lead to sustained changes in palmar sweating.

The level of palmar sweating after the task appeared to be more sensitive to the effects of the exam than the pre-task "resting" measure. This is most probably due to the greater standardisation of the post task measure. Although it might represent delayed recovery after the task in those subjects exposed to the stress of the exam (Pardine & Napoli, 1983).

In contrast to earlier studies, there was evidence of a relationship between subjective mood disturbance and the PSI in this experiment. This effect was not specific to self-report measures of anxiety but included measures of other moods, as well as GHQ scales tapping borderline psychopathology. Mood disturbance appeared to be most strongly related to responsivity, rather than absolute levels of palmar sweating. The strongest relationships were with post-task PSIs and with the change in resting PSIs. Current PSI scores also appeared to be negatively related to future somatic symptoms.

4.2.4 Experiment four. Experiment four revealed no clear effect of self-reported stressful life events on the PSI. Analysis of the life event data from experiment one also failed to reveal any clear association between life events and the PSI.

Self-reported trait anxiety, which was highest in the "medium stress" group did predict palmar sweating prior to the task. The PSI did not seem to be related to self-reported mood disturbance or symptomatology.

The digit-symbol task led to increased sweating, with relatively rapid recovery afterward. While the increase produced in the PSI did not achieve significance by a two-tailed test, there was no evidence of suppression of the PSI during the task.

4.2.5 Experiment five. In experiment five the presence of the experimenter had no effect on the number of active sweat glands observed. One explanation for audience effects is that such effects may be due to evaluation apprehension (Cottrell et al., 1968). In this study, any apprehension aroused by the experimenter's presence was not reflected in heightened levels of sweating. However, the audience manipulation in experiment five was, deliberately, weak. Only one person was present, and the experimenter was not explicitly observing the subject. Furthermore, the presence of physiological recording equipment, together with the knowledge that an experiment was taking place means that there was no true "no-observation" control condition. The absence of an audience effect in experiment five can not be considered evidence against an association between the PSI and evaluation apprehension.

Once again, the digit-symbol task led to heightened levels of

sweat gland activity.

4.2.6 Collaborative studies. The collaborative studies reviewed in the final experimental chapter provide little evidence concerning the relationship between the PSI and experienced stress. Neither of the first two studies found that PSIs taken immediately after subjects had performed a stressful task were significantly different from those obtained prior to the task. Whether measures taken during the task would have shown increased activity can only be a topic for speculation.

The first collaborative study revealed a number of relationships between the PSI and symptomatology. Higher PSIs were associated with greater Thought Disturbance and Hostile Suspiciousness and with lower Anxiety-Depression scores. There was also a positive relationship between the PSI and Activation scores for schizophrenic subjects with a recent onset.

While the earlier studies found few links between the PSI and current mood, this study shows that more extreme differences in mood may be associated with differences in palmar sweating. Higher levels of palmar sweating were associated with more florid symptoms for both schizophrenic and Bulimic samples. The strongest relationship was with Hostile Suspiciousness. The higher levels of sweat gland activity in subjects showing greater hostility probably reflect a reaction to the testing situation. Work on expressed emotion in schizophrenia, reviewed in chapter four, indicates that the presence of a critical and over-involved relative may be a potent cause of elevated levels of skin conductance activity. The positive relationship between PSI scores and ratings of hostility and suspiciousness may reveal a similar sensitivity to the nature of a social interaction, in this

case the interaction between the researcher and the patient.

There was a negative relationship between scores on the Anxious Depression factor of the BPRS and the PSI. Chapter four reviews numerous studies showing a negative relationship between severe depression and EDA. One study by Bagg & Crookes (1966) reports a similar relationship between the PSI and depression. However, studies reviewed in chapter four also indicate that neurotic depression is more commonly associated with higher levels of sweating. Patients with anxiety disorders are also claimed to show higher, not lower, EDA. Examination of correlations between the PSI and the subscales which make up the Anxious Depression factor, indicates that the strongest relationship within the schizophrenic sample is with the Depressive mood scale. Although, for the Bulimic sample, the Psychic Anxiety scale also correlated negatively with the PSI. Within these highly selected samples, the PSI did not show a positive relationship to observers' ratings of anxiety.

The results of the final study are consistent with a decrease in the PSI as a result of decreased anxiety, although the predicted differences between the groups did not emerge.

4.3 Discussion

The first two experiments provide evidence that the PSI is responsive to short-term manipulations of anxiety. Although, in experiment one, this evidence is restricted to the effects of feedback on the PSI. Other aspects of the experiment which might be expected to produce differing levels of anxiety, i.e. task difficulty and the extinction period, had no independent effect on the PSI.

There was no evidence to indicate that cognitive tasks lead to decreased sweating during the task, although levels afterward might be

below those obtained prior to the task. Where such tasks produced significant changes, the result was always an increase in the PSI. There was no support for the proposal of Johnson & Dabbs (1967), that inwardly-directed attention might lead to a suppression of palmar sweating. The sentence verification task and the digit-symbol substitution task both produced increased, not decreased, PSI scores.

It remains to be explained why such tasks should lead to increased sweat gland activity. Such psychological "stressors" have a number of common characteristics. These include demands on working memory and sustained attention, and the probable induction of anxiety. The absence of an effect of task difficulty in experiment one implies that cognitive load does not directly influence palmar sweating. Dabbs, Johnson & Leventhal (1968) also report that the difficulty of a word-identification task had no effect on the PSI response to the task. The small number of published studies showing levels of palmar sweating during experimental tasks to be at or below baseline also mitigate against any explanation which links the PSI to cognitive load per se (e.g. Carver & Scheier, 1981; Johnson & Dabbs, 1967).

Invoking stress or arousal as the link between cognitive tasks and increased palmar sweating explains nothing. Both stress and arousal are themselves ill-defined. Furthermore, the unitary model of stress, involving global sympathetic activation, upon which such a link would rest, is now seen as inadequate (e.g. see Levine, 1986). The sympathetic nervous system is capable of a much more flexible response than was once thought. Rather than one stress response, there are numerous responses (e.g. Mason, 1975), allowing a response which matches the demands of the situation.

The review of studies using the PSI, in chapter three, concluded that the strongest evidence regarding the psychological correlates of

palmar sweating concerned anxiety. The series of studies examining fear of surgery and dental fear provided an impressive range of evidence consistent with a link between experienced anxiety and elevated palmar sweating. Such a link provides the most plausible explanation for the evidence indicating that a variety of cognitive tasks commonly produce elevated levels of sweat gland activity. This explanation can also explain why the observation of elevated levels of sweating during such tasks is common, but not universal. Levels of anxiety will vary, depending upon such factors as the difficulty of the task, the nature of the instructions and the personalities of the subjects.

One other explanation which should be considered, is that tonic levels of palmar sweating may be providing an index of the attentional demands of the task. Ohman (1979) has argued that the occurrence of the orienting response marks a call for central controlled processing. Tasks such as sentence verification or mental arithmetic are likely to make considerable demands on processing resources. Tonic measures such as the PSI may be crudely integrating the number of shifts from automatic to controlled processing. Such an explanation needs to account for the absence of an effect of task difficulty on the PSI in experiment one. One possibility is that the novelty of the task may have prevented an effect emerging. With familiarity, it would be possible for some aspects of the task to be handled by automatic processing. This shift from controlled to automatic processing would occur more readily for the easy task than for the harder task. During the extinction period, SCL declined more rapidly for those subjects performing the easy task. Had subjects been given longer to become familiar with the task, differences in sweat gland activity between subjects performing the two tasks might have emerged.

One attraction of the model proposed by Fowles (1980), is that it can partially integrate these two, apparently conflicting explanations. The Behavioural Inhibition System, which Fowles links to increased EDA, responds to conditioned stimuli for non-reward or punishment and to novel stimuli. Gray (1977) links the OR produced to novel stimuli to the action of the BIS. Thus, both anxiety-mediated increases in tonic EDA, and one category of phasic EDA, may be triggered by the same mechanism. At present, there is insufficient evidence to justify the claim that all orienting responses are associated with the action of the BIS.

The studies described provide considerable evidence that "stressful" tasks lead to elevated palmar sweating. There was no evidence to indicate that the experience of more chronic stress was reflected in elevated sweat gland activity. The effects of the examination failed to achieve significance. Despite indications of effects on electrodermal laterality, there was no clear relationship between life event scores and levels of tonic sweat gland activity. The PSI does not seem to provide an index of general stress. For reasons indicated above, this conclusion was only to be expected.

Three of the studies described provide some support for a link between the PSI and anxiety. While not conclusive, the feedback manipulation in experiment one produced the predicted effects on the PSI during the first task period. Experiment two also indicates that the PSI is responsive to a more naturalistic anxiety manipulation. The results of the final collaborative study are also supportive of the use of the PSI as an index of anxiety.

There is sufficient evidence to support the claim that the PSI may be a component measure of anxiety. However, the PSI appears unrelated to subjective anxiety. In experiment one, the physiological

and subjective measures were most sensitive to different aspects of the manipulation. In experiment two, the PSI showed a tendency to correlate negatively with trait anxiety. In experiment three, where the PSI was found to correlate with subjective measures, the relationship covered a wide range of self-report measures, tapping several different moods. The relationship was not specific to scales tapping components of anxiety. In experiment four, there were no more correlations between physiological and subjective measures than would be expected by chance.

There is an interesting division between the results of experiments three and the first two experiments which included subjective measures. The first two experiments found that the PSI was responsive to manipulations expected to produce anxiety. But these experiments found little evidence of any association between the PSI and subjective measures of stress or anxiety. Experiment three, in contrast, found only weak effects of the experimental manipulation on the PSI, but did find associations between self-reported disturbance and the PSI.

Experiment two included relatively few self-report measures, which may explain the virtual absence of a relationship between subjective disturbance and the PSI. However, experiment one included the Profile of Mood States, and found no relationship between scores on the POMS and palmar sweating. Several of the scales from the POMS correlated with the PSI in the examination study. While experiment four also used the profile of mood states, there were differences in the wording of the scale use in that study. The POMS administered in experiments one and three referred to feelings "right now, at this moment". Because the focus of the study was on long-term stress, experiment four asked about feelings over the past week. Experiments

three and four also both included the General Health Questionnaire, yet only in experiment three were scores on the GHQ related to scores on the PSI.

The most obvious explanation for the differing results is that the relationship observed in experiment three might be due to the effects of the examination. The stress of the exam producing changes in mood and in physiological activity. As well as causing changes in the two sets of variables, the exam would also have served to increase the range of mood scores, thereby increasing the potential for significant correlations. The stressors studied in other experiments may have been weaker, or produced effects which were limited to one domain.

However, in this study the PSI was also related to reported disturbance on two of the GHQ scales in the control group. It should be noted that the relationships within the control group all involved change scores. Within the control group tonic levels of sweat gland activity did not relate to current symptomatology. Rather, the between-sessions change in sweating was predictive of the change in depression and somatic symptoms over the same period. Other studies could not detect such effects, because they took measures on only one occasion. It is possible that the PSI might not be related to acute changes in mood, but might be related to more enduring psychological states.

Two observations count against this explanation. Firstly, the number of significant correlations observed in the control group was small. Secondly, the relationship between the PSI and the somatic symptoms scale was complex. There were positive correlations between the changes in the two measures over time. However, current levels of palmar sweating correlated negatively with somatic symptoms some weeks

later. Further research is needed to investigate the relationship between the PSI and psychological symptoms.

In the first collaborative study, the PSI was also found to correlate with symptomatology. This may provide one link between palmar sweating and stress. There was no real support for a direct effect of exposure to stressful events on levels of sweat gland activity. However, if the PSI is sensitive to more serious psychological disturbance, then changes in the PSI might be expected for those subjects exposed to more serious stressors, or who are especially vulnerable to their effects. The small number of studies reviewed in chapter four, showing changes in electrodermal activity in schizophrenic subjects, following the occurrence of life events, imply that this population may show such vulnerability.

5 Conclusions

This thesis examined four issues. The conclusions to be drawn with regard to each of these issues have been considered. These conclusions will be reviewed, concentrating on the implications for future research using the PSI.

The first issue to be examined was the reliability of the PSI. Inter-rater reliability was shown to be acceptable. A number of suggestions can be offered for future users of the PSI. The comparison of different statistical treatments of the PSI favoured the absolute number of glands, in preference to the proportion of glands which were active. The elevated rates of missing data observed with the ratio measure did not seem to be balanced by greater sensitivity.

When different methods of controlling for baseline differences were compared, the comparison did not clearly favour any one approach. Where baseline differences were suspected, the use of change scores

was effective in removing their effects. However, change scores appeared to reduce the sensitivity of the index, and so their use cannot be recommended where no baseline differences are apparent. The literature on electrodermal measures recommends the use of ANCOVA as a means of removing the effects of the Law of Initial Values. However, there was no evidence for the action of the LIV in these studies.

Only two extraneous variables appeared to influence the PSI consistently. Predictably, higher skin temperature was associated with higher levels of sweat gland activity. Although no such effect was noted when room temperature was recorded. Previous reports of lower sweating with increasing age were replicated. Where possible, future studies should monitor these variables. If necessary, taking steps to control for their effects.

Two issues are worthy of further investigation. Firstly, the PSI was found to show considerable stability over time. The significance of this stability should be established. Some of the results obtained, suggest that levels of palmar sweating may be related to more chronic mood disturbance. It should be established whether stable patterns of mood or symptomatology can account for the stability of the PSI. The literature on electrodermal lability implies that levels of sweat gland activity may be predictive of performance. Similar trends might exist for the PSI. Experiment four demonstrated that the PSI was independently related to both of the components which comprise electrodermal lability.

The second issue in need of further investigation concerns the apparent absence of lateral differences in palmar sweating, when assessed by the PSI. While right hand dominance was consistently observed for parameters of EDA, there were virtually no lateral differences with regard to PSI scores. While worthy of investigation,

this issue is unlikely to be resolved until the significance of lateral differences in EDA is finally established.

The second topic which this thesis examined was the criterion-related validity of the PSI. The PSI was shown to correlate with several parameters of EDA. More importantly, no evidence was obtained to support previous reports of dissociations between the PSI and EDA. It was demonstrated that the PSI is a highly responsive measure and can change very rapidly. Future research should carefully consider the timing of PSI administration. Measures obtained after a task may not provide an adequate index of the response to the task.

The significant correlations between the PSI and a variety of different parameters of EDA are consistent with models of electrodermal activity involving a single effector, see chapter two. However, the moderate size of the correlations obtained implies that the process of transduction from sweat gland activity to psychophysiological measurement may alter the original "signal" considerably.

Finally, the thesis examined the construct validity of the PSI with regard to stress and anxiety. Several "stressful" tasks were found to produce increases in the PSI. No evidence was obtained for an anhidrotic response to stress. Such tasks appear to be effective means of producing increased sweat gland activity. The rapid recovery shown by the PSI provides an explanation for previous reports of reduced sweating after such tasks. Future studies need to give careful consideration to the timing of the PSI.

Public speaking was found to lead to a depression in sweating after the talk. Although this decrease was subsequent to elevated sweat gland counts during the talk, and in the anticipation period. As electrodermal measures were not obtained in this study, it is not

known whether decreased skin conductance would also have been observed. This observation is in need of replication. As well as examining the electrodermal response to public speaking, future research should also examine the timing of the response more closely. In experiment two the mid-task PSI was taken after subjects had been speaking for seven minutes. The response to the talk may have partially declined by the time the mid-task PSI was taken. Similarly, more frequent measures would clarify the timing of the post-talk suppression of sweating. The data obtained in experiment two do not clearly specify when the drop in sweating commenced, or how long the suppression lasted.

The PSI does not appear to provide an index of general stress. Acute, psychological "stressors" appear to lead to elevated sweat gland activity. However, more chronic stressors had no clear effect. Not unexpectedly, the sweat glands do not appear to be involved in a single, unitary stress response.

Several of the studies described do provide support for a link between the PSI and experienced anxiety. The results of experiment one warrant further investigation. Both the PSI and heart rate gave some support for the predictions. It was expected that task difficulty might interact with feedback. However, the interactions observed are different from those reported in the literature (e.g. see Fowles, 1983). What is needed, is a systematic investigation of the effects of task characteristics, feedback type and task difficulty. The model on which Fowles' proposals are based clearly specifies the nature of the stimuli which are claimed to produce anxiety. However, the model is couched within the framework of learning theory. Research is needed to clarify the relationship between Gray's model of motivation and more naturalistic anxiety manipulations.

Inevitably, the studies carried out have raised further

questions, and suggested further lines of research. Several of the original questions have been answered. In particular the relationship between the PSI and EDA has been clarified. The PSI can only be a substitute for electrodermal activity. Where electrodermal recording is possible, EDA remains the measure of choice. What the PSI may do, is to allow sweat gland activity to be assessed in situations where electrodermal measurement would be impractical. Several areas of research have been reviewed where the PSI might make a contribution. The PSI may also provide a means of further examining the relationship between sweat gland activity and the observed phenomena of electrodermal activity.

Many of the outstanding questions identified in this section can not be answered using the PSI alone. There are still important gaps in our understanding of the mechanisms producing electrodermal activity, and in our understanding of the psychological significance of EDA. It is to be hoped that the PSI may provide a useful tool in the attempt to reduce those gaps.

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APPENDIX A: SCORING CRITERIA FOR THE PSI

Wherever possible, all prints are scored from an area centred on the central whorl of the print. Where the print is imperfect and this area is not available, whether because that area is physically missing from the print, or because the print in that area is too dark or smeared, the nearest clear area is used. Where possible, the template is aligned with the long axis of the print, so that the grid is parallel to the axis of the print, and the bottom edge of the template would be at right angles to the finger.

The print is only scored if the whole of the template can be used. If no clear, intact area can be found, no attempt is made to score a smaller area and multiply up. All glands are counted from the light areas of the print, corresponding to the ridges on the finger. Occasional light holes on the grooves of the print are ignored. Several such holes can be seen clustered at the top right of print one. These holes appear to represent drops of water smeared onto the surface of the finger and may be numerous on very active prints.

On the first pass, the number of active glands is determined. Any gland which has a white dot at its centre, however small, is counted as active. The size of such glands can vary greatly, from the numerous large holes seen on print two, to the smaller number of tiny holes seen on print three. Print two also includes a spattering of random holes which would not be counted as active sweat glands. Where such holes are this widespread, the placement of the holes needs to be considered: Only holes which are evenly spaced and which, for small holes, fall near the centre of the surrounding dark ring, are counted as active sweat glands.

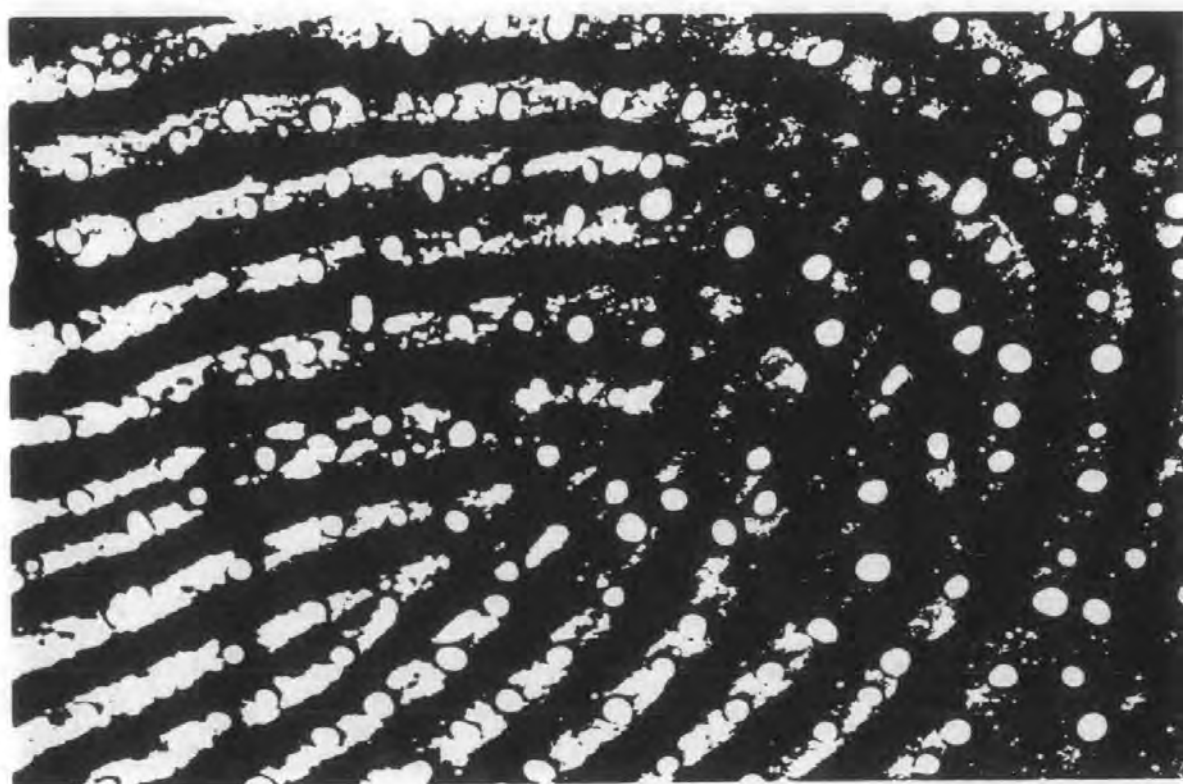
Some glands, particularly if the print is very dark, may appear with "bubbles" of water trapped underneath the plastic film. These correspond to active sweat glands which have not managed to "break through" the plastic film. All of the glands on print four are covered by a thin layer of plastic. These glands appear darker than usual, although still whiter than the surrounding circle, and may have a more noticeable dark ring around them than is usual. Such glands are also counted as active.

At the second stage, the total number of glands, active and inactive, is determined. Inactive glands appear as small black dots. The size and visibility of inactive glands may vary. On darker prints they may appear as black smudges of a comparable size to active glands, whereas on lighter prints they may appear only as small dots. The inactive glands visible on print one vary greatly in size and shade. Occasionally, some prints may be too dark for inactive glands to be seen, although active glands are visible, print four is almost this dark. On such prints only the total number of active glands is scored. Care should be taken, however,

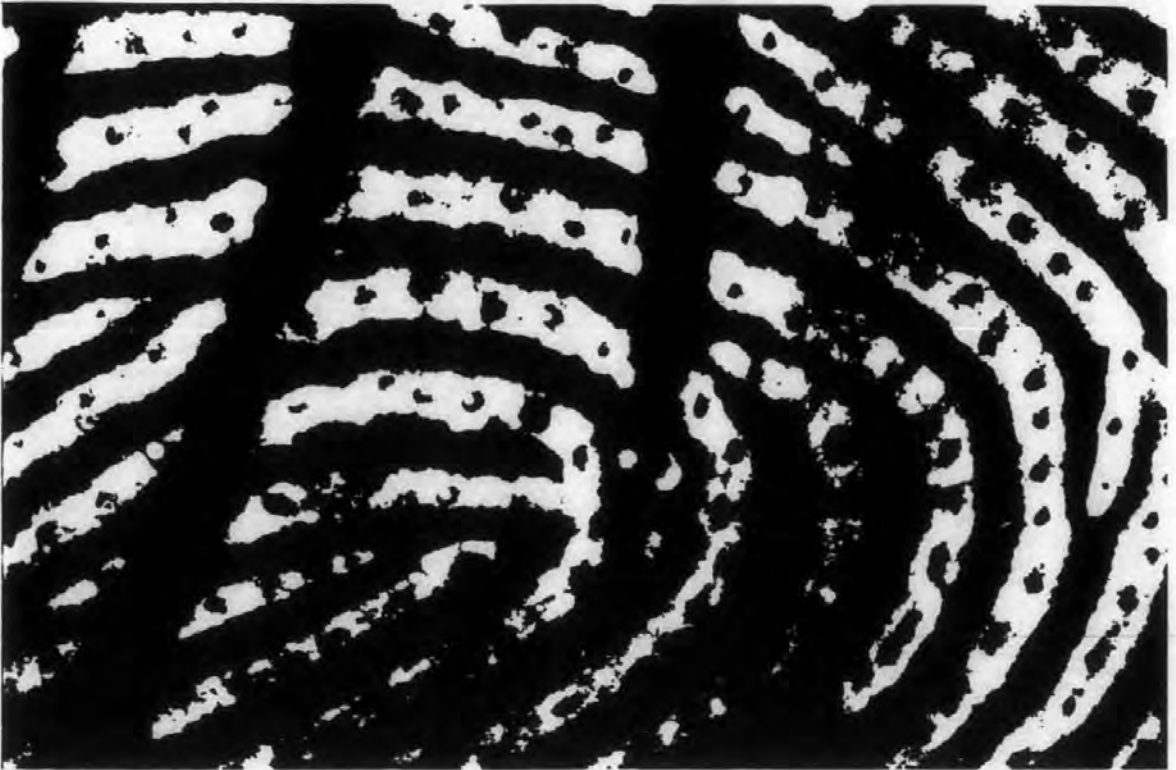
to ensure that active glands, if present, are truly visible over all of the area to be scored. e.g. some active glands at the top right of print four are barely visible, being almost totally covered by solution.



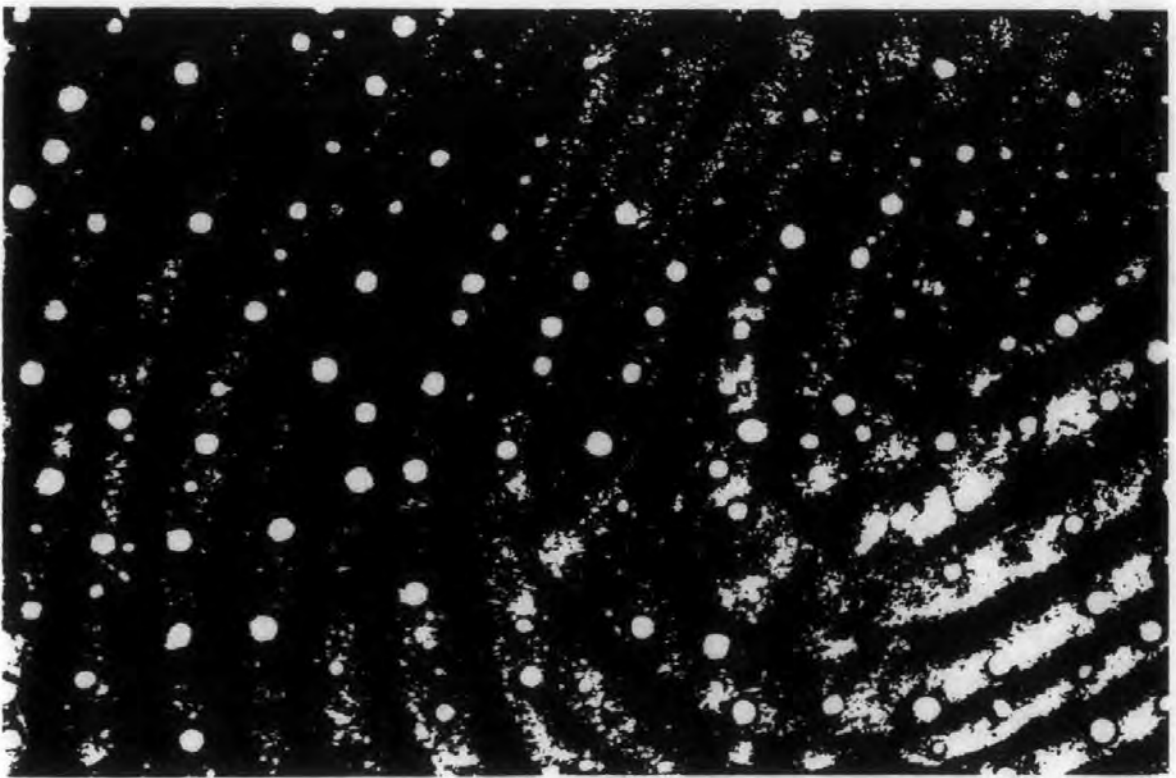
Print One



Print Two



Print Three



Print Four

APPENDIX B: THE DIGIT-SYMBOL SUBSTITUTION TASK

The following task is a digit-symbol substitution task similar to those used in IQ tests. The task is intended to provide an index of physiological reactivity. At the top of the task is a table of the digits from 0 to 9 with a symbol under each digit. When told to start you should fill in each of the boxes underneath with the symbol corresponding to the number above the box. You should fill in as many boxes as you can in the time available. You will be told to stop after one minute.

DO NOT START UNTIL TOLD TO DO SO.

DIGIT	1	2	3	4	5	6	7	8	9	SCORE															
SYMBOL	+	o	c	u	r	-	x	L	/	<input type="text"/>															
2	1	3	7	2	4	8	1	5	4	2	1	3	2	1	4	2	3	5	2	3	1	4	6	3	
1	5	4	2	7	6	3	5	7	2	8	5	4	6	3	7	2	8	1	9	5	8	4	7	3	
6	2	5	1	9	2	8	3	7	4	6	5	9	4	8	3	7	2	6	1	5	4	6	3	7	
9	2	8	1	7	9	4	6	8	5	9	7	1	8	5	2	9	4	8	6	3	7	9	8	6	

APPENDIX C: DETAILS OF THE PSI

The Palmar Sweat Index

Developed by Sutarman and Thompson (1952), this measure provides an index of sweat gland activity which is quick and easy to use, highly portable and less intrusive than traditional measures of electrodermal activity. The PSI consists of a count of the number of active sweat glands in an area 4mm x 4mm, centred on the central whorl of a fingertip. This site is chosen because a fingertip is both more accessible and more easily localised than an area in the palm. In order that the measure be as standardised as possible, it would be advisable for all researchers to use the same finger; the middle finger of the non-preferred hand is recommended.

The PSI is produced using a plastic impression made with the following solution:

Polyvinyl Formal (Formvar)	5gm
Butyl Pthalate	10ml
Semi-colloidal dispersion of Graphite in Trichloroethylene	20gm
Ethylene Dichloride	100ml

Derived from Johnson & Dabbs (1967)

The Formvar is the "active ingredient", as it is immiscible in sweat, so that pores containing droplets of sweat produce holes in the impression. Butyl Pthalate acts as a plasticizer, giving strength to the print, and Graphite aids visibility by making the print darker, so that holes show up more clearly. However, too much graphite will make the solution too thick, so that smaller droplets may be covered and not counted.

The solution reacts with rubber and some plastics, and should be kept in a glass flask, with a glass or cork stopper with a flat bottom. The print can be applied using the stopper. After excess drops of the solution have been shaken off on the top of the flask, the flat end of the stopper should be rolled over the finger once, from side to side, to produce an even, thin layer of solution. This layer dries in about twenty seconds and, once dry, can be removed with ordinary household sellotape. The sellotape is best applied and removed proximal to distal, as the print is less likely to break up when removed this way. Rubbing the sellotape a few times before removal seems to aid the process.

After removal the sellotape can be stuck onto a microscope slide or acetate sheet, and scored under a microscope or magnifying glass of at least 10X magnification (40X is ideal). Active glands appear as distinct white holes on the, lighter, ridges of the fingerprint. Inactive glands show up as darker spots, due to the accumulation of graphite in the pore. White openings on the grooves of the print are not counted as sweat glands. Scoring is aided by the use of a template

4mm x 4mm, especially if this is divided up into a grid. If the grid is centred on the central whorl of the fingerprint, repeated counts may be taken from the same area of finger.

It is advisable for all subjects to wash their hands at the start of session, as not only does this standardise the time since hand-washing, but it also makes the prints easier to remove. Before taking a print, it is advisable to blot the finger to remove residual sweat. As with all measures of sweating, subjects should be allowed to acclimatise to the temperature in the testing room, which should be as stable as possible. If possible, the temperature should be recorded at the start of each session.

Summary of Procedure

Start of Session	All subjects wash hands. Record room temperature.
Each print	Blot finger. Shake flask and remove stopper. Remove excess solution, then roll the stopper over the middle finger of the non-preferred hand. Wait for the solution to dry (approx. 30 seconds). Apply sellotape from base to tip. Briefly rub sellotape, then remove, still base to tip. Apply sellotape to microscope slide or clear acetate sheet.

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