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Subjective pitch and the generalization gradient.

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SUBJECTIVE PITCH AND

THE GENERALIZATION GRADIENT

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ABSTRACT

An attempt was made in the present study to investigate conditioned generalization of the GSR along a subjective pitch continuum. With this purpose in mind, Hovland's classical generalization experiment to various frequencies of sound was, in part, repeated, using the "mel" (ratio) rather than the "jnd" (confusion) scale. Following Stevens' basic assumption of equivalence, on metathetic continua, between these two subjective scales for pitch, it was hypothesized that the slope of the generalization gradient would be similar in shape to that obtained by Hovland, ie., negatively accelerated.

Using electric shock as the conditioned stimulus, 22 SS were conditioned to respond to a tone of 1000 mels in pitch, and tested for generalization at 500 and 250 mels.

In assessing the data statistically, significant generalization effects were found. When mean GSR values were plotted, the resulting group curve approached Hovland's exponential function. Individual gradients also followed the same pattern, with no statistically significant departures from the group curve.

On the basis of this investigation, it was concluded that (a) generalization occurs to subjective pitch, and (b) the shape of the generalization gradient is the same when pitch is scaled in either jnd or mel units. This conclusion lends support to Stevens' suggestion of the equivalence of confusion and ratio scales on metathetic continua. The findings further confirm the validity of Hovland's study and its importance to learning theory in general.

PREFACE

The present investigation stemmed originally out of the author's interest in the possibility of learning the perceptual discriminations and relationships needed in the development of musical ability. Pitch is, of course, one of the most important dimensions in music. The idea of determining a conditioned generalization gradient to subjective pitch, by duplicating in part Hovland's generalization experiment of 1937, was first developed and discussed in the experimental psychology laboratory at Assumption University of Windsor, during lectures given by Dr. A. A. Smith, His professorial teaching and guidance in this research are greatly appreciated.

The author was fortunate to have had the assistance and encouragement of Rev. Brother Roger Philip, F.S.C., Ph.D., first professor emeritus of Assumption University of Windsor, and to whom this dissertation is dedicated. The writer is indebted, also, to Dr. W. G. Benedict, of the Biology Department for his interest and useful suggestions. Special acknowledgement is made to Mrs. E. J. Broy, for more than ordinary care in the preparation of the final manuscript. Finally, sincere gratitude goes to the subjects who participated in the research experiment.

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CHAPTER I

INTRODUCTION

Conditioning in Learning Theory

Conditioning has become a well-established principle of learning in psychology. From the time of Pavlov (1849-1936), who originally devised the experiments and coined the term, hundreds of articles on conditioning have appeared. Many of the leading articles on this topic were summarized by Hilgard and Marquis, in their book, Conditioning and Learning, (1940). Since that time, interest in this area has not slackened.

The terminology varies somewhat, but for purposes of this research the terms and definitions given below will be used. The phenomenon of conditioning is described in the Encyclopedia Britannica (VI, 221) as follows:

> Conditioning is applied to certain processes and products which characterize the acquisition of learned behaviour . . . . [and] . . . . has two aspects: 1. a given stimulus (S_1) which normally activates a primary (unconditioned) response (R_1) is made to elicit a secondary (conditioned) response (R_2); 2. a given response (R_1) which is normally elicited by the primary (unconditioned) stimulus (S_1) can now be activated by a secondary(conditioned) stimulus (S_2).

This definition categorizes both classical and instrumental or operant conditioning. A third main aspect which governs the principle behind the formation of habits is called multi-response learning. In classical conditioning phenomena, a neutral stimulus which immediately precedes or occurs simultaneously with an unconditioned reflex stimulus in a paired fashion, will tend to assume characteristics of the original stimulus and thus elicit by itself the reflex movement. This process is sometimes referred to as "stimulus substitution". The scope of this paper merely allows an account of classical conditioning.

Conditioned responses were first tested in the laboratories of the Russian physiologist, Pavlov. He observed that either learning or direct physiological methods could be adopted in controlling secretions from the dog's salivary glands. Dethier and Stellar (1961, p. 83) give an appropriate illustration:

> In his classical experiment, Pavlov lightly restrained a dog in a harness and repeatedly blew meat powder into its mouth and recorded accurately the amount it salivated. Then he associated the sound of a bell with the meat powder and repeated this procedure many, many times at successive intervals. The bell, of course, did not at first elicit salivation, but after repeated pairings with meat it came to do so. In describing this experiment Pavlov called the salivation to the bell a conditioned reflex (CR), the bell a conditioned stimulus (CS), the salivation to the meat powder an unconditioned reflex (UCR) and the meat itself an unconditioned stimulus (UCS).

Several basic phenomena of the conditioned response were observed and isolated by Pavlov and his co-workers within the stimulus-response relationship of conditioning. These can be enumerated as reinforcement, generalization, discrimination, and extinction. Reinforcement is the pairing of conditioned and unconditioned stimuli. Generalization is the ability on the part of the organism to transfer or react to similar stimuli; whereas its complementary process of discrimination is described as that ability to react to differences. Generalization has often been considered, by many leading psychologists, as a lack of discrimination. Repetition of the conditioned stimulus without reinforcement is known as extinction.

After Pavlov's major work, Conditioned Reflexes, was translated into

English in 1927, both research and theory in this area grew in America. It was Hull (1884-1952) who first attempted to construct a theory that encompassed fully the conditioning phenomenon and set the pace for investigating the complexity of learning theory linked with it. Reviewing conditioning, Hull (1934) lists numerous types of responses most commonly conditioned, and the particular types of stimuli that have been used to a great extent in human studies. The list includes hand withdrawal, eyelid closure, knee jerk, and vasomotor and psycho-galvanic responses.

The Conditioned Generalization Gradient

Following Pavlov's physiological findings, which form the basis for conditioning research in the literature, "conditioned generalization" has come to be regarded as one of the fundamental principles for the newly-forming "objective" science of behaviour. Today "conditioned" has become the synonym for "learned" behaviour. Subsequently, there arises the logical necessity of formulating some principle that extends primary conditioning to a range of stimuli, not merely to the original or conditioned stimulus (CS). The phenomenon of "generalization" provides for just such a principle, that is, a mechanism whereby this process will occur with relative consistency. Assuming that stimulus "A" has conditioned response "R", this same response may follow from a whole range of stimuli "B', "C", "D", etc. Do generalized stimuli, then, evoke responses with the same or different magnitude; and if so, what is the relationship? Furthermore, can the strength of a response to generalized stimuli be predicted to vary with its degree of similarity to the basic CS originally conditioned?

Hence, when a conditioned response (CR) to a particular stimulus has been acquired by the organism, other similar stimuli will also evoke the response. The relatively equal ability of various stimuli to condition a response is commonly referred to as "stimulus or sensory generalization". Similarly, generalization occurs on the response side, such that a stimulus which originally elicited a particular response in the training period will, in certain instances, evoke a different response without additional training. The degree of equivalence among responses is known as "response generalization" (Hilgard and Marquis, 1940).

Following Pavlov's and Anrep's laboratory findings, cortical "irradiation" of excitatory nervous processes was considered to be the cerebral mechanism underlying the active process of generalization. When a novel situation develops, the organism's successful approach to it by the conditioned reflexes involved is preceded by a "period of generalization": (Pavlov, 1927, p. 113)

> For instance, if a tone of 1000 d.v. is established as a conditioned stimulus, many other tones spontaneously acquire similar properties, such properties diminishing proportionally to the intervals of these tones from the one of 1000 d.v. Similarly, if a tactile stimulation of a definite circumscribed area of the skin is made into a conditioned stimulus, tactile stimulation of other skin areas will also elicit some conditioned reaction, the effect diminishing with increasing distance of these areas from the one for which the conditioned reflex was originally established. The same is observed with stimulation of other receptor organs.

Generalization of conditioned reflexes with auditory stimuli was first carried out by Beritov, as reported by Hovland (1937 a), who employed the conditioned leg-withdrawal in dogs, and obtained data both on generalization and discrimination. According to the Russian school, the slow spread effect of excitatory neural processes and their assumed proportional association to the intensity of their excitation, seemed to furnish the answer to the "behavioral phenomenon" of generalization.

In summary, then, generalization is that principle that extends over a range of external stimuli. It applies only to adjacent stimuli which may not be actually present at the specific time of conditioning or training. Above all, it is a natural phenomenon in everyday experience; but in the laboratory it can easily be disposed of by "discrimination" or "concentration".

Various other definitions have in the past been assigned to generalization phenomena. Some even have suggested the possibility that sensory generalization is non-existent in learning psychology. These theorists would profess that what we know as stimulus generalization is nothing but a lack of discriminatory ability on the part of the organism. Lashley's rats, for instance, failed to generalize to certain patterns of stimuli (Hebb et al., 1960). It is clear from the writings of both Hull and Lashley that they strongly disagree on this very point. Hull (1943) sets down his definition of primary stimulus generalization in one of his main postulates of learning theory. He has borrowed a great deal from Hovland's investigation of generalization of conditioned responses. The writer uses Hovland's own definition of conditioned generalization given in the first of a series of meticulous studies (1937a, b, c, d) carried out by him and, in part, duplicated here.

For the present purpose, therefore, "generalization" will be used throughout this study as it was first conceived by Bass and Hull (1934) from whose study the connotation of the term was used appropriately in the work of Hovland (1951), where it is described as follows: "When a response is conditioned to a particular stimulus, the conditioned response is also made to similar stimuli without specific reinforcement." (p. 616).

A complete account of Hovland's (1937a) experiment at this point, along with mention of deviations from it and supplementary studies comparable to that experiment, will be closely described. Hovland's purpose of the investigation was, by using farious frequencies of tone, to arrive at a "relationship between the magnitude of the response and the proximity of the test stimuli to the conditioned stimulus in frequency". (Hovland, 1937 a, p. 126). Tonal stimuli could be nicely controlled, while the separation of different test tones along the pitch continuum could be accurately determined in terms of psychophysical units. These were subjective just noticeable differences (jnd's) and were scaled equally apart between the various tonal frequencies. The galvanic skin response (GSR) could be easily conditioned and satisfactorily measured in absolute millimeter units. When a slight electric shock was delivered to the wrist, the reaction was presumably beyond S's voluntary control. The tone, equated for loudness by the appropriate psychophysical method, served as the CS; the shock, as the UCS.

After sixteen pairings of CS and UCS, the tone alone caused pen deflection due to a change in the GSR. Then each S was tested with three new tonal stimuli: 25, 50 and 75 jnd's, removed in frequency from the original tone. As a standard for establishing his continuum of subjective pitch, Hovland first chose a tone of 1000 cycles per second (cps), at an intensity of 40 decibels (db's) above reference level (.0002 dynes/cm^2). The mean frequency of the tone 25 jnd's above the standard 1000 cps tone was 1967 cycles; that of the tone 25 jnd's below, was 468 cycles; the fourth point, 25 jnd's below the latter, had a mean frequency of 153 cycles. The respective intensities were 60 db of attenuation for the standard 1000 cps tone; 42.1 db for the tone above it; 27.9 db for the 153 cps tone; and 43.7 db for the intermediate 468 cps tone. One-half of his Ss were conditioned to the highest tone of 1967 cps and then tested for generalization to the other three tones, with a random order of presentation. The other ten of Hovland's 20 Ss were conditioned to the lowest of the four frequencies, that of 153 cps, and generalized on the other three tonal stimuli. When these two random orders had been pooled, a generalization gradient (GG) of mean GSR's was obtained from the entire group. As a result of this pooling, the galvanometer indicated mean pen deflections of 18.30 mm. to the original stimulus; 14.91 mm. to the tone 25 jnd's removed from the standard; 13.62 mm. to the tone 50 jnd's removed; and 12.89 mm. to the tone 75 jnd's removed in frequency. Thus, the less similarity existing between the new and the "old" or the original stimulus, the less effective was the new stimulus in eliciting the conditioned galvanic reaction. The absolute mean values of the GSR were finally plotted, and yielded a GG which was concave, or negatively accelerated in form.

It was from the foregoing experiment that Hull took over Hovland's findings and incorporated them in the postulate formula which assumes the "negative exponent" of the generalized function. Several other investigators have tested Hull's postulate function. Littman's (1948) repetition of Hovland's experiment, for instance, resulted in a differently shaped gradient. Twenty-two Ss were conditioned in the same fashion and tested for generalization. All showed conditioning and generalization, but the obtained function approached a zero-slope. In view of questionable evidence regarding its form, further research was suggested.

Another study involving three groups of Ss, conditioned to a standard tone and tested against a control group to tones with frequency values of 256, 512 and 1024 cps, was carried out by Wickens (1954). Although octave effects were produced by this method, response generalization occurred during stimulus generalization. However, no significant difference in the frequency of the responses existed in the three groups.

Razran (1941) carried out a study in which the salivary responses of 21 Ss were conditioned to a tone and a word. They were then tested for generalization to different tones and words. Conditioned generalization took place to certain induced attitudes by instructions given by the experimenter. It was found that various instructions had no radical effect on the GG's obtained.

Grant et al. (1953) investigated the nature of a gradient for the GSR by giving 25 conditioning trials to visual stimuli. The used a 1 x 12 inches rectangle as CS and shock as UCS. The CR's of different groups were then extinguished with stimuli 1 inch wide and 9, 10, 11, 12, 13, 14, or 15 inches in height. It was discovered that in "the first extinction trial a pure generalization curve was obtained which was convex upward from the CS of 12 inches to the 9 inch test stimulus, and convex upward to the 14 inch test stimulus, but the result for the 15 inch test stimulus showed an inversion in the function." (1953, p. 313.) A similar study on primary stimulus generalization was carried out by Wickens et al. (1954) under two separate conditions. In the first part of the experiment, 72 Ss were given pairs of tone and shock for 16 trials, and the CR's were then extinguished to one of three tone stimuli. The latter consisted of either the training tones or different tones separated by 25 or 50 jnd's. Each extinction group contained 24 Ss, and S's responses were extinguished to only one tone. In the second experiment, non-reinforced clicks were presented during training period, but very little else was changed from the previous experiment. In the first experiment, the GG was more bell-shaped than concave upward, and it was generalized by the extinction process; Whereas in the next experiment no gradient was found to exist, a fact attributed to partial reinforcement theory. In still another generalization study, when the eyelid response was conditioned to auditory stimuli, generalization did, in fact, occur (Taylor, 1954).

It is evident, therefore, that sizeable discrepancies exist in the foregoing studies. Additional evidence of variation was the positive acceleration resulting from Hovland's arithmetical means when Littman (1949) repeated his experiments of 1937. Better GSR scaling and other improvements in measurement techniques were adopted. Of further evidence are Spence's medians, which yielded a convex-shaped gradient. But Humphreys' study, employing closely-spaced stimuli with GSR, showed a negatively accelerated gradient of generaliztion. Finally, experimentation carried out by Grant, Hake and Hornseth (1948), found the opposite to be the case. Hence, even when a number of studies are repeated under similar conditions and with equal objectives in mind, the results obtained may invariably differ a great deal one from another. Only better controlled research with conditioned stimulus generalization (CSG) looks promising for future investigators in the field of learning.

Early SR psychologists have tended to lean heavily for theory formulation on empirical data stemming from "the fundamental law of irradiation and concentration" (Pavlov, 1927). Whether it be "irradiation", "equivalence", "transposition", or the "law of similarity", learning theorists have taken the label "generalization" and have tested it in the laboratory. One such theorist, Hull (1943) has advanced the type of generalization construct that has had vast heuristic significance for the experimentalist.

Whereas other psychologists (Spence, 1956) deal with CSG as a "motivational" construct, Hull deals with generalization as a "mathematical" construct (Osgood, 1953). He has drawn heavily on Pavlov's empirical data, although he has seemingly avoided the neuro-physiological terminology of the Russian school. In an experiment (Bass and Hull, 1934) vibratory stimuli were applied at four different points of the skin along S's left side. After recording the GSR, the resulting generalization yielded a "positively accelerated" gradient similar to that found by Anrep in 1923. The response to a stimulus other than the original CS was greater than the CR.

Moreover, Hovland's findings, in 1937, of a "negatively accelerated" gradient for both "excitatory and inhibitory generalization" were formally incorporated in Hull's learning theories. Hovland had measured his stimulus continuum in equal psychological units of jnd's.

Hull's (1943, p. 199) formal statement of "primary generalization" is formulated in his POSTULATE 5:

> The effective habit strength $\overline{{}_SH_R}$ is jointly: 1. a negative growth function of the strength of the habit at the point of reinforcement (S); and 2. of the magnitude of the difference (d) on the continuum of that stimulus between the afferent impulses of $\dot{s}$ and s in units of discrimination thresholds (jnd's); where d represents a qualitative difference, the slope of the negative growth function is steeper than where it represents a quantitative difference.

The affinity of this viewpoint to that of Hovland can be readily seen; the latter's findings have been incorporated in Hull's theory as set down by the principle of "primary stimulus generalization". (1947)

Hull (1943) has further distinguished between the concepts of "stimulus dimension" and "afferent generalization continuum". The former aptly describes the physical character of the stimulus energy; the latter expression refers to the "corresponding afferent discharge" characteristics used by the appropriate receptor in activating the intensity of the stimulus. Lashley, on the other hand, feels that generalization may depend on the stimulus "dimensions" when two or more stimuli are compared (Hilgard, 1948). Hull, however, bases his conviction upon the fact that experiments in discrimination lack the one-to-one relationship presumably said to exist between these two variables. With respect to this he writes the following:

> It is held that the number and nature of the various primary generalization gradients are caused jointly by the nature of the stimulus energy and the nature of the receptor response. It is probably because of this that generalization is a more simple and uniform function of distance on the generalization continuum when the latter is measured in jnd's than when measured in the ordinary physical units of the stimulus. (Hull, 1943, p. 198)

Furthermore, Hull (ibid.) "demands" the presence of a second principle of generalization, immediately after describing a second form of stimulus generalization, that is, "stimulus compounds". It is stated thus:

> The range of primary stimulus generalization has limitations, particularly in the spread of reaction tendencies from one receptor made to another. Stimulus equivalence in such cases is brought about by an indirect process known as (indirect) secondary generalization. (Hull, 1943, p. 198)

Out of Pavlov's laboratory first came "the form of the spatial gradient of excitation and inhibition" and this gradient was adequately plotted by Anrep, as cited by Hovland (1937a). In general, Hilgard (1948) tells us that the more similar one stimulus is to another, the more nearly it can substitute for the other in evoking CR's. Hence there may be described the so-called GG. He cites the example that Anrep stimulated one point of the dog's skin surface, so that tests of salivary reaction at other points yielded such a gradient, although, unlike Hovland's, it was convex in shape.

Similarly, following Pavlov's empirical data, Bass and Hull (1934) set out to investigate the GSR in human subjects by applying vibratory stimulations to the skin at four various points. Once again, their findings resulted in "a convex gradient of excitatory generalization" similar to Anrep's. While incorporating Hovland's data in his theory, Hull (1943) recognized that only a certain group of stimuli could be ordered along simple psychophysical continua. Hence he leaves room for what he has called "secondary generalizations" which could not be ordered quantitatively. These were presumably not included in his major Postulate 5. He seems to conclude that the GG is steeper for qualitative (e.g. pitch) than quantitative (e.g. loudness) continua. Such observations are also made by Woodworth (1954) who considers loudness a poor continuum to use in generalization experiments. Grice and Saltz (1950) obtained gradients similar to Hull's, finding that the convexity or the concavity of the gradient depended, to a large extent, on the intensity of the stimulus performing the generalizing.

Humphreys (1939), convinced that the exact shape of the function plays a significant role in such discrimination theories as those advanced by Spence (1936) and Razran (1938), decided to test the GG, measuring the generalization to tones within the first 25 jnd's interval. Hovland had found this first interval to yield the greatest degree of generalization. By interpolating between Hovland's frequencies of 1000 and 1967 cps, Humphreys selected three frequencies of 1718 and 1311 cps which were representative of 5 and 15 jnd's removed from the CS. Although Humphreys obtained a GG that was apparently concave in form even for stimuli only slightly differing from the CS, he cautioned that such a decelerated gradient was far removed from the ideal type of GG.

Blackwell and Schlosberg (1943), adding to the present controversy regarding the GG, concluded that the pitch dimensions presented difficulty in arriving at a basic form of the function, due to greater generalization over the octave than to intermediate points of the continuum. Schlosberg and Solomon (1943) have obtained a GG approaching a straight line form. Spence (1951) and Lashley and Wade (1946) seemed to reject Hull's theory of generalization in the light of their own empirical findings. Littman (1949) repeated Hovland's experiment and obtained curves much shallower in form. Wickens (1943) failed to arrive at any type of gradient. Razran's (1949) criticism was directed mainly at Hovland whose

Ss failed individually to reveal a consistent GG, a point which Dember (1960) also has attacked.

Not only does the shape of the gradient depend to a large degree on the method of training, as found by Humphreys (1939), but also on the stimulus intensity and the steps used in separating the stimulus continuum. It also depends, in part, upon the units that measure or scale any stimulus dimension. Several other influential investigators of the field of generalization, such as Philip (1961)[1] et al., have emphasized the variability factor of the generalization point among numerous clusters of other such points. The GG, they contend, is generally obtained by plotting mean values of responses given at several points along a continuum. Owing to the variability of the series of responses determining each mean, the actual mean is but a sample from the population of similar means. As a consequence, the true means at each point along the continuum might be slightly displaced either above or below the actual mean; hence the GG could readily be convex or concave. It has further been suggested that the shape of the GG may be a function of existing central tendency (Philip, 1947).

In view of varied criticism directed at the concept of slope of the generalization function, and in particular at Hovland's negative exponential, much clarification is still needed in this area of research. The shape of the gradient is still a widely disputed point in generalization theory. It seems only proper, therefore, that the GG be investigated once again. The slope of any such gradient obviously depends in part on the choice of units measuring the stimulus continuum. This leads to psychological scaling methods, particularly to stimulus

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1 Personal communication

scaling techniques, whereby "qualitative subjective judgments . . . are dealt with . . . in a quantitative fashion". (Gulliksen, 1960, p. 1).

Of outstanding interest to the present study, then, are the various psychophysical scaling methods that have been recently developed. Stevens (1960) has advocated a theoretical approach of quantifying "subjective magnitudes" in experimental psychology. Since pitch is one such dimension of sound, its properties can be measured subjectively. Qualitative in nature, pitch is said to belong to the "metathetic" continua rather than to "prothetic" or quantitative continua to which loudness, for example, belongs. These new scaling techniques, while making use of "cross-modality comparisons" (Stevens, 1959), allow an observer to compare or to match subjectively various tones differing in frequency. This method borrows a great deal from traditional psychophysical procedures such as the "method of limits". Such an approach, moreover, has proven extremely useful in avoiding S's forced decision-making to various magnitude estimations.

Although simple linearity does not exist between "ratio" and "confusion" scales when these are applied to prothetic continua, such as stimulus intensity, they are in effect related when measured on metathetic continua (Stevens, 1956). Hence, psychologically scaled "mel" and "jnd" units are theoretically equivalent in their application to a particular type of continuum (Stevens, 1960). Moreover, Luce (1959) considers that, on all scale ranges, the feature most peculiar to metathetic continua seems to be the subjective uniformity of discrimination throughout.

This sort of theorizing could be tested very effectively by simple laboratory techniques. The experiment used to investigate these basic assumptions is "conditioned generalization" for the purpose of determining the shape of the GG and comparing it with that obtained by Hovland. By closely duplicating Hovland's CSG study (1937a), where the GSR was conditioned to varying frequencies of tone, a similar negative exponential function is expected. But his stimulus-increment (jnd) continuum will be replaced with one measuring subjective pitch in mels.

Searching for ways of measuring or scaling sensation, Fechner long ago claimed that the appropriate unit would be the jnd. He had been borrowing from Weber's fraction, $\frac{\Delta I}{I} = k$, a law suggesting that a constant minimal change produced a jnd. Hence the smallest unit of sensation to be scaled was set at one jnd. From this point, all jnd's were assumed by Fechner to be perceptually, subjectively and psychologically equal. Stevens (1938) feels that this is an "indirect" type of scaling method. He, likewise, arrived at a loudness scale from measurements of physical stimulus intensity. Having advanced in scaling techniques to both "ordinal" and "equal interval" scales, the ultimate refinement achieved by Stevens was the "ratio scale". In ordinal scaling, one relationship is merely said to be larger or smaller than another; equal interval scales, on the other hand, involve the mathematical relationship of a straight line.

Fechner was of the opinion that psychological ratios could not be established directly in jnd units. But in his investigations, Stevens has come up with some interesting results that seem to have proved satisfactory, Fechnerian contentions to the contrary. His findings yielded affirmative answers. Given a certain dimension of sound -- pitch, for instance -- can a second one be produced consistently to be twice or three times, etc. as large or as small? Stevens insists that this difference will be perceived with relative consistency. This is exactly what the so-called "fractionation" methods of scaling have attempted to do with subjective magnitudes of sound. For example, S must judge some other pitch to be one-half or one-fourth as small as a standard pitch. With well-trained Ss, a fairly good matching can be obtained within limits of experimental error. Another way by which S makes direct numerical judgments of several subjective impressions is by what is called magnitude, or ratio, estimation. By this technique a stimulus is assigned a number proportional to the apparent magnitude of a standard value unit; that is, as S himself perceives the stimulus.

In his selective investigation of the psychological magnitudes for both pitch and loudness by direct estimation, Stevens (1956) arrived at appropriate scales to measure these dimensions of sound. Of particular interest, here, is the "subjective pitch" scale he constructed following observations from five trained Ss who were to judge "half-value" pitches of different frequencies at 60 db loudness level. Out of these bisections or fractionations, the resulting scale was "pooportional to the perceived magnitudes" of subjective pitch. Hence, the 1000 cps tone value on this scale was assigned 1000 "subjective units" or <u>mels</u> of pitch. Subsequently, a 1000 mels pitch was subjectively "twice as high" as one of 500 mels (Stevens, Volkmann and Newman, 1937).

When the three types of scales, that is, partition, ratio and confusion, are applied to quantitative or prothetic continua, it was found that linear relationship was lacking. But on subjective, qualitative or metathetic continua, however, all three "may prove linearly related and therefore essentially equivalent subjective measures" (Stevens, 1960, p. 49). And pitch, among others, is of this type.

In his classical experiment, Hovland (1937 a) adopted Fechner's subjective equality of jnd's to measure his stimulus continuum. The present investigation sets out to use the mel, the psychological unit of pitch, as a measure of this continuum. Its equality has been determined, in previous research, by the fractionation technique, a method employing bisection of the pitch stimulus. A tone is judged by S to be subjectively half in pitch as a given standard tone; S thus arrives at a "numerical ratio" between the apparent differences contained within the properties of the two pitch stimuli presented to him. The danger of committing what Titchner has called the "stimulus error", however, seems ever-present when an objective measure is predicted from the subjective judgments of any one S.

On the other hand, one efficient method that has long enjoyed much popularity in psychology is that by which "activation" or "emotion" is measured on the <u>response</u> continuum. This ordinarily entails measuring the electrical conductance (or its inverse, resistance) present at any particular moment on the palm of S's hands. It has been found more convenient to measure resistance (in ohms) than conductance (in mhos), mainly because of the way the measuring instrument was built and calibrated. Since no calibrating technique was made available in the present experiment, the unit by which resistance was measured was not sufficiently valid.

Skin resistance, however, has been found to be fairly high and adequate in measuring the response. A moistened electrode attached to the palm of the hand can, in fact, show resistances ranging from 10,000 to 1000,000 ohms. The GSR or, as it is otherwise referred to, the psycho-galvanic response (PGR), can readily lower S's resistance to about half its value when shock is used, in comparison to only about one-twentieth reduction in resistance to verbal stimuli. The current that flows through the skin can easily be measured by the applied potential, usually a volt or two in value (Woodworth, 1954).

Moreover, as reported in the same work, Haggard and Lacey have recommended measuring the GSR by the logarithm transformation. More recently, however, Davis has advocated that logarithms should be used consistently, whereas Malmo, Smith[1] et al. have not found this transformation necessary. Finally, Mueller (1949) reports that Haggard and Garner show GSR variability to be proportional to mean GSR values, an argument in favour of the appropriateness of transformation, particularly if an analysis of variance is to be used. According to their computations, however, variance heterogeneity does not result, even though Mueller (ibid.) considers that it should.

The GSR was found most effective in assigning response values to the stimuli used. Since it lies outside S's voluntary control, it proved an effective measure of his response to shock. Being a function of stimulus (shock) intensity (Hovland and Riesen, 1940), it was necessary to keep the GSR magnitude reasonably high by adjusting the level of shock before the experiment proper. The latency of the GSR, reports Woodworth (1954), has been found to remain about equal for either strong

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or weak stimuli, according to Davis. It is considered to be one of the easiest and most practical of conditioned responses.

Need and Purpose of Present Research

The experiment under study is modelled after investigation on the generalization of conditioned responses carried out by Hovland in 1937, who found a concavely-shaped gradient of generalization in his Ss' responses. Many such studies have since been made with sensory generalization of responses conditioned to tonal stimuli. Most have obtained a certain degree of generalization; few have arrived at the same shape of GG. Some have used the GSR on the response side and subjective pitch on the stimulus continuum of their experiments. Frequencies of various tones have been previously scaled along this continuum and equally separated into jnd's. But no study has yet been made in CSG, using the psychological unit of pitch, the mel, in separating frequencies of tones equally along the stimulus continuum. Thus, assuming what Stevens has theoretically suggested, findings similar to those of other studies are expected. In general, the obtained results should throw light on both subjective scaling methods and the much disputed slope of the generalization function.

Hovland's methodology was followed as closely as possible, so as to be of value in verifying present experimental findings. Few changes were made in keeping with present-day technological advancement, other factors remaining constant. In accordance with our main hypothesis, generalization is predicted to appear in the sample of Ss used. Next, and of special importance, is the fact that generalization, if present, should fall off as a negative exponent, thus yielding the negatively accelerated or concave gradient also found to exist in Hovland's study of conditioned responses to varying frequencies of sound. His data, leading to the GG, was derived from use of a jnd scale. The appropriate scale to measure the pitch continuum in subjective psychological units of pitch is the mel scale. This was plotted against response magnitudes of the GSR, measured in mm. of amplitude.

Stevens (1957) has argued that the findings of any one experiment certainly depends, either totally or in part, upon certain psychophysical scales that measure the psychological dimension used along stimulus continua. More recently, he has suggested further that, on metathetic continua, confusion (jnd) and ratio (mel) scales should be equivalent. If this is true, then in can consequently be tested by application to stimulus generalization. Hence the basic problem of the present investigation is to determine whether the slope of the predicted gradient differs or not from that obtained by Hovland's classical generalization experiment. The mean GSR values of his 20 Ss fell off as a negatively exponential function on a jnd stimulus continuum of pitch. Following a basically similar pattern, the amount of generalization should yield, accordingly, a negatively accelerated gradient. But if, on the other hand, the generalized mean response to the 500 mel pitch turns out consistently greater than it is to the conditioned tone frequency of 1000 mels, a gradient sloped like the Bass-Hull positively accelerated function will result.

Assuming Stevens' suggestion of confusion-ratio scale equivalence on metathetic continua to be correct, it is hypothesized that the mel (ratio) scale will yield both stimulus generalization and a gradient of mean responses. It is further hypothesized that this gradient will be equal in shape to Hovland's negative exponential function plotted on a jnd (confusion) continuum of subjective pitch.

CHAPTER II

METHODOLOGY AND PROCEDURE

Subjects

Altogether 41 Ss took part in the experiment. From two separate pilot studies carried out prior to the experiment proper, it was determined which of several approaches would ensure the most effective of possible procedures. No subject showing any noticeable hearing defects was included in any of the groups.

The seven Ss making up the first pilot study were post-graduate students in Psychology, and included six males and one female ranging in age from twenty-one to twenty-six years. The second pilot group, consisting of two male and three female Ss, was made up of students from introductory psychology courses; these ranged in age from eighteen to twenty-one years. Both groups were presumably experimentally naïve with regard to what was to take place in the experimental room.

The main experimental group was composed of 29 Ss. All went through every condition determined by the findings of two previous pilot studies. Instrumental failure, however, made it impossible to score 7 of the 29 records. In compiling the data, it was found that these rejections were due, in part, to shifting baseline variability (resistance), although baseline stability did not necessarily determine Ss' selection. Some varied to such a great extent that the stimulus could not be adequately applied within a time interval of two minutes.

The remaining 22 Ss were all undergraduate students registered in introductory psychology courses at Assumption University of Windsor. The sample included fourteen females and eight males ranging in age from nineteen to twenty-three years. They were assigned at random to take part in the experiment, but when possible, male and female Ss were put through in alternate order. All Ss were volunteers and were unaware of what would take place during the session.

Every S was instructed as to the reason he was asked to participate in this particular experiment. He was told to refrain from asking questions until the end of the session. He was also instructed not to talk or move unnecessarily; to sit back, while remaining facing E; to relax comfortably without falling asleep. At the end of the experiment, S was asked whether he had felt or noticed anything strange or unusual and if so, to relate it to E. If his curiosity needed satisfying at this point, he was told something about the apparatus and was shown his own GSR chart.

Apparatus

A block diagram of the apparatus is given as Figure 1 (see Appendix A). A dermograph (Stoelting, model M-24203) traced the galvanic skin reflex (GSR) on a paper strip chart (model M-11). A second pen on the galvanometer traced the time of the conditioned and unconditioned stimuli (tone and shock) on the same chart. The chart paper was fed automatically under the two pens at a uniform speed of six inches per minute. Finger electrodes (Sherping type) were fitted to the index and ring fingers of S's left hand, with application of electrode jelly for better skin conductance. The bridge resistance of the apparatus was adjusted for each individual S, while the amplifier gain was held constant (fixed at 30 units). The dermograph was not calibrated due to lack of instrumentation available for this purpose. It remained hidden from S's view, to E's left side, by means of a screen.

A shock stimulator (Harvard Apparatus, model 935A) fed a slight shock to a reflex conditioning apparatus (Stoelting type) on which rested S's right hand. The shock administered was effectively instantaneous.

Two Hunter decade timers (model 100C), connected in series, controlled the duration of the tone and the time of occurrence of the instantaneous shock. The "tone" timer was started by a silent mercury switch mounted to E's left side, hidden from S's view. The second timer determined the shock duration.

The tone was generated by an audio-oscillator (EICO model 377) feeding one channel of a stereo-amplifier (EICO model HF-81). The output of the amplifier passed to head-phones (TRIMM "Pro" model) via the contacts of the first Hunter timer. A screen concealed the main apparatus from S.

Experimental Procedure

Both preliminary and main experimental procedures were used. The former entailed adjusting the tone and the shock levels for each S; the main experiment consisted of putting S through various experimental conditions. A tone of 1000 cps, at a reasonably high level, served as the originally conditioned stimulus; and, for purposes of analysis, was considered to be at a pitch of 1000 mels.

At the outset of each experiment, S was asked to adjust the intensity of the generalization stimuli (chosen to be 500 and 250 mels) until they appeared to him equal in loudness to the standard pitch (1000 mels). This was done by the psychophysical method of "adjustment",[1] using a second EICO audio-oscillator to facilitate comparison of the tones. During this same preliminary session, the intensity of the shock was also adjusted until S judged this to feel uncomfortable but not painful. S was asked to place the right hand, palm down, on the reflex conditioning apparatus, and was told that the shock caused merely a muscle-flexing sensation to the side of the hand. Lastly, S was asked to avoid unnecessary movement, to sit back comfortably and not to fall asleep.

During the main experiment, the shock level was raised occasionally so as to maintain the magnitude of the unconditioned GSR at a satisfactory level, the criterion for which was that the shock applied to the second stimulus of the second set of trials be approximately equal to that yielding the second GSR of the first order of trials. It was felt that this procedure would, on the average, successfully stabilize the level of shock. The tone duration was one-half second, followed by a one-fifth of a second delay prior to shock. The 1000-cycle frequency, 40 db. above threshold, was treated as equivalent to 1000 mels in pitch; two generalization frequencies, 404 and 161 cps., were derived mathematically from the mel scale to be at a pitch of 500 and 250 mels respectively (Torgerson, 1958).

The choice of two separate experimental conditions (Order 1 and Order 2) was in part determined by the results of two pilot studies carried out

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[1] This is a method by which S adjusts a certain stimulus until it appears subjectively equal or in some ratio to a standard; equality precision is measured by the average of errors S makes in any one setting.

prior to the experiment proper. In the first session (Order 1) S was given seven training trials with the standard 1000 mels tone, paired with shock; one test trial without shock, to the same pitch; and two other test trials to generalization stimuli of 500 and 250 mels in pitch. The second condition (Order 2) involved six training trials to 1000 mels, paired with shock; one test trial to the same mel value, but with an inverse order of generalization test trials of 250 and 500 mels, respectively. Immediately following this last test trial, an extinction test was administered, but only in the second session of the experiment. A total of thirteen reinforced and seven non-reinforced trials was given to each S. All Ss followed both order schemes. At the beginning of each order condition, the internal bridge circuit of the dermograph was balanced against S's resistance and his base-resistance level recorded. The potentiometer served to alter S's basal resistance when needed. At the end of the experiment, each S was asked to comment on his experience during the experiment. These protocols were preserved for future examination.

Collection of Data

Although calibration of the GSR apparatus was not available, responses were recorded and measured for amplitude by taking the difference, in mm., between the baseline and response-peak tracings. As portrayed in Figure 2, parallel hairlines were drawn at the height of the GSR at right angles to an estimated baseline. The resulting baseline was considered to be that straight line which, by visual determination, best represented the average position of the recording pen during the ten-second interval prior to stimulation. This procedure permitted GSR amplitude measurements to the tallest peak rising within a fifteen seconds interval immediately following stimulation to the ear and skin. Additional maxima were disregarded if these occurred after the 15-second interval criterion. If the pen deflection went to the maximum permitted by the galvanometer, a fifty-per-cent increment to the already measured GSR amplitude was arbitrarily assigned.

Impartial observers were asked to evaluate the 22 records on the basis of baseline variability. The criterion employed in determining pen stability at basal resistance intervals was that no more than one vertical interval of the graphed chart be traced in a downward direction prior to stimulus pairings. The first observer sorted the records into two groups: those whose baseline seemed fairly variable and those whose baseline seemed fairly stable. This sorting yielded ten "varying" and twelve "stable" baseline records. It was desired that these be assigned an equal number of Ss per group for added statistical analysis. Thus the task of a second impartial observer was to re-evaluate the twelve stable records, and among these choose one that was least stable and place this with the ten varying-baseline records.

CHAPTER III

PRESENTATION AND ANALYSIS OF RESULTS

The main statistical analysis entailed the application of a 3-way analysis of variance, based upon the shape of the generalization gradient and other existing relationships. The mel (M) effect referred to the generalization gradient; the subject (S) effect detected individual differences in each order condition; the order (O) effect accounted for the overall difference in response on two experimental sessions. Individual differences were mixed in the appropriate error term of the triple interaction (O x M x S). Error terms for M differences and O conditions were their simple interaction effects (M x S and O x S respectively). The appropriate error terms for simple interaction O x M, O x S and M x S rested within the triple interaction (O x M x S) also. (McNemar, 1955).

A maximum number of 20 GSR's per subject was recorded; this included responses to thirteen training trials and seven test trials. A specimen record illustrating these 20 GSR's elicited by a single S is aptly represented by Fig. 3. In the first of the two order conditions ten GSR's were evoked by: seven conditioning trials (1000 mel tone followed by shock); the next, by a test trial of the same pitch without shock; and an additional two trials by generalization stimuli of 500 and 250 mels, also without shock. In the second condition, immediately following, six GSR's were elicited by training trials (tone plus shock), three by test trials without shock, in the order, 1000, 250 and 500 mels respectively. And immediately

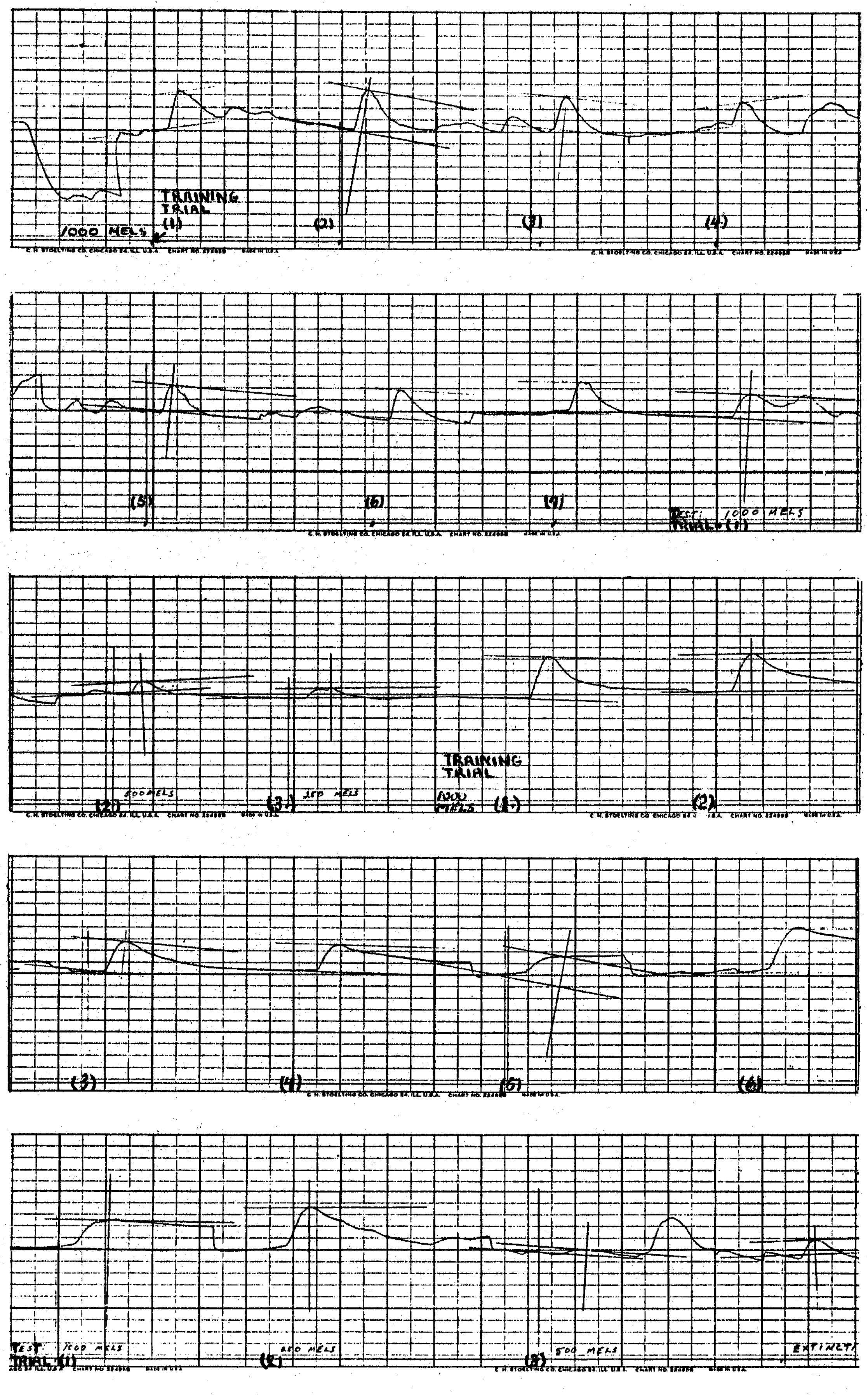


Fig. 3. Sample Tracing of GSR Recording

following these test trials, an extinction test (1000 mels without shock) was administered; four Ss showed no response on this trial. (Hovland gave 16 reinforcing and 4 non-reinforcing trials in one single presentation). Six Ss , five females and one male, failed to respond to some stimuli when both orders of presentation were considered. Three Ss within this group had been judged as having varying baselines, and three, stable baselines. Generally, each S gave an average of 19.18 GSR's. The time interval between responses ranged on an average of 33 second minimum and 95 second maximum, for the group. The average session for the experiment averaged 26 minutes per S for both order conditions.

Mean GSR's resulting from conditioned and generalization trials for first and second order conditions were recorded for all 22 Ss. Their values, measured in mm. of amplitude, were set down as shown in Table 1; the means were plotted in Figure 4, in much the same fashion as Hovland's original findings. Tentatively entertained was the possibility of a more sophisticated method for measuring the GSR, but this course was discarded on the basis that it was theoretically unwarranted. (Hovland's absolute GSR's, measured in mm. also, fell off as a negative exponential function when jnd's were used on the stimulus continuum.) The present study has altered the stimulus unit from jnd's to mels, but it was thought inadvisable to alter simultaneously the absolute unit (mm.) of GSR measurement.

On both orders of presentation together, six Ss, including four females and two males, displayed the kind of generalization typified by Hull's negative exponential formulation. Two of the Ss arrived at a consistent gradient of generalization in all six test trials of first and second order conditions. A total of

Table 1

Amplitude of the GSR (in mm.) to Conditioned and Generalized Tonal Stimuli (in mels)

Subject	Mel Value 1000 0_1	1000 0_2	500 0_1	500 0_2	250 0_1	250 0_2
I	5.5	37.0	6.5	3.5	18.5	10.5
II	19.0	3.5	1.0	0.0	10.5	16.5
III	8.0	0.0	5.5	0.0	2.5	0.0
IV	10.5	8.5	10.5	4.0	13.5	5.5
V	12.5	31.0	9.0	26.0	5.5	7.5
VI	18.0	20.5	12.5	22.0	22.0	25.5
VII	7.5	3.5	3.5	7.0	12.0	1.0
VIII	10.0	16.5	10.0	13.0	5.5	21.0
IX	43.5	0.0	3.5	10.0	5.0	1.0
X	13.0	16.0	5.5	3.0	5.5	23.0
XI	46.5	35.5	26.5	33.5	24.0	32.0
XII	0.0	4.0	8.5	8.0	0.0	2.0
XIII	32.0	58.5	5.0	19.0	1.5	44.0
XIV	16.5	86.5	5.5	17.0	0.0	42.5
XV	42.5	58.5	98.0	52.0	60.5	57.0
XVI	48.0	21.5	42.5	14.0	25.0	32.0
XVII	42.5	23.0	24.5	5.0	0.0	18.0
XVIII	39.5	39.5	43.5	25.5	48.5	47.0
XIX	27.5	6.0	13.5	10.5	15.0	12.5
XX	14.5	43.5	7.5	31.0	27.5	35.0
XXI	15.5	35.5	25.5	56.0	1.5	50.0
XXII	43.5	44.0	47.0	50.0	44.5	37.0
Mean	14.6	19.1	14.5	13.1	10.1	17.1

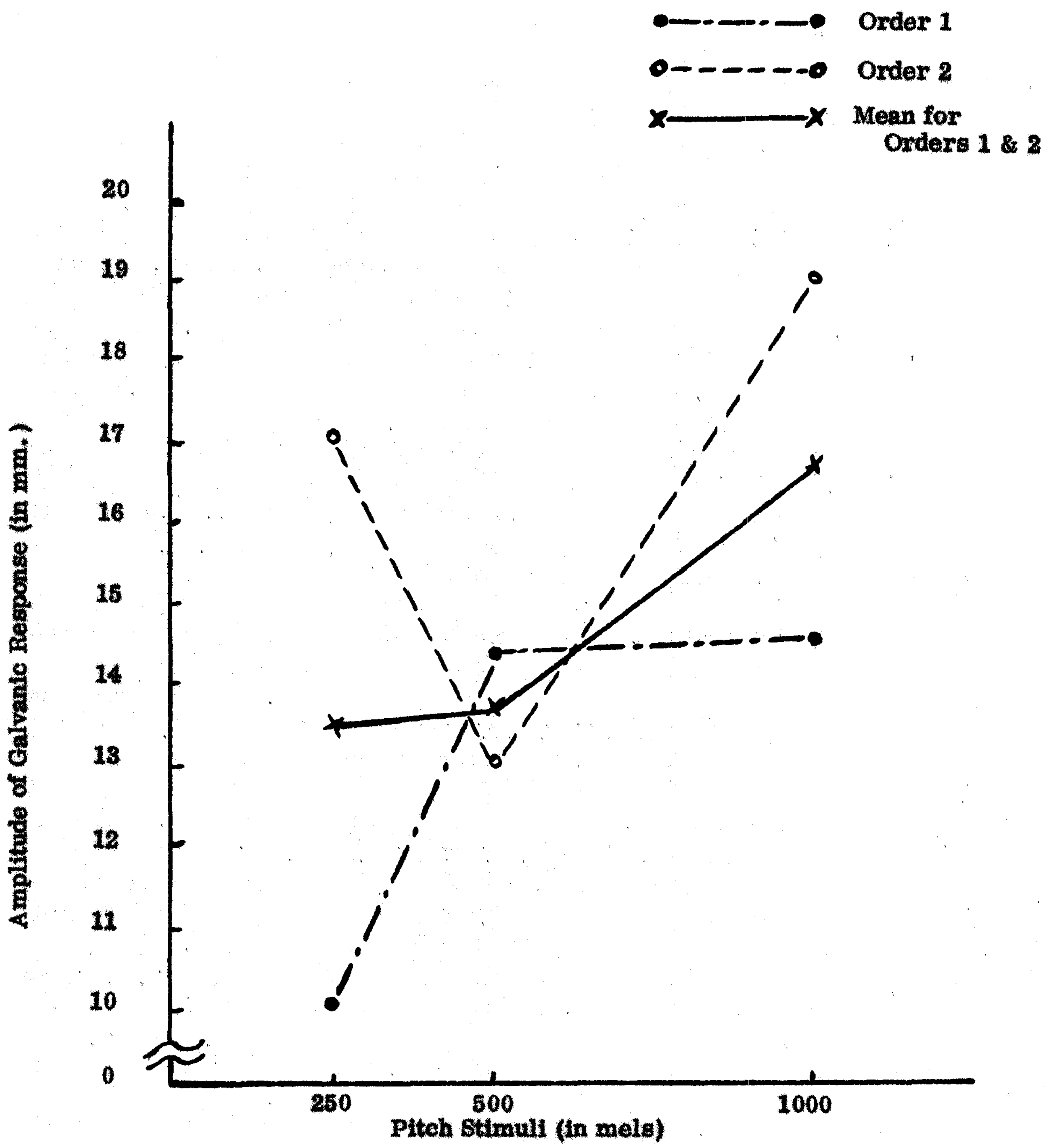


Fig. 4. Group Generalization Gradient of the GSR as a Function of Subjective Pitch and Order of Presentation.

eight Ss obtained consistency of CSG on either Order 1 or on Order 2. (Hovland has been widely criticized due to the fact that only one of his 20 Ss showed consistent individual generalization, although a group GG was obtained.)

In the present study, the mean GSR values obtained from stimuli of 1000, 500 and 250 mels in pitch, yielded GG's for Orders 1 and 2 (Fig. 4 supra). Since the results from the two orders of presentation do not differ significantly (Table 2, $F = 1.35$), they were pooled. The resulting gradient is, like Hovland's, negatively accelerated.

The present experimental findings, moreover, as confirmed by an analysis of variance represented by Table 2, lend substantial support to the presence of a gradient of CSG. The generalization factor (M) was significant ($F = 4.16$) at the .05 level of confidence. Its significance was indicative of a GG for the group as a whole; the $M \times S$ interaction was non-significant ($F = 1.16$), suggesting that individual gradients did not depart greatly from group trends. The fact that the order condition (O) effect appeared also non-significant ($F = 1.35$), suggested, on the average, that responses elicited in Order 1 are fairly comparable to those given in Order 2. A value of $F = 1.68$ for the $O \times M$ interaction reflected no significant difference in the shape of the GG between Order 1 and Order 2. A non-significant $O \times S$ interaction seemed to suggest little overall variability existing between GSR's elicited by the group for the first Order and those by the same group of Ss for the second Order.

In addition to the above results, other findings were made that may be of interest for further studies of the GG. Difficulties were encountered, for instance, in attempting to stabilize the baseline, that is, in finding one that remained reasonably close to the midline of the chart. A sufficiently stable baseline was established by approximately one-half the Ss; the remaining half displayed much greater baseline variability. Hence discrepancies were to be found in sub-groups of Ss differing both in baseline variability and sex as well, when _t_ tests were applied. Pooling orders of presentation, two separate and unequal groups of Ss differing in sex and two other equal groups differing in basal resistance level were compared on five trial criteria by means of _t_ ratios. These criteria included 13 training or reinforced trials to a pitch stimulus of 1000 mels, one test trial to the conditioned stimulus of the same mel value, two additional test trials to generalization stimuli of 500 and 250 mels each, and an extinction test to the 1000 mel tone.

Table 2

Analysis of Variance of the GSR

Source	Sum of Squares	df	s^2	_F_ Ratio
Order Condition (O)	465.94	1	465.94	1.35
Mel Value (M)	1,069.29	2	534.65	4.16*
Subjects (Indiv. diff. (S)	27,637.70	21	1,316.08	
Interaction (O x M)	377.93	2	188.97	1.68
Interaction (O x S)	7,246.96	21	345.09	3.07
Interaction (M x S)	5,395.78	42	128.47	1.14
Triple Interaction (O x M x S)	4,727.20	42	112.55	
Total	46,920.80	131		

* $p < .05$ (F = 3.23)

Tests for sex differences yielded results found in Table 3. With 20 df for significance at the .05 level of confidence, t ratios of 2.086 are required; no t ratio yielded this value. Hence comparison of mean GSR's for the group composed of 14 female Ss with mean GSR values of the second group composed of eight male Ss yielded no significant results in all five trial conditions.

Table 3

Sex differences in the GSR for Training, Test and Extinction Trials

Trial	Mean GSR Female (N = 14)	Male (N = 8)	t ratio
Training Trials	30.27	26.43	0.63
Test 1000 mels	26.34	24.28	0.30
Test 500 mels	17.38	20.75	0.49
Test 250 mels	18.95	20.34	0.11
Extinction	14.14	25.38	1.35

The effect of variability of baseline was then determined. The mean response values of the 11 Ss with a stable baseline (SB) were compared with the mean response values of an equal number of Ss with a varying baseline (VB). The mean values were combined for both order conditions, and comparison of the two group means was based on the five different trial criteria which have been described above. The findings have been set down in Table 4.

With 20 df, all t ratios appear significant either at the .05 level of confidence or at the .01 level of confidence. The more significant discrepancies were found on the conditioned test trial to 1000 mels and on the extinction trials.

Table 4

The Effect of Baseline Variability on the Mean GSR for Training, Test and Extinction Trials

Trial	Mean GSR		t ratio
	Varying (N = 11)	Stable (N = 11)	
Training Trials	35.82	21.93	2.78 *
Test 1000 mels	33.73	16.64	3.12 **
Test 500 mels	27.66	9.82	2.85 **
Test 250 mels	27.36	11.95	2.70 *
Extinction	26.36	5.55	3.45 **

* $p < .05$ ($t \geq 2.086$)
** $p < .01$ ($t \geq 2.845$)

From Table 5, conditioned and generalization GSR values have been plotted for both those groups (SB and VB) in Fig. 5. When the data are pooled for Order 1 and Order 2, they yield a gradient that is concave in form.

Since stimuli were presented only when the GSR of S had adequately stabilized, the inter-stimuli interval, including intervals between training, test and extinction trials, varied considerably among Ss. This inter-trial time interval was estimated at an overall average of 62 seconds for each S. (Hovland used a 60-second time interval between stimuli.) As a group, the female Ss required a mean 60 seconds interval; while the male Ss required a mean interval of 65 seconds. Their respective periods of time ranged from 33 seconds to 93 seconds, in the female, and from 34 to 99 seconds in the male group. On the other hand, the 11 Ss having a stable baseline required a mean time interval of 51 seconds, compared with a 73-seconds interval for the 11 Ss with a varying baseline. Both SB and VB groups had a mean time-range of from 32 seconds to 83 seconds, and from 34 seconds to 107 seconds, respectively.

Table 5

Mean GSR Amplitude (in mm.) to Conditioned and Generalized Stimuli for Pooled Orders 1 and 2 with Respect to Baseline Variability and Sex

Subject	Stimuli (Mel Value)			Sex
	1000	500	250	
<u>Stable Baseline</u>				
I	21.25	5.00	12.00	Female
II	11.25	.50	13.50	"
III	4.00	2.75	1.25	"
IV	9.50	7.25	9.50	"
V	21.75	17.50	6.50	"
VI	19.25	17.25	23.75	"
VII	5.50	5.25	6.50	Male
VIII	13.25	11.50	13.25	"
IX	21.75	6.75	3.00	"
X	14.50	4.25	14.25	"
XI	41.00	30.00	28.00	"
Mean	16.64	9.78	11.86	
<u>Varying Baseline</u>				
XII	2.00	8.25	1.0	Female
XIII	45.25	12.00	22.75	"
XIV	51.25	11.25	21.25	"
XV	50.50	75.00	58.75	"
XVI	34.75	28.25	28.50	"
XVII	32.75	14.75	9.00	"
XVIII	39.50	34.50	47.75	"
XIX	16.75	12.00	13.75	"
XX	29.00	19.25	31.25	Male
XXI	25.50	40.50	25.75	"
XXII	43.75	48.50	40.75	"
Mean	33.73	27.66	27.32	

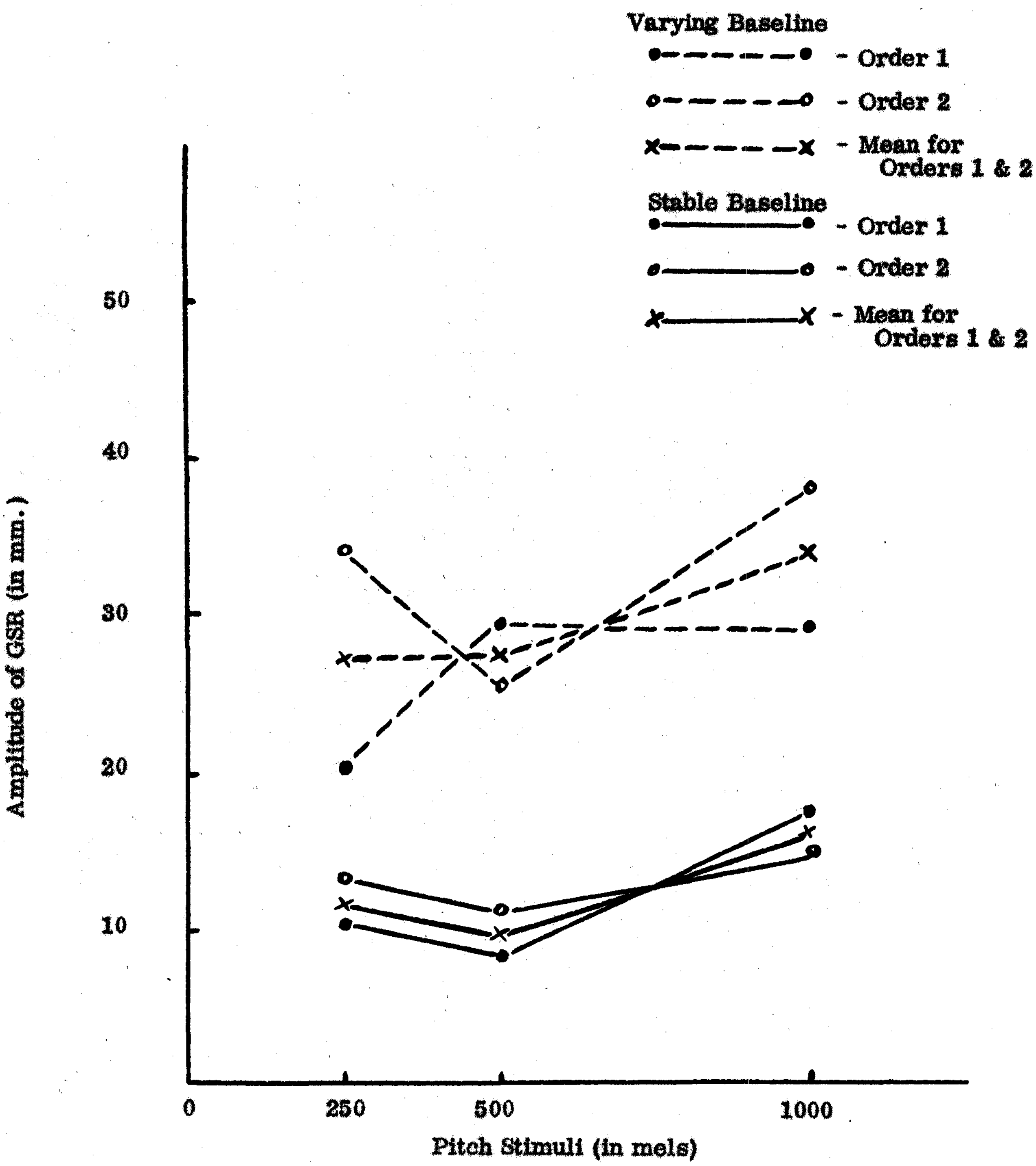


Fig. 5. Group Generalization Gradient of the GSR as a Function of Subjective Pitch, Order of Presentation and Baseline Variability.

CHAPTER IV

GENERAL DISCUSSION OF RESULTS

The present study seems to have confirmed Hovland's GG of a negative exponential, but more than this, it has demonstrated that generalization does occur along a subjective pitch continuum. Hence it can be concluded that there is a gradient of generalization to subjective pitch.

The shape of the GG, however, has been for quite some time a subject for considerable controversy in learning theory. Hull formulated his theory of generalization on the basis that the gradient of CSG was negatively exponential in form, and from which is derived Postulate 5 dealing with primary stimulus generalization. In his experiment, Hovland conditioned the GSR to tonal stimuli measured in equidistant units on a stimulus continuum, and his subjective unit of pitch was the jnd. In the present investigation the mel, a unit of subjective pitch, determined the distance of tones along the frequency continuum.

Stevens (1960) has suggested the equivalence of the mel and jnd when these units are measured on a metathetic continuum, such as the pitch continuum. It was hypothesized, therefore, that by substituting the mel on the subjective pitch continuum, a gradient similar in shape to that obtained by Hovland (1937a) would result. This hypothesis was confirmed and a gradient was found to exist, similar in slope to Hovland's.

Furthermore, Stevens has suggested that such scaling equivalence would not hold for a prothetic continuum, such as loudness. A ratio scale for loudness has been erected in the past, the unit assigned to be the sone, which was defined as the psychological intensity of a 1000 cycle tone 40 db above S's threshold. Should this sone scale be used in Hovland's (1937b) experiment with intensities of tones to measure the stimulus continuum, it could be predicted that a different shape of GG to that obtained by Hovland might well be expected. Instead, a positively accelerated function of the Bass-Hull (1934) type might result. Thus, if Stevens' theoretical assumption holds, when loudness is used instead of pitch, the acceleration of the gradient should be positive rather than negative, as found by Hovland.

A great deal of controversy has arisen out of Hovland's individual and group gradients. Razran (1949), especially, has bitterly criticized him, since only one of Hovland's 20 Ss arrived at a consistent GG. The issue here is the shape of such gradient. A fair percentage of Ss in the present study followed a consistent generalization pattern. Statistical analysis has pointed to the possibility that individual gradients do not depart greatly from the group gradient, suggesting that the latter adequately represents all individual gradients.

CHAPTER V

SUMMARY AND CONCLUSIONS

The presant investigation has attempted to duplicate, in part, Hovland's experiment on conditioned generalization of the GSR to pitch. Stevens' (1960) basic assumption, which considers the jnd (a confusion scale) equivalent to the mel scale (a ratio scale for subjective pitch) was tested by the present study. Hovland's (1937a) work had made use of various frequencies of tone along the stimulus continuum. The present research has also made use of tonal frequencies, but the units employed for measuring these along the pitch continuum were Stevens' mels; whereas Hovland employed equally spaced jnd's to measure his pitch continuum. The GSR was then conditioned to one of these tonal stimuli and tested for generalization on all the others. The gradient obtained in his study, while falling off rapidly from the conditioned to the first generalization stimulus, and tending to level out to the other test stimuli, indicated generalization for the group as a whole. It was hypothesized, in the present study that, if Stevens' assumption of confusion-ratio scaling equivalence on metathetic continua were correct, the resulting GG should be a negative exponential function, as was Hovland's.

The experiment involved testing 22 Ss, on two orders of presentation of pitch stimuli. Following seven reinforcement trials in Order 1, three test stimuli were administered to 1000, 500 and 250 mels in pitch. Immediately following this first order of presentation, six additional training trials were give in the second order condition, and test trials to 1000, 250 and 500 mels, and an extinction trial to the standard 1000 mels tone, were presented after the last six reinforcing trials. Mean GSR values were then calculated and tested statistically for significance.

Overall generalization to subjective pitch was found to be significant at the .05 level of confidence. Also the gradient for the 22 Ss as a group tended to approach a negative exponential. Hence the present findings seemed relatively favourable to Stevens' fundamental hypothesis of existing equivalence between two subjective scales for pitch, the jnd and the mel scales. The results seemed to suggest further that the GG is negatively accelerated even when the pitch continuum is scaled in terms of Stevens' mels, rather than by Hovland's jnd units.

It was concluded from the results of this CSG research that, not only was generalization of the GSR obtained, as has been determined by other observers using auditory stimuli; but that there exists, in addition, a gradient of stimulus generalization to subjective pitch. It was discovered further that the gradient obtained was negatively accelerated in form. This finding agrees with Hull's hypothetical primary generalization function demanded by his Postulate 5. Furthermore, this study has shown that the GG based on group averages is the same gradient obtained by Hovland from his group averages. Using scores of individual Ss, only one of Hovland's 20 Ss showed a clear-cut negatively exponential shape of the gradient, whereas six of the present 22 Ss did so. Individual curves did not depart significantly from the group curve.

Although significant generalization effects were found when both orders of presentation were pooled, the fit to Hovland's gradient appeared better for the second order of presentation than for the first order. Nevertheless, the fact that the group gradients obtained in the present experiment and in that of Hovland were both negatively accelerated, seems to confirm Stevens' suggestion that confusion (jnd) and ratio (mel) scales should be equivalent on a metathetic continuum such as pitch.

Finally, it was suggested that, were Hovland's (1937b) experiment with varying intensities of tone, such as loudness, replicated in future research of this kind, a somewhat different slope of GG might be expected to appear.

APPENDIX A

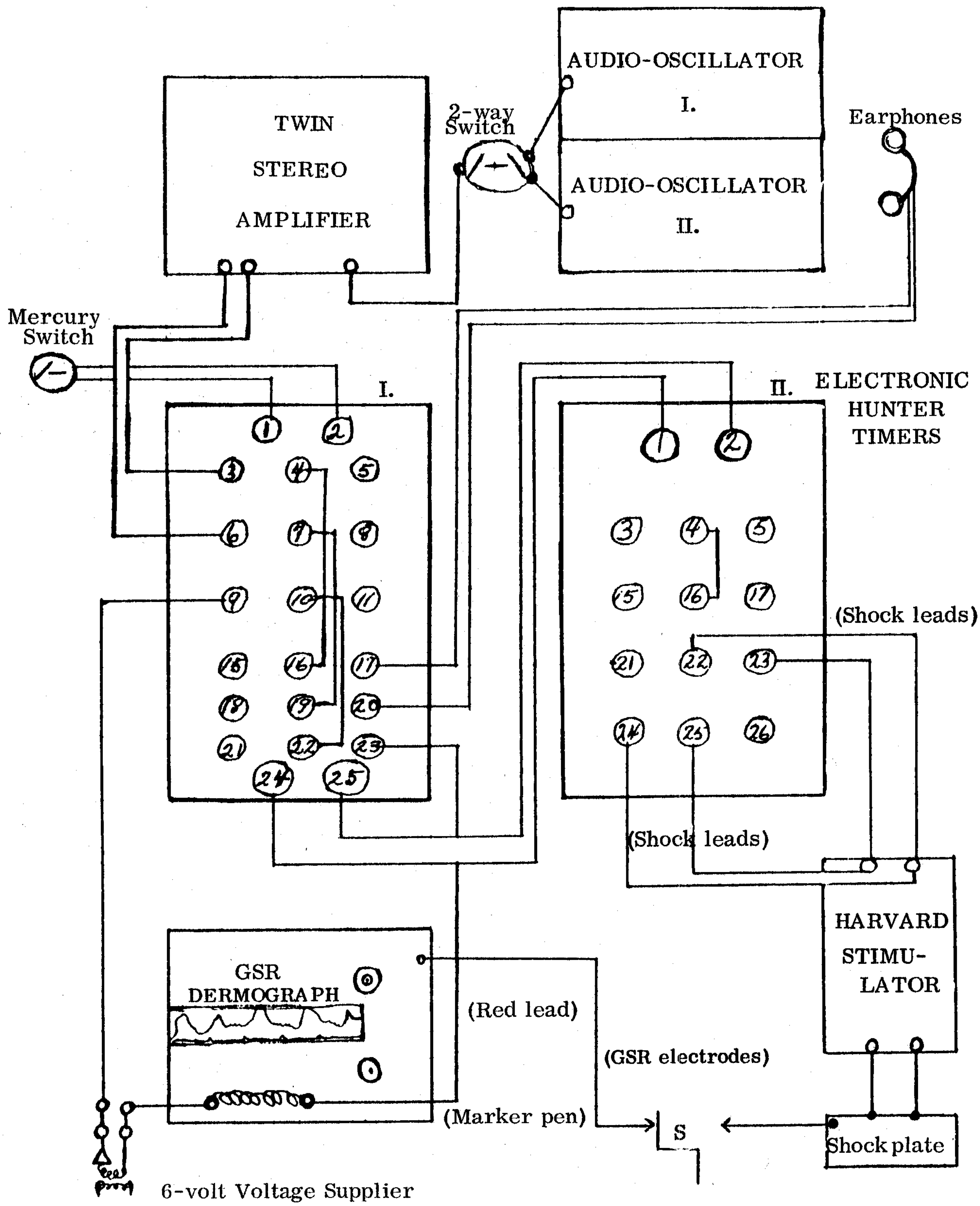


Fig. 1. Block Diagram of Apparatus.

APPENDIX B (1)

Table 6

Raw Scores of the GSR (in mm.) for First Order Training and Test Trials with respect to Baseline Variability and Sex

Ss	(O_1)	Training Trials (1000 mels)						Test Trials 1000	500	250
Female										
I	98.0	60.0	55.5	22.5	32.5	38.0	17.0	5.5	6.5	13.5
II	55.5	23.0	25.5	28.0	14.5	20.5	22.0	19.0	1.0	10.5
III	14.0	40.5	17.0	35.5	29.0	16.0	17.5	0.0	8.5	0.0*
IV	7.5	18.0	5.5	72.0	5.5	0.0	1.0	8.0	5.5	2.5
V	15.0	26.0	6.0	13.5	14.0	4.0	8.5	10.5	10.5	13.5
VI	15.5	22.0	15.5	35.5	16.5	14.0	14.0	32.0	5.0	1.5*
VII	103.5	58.5	63.5	53.0	0.0	0.0	38.0	16.5	5.5	0.0*
VIII	102.0	59.0	57.5	60.0	56.0	47.5	44.0	42.5	98.0	60.5*
IX	67.5	15.0	26.5	26.0	18.0	10.5	7.5	48.0	42.5	25.0*
X	36.5	37.5	55.0	20.5	48.0	19.5	30.5	42.5	24.5	0.0*
XI	53.5	36.0	36.0	38.0	34.0	54.0	47.5	39.5	43.5	48.5*
XII	12.0	10.5	13.5	11.5	11.5	17.0	13.5	12.5	9.0	5.5
XIII	12.5	13.5	17.0	23.0	17.0	23.5	14.5	18.0	12.5	22.0
XIV	50.0	35.5	33.0	27.0	22.0	29.5	44.5	27.5	13.5	15.0*
Male										
XV	8.0	16.5	10.0	18.0	15.0	38.5	19.0	7.5	3.5	12.0
XVI	13.5	24.5	20.0	13.5	5.0	6.0	6.5	10.0	10.0	5.5
XVII	22.5	24.5	13.5	15.0	13.5	8.0	24.0	43.5	3.5	5.0
XVIII	22.0	8.0	10.0	14.0	1.0	11.0	11.0	14.5	7.5	27.5*
XIX	18.5	22.5	17.5	12.0	14.0	15.0	17.0	13.0	5.5	5.5
XX	31.5	22.5	13.5	9.5	16.5	17.5	7.5	15.5	25.0	1.5*
XXI	111.5	31.5	34.5	35.5	39.5	40.5	37.0	43.5	47.0	44.5*
XXII	119.0	46.5	81.0	46.0	33.0	43.0	26.5	46.5	26.5	24.0

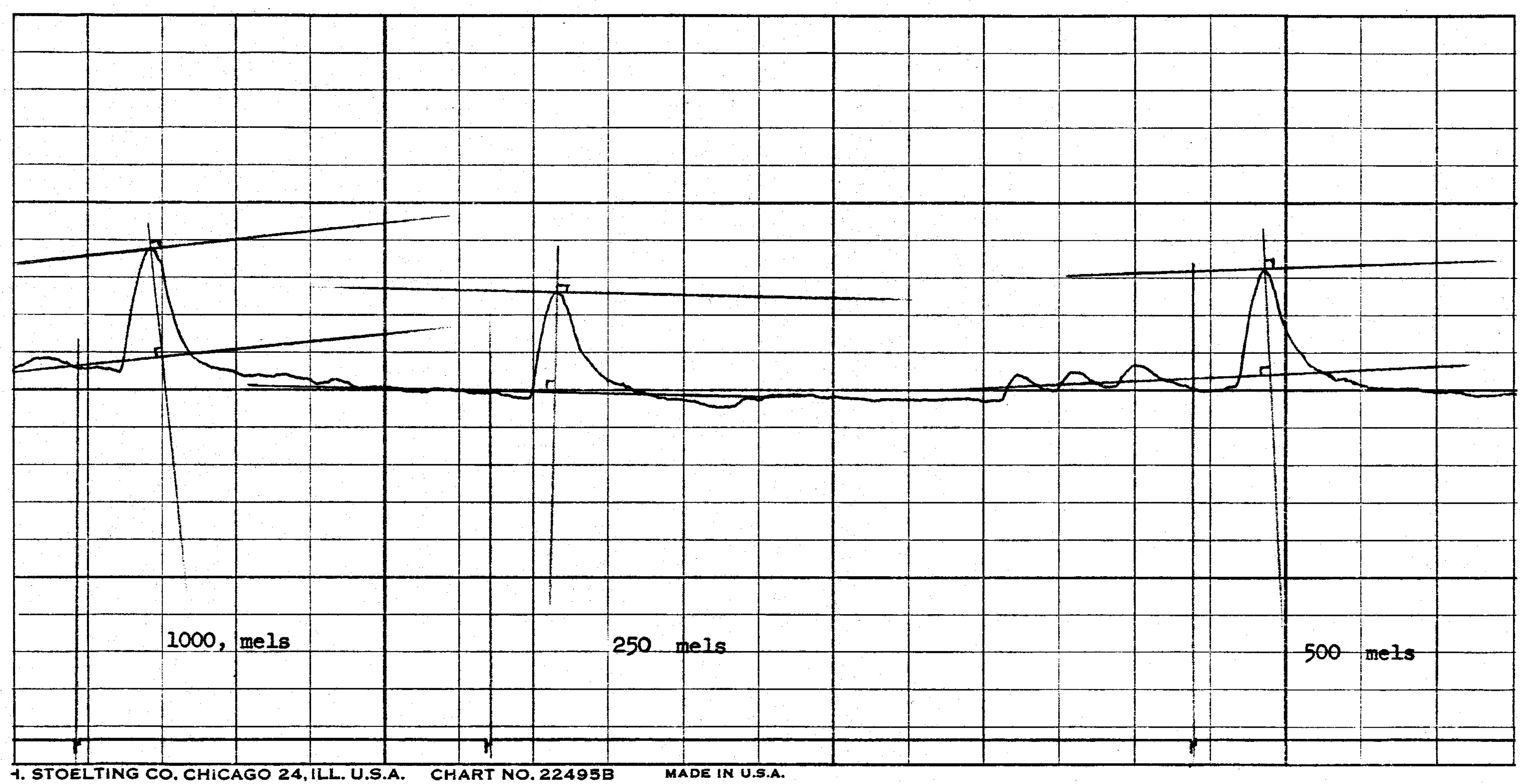
* varying baseline

Table 7

Raw Scores of the GSR (in mm.) for Second Order Training and Test Trials with respect to Baseline Variability and Sex

Ss (O_2)	Training Trials (1000 mels)						Test Trials 1000	250	500	Extinction 1000
Female										
I	35.5	24.0	19.0	32.5	55.0	10.0	37.0	10.5	3.5	1.5
II	36.0	45.5	33.5	35.0	15.0	8.5	3.5	16.5	0.0	0.0
III	48.5	43.0	74.5	53.0	44.0	12.0	4.0	2.0	8.0	0.0*
IV	6.0	13.0	18.5	16.5	3.5	10.0	0.0	0.0	0.0	0.0
V	14.5	9.5	8.0	10.0	10.5	10.5	8.5	5.5	4.0	2.0
VI	38.0	17.5	39.0	46.0	29.5	49.5	58.5	44.0	19.0	37.0*
VII	0.0	0.0	90.0	88.5	11.5	24.0	86.0	42.5	17.0	61.0*
VIII	63.5	60.5	61.0	63.5	65.0	59.0	58.5	57.0	52.0	23.0*
IX	44.5	53.5	42.0	35.5	34.0	63.0	21.5	32.0	14.0	12.5*
X	28.5	13.5	14.0	29.0	91.5	63.0	23.0	18.0	5.0	4.0*
XI	39.0	37.0	32.5	24.5	29.0	28.0	39.5	47.0	25.5	10.5*
XII	16.5	15.0	15.5	13.5	14.5	25.5	31.0	7.5	26.0	14.0
XIII	16.5	14.0	17.5	18.5	11.0	18.0	20.5	25.5	22.0	19.0
XIV	11.5	29.0	25.0	27.5	16.5	15.0	6.0	12.5	10.5	13.5*
Male										
XV	35.0	16.5	19.0	11.0	26.0	4.0	3.5	1.0	7.0	1.0
XVI	11.0	17.0	20.0	18.5	13.0	14.5	16.5	21.0	13.0	15.5
XVII	25.0	16.5	12.0	16.0	12.0	23.0	0.0	1.0	10.0	0.0
XVIII	42.5	36.5	30.0	24.0	34.5	42.0	43.5	35.0	31.0	45.5*
XIX	23.0	20.0	17.5	15.0	16.5	24.5	16.0	23.0	3.0	8.0
XX	35.0	23.0	43.0	39.5	30.0	50.5	35.5	50.0	56.0	44.0*
XXI	35.5	50.0	49.0	41.5	46.5	40.0	44.0	37.0	50.0	39.0*
XXII	40.5	41.0	44.0	42.5	53.5	46.5	35.5	32.0	35.5	50.0

* varying baseline



APPENDIX C

Fig. 2. Specimen Record showing Technique of Measuring GSR Amplitude

GLOSSARY OF TECHNICAL TERMS AND SYMBOLS

decibel (db): unit of relative sound intensity; one-tenth logarithm of ratio of two sound pressures.

galvanic skin response (reflex) (GSR): measure of autonomic activity associated with affective and emotional states.

just noticeable difference (jnd): the minimum detectable difference between two stimuli.

mel: unit of pitch scale, determined by "fractionation" judgements, in which the listener adjusts one tone until it sounds half as high in pitch as some standard tone.

metathetic: class of "qualitative" continua characterized chiefly by the fact that the observer's sensitivity to differences tends to be constant over the subjective scale.

mho; unit of conductance, reciprocal of ohm, the unit of resistance.

pitch: a psychological attribute of the perceived sound, related to the physical frequency of the sound wave.

prothetic: class of "quantitative" or intensitive continua on which the observer's sensitivity to differences tends to be good at the low end and poor at the high end of the scale.

sone: unit of the loudness scale, derived in the same manner as the mel.

****

CSG: conditioned stimulus generalization
GG: generalization gradient

CR: conditioned response
UCR: unconditioned response
CS: conditioned stimulus
UCS: unconditioned stimulus

SB: stable baseline
VB: varying baseline

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