Electrophysiological Correlates of Intellectual and Emotional Intelligence

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Dedications / Acknowledgements

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Declaration

This thesis has been composed by myself, and the research presented is my own. No portion of this work has been submitted for any other degree or professional qualification.

Abstract

This thesis examines the electrophysiology of several inspection time (IT) tasks, specifically extending two strands of work from Edinburgh by Austin (2004 and 2005) and Zhang et al. (1989a and 1989b).

Austin designed a new emotional inspection-time task using human faces as stimulus items. The original pi-figure IT task, extensively investigated since 1970, has been found to generate robust correlations with assorted IQ measures. A potential confound in existing IT methodologies is that the IT-IQ relationship may not arise from particular stimulus presentation methodologies, but be due to a process of rapid strategy formulation. Variation in the stimulus forms (e.g. pi-figures, human faces, geometric shapes or auditory tones) affects the robustness of the IT-IQ relationship. Austin's tasks were modified to permit the acquisition of ERP data to examine the effect of stimulus emotional expression and to explore the relationship with existing psychometric scales. Early differences in ERP related to IQ were reported by Zhang. A key additional element of this thesis is the examination of relationships between ERP and the emotion shown on stimulus faces, since differences in emotional expression form the basis of the emotional-IT task.

Four major experiments were conducted. Experiment 1 piloted the face presentation task and set baseline timing values for presenting human face stimuli; participants identified gender from each stimulus. A psychophysical curve was constructed, and the difficulty scaling of the task suggested that the longer timing durations should be removed in favour of additional, shorter durations in subsequent experiments.

Experiment 2 was the first attempt in the literature to collect ERP data from the emotional-IT task. The expected negative correlations between psychometric IT and IQ measures were reproduced, but the correlation between IT and EI scores was found to be positive; higher EI scores resulted in slower IT values. A P100→N170→P300 ERP complex was evoked, with maximal amplitudes at parietal electrode sites, and maximal activations in response to happy-face stimuli, especially among males. When divided into high- and low-IQ groups, higher-IQ individuals showed steeper mean gradients, and gradient-IQ correlations 50ms earlier than among the lower-IQ group.

Experiment 3 evaluated different backward masking techniques. In the ERP data, traces elicited by the stimulus face could potentially be contaminated by activity related to the backward mask. A P100→N170→P300 ERP complex was re-produced, but despite very high participant success rates (95.3%), effects of stimulus emotion within this ERP were not pronounced. A newer non-face mask was adopted for future studies to minimise other mask-contamination confounds from larger population samples in subsequent experiments, and to avoid potential apparent motion effects, another known confound in IT methodologies.

Experiment 4 featured three consecutive ERP acquisitions (face-IT-1, line-IT and face-IT-2) and was analysed in two stages. ERP effects related to stimulus emotion were inconsistent; the responses to stimulus emotion were neither identical nor prominent in each emotional-IT task. Psychometric effects were more consistent. IQ and IT were negatively correlated as expected, while IQ, IT and emotional intelligence were positively correlated.

Throughout the present series of experiments, the expected relationships between IT and IQ were robust across non-traditional emotional-IT tasks. The effects of stimulus emotion on ERP traces were not prominent despite relatively large sample sizes and adequate effect-size estimates. The ERP relationships with IQ previously found at Edinburgh and by others in line-IT tasks were not replicated here, although the lack of such a relationship has precedence in the broader literature.

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CHAPTER 1

ERP Responses to Faces

A principal aim of the present series of studies was to discover if the expression of emotion resulted in unique or otherwise characteristic modulations of ERP activity, spurred by the fact that research interest in the manner in which human beings process and perceive other human faces is a relatively recent phenomenon. Research interest is considered to have begun with the first verifiable case studies and naming of prosopagnosia (Bodamer 1947) – a specific inability to detect faces in one's field of vision – and progress has started and stopped in this area over the years. Interest in face processing in normally healthy individuals began in earnest in the 1970s, with Goren et al.'s (1975) discovery that human infants, on average only 9 minutes old, showed greater apparent interest in viewing human faces over other stimuli, raising the possibility that humans possess a biologically innate ability to detect and preferentially attend to faces – in Bentin et al.'s (1996) words :

> "…a specialised neural subsystem for processing physiognomic information and relating the perceived input to prestored face representations."

Between 1986-1996, six ERP studies were conducted using faces as stimulus items (Small, 1986, Smith & Halgren, 1987, Barrett, Rugg, & Perrett, 1988, Renault, Signoret, Debruille, Breton, & Bolger, 1989, Hautecoeur, Debruyne, Forzy, Gallois, Hache, & Dereux, 1993; Begleiter, Porjesz, & Wang, 1995), but importantly, perhaps the single major ERP phenomenon in face processing to date was overlooked in all of these 6 cases – Bentin et al.'s (1996) N170 component (discussed later), with the focus instead being on familiarity effects from perception of stimulus faces. Animal studies in the 1980s indicated that at least one neurological structure in the extrastriate cortex was probably a face-specific region of the macaque monkey brain (Perrett et al. 1982). In the same year, prosopagnosia was suspected to be due to lesions in the occipito-temporal region (e.g. Damasio et al. 1982). Greater progress was made in the 1990s within neurosurgical patient populations (e.g. Allison et al. 1994c, and 1999). The increasingly availability of functional scanning technologies (primarily fMRI), and notably, the advent of a particularly incisive experimental methodology (Allison et al. 1994, Bentin et al. 1996, and Kanwisher et al. 1997, discussed later), culminated in positive identifications of brain regions specialised for the detection of faces and related electrophysiological phenomena.

The facial region of the body is considered to be a “biologically salient” and complex stimulus to humans (and for those animal species which possess a recognisable face) as a primary indicator of another individual’s current state of mind and intention (Williams et al. 1988, Mogg and Bradley 1999, Öhman, Flykt and Esteves 2001). Expressions of fear in one’s fellows, or an angry facial expression may signal impending danger, and such expressions will typically and rapidly draw other individuals’ attention (Öhman and Mineka 2001) - probably for simple reasons of self-preservation. If there is danger in one’s vicinity, it is obviously advantageous to know of it. Perrett et al. (1985) suggested that in animals and humans, attending to the face region - especially the eyes, rather than the head in general, also gives information on the direction of others’ gaze as a social signal of interpersonal attention.

Considerable subsequent work has been carried out in the cognitive aspects of human face perception and processing (Bruce, Green and Georgeson 1996), confirming the actuality and location of dedicated face-processing structures in the brain (specifically the fusiform gyrus and fusiform face-area), and this section will explore contemporary trends in electrophysiological and biological research in face-processing. Research in face-processing can be divided into two main areas; firstly, theoretical and cognitive models such as e.g. Bruce and Young’s influential 1986 model of face processing. This work drew from conclusions from a range of different studies, and was not derived from a specific experiment or series of experiments conducted by Bruce and Young per se. The second direction of research is that of empirical experimentation in the face-processing literature, in which four individuals feature prominently – Truett Allison, Aina Puce, Gregory McCarthy, and Shlomo Bentin. Since 1994, their work has included four comprehensive and highly influential imaging and electrophysiological investigations of human face-processing. Alison et al. (1994c) began with a study of 34 epilepsy patients with surgically implanted electrodes situated “on the cortical surface” (the precise location was not disclosed in detail in the article) around the inferior temporal gyrus. This study is one of relatively few which appears genuinely interested in answering the immediate and simple question of how evoked potentials show responses to faces – the face-familiarity studies between 1986 and 1996, in this reader's opinion, omitted fundamental stages in the initial perception and detection of faces in humans. In Allison et al. (1994c), participants simply viewed a series of stimuli, some of which were faces, with an instruction to count the occurrence of one stimulus category. This methodology was adapted from studies by Shlomo Bentin in progress (but not yet published) in 1994 (cited in Alison et al. 1994c) - Kanwisher et al. (1997) would later use a very similar methodology for functional imaging of putative face-responsive areas. Results from 70% of Alison et al.'s patient group showed large individual differences in responses from areas in the superior temporal sulcus region, which Allison et al. interpreted as showing "variability in the location of these "face-modules"….", and, a prominent bilateral N200 component. The N200 was present only when patients viewed faces, and not when viewing scrambled faces, images of cars, or scrambled images of cars, although complementary studies by Puce et al. (1999) showed anatomically nearby regions were also activated by e.g. checkerboard patterns. Allison et al. also noted the rapidity of the response, occurring around 140ms after stimulus presentation, which was interpreted as showing that "…..a considerable amount of stimulus processing occurs between initial activation of striate cortex and activation of face modules.". In this relatively early study, stimulus faces were shown to rapidly generate distinctive ERP activity, in a relatively localized brain region (i.e. processing faces did not require the activation of much larger or apparently non-specialised brain areas to evoke the N200 response), within a region which was approximately analogous to previously discovered face-sensitive regions of the macaque monkey cortex (e.g. Desimone 1991, and later Tootell et al. 1995).

The most recent, fundamental, and influential electrophysiological finding in this area was Bentin et al.'s (1996) discovery of the N170 potential – a face-specific ERP potential (Bentin's 1996 colleagues included the previously referenced Allison, Puce and McCarthy). Bentin et al. conducted 5 experiments, with the first replicating Allison et al. (1994), all using normally healthy individuals and scalp-mounted electrodes.

Study 1 : Participants were required to silently count the occurrence of images of butterflies on-screen during presentation images of cars, (unfamiliar) faces, scrambled faces and scrambled cars. As the focus of the task, images of butterflies evoked P300 potentials with the largest amplitude. Although the N170 potential was not absent for other stimulus classes, the N170 was invariant to those classes, whilst faces elicited a larger N170 response in the left hemisphere.

Study 2 : Participants counted the occurrence of images of cars, amongst images of human hands, human faces, animal faces (using unspecified animals with prominent eyes, but excluding primate faces), and items of furniture. Again, human faces elicited the largest-amplitude N170 deflections, with all other stimulus categories showing no statistical differences to each other (cells with prominent responses to hands were previously found in monkey cortices; Gross et al. 1969).

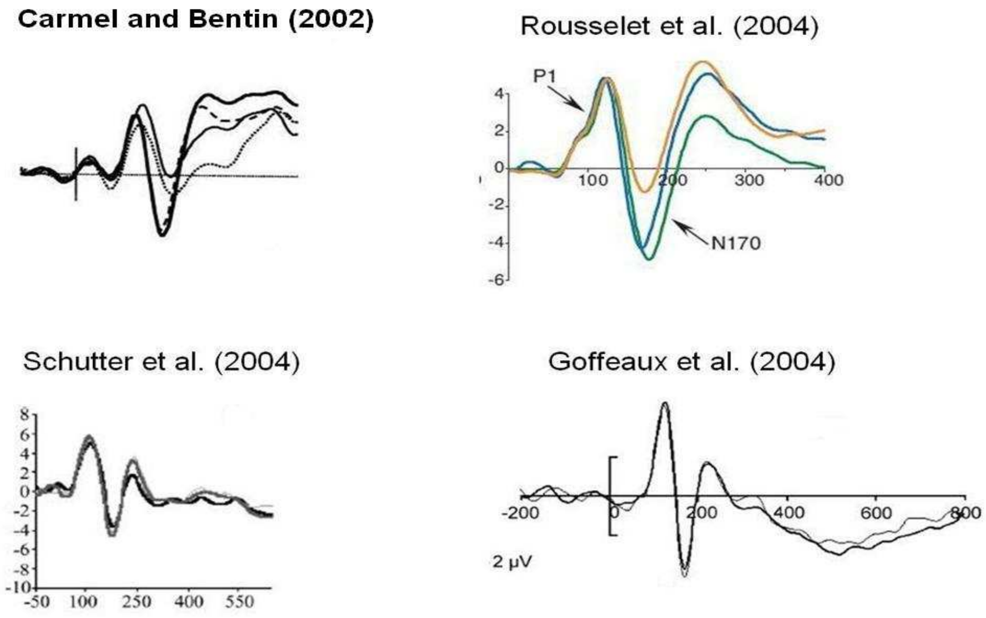
Study 3 : Using a larger 28-electrode montage, participants now viewed inverted and non-inverted images of butterflies (the target stimulus), human faces, and cars. Now, while N170 deflections were absent for car-stimuli, normal and inverted faces evoked similar deflections, again, largest in the left hemisphere. Inverted faces actually evoked N170 amplitudes described as “somewhat larger” than standard faces.

Study 4 : Participants were now presented with (target) butterfly stimuli, human faces, and individual pairs of lips, eyes, and noses. Now, N170 amplitudes to whole faces and pairs of eyes were significantly larger than those for lips or noses. N170 latencies for eyes and whole faces were identical, and significantly faster than those for lips or noses alone.

Study 5 : Stimuli were presented as in study 4 previously, but now, normal faces were “distorted”, with individual features placed in the wrong location (e.g. eyes placed where the mouth should be; noses and mouth where each eye should be etc.). Here, distorted faces (and isolated pairs of eyes) still elicited N170 deflections.

In all aspects of Bentin et al.’s (1996) study, the N170 component varied only in response to human faces and human eyes. Although the N170 component is evoked by other forms of stimuli such as words (Carmel and Bentin 2002), its amplitude is greatest and its onset most rapid when it is produced in response to faces. Amongst a stimulus set comprising only human faces, then, the N170 component is more diagnostic of the presence of whole faces within an individual's field of view (i.e. in a properly conducted methodology using human faces, the N170 should be apparent within the waveform), though it is perhaps not entirely specialised for whole faces. The N170 does, however, appear sensitive to the detection of human eyes, and it is otherwise invariant to non-face stimulus categories. Bentin et al. (1996) surmised that the N170 may reflect "part of the operation" of "…a structural encoding stage….initially processed independently of personal identity or facial expression….". The use of inverted faces apparently does not prevent the face-recognition process from occurring, and the process is initiated by parts of the face, as well as whole faces, and especially the eyes. The waveform typically evoked from face-processing studies is illustrated in figure 1 below, reproduced from 4 face-processing studies :

Figure 1 : Sample P100 → N170 → P300 waveform evoked by faces.



Carmel and Bentin (2002)

Rousselet et al. (2004)

Schutter et al. (2004)

Goffeaux et al. (2004)

Allison et al. (1994) referred to facial ERP components as N200s, and whether it is termed the “subdural N200” by Allison et al. (1994) or the N170 by Bentin et al. (1996), controversy was and still is present over the laterality of these face processing effects. Using direct cortical recordings, Allison et al. (1994) found bilateral effects of face processing, whilst scalp surface-mounted electrodes showed inconsistent effects in Bentin et al.’s study between the T6 and T7 electrode sites. The nomenclature of ERPs is such that the onset time for which components are named is never exact, and figure 1 illustrates that the N170 labelled from Rousselet et al’s (2004) work could as easily be renamed the N200. Allison et al.’s N200 face-component was actually onset at 140-192ms, yet was formally labelled as N200. Bentin et al (1996) suggested that “their” N170 and Allison et al.’s (1994) N200 could be different processes, with different timing onsets due to the nature of Allison et al.’s sample group being epileptic patients, rather than healthy individuals. The N170 was also suspected of being an “eye processor” versus the N200 as a “structural encoder”, due to the N170’s enhanced amplitude responses to pairs of eyes. Eimer (1998, 2000c), however, believes that the N170 is related to late structural encoding processes despite the greater variations in N170 amplitude and latency which would be shown by Allison et al (1999 I-III); in two studies by Eimer, the N170 was affected by featureless face shapes, but not by faces without eyes. Since 1999, however, the N170 appears to have gained substantially greater acceptance as “the” face-specific ERP component, with the N200 typically remaining associated with the (especially auditory) general oddball paradigm.

Although the presence and defining characteristics of Bentin et.al’s N170 component leant additional credence to the existence of biological mechanisms devoted to the detection of faces and face-like stimuli (e.g. animal faces, or schematic cartoon-like faces), the N170 itself is relatively invariant when compared to other ERP deflections, and its presence can be more regarded as a diagnostic criterion of methodological success in ERP face-processing studies. From Bentin et al.’s study, it appears that the N170 only shows variation when whole stimulus sets present both faces and face elements, or both faces and non-face items. With this in mind, it becomes unsurprising that the face familiarity studies from 1986 – 1995 did not identify a face-specific N200 or N170 component : when stimulus items are largely or exclusively composed of entire faces, the N200 / N170 component is unlikely to show any substantial variation since it is already highly responsive to the presence of whole faces. Additionally, the N170 component is apparently unaffected by face familiarity (Soroker 1999, Puce et al. 1999), indicating that there are possibly several distinct sub-systems involved in the entire process of face recognition (Kanwisher and Moscovitch 2000).

The increased availability of imaging technology during the 1990s rapidly lead to a series of studies directly pointing to candidate areas in the human brain for face recognition sites. The fusiform face area (FFA), within the fusiform gyrus, was found to be preferentially activated upon the perception of faces and face-like stimuli across a variety of methodologies. In comparison to viewing scrambled faces, consonant strings, textures, or during face-matching tasks (Haxby et al., 1991, Sergent et al. 1992, Haxby et al. 1994 , Puce et al. 1995, Malach et al. 1995, Tootell et al. 1995, Clark et al. 1996), the human FFA has shown consistent right-sided activation, greatest when an individual is viewing either an animal or human face.

Kanwisher, McDermot and Chun (1997) produced what has become a landmark, and lengthy, study in the biology of human face processing, confirming the presence of brain regions perhaps not dedicated, but specialised for the perception of face stimuli. Kanwisher et al. (1997) performed an fMRI investigation of a population of 15 individuals (sample size per task, however, varied upon the clarity of participants' responses), requiring them to complete 5 tasks. Within each task, participants were selected for participation in the next task based upon the presence of a clear effect. Using passive viewing techniques, participants viewed :

(i) Human faces vs. various non-face objects (e.g. telephones, vegetables, or animals without obvious faces such as crabs.)
(ii) Intact human faces vs. unrecognisable scrambled faces.
(iii) Faces vs. front views of houses.
(iv) Three-quarter-profile faces vs. human hands.
(v) Task (iv), with a “1-back” manipulation where stimuli were occasionally repeated, with participants signalling the detection of repeated stimuli.

In this manner, Kanwisher et al. compared responses to faces with animate and inanimate objects, animate but non-face objects (animals and human hands), familiar vs. unfamiliar faces, and face-components as well as controlling for stimulus luminance via the scrambled faces in a manner similar to Allison et al. (1994). In all cases, a region of the fusiform gyrus labelled “area FF” responded most strongly when human faces were shown, with signal intensities up to 600% higher than during other conditions. When faces were scrambled, or some recognisable features were hidden (i.e. in conditions (iv) and (v), where individuals in the stimulus photographs wore ski-caps, hiding their hair), area FF still responded more strongly than when non-face stimuli were shown. From this, Kanwisher et al. decided that area FF was not “head-specific”, but face-specific. Although a single study, Kanwisher et al.’s evidence and methods provide compelling evidence for the presence of a module that if not wholly and entirely dedicated for face-processing, was nonetheless apparently highly specialised, and strongly preferential for this stimulus class.

The notion of the fusiform face area as face-specific processing site has been strongly upheld until very recent work by Grill-Spector, Sayres and Ress (2006), who claimed that the FFA may not be wholly and entirely specialised for faces per se, but contains several sub-populations of neurons which are selectively much more responsive to faces than are other regions to other objects, and which outnumber less specifically responsive neuronal areas- i.e. the FFA contains larger numbers of face-specific neuronal populations than other areas responsive to other stimulus types. This is consistent with Allison et al.’s (1994) finding of individual differences in sub-dural ERP responses from the extrastriate cortex; in some individuals, responses to faces from multiple “face modules” may be more pronounced than those of others, resulting in slight inconsistencies in ERP effects. For the moment, however, the fusiform face area itself remains the locus of imaging investigations of face-processing, with no other strongly face-preferential candidates. In the past, some regions of the amygdala (Rolls 1992) and frontal lobe (Wilson et al. 1993) have also shown responses to faces, but these areas are no longer emphasised within the contemporary face-processing literature.

Allison, Puce and McCarthy (1999a) returned to their electrophysiological work with a series of 3 contiguous articles detailing sub-dural electrophysiological studies of 98 epilepsy patients (Allison et al. 1999, McCarthy et al. 1999, and Puce et al. 1999 – Allison, McCarthy and Puce contributed to all three articles.). The emphasis upon the N200 potential rather than the N170 remained despite the intermediate N170 work by Bentin et al. (1996). Allison et al. also referenced four other components – the P150, N290, P350 and N700, all four of which have become obscure within this literature and have seldom been referenced outwith Allison et al.'s three articles. Although the P150, N290, P350 and N700 components may have shown variation in these studies, they are unlikely to be face-specific potentials and may reflect differences according to other task demands.

In Allison et al (1999) part I, 75 face-specific sites were found to generate the N200 when participants viewed faces (scrambled and normal), cars (scrambled and normal), letters and numbers, flowers and "phase-scrambled" images of faces, numbers, flowers and cars. Faces still evoked the largest N200 response (now beginning to seem as merely a differently labeled N170), without either prominent hemispheric or gender-related differences.

In McCarthy et al.'s second study (part II of Allison et al. 1999), more detailed examinations of faces and animate objects were undertaken, with stimulus classes now including full faces, three-quarter profile upright faces of various sizes, blurred, inverted, and line-drawn human faces, face components, faces with eyes open and closed, canine and feline faces, human hands, and face contours without details. Again, only full human faces resulted in maximal N200 amplitudes (including three-quarter profile faces), although animal faces evoked N200s "73%" as large as those to human faces. A steady progression in decreasing N200 amplitude was noted (similar to Bentin et al. 1996) when facial components were shown, in order of eyes, face contours, lips and noses. Lastly, the right hemisphere was shown to respond more strongly (i.e. with larger N200 amplitudes and lowered latencies) to normal faces, whilst the left hemisphere responded similarly to inverted faces. Varying the size of the stimulus head items also evoked no difference in responses.

In the final part of their study, Puce et al. (1999, part III of Allison et al. 1999) addressed the issue of bottom-up vs. top-down processing by introducing additional elements into the stimuli. Here, the focus of study was attentional orienting, habituation to and learning of stimulus materials, and the emotional content of image processing. Although the stimulus images in this study contained faces, now, other body parts were also present in the same scenes. Puce et al.'s participants viewed normal, unfamiliar male human faces, recognizable celebrity faces, "attractive semi-nude males" (e.g. an image of body-builder's upper torso and face), violent and aversive stimuli (e.g. the notorious 1968 image of the pistol execution of a suspected Viet Cong officer), and emotionally neutral landscape scenes. Findings from these studies revealed that

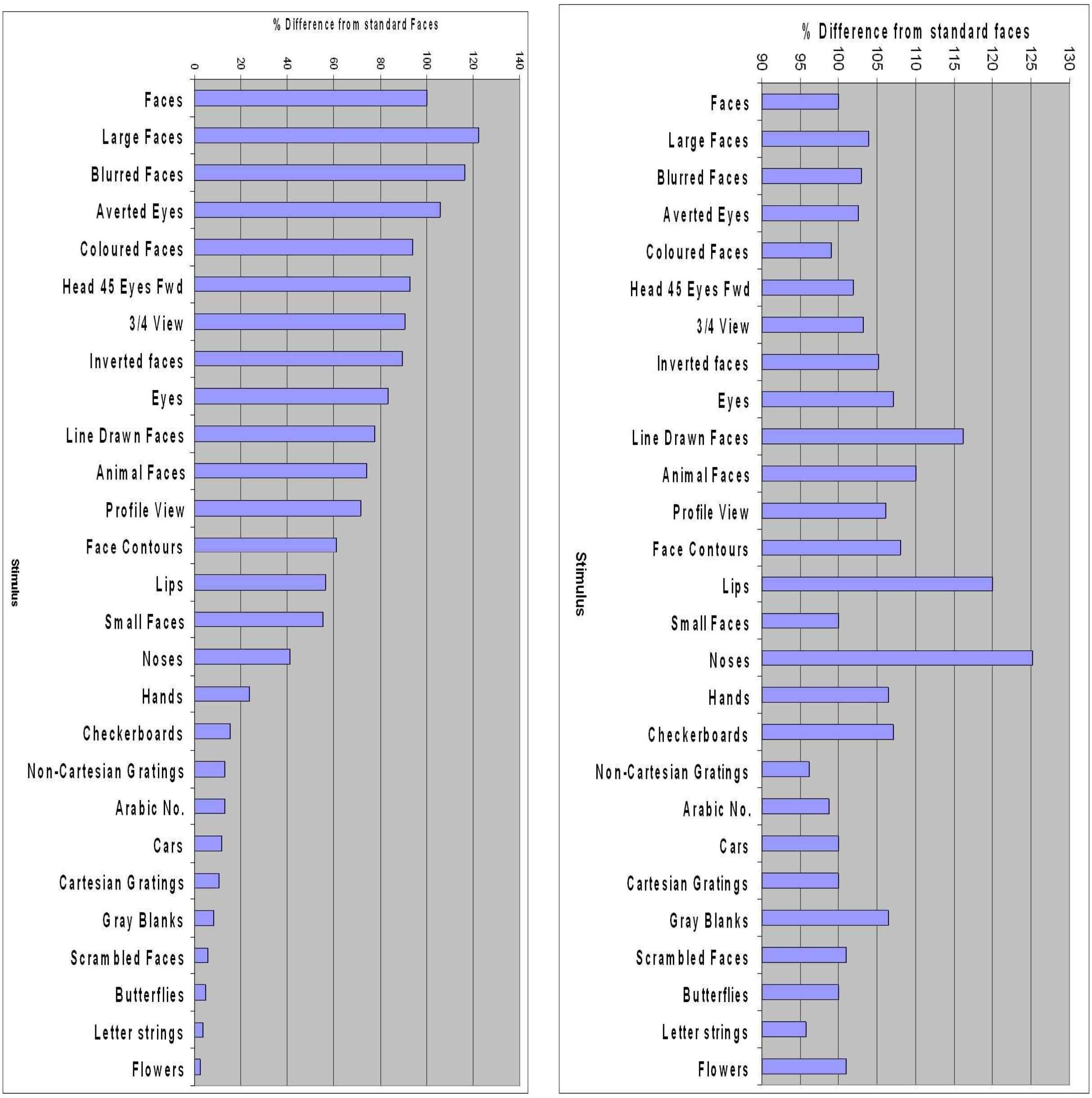
(i) N200 responses to faces were consistently larger than those to all other stimulus categories, suggesting that the emotional content of an entire scene was less well attended to than the presence of whole faces.

(ii) When repeatedly shown unfamiliar faces, the N200 showed significantly lowered amplitudes between the first and second presentations, but amplitudes were not further reduced in the 3rd to 8th presentation of each stimulus – however, a subsequent N290 response increased marginally in amplitude following subsequent presentations. Later components (the P350 and N700) showed larger decreases in amplitude here.

(iii) The familiarity of faces had almost no effect on any component (N200, N290, P350, or N700) in any way – either latency, amplitude or area under the curve, at any previously recorded face specific site.

Perhaps the most salient discovery from Allison et al's (1999) work is illustrated most effectively by Figure 2 :

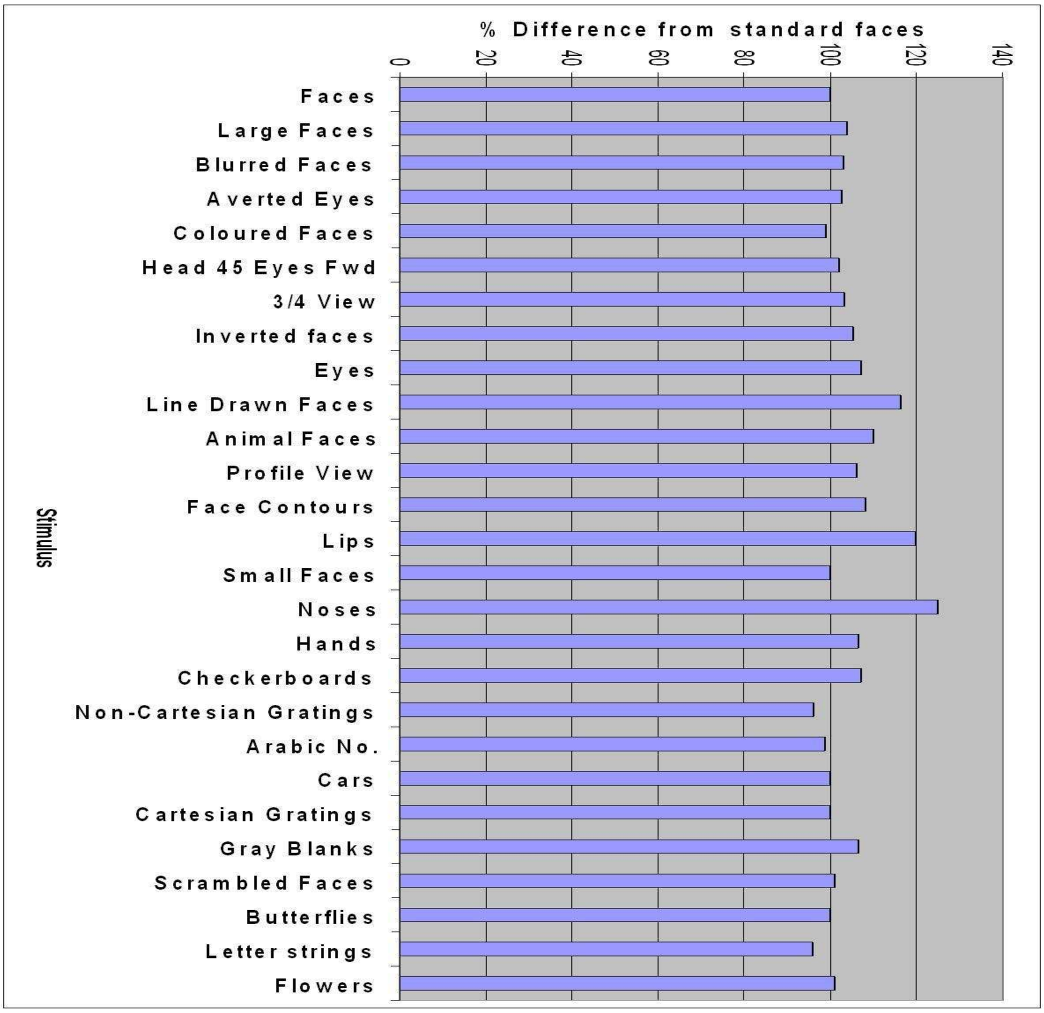
Figure 2 : N170 amplitude and latency variations, redrawn from Puce et al. (1999).



Amplitude Variations Latency Variations

ERP amplitude variation in response to human faces clearly shows that faces of any kind, including component parts, resulted in substantial deflections across stimulus categories, and the progression of amplitude change can be ordered in an obvious manner by stimulus category. Latency variations, however, showed a far more indistinct pattern, with whole faces constituting an approximate baseline value rather than the most rapid response. From figure 2, normal faces, coloured faces, and reduced size-images of faces generate more rapid responses, probably due to the activity of the FFA areas quickly making the appropriate determination. In contrast, some face components (lips and noses) seem to require much longer processing times, while obviously non-human or non-face images such as cars, animal faces, and checkerboard patterns may be so obviously non-face stimuli that discrimination is very rapid. Puce et al.'s graphical depiction of the latency variations, however, is somewhat misleading. The Y-axis in the original figure was artificially and considerably shortened, covering only 40% of the full range (i.e. 90-130%). By plotting a new chart with a Y-axis based on a full percentage scale (figure 3), the evident variations in latency are dramatically reduced, and though statistically significant, are seen to be very marginal in comparison to the wave <u>amplitude</u> changes in figure 2.

Figure 3 : Rescaled N170 latency differences from Puce et. Al (1999).



An ongoing problem for this face-processing research is that there are many other stimulus classes which could be considered somewhat face-like e.g. the apocryphal “faces in clouds” phenomenon from common myth, or the front-grille sections of cars, whose two prominent headlights may trigger the N170’s preferential response to the presence of eyes, as used in Carmel and Bentin (2002). There are also many thousands of other stimulus forms which constitute entirely non-facial stimuli. Carmel and Bentin (2002) conducted one of the most recent, and relatively scarce examinations of simpler responses to faces without the use of faces as complex attentional manipulators. In two separate studies, participants were asked to identify animate or inanimate objects, and later to distinguish between human and ape faces. Results were consistent with previous studies, again showing maximal N170 amplitude responses to human faces over other stimulus types, and a delayed latency for non-human face stimuli. Carmel and Bentin concluded from these studies that the role of the N170 is an indicator of a face-specific visual mechanism specialised for the perception of human faces, rather than activity of a more general visual processing system. When human faces were non-target stimuli or relevant targets, the N170 deflection did not differ in response to those faces.

More recently, Rousselet et al. (2004) and Palermo and Rhodes (2007) have provided a reviews of face-processing literature, although these reviews are primarily related to the N170’s response to various stimulus inversions (Rousselet et al. 2004) and attentional effects from fearful faces (Palermo and Rhodes 2007). Phenomena listed by Rousselet et al. (2004) included processing delays in the N170 induced by face inversion (Eimer 2000c, Rossion et al. 1999 and 2000), increased amplitudes in response to face inversion (Sagiv and Bentin 2001), and the effect of inverting other stimuli in conjunction with faces, such as cars and words (Rossion, Joyce, Cottrell, & Tarr, 2003).

Palermo and Rhodes’ (2007) summary of 24 face perception studies integrated cognitive, electrophysiological, and imaging work from 1999 to 2006. It seems that the most recent contemporary trend in ERP studies of face processing is a heavy emphasis upon the manner in which faces can serve as attention-modulating stimulus items (i.e. evoking top-down processes), rather than a more general focus on the manner in which task demands can induce differences in ERP waveforms to faces (bottom-up processes). Fearful facial expressions in particular seem able to quickly attract individuals’ attention (Öhman 2002). This has posed considerable difficulties in the accumulation of precedents for comparison with the present series of studies. Of these recent studies, only two have involved an analogous task and key comparison using a scalp ERP methodology – i.e. the identification of emotional responses (Streit et al. 2000, and Balconi and Pozzoli. 2000). From the previous discussion, the N170 / N200 component has been shown to be invariant when only faces are used as stimulus items, and specifically (Puce et al. 1999), the N200 is invariant to the emotional expression worn by human faces, leaving researchers still seeking new ways to examine ERP data for a deeper understanding of the processing of emotional facial expressions. Streit et al. (2000) noted that when participants viewed blurred and non-blurred emotional human faces, changes in amplitude were present between these stimulus classes between 180-300ms, concluding that emotional processing was rapid, and distinct from other aspects of face processing. Balconi and Pozzoli (2003) conducted a much simpler, and potentially more useful study by simply asking participants to passively observe human faces in preparation for a subsequent “recognition task” with no other specific instructions given. Interestingly, Balconi and Pozzoli observed a deflection termed an N180 rather than the expected N170, and which was heavily attenuated in comparison to other grand average ERPs in this field. The final grand average ERP was quite different in nature from the typical N100 → N170 → P300 pattern of deflections typically observed throughout the rest of the face processing literature, and this study is interesting simply because it began with a basic task without elaborate manipulations or task demands.

In this researcher’s opinion, much fundamental information has been, and still is potentially being lost through the use of ever more complex manipulations of participants’ attention, essentially through the experimental equivalent of “muddied waters”. In what appears to be a relative “rush” to carry out original experimentation, smaller and more basic issues are seemingly being overlooked in favour of more complex methodologies, resulting in a plethora of small contributions to a very large field, none of which point in any particular direction.

Since the 1990s, functional imaging studies of face perception have made great progress in localising the physical structures of the brain involved in face processing, albeit it at considerable financial cost in the case of each study. In contrast, substantially less expensive ERP work in face-processing has actually focused somewhat less upon actual face-processing itself, and more on the use of the human face as a complex stimulus and manipulator of participants' attention. Somewhat paradoxically, although researchers are now possessed of considerable evidence which localises the source of face-processing behaviours using highly expensive imaging technologies, the relative ubiquity of ERP equipment and application has seemingly not contributed a similarly large body of fundamental information in this field. Although a great many individual phenomena have been highlighted in the previous studies, very few have been systematically re-investigated in order to produce an empirical, unified theory of face processing, and the critical ERP findings from the last 17 years are contained in only 5 studies (Allison et al. 1999 parts I-III, Kanwisher et al. 1997, and Bentin et al. 1996). In fact, there are essentially only two principal ERP findings from approximately 11 years of work, owing to inconsistent attempts at replication and an apparent lack of overall direction across studies since 1996 :

(i) the evocation of the N170 (or N200) potential in response to faces as stimulus items, and the sensitivity of this component to changes in face elements versus other, non-face stimulus items, and stimulus inversion (Allison et al. 1994, 1999 I-III, Bentin et al. 1996).

(ii) the presence of larger ERP amplitude responses from fearful faces when whole emotional faces are shown (Palermo and Rhodes 2007).

For the present series of studies, however, relatively little new and more basic information has been produced in recent years specifically investigating the manner in which emotional processing is reflected at the level of ERP responses – a circumstance which this series of studies hopes to correct.

CHAPTER 2

ERPs and Intelligence

Until the advent of functional scanning techniques, EEG and ERP provided the most direct measure of brain activity and cognition, and both techniques have received considerable use. ERPs are valuable in the study of brain activity due both to their non-invasive nature and high temporal resolution. Although not common, sampling rates up to 10Khz are possible (Fabiani, Gratton and Federmeier 2007), giving the fastest moment-to-moment reflection of changes in brain electrical states available with current technology. In contrast, functional MRI techniques, although more precise in terms of functional anatomical localisation, rely on the BOLD (blood-oxygen level dependent) measure, essentially the relative difference in the magnetic properties of oxygenated and de-oxygenated haemoglobin in the blood, which requires several seconds before changes are evident (Wager et al. 2007). ERP techniques are also considerably less expensive per participant beyond the initial cost of the equipment, resulting in a relative ubiquity of studies when compared to other imaging techniques.

Another source of popularity for EEG techniques has been the hope that their use would provide a measure or correlate of intellectual ability which was truly "culture-fair" (Crawford 1974, Deary 2000). Free EEG work has varied in popularity, and using this technique, such a culture-fair measure has yet to be found - i.e. non-event related, waking EEG phenomena which could be strongly linked to individual differences in intellectual ability. Any event-related evoked potential (ERP) work remains subject to the usual problems of culture-fairness in any other realm of experimentation – the stimuli which evoke the brain activity must themselves be culture-fair, which can be an issue for virtually all forms of experimentation, psychophysiological or otherwise. It should be noted, then, that despite some unique attributes, EEG and ERP measures nonetheless remain "merely" another form of dependent variable, and their nature as measures of change in brain electrophysiology still requires some caution in their interpretation.

Deary and Caryl (1993), Caryl et al. (1999) and Deary, Caryl and MacLullich (in Deary 2000) have provided reviews of experimental findings in the exploration of brain electrophysiology and IQ since Knott, Friedman and Bardsley (1942). From then until the present day, many analytical techniques have been applied to the waveforms evoked by brain activity. The waveforms recorded by EEG and ERP are not dissimilar to those generated by many other forms of electromagnetic radiation - the EEG trace is a graphical representation of sequential changes in electrical states over time; in this case, electrical states generated by brain tissue. Because of these similarities, analytical techniques otherwise applied in the study of electrical, acoustic and electromagnetic phenomena are equally applicable to EEG and ERP data, e.g. analyses of wave frequency, spectral composition, frequency coherence across scalp or generator structure locations, onset latency, and voltage amplitude. Deary and Caryl (1993) note that rather than producing consistently directed research, this plethora of analytical methodologies and practical techniques has resulted in few “directly comparable” studies over time, most especially in regard to explorations of putative links between brain activity and IQ. As EEG is inherently imprecise in terms of the localisation of these changes, although it provides a sensitive measurement of changes in electrical activity over time, minor differences in methodologies (or individual differences within participant samples) between studies can result in an apparent lack of consistency in findings.

Studies between 1942 and 1969 made extensive use of frequency analysis of free EEG, and demonstrated very clearly the issues of replicability and consistency in findings mentioned by Deary and Caryl (1993). Frequency analyses were probably borne from the earliest EEG-related phenomena. Hans Berger (1929), a psychiatrist accredited with the invention of the basic electroencephalographic technique in humans, was the first to notice that the frequency of EEG activity could be used to approximately classify the conscious or unconscious state of an individual (Adrian 1935). The “Berger Rhythm” later became known as “alpha-wave” activity, an 8-13Hz periodicity in brain electrical activity manifest by idle or resting, but otherwise wakeful human volunteers. Berger (1929) also noted that when a participant performed mental arithmetic, the frequency of their alpha rhythm was reduced (Batt et al. 1999), implying that active cognitive processes could affect the electrical state of the brain. Other frequency bands have similarly been associated with different cognitive states; from 1-8Hz, delta- and theta-band activity denote the stages of sleep

(Niedermeyer 1993, Schacter 1977), while frequencies from 13-20Hz and 20-44Hz respectively denote the beta and gamma-bands, associated with focused attention (beta activity, Steriade 1993) and sensory perception and "binding" processes of attention (gamma activity, Rodriguez et al. 1999). Thus, analyses of the frequency of resting, wakeful brain activity were a logical place to look for links with IQ; as with T.E. Reed's studies of nerve conduction velocity, it has been theorised that intellectual abilities may be influenced by low-level functions of the brain such as individual differences in the speed of neuronal activity. This "rhythmic" activity of the brain at rest is consistent with the findings from later event-related methodologies. If one reviews ERP waveforms throughout the majority of the ERP literature, at least three major deflections are very commonly present during task performances - usually the P100, N200, and P300 components in that order – and which cycle over a time course of approximately 1-2 seconds. It is therefore apparent that normal human brain activity either at rest or during the performance of a task appears to involve highly regular, cyclical shifts in the electro-chemically mediated activity of neurons. This activity results in the production of short-term, modulated electric fields from synapses and axons "around their resting levels" (Nunez and Srinivasan 2006), either spontaneously in accordance with the normal "background" operations of the brain in the absence of overt stimulation, or literally "on average" during event-related recordings synchronised to stimulus presentations and task performances.

Knott, Friedman and Bardsley (1942), Shagass (1946), Kreezer and Smith (1950), Mundy-Castle (1958), Mundy-Castle and Nelson (1960), and Giannitrapani (1969) measured correlations between individuals' alpha wave frequencies (i.e. from non-event-related EEG) and assorted IQ measures, including the Stanford-Binet (Kreezer and Smith) and WAIS-R (Gianniatrapani) tests in populations including children, mentally retarded adolescents, and normally healthy adults. Across all five studies, however, the alpha wave-IQ correlations were variously negative, positive, and absent. Work between 1969 and 1974, however, showed some indications that within populations of intellectually diverse individuals, relatively more intelligent individuals showed a negative EEG coherence – IQ correlation, interpreted as tentative evidence that higher IQ was manifest in some form of more rapid or more diverse brain activity (Osborne 1969; Everhart, China and Auger 1974). Thatcher et al. (1983) and Gasser, Jennen-Steinmetz, and Verleger (1987) were able to show that coherence (i.e. the synchronisation of the frequency of different brain regions according to task demands) varied in a consistent manner between normal-IQ, high-IQ and mentally retarded populations of children – specifically, patterns of early activation in the brighter children were manifest relatively later in the recordings from retarded children. Deary and Caryl (1993) interpreted this finding as a reflection that "….progressive differentiation of the brain (which is less complete in retarded subjects) will reduce coupling between different regions…", resulting in a delay in the conduct of similar processes in mentally retarded individuals when compared to more intelligent individuals.

Burns et al. (1997) noted research interest in evoked high-gamma-band activity and the origins of consciousness, but such work is broadly outside the realms of the current studies and not necessarily related to IQ. In general, the use of spectral and frequency-based analyses of free EEG has become less popular over time than the use of averaged (AEP) or event-related (ERP) EEG measurements, likely due both to an inherent and important methodological problem for "free" EEG recording techniques, and also to shifts in the subject area under investigation. The inherent and important methodological problem for free EEG and IQ is that whenever the EEG is not produced in response to task demands, there is poor control over participants' actual mental activity at the time of recording, and the experimenter knows nothing of the participants' mental activity beyond the spectral activity associated with wakefulness. As will be shown in a later study in the present series, alpha-wave activity may also be present during task performances, and thus is not a reliable indicator of <u>only</u> relaxed wakefulness. Although the experimenter may request that the participants e.g. sit and observe images, or simply do nothing during the EEG acquisition, there is every possibility that some participants are actually engaged in mental activity, e.g. mentally reviewing an upcoming shopping list, or otherwise day-dreaming during an idle moment.

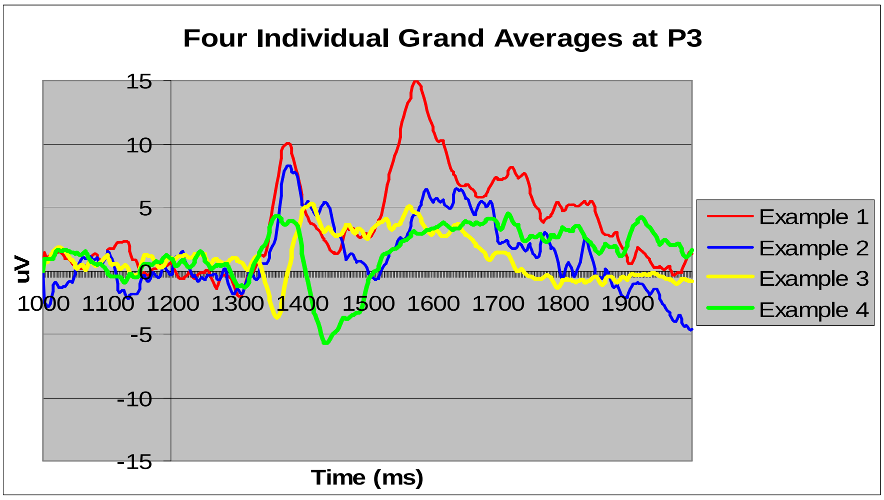
In contrast, event-related potential methodologies (ERP) allow for much greater control in this regard. Typically, the participant is given an explicit task to complete per stimulus presentation, and the recording of evoked potentials is synchronised from the moment of the perception of stimuli until one or two seconds have elapsed – usually long enough to record the electrophysiological processes underlying the perceptual, decision-making and response-selection processes of cognitive tasks. The participants' success in the completion of the task at hand is therefore a valuable index and indicator of whether or not a participant was actively engaged in the task – i.e. there is an adjunct measure of whether or not the experimenter's instructions were obeyed. In contrast to free EEG techniques, brain activity during ERP methodologies can be quite strongly causally linked to task performance. Deary and Caryl (1993, 1997) and Caryl et al. (1999) discussed some aspects of ERP waveforms which have shown relationships with various IQ measures.

1. Component Latency

When one or more areas of interest have been defined within an ERP, differences in the onset time of these components may be examined for differences related to I.V. manipulations and / or individual differences. Caryl et al (1999) cite, uncontroversially, that such onset variations may be related to the speed of operations within the central nervous system. Within the realm of event-related methodologies, however, the timing of operations in the CNS may indicate the existence of influences not solely related to, in this case, intellectual ability. When ERP components begin at relatively different times at either the individual or group level, the causes of these onset time differences may be bottom-up processes related to neuronal transmission speed, or top-down processes of directed attention, and it is difficult to state which explanation is more likely correct.

The concept of neuronal transmission speeds playing a role in IQ is not dissimilar to the underlying concepts of the IT methodology or nerve conduction velocity, i.e. fundamentally faster CNS activity can result in more rapid cognition in various ways. ERP component onset latency is a common dependent variable within ERP studies whether or not it is correlated with IQ or other measures, but the determination of onset latency can be a difficult and subjective dependent measure to evaluate as shown by the following waveform.

Figure 1 : Sample waveforms from the first in the present series of studies.

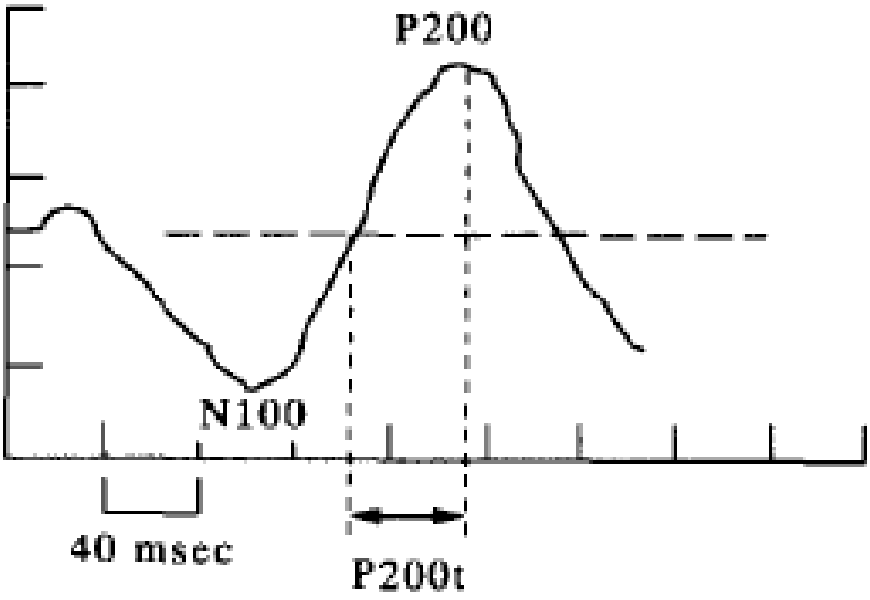


Although there are several methods of defining ERP regions of interest, the simple presence of visually-apparent peaks in the waveform remains a valid means of identifying prominent components. In Figure 1 (a copy of Figure 8 from the first ERP study in the present series) the evidence of individual differences in ERP waveforms is clear – some individuals simply do not show peaks which can be readily identified as components (the traces for examples-3 and -4 in figure 1), while other individuals do (examples-1 and -2 from figure 1), and the issue of individual differences in ERP waveforms is a highly prominent concern in this area of research. In figure 1, example-3 does not show a prominent P100, while example-4 does not show a prominent P300 region. Luck (2005) advocates a technique which requires individual scrutiny of the grand average waveform per participant, per experimental condition, and per analysed electrode site, and in the absence of clearly distinguished peaks in individual waveforms, subjective judgement is required to determine onsets. Clearly, this lack of a definitive procedure for determining component onset is a problem for objective and rigorous experimentation, and the time-consuming practicality of a method requiring individual scrutiny of individual waveforms also poses considerable real-world difficulties - i.e. it is possible that an experimenter may have to individually examine many hundreds of waveforms in exacting detail, and then still be required to make judgements open to criticism. An alternative procedure to derive component onset latency is similar to that of deriving amplitude values – a time window is derived from a group grand average ERP in some way, and the largest or smallest value with that window per participant is deemed to represent the onset time of the component in question. Figure 1, however, shows the other potential problems this approach may incorporate – any time window selected from a group grand average as showing criterion deflections may show few similarities to those obtained from individual participants' data.

2. ERP Morphology and Complexity

Measures such as Rhodes et al.'s (1969) "excursion" measure, the Hendrickson (1980, 1982) "string length" technique and Zhang et al.'s (1989) $P200_T$ gradient measures have all been used as methods of examining whether modulations of ERP wave shape were related to IQ. As an ERP's shape is determined by the magnitude of and changes in the direction of the electrical polarisation of neurons over the recorded epoch, it is possible that some aspect of processing complexity could affect the wave modulations over the time course of the ERP. The "string length" and "excursion" techniques attempted to evaluate the size of, and variation in the waveform's perimeter, as a measure of the complexity of ERPs' shape. The $P200_T$ measure was otherwise quite different, and was used to evaluate the rapidity with which the N150-P200 wavefront rose from the mean amplitude value between a window of 75-275ms to the peak of the P200 component (see figure 2).

Figure 2 : Illustration of $P200_T$ region from Vigil-Colet et al. (1993)



A third potential ERP-IQ correlate of IQ not explicitly covered by Caryl et al. (1999) is that of component amplitude. As with component latency, variations in wave amplitude are a common dependent variable in ERP methodologies, and amplitude may vary in response to task demands across conditions. Amplitude variations are produced by the summation of polarisations across relatively larger or smaller neuronal populations in relationship with the cognitive demands of the task. As such, some variation in component amplitude is extremely common in ERP methodologies, although as stated earlier, the sensitivity of the ERP technique to individual differences is also an issue here, but one which can be compensated for by later statistical analysis and correction.

Burns, Nettelbeck and Cooper (1997) make brief mention of 28 studies where component amplitude measures were related to IQ. Of the 28 studies, 17 showed "…a positive although not necessarily large or significant relationship (with IQ)…." (e.g. Perini et al. 1989, Stough et al .1990) while the remaining 11 showed a "…a negative although not necessarily large or significant relationship…" (e.g. Daruna and Karrer 1984; Egan et al. 1994). Although there appears to be slightly and literally more evidence in favour of positive associations with amplitude and IQ than negative, some of the studies cited in the list of 28 are not reputed for showing amplitude-related differences as primary effects. Caryl (1994), Rhodes et al. (1969), Hendrickson and Hendrickson (1980), Zhang et al. (1989) and Jossiassen et al. (1988) are included in the list of 28, but these studies found complexity, latency or gradient-based differences to be of note – and did not emphasise amplitude-based differences. From the full list, however, component amplitude seems to be hugely variable across tasks, featuring sometimes diametrically opposing associations with IQ.

Although several measures of ERP component latency and amplitude have shown some correlation with IQ (e.g. Shucard and Horn 1972; Shucard and Callaway 1974; Sandman and Barron 1986; Barrett and Eysenck 1994; Caryl 1994; Deary and Caryl 1997; Burns, Nettelbeck and Cooper 2000), these relationships have also been difficult to replicate and do not point to an obvious conclusion - different temporal regions of the ERP, and their scalp distributions, reveal statistically significant associations between different measures of IQ and brain electrical activity across studies. The first, and major investigations of averaged evoked potential latency and IQ are largely accredited to J. Ertl in a series of articles from 1965-71 (Chalke and Ertl 1965, Ertl and Schafer 1969, and Ertl 1969, 1971). Ertl's work was broadly based on the assumption that speeded mental processes were the basic underpinnings of intellectual ability, from which AEPs (average evoked potentials) could be used as relatively pure measures of brain activity free from e.g. behavioural or other confounds. Ertl's methods recorded AEPs from an electrode montage described as "a peculiar bipolar…placement" (Calloway 1975; presumably, Calloway was referring to Ertl's electrode montage, which did not use a reference site which was relatively free of ERP activity) in response to randomly-timed light flashes. Ertl variously noted that the responses of a group of individuals described as possessing "superior" intelligence showed significantly faster component onset times than an intellectually less capable group. Deary and Caryl (1993), however, noted that there was no formal IQ testing of participants, and Ertl and Chalke's original study involved individuals described only as postgraduate students, military cadets, and mentally retarded. Ertl and Schafer (1967) performed a similar study using 573 schoolchildren, and cited significant correlations between four AEP components and three separate IQ measures.

Ertl also devised and attempted to popularise a "neural efficiency analyzer" device which aimed to apply his AEP methods to provide a testing system and intelligence index for schoolchildren, but criticism of Ertl's general methods (and concomitant findings) have been numerous and the device was never generally adopted. Calloway (1975) devoted approximately 5 pages of his book in enumerating various problems with Ertl's studies, including Ertl's non-standard methods of peak detection based on zero-crossing analyses. Ertl's AEPs were interpreted in terms of polarity changes from positive to negative or vice versa, rather than the "standard" manner of using average voltage magnitudes or specific onset times within pre-defined regions. These methodological irregularities apparently caused confusion in interpreting Ertl's findings, and Calloway attributed this to "…a natural tendency to equate events identified Ertl's way with components identified the way almost everyone else does things…" (Calloway 1975, p45). Ertl's methods of component identification, therefore, no matter how well described, were irregular and unusual – although Calloway did acknowledge that this was perhaps more of a problem for readers of Ertl's work rather than Ertl's methods per se. Regardless, the zero-crossing analysis technique Ertl used was unpopular at the time, and has remained uncommon in EEG methodologies.

A greater problem for Ertl's findings was that of inconsistencies and difficulties in replication of these speeded latency findings. Rhodes et al. (1969) found differences in waveform complexity (using an early version of Hendrickson's "string-length" measure which involved a cartographer's map-wheel) among high- and low-intelligence groups of children, as well as amplitude differences during the P100, N140 and P190 components which visually differentiated both groups. Their latency measures, however, showed no noteworthy differences or associations, indicating nothing of interest related to speeded mental processing. Dustman and Beck (1972) also found no prominent or consistent differences in latency related to IQ (nor in component amplitude), although Bennet (1968), Shucard and Horn (1972) and Caryl (1994) were successful in finding some latency differences. Differing task methodologies seem to result in inconsistencies of the presence of components and their onset latencies in correlations with IQ. Shucard and Horn's methods, for example, bore some similarities to Ertl's in that a neutral EEG reference site was not used, leading to confounds in the detection of activity in the resultant AEP or ERPs. It seems that Ertl's work was replicable, but only so far as experimenters were willing to use the same non-standard methodologies as Ertl did originally.

Caryl's (1994) methods have been applied to a data set from the present series of studies, and are presented as findings in the final experiment. Caryl's method involved correlations between participants' IQ scores and the gradient of the ERP measured across a moving "boxcar" window. Caryl (1994) found that brighter subjects (i.e. with higher IQs or more rapid inspection time values) showed early correlations in ERP gradient between 100-200ms after stimulus onset and their IQ measures, and stated that :

"….rather than demonstrating that stimulus processing is uniformly different between subjects……studies may locate certain critical stages where intelligence-related differences are apparent……Neither the global measures of ERP …..nor conventional measures of the latency and amplitude of major peaks and troughs of the ERP….have been able to provide information on the precise time course of intelligence-related differences in stimulus processing”. (Caryl 1994, p16).

Caryl’s (1994) findings were consistent with two earlier (Zhang et al. 1989a and 1989b) and one later study Morris and Alcorn (1995), all of which used inspection-time type methodologies for stimulus presentations. Across these four studies, the rise-time of the region between the N150 and P200 components (labelled the $P200_T$, or the N1P2 by Morris and Alcorn) was found to be significantly, and highly correlated with two different measures of IQ (Raven’s Matrices and the AH5 battery) and one known, strong correlate of IQ (inspection time). Higher-IQ participants showed steeper gradients during the rise to the $P200_T$ region in all cases, resulting in strong, positive correlations between IQ and $P200_T$ (approximately 0.59). The N150-P200 region has previously been associated with processes involved in identifying and making decisions about stimuli (Lindholm and Koriath 1985). Chapman et al. (1978) suggest that this early region may also reflect transferral processes in short-term memory, and thus there are some obvious associations with the onset time of the P200 region and intellectual ability – faster decisions from a more reliable short-term memory may constitute an advantage in simpler cognitive testing. These four studies, although showing some inconsistencies with each other (e.g. Zhang et al’s correlations were present only among non-masked stimuli, while Morris and Alcorn’s effects were manifest only at certain electrode sites), provide probably the strongest and most consistent links with intellectual ability found thus far.

Several ERP studies have therefore demonstrated that latency, amplitude and gradient measures of ERP waveforms are related to IQ, but in the case of latency and amplitude, in variable and inconsistent ways, and in the case of gradient measures, in only 4 studies. Barrett and Eysenck (1994), however, note that there is “too much meaningful agreement” to completely discredit the concept of electrophysiological correlates and origins of IQ, but nonetheless, the relationships between the P200 region and IQ measures shown by Zhang et al, Caryl, and Morris and Alcorn, and some later string-length work, remain among the few consistent phenomena in this literature. Vigil-Colet et al. (1993) also found correlations between participant IT and onset latencies for the $P200_T$ and P300 components, although the strength and significance levels of the correlations were not particularly robust despite a very large sample size for an ERP study (N=200; r=0.355 to .55, p<0.01). This large sample size and relatively low significance level was perhaps made possible by, and arose due to a relatively crude definition of onset latency for the components of interest; components were not identified by any visual or statistical presence, and instead, were defined "conventionally" as occurring within pre-defined epoch windows without individual scrutiny of the waveforms. Vigil-Colet et al. also did not collect any information on participants' IQ, and their study is therefore somewhat bereft of an overall context; although IT is a known and frequently strong correlate of IQ, it remains no substitute for a psychometric measure of IQ. Aside from these "4 and a half" studies, this work does not appear to have been pursued further. The onset latency and amplitude of waveform components seem particularly prone to inconsistencies in results, and it is further difficult to create direct links between CNS functions or neurophysiology and ERP component latency. The cellular structure of the outer cortex of the brain is incredibly dense and complex, and recordings from any individual electrode placed on the scalp (even in very large electrode montages) necessarily show the summed activity from perhaps tens of thousands of neurons immediately beneath it - the outer cortex as whole is estimated to be composed of approximately 10 billion neurons (Nunez and Srinivasan 2006). In this sense, although the temporal resolution of ERPs is an undisputed strength, it is also very difficult to state precisely how ERP component latency is related to any neurological or electrophysiological function(s) involved in a cognitive task at hand. Component latency may also be affected (or perhaps unintentionally confounded) by top-down attentional processes, where more rapid onset times may reflect a greater tendency to draw participants' attention, rather than lower-level differences in cognitive processes. In contrast, the difficulties of resolving component amplitude differences pertain to the confidence with which assumptions of functionality can be made regarding the activations of literally billions of neurons per millisecond.

Although subject to criticism and difficulties in replication, Deary and Caryl (1993) noted that Ertl's methods could be regarded as a forerunner to the concepts of waveform complexity later adopted by Hendrickson and Hendrickson (1980, 1982) and Blinkhorn and Hendrickson (1982). Adopting a different viewpoint from that of speed-related differences in processing, notions of string length and evoked potential wave complexity re-considered notions presented by Calloway (1973) that higher-IQ individuals may show greater variations in combinations of EP amplitude, latency and symmetry over the course of entire ERP waves.

It is acknowledged that ERP amplitude is related to the overall size of the neuronal populations activated during task completion, and that onset latency is probably related to the detection of task-relevant stimulus features, but there are relatively few ERP components which can be tightly defined as representative of highly specific mental processes. The N170 component, for example, is known to be indicative of processes involved in the identification of the component parts of human and animal faces (e.g. Bentin et al. 1999), while the P300 component is strongly related to attention, stimulus novelty and the difficulties of stimulus discrimination (e.g. Tueting et al. 1970, Hillyard et al. 1973). The cognitive or electrophysiological processes which evoke the P300, therefore, are very broad when compared to those attributed to the N170, and can also be applied to highly diverse task demands – i.e. a P300 will be evoked by virtually any task which involves a prompted discrimination. The P300's presence is therefore not limited to any specific task or methodology, and according to Luck (2005), there remains no definitive statement of the actual cognitive processes underlying the P300 component. When the P300 is present in an ERP, however, statistically significant differences in its onset times or amplitudes between conditions can otherwise strongly indicate that a participant was awake, alert, and attempting to fulfil the task demands. There may therefore be many reasons why an EP or ERP waveform may vary, subsuming multiple mental processes (and individual differences) as it was recorded. This is one of the reasons why ERPs should be considered "merely" as an alternative DV – there are occasions when it remains unclear exactly how the ERP arose from cognitive activity – and vice-versa.

Hendrickson and Hendrickson (1980) proposed that EP variations may also provide some measure of *complexity* (essentially quantified by a standardised measure of the length of the ERP's contour or perimeter distance over component windows) and *variance* in mental activity (i.e. "the average variability of each sample point on an AEP over a number of epochs" – Barrett and Eysenck 1994), and that these variations could be related to IQ. Tongue-in-cheek, Hendrickson and Hendrickson (1980) described the method of measurement as a "…sophisticated means of sticking pins in an enlarged copy of the published waveforms, and carefully drawing a thread between the pins so that it superimposed the waveform….".

Hendrickson and Hendrickson found that the length of the string, or perimeter length of the ERP, correlated highly (0.77) with WISC scores from participants. This complexity measure became known as "string length" , and a larger string-length measure, coupled with lower variability, was taken to indicate the presence of a higher IQ (i.e. a "lower pulse transmission error"), while the converse of this indicated relatively lower IQ values. Thus, the EP generated from high IQ individuals was expected to possess diversity in the number and magnitude of its deflections, resulting in a larger / longer perimeter, and was also expected to show consistency across higher-IQ individuals in displaying these more numerous deflections. Hendrickson and Hendrickson's theory was based on concepts of neurological transmission and filtering within the brain; of all the information conveyed by the senses, much of it is necessarily filtered at any given moment by our attentional focus. This notion of "consistently complex" variation in evoked potential recordings is not dissimilar to Detterman's (1987) theories on the variability of responding in RT tasks among the mentally retarded, where a putative mechanism in intellectually normal individuals is impaired, resulting in a reduced ability to achieve an optimum level of performance and maintain it for as long as possible.

Hendrickson and Hendrickson proposed that "pulse trains" of activity in neurons comprise the transduction process of converting sensory information into an as-yet unknown form of neurological coding, and that the neural encoding was or is probably based around frequency variation in these pulse trains, as well as the use of specific pathways ultimately causing summation in specific neuronal regions "downstream". These pulse trains were theorised to be rapid, since the transduction of sensory information and the initial perception of it can often be very brief – i.e. what information there is must be detected and transduced quickly to be usefully perceived by the organism. Hendrickson and Hendrickson theorised that additional information must be present among these pulse trains given that spreading activation of successive neurons in a neuronal firing sequence would necessarily result in neurons farther along the chain of activation losing information from the prior pattern of stimulation as it travelled onward. When these pulse trains are encoded and transmitted accurately, the result is said to be manifest in AEP waveforms which possess more diverse morphologies than when errors are present in the transmission, with errors reducing the size and number of deflections in the final AEP wave. Hendrickson and Hendrickson's further theoretical considerations of the interactions between intracellular sodium ion pumps, putative eRNA molecules, and "error" interactions in neurological transmissions have not attracted much further theoretical or experimental interest – Batt et al. (1999) cite Robinson's (1993) opinion that "…the Hendrickson theory is "at odds with fundamental neurological facts"….". Nonetheless, the Hendrickson string-length measure has been re-investigated on several occasions.

Blinkhorn and Hendrickson (1982) replicated the original Hendrickson study, this time using a mathematical expression to derive the ERP string length rather than literal string measurements, and the idea of string length as a correlate or measure of intelligence proved compelling :

"…..Kline (1991) has commented that if some of the reported results were taken at face value then the string measure would be an almost perfect test of intelligence….." (Batt et al. 1999).

Numerous studies attempted to replicate these findings, but have also revealed the semi-familiar pattern of inconsistent results between brain electrophysiology in general and IQ. Burns, Nettelbeck and Cooper (1996) provided a review of electrophysiological studies using string length measures. Of 14 studies using string length :

- One found correlations in the <u>opposite direction</u> to Hendrickson and Hendrickson's (1980) results - Bates and Eysenck (1993), a finding later repeated by Bates et al. (1995) and Batt, Nettelbeck and Cooper (1999). (Bates and Eysenck, however, do not regard these opposing results as inconsistent with the theoretical biological origins of string length.)
- Seven studies found near-zero correlations (Shagass et al. 1981; Sandman and Barron 1986; Vogel et al 1987; Barrett and Eysenck 1992b, 1994; Widaman et al 1993; plus Burns et al.'s 1996 study itself.).

- Three studies found moderately high correlations (Haier et al. 1983; Blinkhorn and Hendrickson 1982; Gilbert et al 1991).
- Three studies found moderate to strong correlations (Hendrickson 1982b; Stough et al. 1990, 1992).

The string length technique has been criticised over time, however, chiefly due to an inability to agree on exactly how the perimeter excursion of an ERP should be related to IQ in principle, and therefore precisely what is being measured by the string length technique. Vetterli and Furedy (1985) made early criticisms of the string-length measure related to issues of standardising the ERP recording methods and deriving the string length values themselves; the use of different sampling rates can affect the string value, as can the scaling of the print-outs from which the early string values were derived (which were subsequently corrected in later studies by using computerised arithmetical derivations of the string length value.). Bates and Eysenck (1993), and later, Bates et al. (1995) proposed and demonstrated that the string length measure was also strongly affected by attentional factors rather than purely by IQ differences, with higher-IQ individuals being able to devote less attention, with excess attentional capacity remaining to spare, whilst using less metabolic "effort" to do so than lower-IQ individuals. Batt, Nettelbeck and Cooper (1999) state that Bates et al.'s interpretation of the string length phenomenon can be described as similar to a measure of metabolic energy consumption during cognition. Bates et al. (1995) were able to show this to be the case by manipulating participants' attention, finding that high-IQ participants showed <u>reductions</u> in string length during tasks requiring focused attention, rather than a larger string length value as would be predicted using Hendrickson and Hendricksons' original concept.

Although this reduced string length effect has been found on at least three occasions (Bates and Eysenck 1993, Bates et al. 1995, and Batt, Nettelbeck and Cooper 1999), some doubt has been cast on the general validity of the string length measure as a theoretical construct. Robinson (1993) criticised string length for its non-specificity. As the string length measure of an evoked potential is naturally affected by the frequency and amplitude of the brain activity which produces it in a "global" manner, there are several reasons why it may vary - Haier et al. (1983)

criticised its reliance on amplitude, while Burns, Nettelbeck and Cooper (1996) view the string length measure as “non-specific and consequently not useful” in further understanding putative links between brain physiology, brain electrical activity, and intelligence. Interestingly, however, Nettelbeck appeared undecided on the issue of the validity of the string length measure, having been accredited as a second author in both the Burns et al. (1996) study stating that string length was no longer useful, and Batt et al.’s (1999) study which re-evaluated the string-length measure. Batt et al. (1999) found no differences between 4 high- and 4 low-IQ individuals in terms of waveform complexity, and, significant correlations between string length and IQ were associated only with some sub-scales of the WAIS-R scale rather than full-scale IQ. Batt et al. eventually concluded that “….Whether the string length measure constitutes the wheat or the chaff is an open question….” – a conclusion that neither confirms nor precludes Burns et al.’s (1996) opinions. Further work in the area of AEP or ERP correlates of IQ has apparently shifted focus; relatively few studies were subsequently published concentrating on normal adult populations since 1999, with much of the work in this area focusing on e.g. links with dyslexia, clinical syndromes, developmental issues and genetic influences (e.g. Rodriguez et al. 2006, Ikebuchi et al. 1996, Boomsma 1998 and Hansell et al. 2005).

Drawing together all of the areas of research here so far results in a disjointed view of the contributions of EEG, AEP, and ERP to the study of intelligence. As Barrett and Eysenck (1994) noted, it is apparent that the studies listed were not in vain given that some correlational phenomena were present between assorted psychometric measures of intelligence and brain electrical activity (including well-respected and standardised psychometric tests such as Raven’s Matrices, the Wechsler adult and child batteries, and the AH5 series) more often than not. However, these phenomena are demonstrably highly variable and most importantly do not point clearly to any “integrated” or complete theory of the relationship between brain electrophysiology and IQ. Two of the more historically robust and replicable measures, namely the gradient studies by Zhang et al., Morris and Alcorn, and Caryl, and the later string-length measures (i.e. the rapidity with which certain ERP components change polarity, and the general amount of variation shown within the typical 1-2 second ERP durations) suggest that some form of speeded mental processes or metabolic energy expenditure are probably relevant. Individuals with relatively higher IQs tend to show steeper gradients within certain early regions of the ERP, and also show simply larger numbers of potential regions of interest via greater numbers of deflections within their ERP. However, the origin of these speeded mental processes or metabolic exertions remains unclear in strictly biological terms, and it appears likely that such speed is not a purely biological matter of the propagation speed of action potentials along neurons. Were this the case, effects related to mental speed would likely be highly pronounced, more consistent, and more easily replicated.

CHAPTER 3

Inspection Time and Intelligence

Research in the causal factors of intelligence has its formal origins with Galton (1883), and became a hugely diverse topic area over the whole of the 20th century, with potential influences including individual and population genetics, biology, learning over the lifespan, and individual psychological / mental variability, comprising thousands of individual items of research. The inspection time (hereafter IT) task's essential rationale has its theoretical underpinnings in Sir Francis Galton's (1883) notion that intellectual capacities were related to an individual's innate quickness. Galton had been influenced by Darwin's theories of evolutionary selection, and was especially interested in reaction time (RT) and sensory discrimination as potential indices of individual differences (Deary 1986, 2000). Stankov (2005) noted that research interest in perceptual and cognitive speed as implicit in IQ has waxed and waned over the 20th century, and interest remains in the concept, along with increasing evidence that human intellectual abilities may be related not solely to an individual's life experiences and various learning experiences, but may also possess a biological basis.

Arguably one of the most profound discoveries in human intelligence is the psychometric concept of "g", or "general intelligence". General intelligence has been observed since work by Spearman (1904) and is quite similar in concept to Cattel and Horn's "fluid" intelligence (1966a). The application of principal component and confirmatory factor analysis to tests of intellectual ability consistently shows the existence of a large, "superordinate" factor (Deary 2000) which accounts for substantial proportions of total test score variance, and whose existence therefore influences scores on almost all sub-test items. According to e.g. Crawford et al (1989), the first, un-rotated factor or principal factor of the WAIS-R scale accounted for 52.9 % of the total variance of all eleven sub-scales in a sample size of n=120; very close to the 55.3% shown by the original WAIS-R test development population more than ten times as large (1880 individuals).

This principal factor accounts for a large proportion of variance in intelligence test scores, including test items related specifically to subsequently learned cognitive abilities (e.g. verbal fluency, vocabulary, mathematical computation etc.), and it is often considered to be an innate feature of each individual's biology, contributing to and perhaps underpinning most other aspects of their intellectual ability. Although the notion of *g* is an early feature in work on human intelligence, first cited by Spearman in 1904 and 1927 as half of his "two-factor theory", *g* was relatively controversial until the 1980s, despite e.g. similar previous assertions by Horn (1967) that "fluid" intelligence was not learned or acquired, but innate. Thurstone (1938), a contemporary of Spearman, was an influential proponent of multiple "primary mental abilities" rather than a single over-arching factor, while Guildford (1985) "…tended to implement factor analytic techniques that ignored *g* …..“ (Deary 1992). Deary also quotes Sternberg's (1981) question :

"Almost eighty years after the first presentation of Spearman's (1904) two-factor theory, has anyone answered through factorial means the question of whether a general factor exists ?".

The answer would seem to be "yes"; subsequent to Sternberg's question, Gustafsson (1984) and Carroll (1993) published comprehensive and independent studies again showing the existence of a large principal factor in multi-task intelligence batteries, largely ending the controversy of *g*'s existence. Gustafsson (1984) and Carroll's (1993) work separately examined over 450 data sets in total, including data from Thurstone and Guildford in the early half of the 20th century (Deary 2000, Jensen 2005). Both Gustafsson's (1984) "unifying model" of intelligence and Carroll's (1993) models produced hierarchies of contributory components of intelligence. Gustafsson's model of confirmatory factor analysis (from his own study of 981 individuals) produced four orders of factors comprised of 31 components, of which three third- and one fourth-order factor involved "general" components – *g* itself, G_{verbal}, G_{fluid}, and $G_{crystallised}$, with *g* and G_{fluid} showing a perfect correlation. Gustafsson's analysis was also "unifying" in the sense that it leant support to three other models of intelligence (Spearman's two-factor model ; Thurstone's (1938) primary mental abilities, Cattel-Horn's (1966a) fluid and crystallised intelligence, and Vernon's (1950) group-factor theory) all of which shared individual test components of Gustafsson's model as interacting contributors to overall intellectual ability. From Gustafsson's model, two large superordinate factors (*g* and G_{fluid}) provided a basis for abilities in several smaller sub-populations of test items, validating both the concept of general intelligence as an over-arching contributor to variance (Spearman, Cattell and Horn's general intelligence theories), and the contributions made by smaller factors comprising sub-sets of more specific abilities (Thurstone and Vernon's group-factor abilities).

Although larger in initial scope, Carroll's (1993) interpretation incorporated 450 other datasets from an initial population of 1500, and generated three orders of factors rather than Gustafsson's four. Carroll's work again indicated the presence of a general factor followed by numerous smaller factors, and *g* was again a final-order factor (in this case, third-order rather than fourth). Both Gustafsson and Carroll's analyses showed that a general factor tended to account for 30-50% of all variance in sub-test scores, including many very commonly-used and some subsequently learned cognitive abilities such as verbal and printed language comprehension, free memory recall, memory for sound patterns (e.g. music and number sequences), reading speed, figure copying, and the manipulation and estimation of spatial objects. Given the repeated presence of a general factor in large scale analyses, further dispute of *g*'s existence would have to fundamentally criticise the basis of factor analysis as an entire analytical technique, and, criticise a multitude of studies which showed *g* as a factor as having been severely flawed. Even earlier than Carroll's (1993) study, Detterman (1987) stated that "It is impossible, I think, to deny the empirical reality of the phenomenon." (p.181) – i.e. the existence of *g*.

The further nature of *g*, however, is not clear despite the statistical evidence for its existence. While *g* can be defined as a statistical factor in intelligence testing, its literal nature as a specific cognitive ability or biological function which facilitates intellect remains unclear. Although several biological factors do correlate with measures of *g*, such as brain size and volume, nerve conduction velocity and myelination of CNS tissue, ERP and EEG characteristics, and neural pruning (Haier 1993; Miller 1994; Rushton and Ankney 1996; Deary and Caryl 1997; McRorie and Cooper 2004; Reed et al. 2004; Neubauer and Fink 2005), there appears to be much correlational phenomena associated with *g*, but little definitive statement of how *g* arises from our physiology and thereby influences intellectual functions. Nerve conduction velocity (NCV), for example, was an obvious place to begin looking for individual differences in intelligence, under the supposition that individuals who were more intelligent than others possessed nervous systems which somehow responded more quickly or efficiently, perhaps at the level of individual neuronal transmission rates. T.E. Reed has been a long-time advocate of work on NCV, but has been unable to show that correlations between NCV and several cognitive tests including Raven's Matrices or the Multi-Assessment Battery exceed +.256 (Reed and Jensen 1992, Reed et al. 2004). NCV is seemingly a moderate predictor in cognitive processes and intelligence; it is apparently not highly influential and this may be the case for some or all of the other physiological correlates. While no single physiological correlate discovered thus far accounts for a large proportion of the variance in ability, several acting in concert may be influential.

As noted by Jensen (2005, p33) from Spearman's original work, "…*g* is known not by its nature, but by the variation in its loadings on a wide variety of mental tests." . In simple terms, current research does not fully understand the biological (and most likely neurological) cause or causes of general intelligence. Kanazawa (2004) and Miller (2004) have stated that *g* poses a problem for the concept of "strong modularity" in the mind; *g* is apparently a "module" that affects almost all everyday activities (Gottfredson 1997). Kanazawa (2004) proposed that alongside a multitude of evolved, and specific cognitive modules (citing, for example, modules that detect faces, assist in selecting mates, or urge parents to favour one child over another), cognitive module(s) may also exist which assist in coping with "novel, non-recurrent problems" such as contextually- and environmentally-specific survival crises. If the human mind is composed solely of strongly specific, and importantly, <u>evolved</u> cognitive modules, <u>novel</u> crises cannot be solved unless a module exists for improvisation and abstraction in response to unique or very infrequent events. Kanazawa, therefore, suggests that *g* is such a module for dealing with real-world difficulties which require abstract and improvisational thinking, but for which an innate cognitive module does not exist. If a problem at hand is one for which an <u>evolved</u> module already exists (e.g. identifying an angry face in our vicinity), then Kanazawa is of the opinion that "thought" per se is not necessary – the face-detection module will perform this task without conscious intervention. Detterman (1987) states a similar opinion in specific regard to *g* and task performance –

“IQ tests are highly correlated with each other because they consist of complex items, and involve all of the basic processes in each test.” (Detterman 1987, p182).

Detterman’s view is similar to Kanazawa’s rationale in that both imply that *g* is a cognitive module of some kind which may interact with others. This notion is tacitly supported by anecdotal observations; although individuals with high measured general intelligence are at an advantage in many situations, they nonetheless also have their own individual intellectual strengths and weaknesses. The notion of *g* as a cognitive module, however, nonetheless still reveals very little of concrete or biological manifestations of *g*.

The question of precisely what it is that IQ tests measure has remained controversial ever since their inception. Deary (2000) deals with this issue on the first page of his book, and by page 4 offers not a definition, but a diagrammatical representation of “….phenomena to be described and explained…”. Regardless of specific definitions, in various intelligence tests, accuracy of response to individual items alone is often not sufficient for success; instead, both speed of apprehension, speed of response, <u>and</u> accuracy combined are needed in order to score highly. Further, the advent of the IT task (Vickers, Nettlebeck and Willson 1972) has suggested quite strongly that some as-yet undefined process of speeded mental processing is, if not clearly causally related to the overall construct of intelligence, then at least a stronger correlate than many of the physiological factors mentioned so far. Carroll’s (1993) factor analyses featured several sub-tasks which incorporated a speeded element as part of his model; “Processing Speed for RT decisions” itself was a second-order factor, incorporating the speed of mental comparisons and semantic processing, as was “Broad Cognitive Speediness”. Additionally, “Broad Visual Perception” and “Broad Retrieval Ability” were heavily dependent upon other speeded processes such as expressional and ideational fluency, naming facility, spatial scanning and relations. At an anecdotal level, accuracy, speed and efficiency in various task completions - especially in simpler cognitive tasks such as basic arithmetic or reading comprehension – are both generally useful within everyday life, and valued as skills in a variety of occupational settings. Many of the tasks we may be called upon to perform throughout our lives are time-limited in some way, and as a society, there is therefore an obvious advantage in various real-world settings for those individuals who can achieve various task demands quickly and accurately. Educational systems may foster this throughout an individuals' formative years, while IQ tests measure aspects of the results later in life.

Inspection Time

A newer approach to the study of speed-related correlates of intelligence is known as the inspection time, or IT paradigm, and continues to receive contemporary research consideration. Kranzler and Jensen (1989) and Deary (1986) accredit the earliest studies of IT to James McKean Cattell "in the 1880s", but IT did not receive popular attention until Nettelbeck and Lally's (1976) study – after three earlier studies in IT and intelligence at the University of Adelaide (Vickers, 1970, Vickers, Nettelbeck and Willson 1972, and Nettelbeck 1973). The essential concept of IT was based on Vicker's (1970) early theory that individuals apprehend information from the environment in a series of discrete "inspections" (Nettelbeck 1987, Deary 2000), a notion not dissimilar to the "bits" featured in the Hick Paradigm (1952), and to Galton's interest in rapid sensory perceptions as related to intelligence. Essentially, Vickers initially theorised that the rate of intake of sensory information was a limited innate capacity affected by individual differences, and the IT task was designed around this assumption.

An attractive element of the IT paradigm is the relative simplicity of the concept; participants are prompted by a warning cue, and then asked to identify aspects of stimulus items (to date, these have most often been simple geometric figures) at various presentation durations (known as stimulus onset asychronies or SOAs), which are immediately backward masked by a different stimulus figure in order to minimise any visual or iconic memory cues. An individual's "inspection time" is the minimum SOA value at which they can achieve a high, predetermined success rate in fulfilling the task demands, which are usually the identification of "…a highly evident feature of the stimulus display…" (Levy 1992) – i.e. the minimum stimulus presentation duration which is required for the individual to achieve e.g. an 85% success rate. Nettelbeck and Lally's (1976) IT task used geometric line stimuli similar to an inverted "U" (sometimes known as the "pi-stimulus" or "horizontal crossbar" figure), with one of the vertical legs of the figure being obviously longer than the other. The participants' task was simply to state whether the vertical line on the left or the right was the longest. Varying the time participants are permitted to view each stimulus markedly changes the difficulty of the task; when the SOA value is relatively high (e.g. 100ms or more), the typical IT task using geometric stimuli is quite easy, resulting in high success rates. The opposite is generally true when SOAs are very brief (e.g. 15ms) – participants perform poorly, often at approximately chance levels, simply because they have not perceived sufficient sensory input of the target stimulus as to be able to discern its salient features.

The IT paradigm is therefore quite different from the older RT methods. Where the latency between stimulus presentation, subsequent apprehension, cognition and then behavioural response is the dependent variable of RT tasks, IT tasks do not require speeded behavioural reactions to derive the dependent variable, and participants are advised to respond as accurately, rather than as rapidly as possible. Repeatedly accurate performance at varying stimulus presentation times is critically important within the IT task, because it is the only dependent variable - behavioural RT (i.e. the latency between stimulus perception and the behavioural act of e.g. a button press) itself is no longer a factor. The IT task, then, relies at least somewhat on the rate of apprehension the individual is capable of achieving, and not the overt physical speed with which the individual can make a behavioural response (although as will be shown, later studies have shown the IT task to be more psychologically complex than previously thought). With overt behavioural RT as a factor effectively removed (a "vulnerability" for behavioural RT tasks highlighted by Egan and Deary, 1992), the IT task is also suitable for use with e.g. individuals with physical disabilities. A less well-noted aspect of the IT task is that it is also particularly well-suited to assisting in the development of other experimental tasks. A population tested with stimuli at varying SOAs can be used to generate information on the difficulty scaling of the task, making the IT task useful in piloting studies, with the ability to calculate psychophysical curves from IT paradigms serving as an index of the success of the task and participant performance based on known correlates and performance characteristics of the IT task.

The primary research interest in IT is due to the repeated presence of moderate to strong negative correlations of IT and various measures of IQ, and in particular, those IQ measures regarded as heavily loaded on general intelligence – something quite unusual given that the IT task is very basic in its demands, while *g* constitutes a complex inter-relation of disparate and seemingly fundamental cognitive abilities. The existence of IT as a correlate of general intelligence is quite undisputed (Waiter et al. 2008), with Nettelbeck (1987) able to list 27 separate and specific studies of IT and performance IQ between 1973 and 1987. Of these 27 studies, 34 separate IT-IQ correlations were conducted, with only 3 measures showing positive (and therefore abberant) correlations with IQ. Essentially, individuals with higher IQ scores show a consistently superior ability to respond correctly in IT tasks at relatively faster SOA durations, and the task is regarded as able to explore the initial elements of visual processing (Deary et al. 2004a). Auditory IT tasks also exist, but the majority of the literature in the IT-IQ relationship pertains to visual stimulation. The strength of the IT-IQ correlation is often large; e.g. Bates & Eysenck (1993) reported one of the largest IT-IQ correlations (-.624 using the MAB), while McRory and Cooper (2007) stated that the IT-IQ correlation value is “reliably…..around -.50”. Most recently, Sheppard (2008), found a mean correlation of -.36 between IT and IQ across 46 studies. IT tasks, then, demonstrate that individuals with higher IQs as measured by various tests (Raven’s Matrices (Nettelbeck and Kirby 1983a); the MAB (Bates and Eysenck 1993); the WAIS-R (Crawford et al. 1998)) also tend to show lowered IT values. Beyond this statement, however, the interpretations of why IT correlates so strongly and reliably with general intelligence become theoretical, and less well understood.

Although the task demands of IT tasks are simple, the construction of the task itself and production of the IT value can be complex. Two main IT methodologies are the method of constant stimuli (MCS) and parameter estimation from sequential testing (PEST) – a variant of Wetherill and Levitt’s (1965) staircase procedure. The MCS procedure is the simpler approach, requiring only a series of stimulus presentation at various SOAs in a random or fixed order. The PEST method (Taylor

& Creelman 1967) is an "adaptive" method which relies on a more complex presentation algorithm, systematically varying SOAs to compensate for high and low participant success rates. According to the participant's success rate, the PEST algorithm changes the SOA values, making the task harder or easier as required to determine upper and lower SOA thresholds. PEST methods may generate more accurate IT values, but are more complex to implement, and may require varying numbers of trials in order to derive the participant's IT in contrast to the fixed number of trials in an MCS methodology (i.e. PEST methods are naturally less predictable if e.g. the length of time required to perform the task is important.). From Nettelbeck's (1987) selection of exemplary studies, PEST and MCS methods are equally successful, as are both a fixed-but-random order of SOAs (i.e. a series of randomly ordered presentations in the manner 25ms, 15ms, 40ms, 120ms etc.), or the use of sequentially longer or shorter SOAs in a fixed order (5x15ms, 5x25ms, 5x40ms etc.). The final computation of IT measures also requires the use of regression techniques to fit a psychophysical curve to the group data, plotting mean percentage correct within SOA duration range, and thereby allowing the selection of the inspection time value itself. More recently, however, Austin (2004) and (2005) has employed the variant of the IT task used in the present series of studies which used total number of correct responses, rather than IT values themselves as DVs for further analysis.

Deary et al. (2001) stated that the IT-IQ relationship may either be the result of "strategies, learning and motivations" arising from superior intellectual abilities, or Vickers' original notion that the IT task highlights limits on the rate of individuals' ability to take in external stimulation. Kranzler and Jensen's (1989) meta-analysis stated that the IT-IQ association "taps abilities related to perceptual organization", while Nettelbeck (2001) suggested that rapid sensory apprehension was not sufficient to describe the individual difference(s) that IT tasks show; and instead that :

> "….IT is probably sensitive both to focused attentional capacities to detect organization and change under severe time constraints and to decision processes, ongoing beyond mask onset, that monitor responding."
>
> (Nettelbeck 2001)

Nettelbeck's (2001) statement is quite broad in its implications, and although "sensory acuity…..is probably not important to intelligence", Nettelbeck states that "….low-level capacities influence both IT and psychometric test scores and are the psychological foundations to the psychometric construct ‘‘speediness’’ (or "Gs"…" (Nettelbeck 2001, and 1994); Mackintosh and Bennet (2002) also found reasonably strong correlations (0.43) with perceptual speed and IT measures when using Raven's Matrices in a population of 16-17 year olds. Crawford et al. (1992) noted that IT values were normally distributed among a "reasonably representative" sample of 134 individuals across social classes, and loaded most heavily on a complex of *g*, vocabulary, perceptual organisation, and attention / concentration measures from the full WAIS-R battery. McCrory and Cooper (2007) found significant associations with IT and verbal ability, and IT and *g,* which they suggest shows an underlying "information processing parameter related to *g*", and, they review some of the other causal theories involved in the IT-IQ relationship, of which there seem to be three principal schools of thought :

(i) IT as a measure of a low-level, innately limited perceptual apprehension or speed capability (Vickers 1970's original position, Burns et al. 1998).

(ii) IT as the result of the application of a complex of superior cognitive strategies - i.e. "…habitual ways of selectively attending to information and organizing it into meaningful categories" (Mischel 1973) - shown by more intelligent individuals, including perceptual speed. i.e. IT is not accounted for only by the speed of stimulus apprehension (Nettelbeck 1994, 2001, Vickers and Smith 1986), but probably by several different combined or interacting psychological phenomena.

(iii) IT as a phenomenon which may arise from and vary according to the specifics of the task and methodology which are implemented (Levy 1992). i.e. Differences in the methodology of the IT task (including curve-fitting methods, MCS vs. PEST, and the nature of the stimulus items and masks – virtually all aspects of the task - may be measuring different cognitive abilities, rather than any theoretical "unified IT ability", depending literally on the manner in which the test was constructed, participants were tested and the data analysed.)

Item (ii) from the previous list is a somewhat broad statement, and could be interpreted as stating that "IT is complex and reliant upon several sub-factors" – but it is undeniably an entirely logical basis for further investigation. Egan (1986) studied the issue of what cognitive strategies could be used in the IT task, citing the potential for participants to successfully adapt to randomized stimulus sets in a manner evoking the IT-IQ relationship. Two main strategies were thought to be most probable :

(i) Simple "Beating the odds" : Here, participants may choose to respond in a systematic manner on the assumption that, depending on the number of target stimuli, some proportion of responses will be correct simply through chance. Although not impossible as a strategy, this would seem likely to fail. Egan proposed that with "minimal" feedback within the task, there is little information with which a participant could deliberately attempt to alter their performance. Further, it would be hoped that detectable patterns in the response data from participants would be noticed by the experimenter as non-indicative of a genuine attempt to fulfill the task's demands, and result in the discarding of that data.
(ii) Apparent motion strategies : Apparent motion arises when the backward mask fails, often due to an insufficiently complex mask, resulting in clear differences between the target stimulus and the mask. Inadequate masking generally results in "apparent motion" or "line-end flicker", which was examined in-depth by Burns, Nettelbeck and White (1998) following criticism of the IT task by White (1996).

Burns, Nettelbeck and White (1998) suggested a new alternative measure to IT, the "CSOA" or, "critical stimulus onset asynchrony" defined as a point "midway between chance performance and perfect accuracy." . If the target mask and stimulus figure possess easily discriminable differences, then these differences become the object of the task for the participant, rather than differences within each target stimulus. If apparent motion is noticed and used by the participant, changing the number of target stimulus elements for discrimination ceases to affect the subsequent IT psychophysical curve. (e.g. adding more vertical lines of a pi-figure, or, as in Burns, Nettelbeck, and White (1998), identifying digital LED displays of numbers and figures).

While the notion of CSOA does not appear to have become standard practise for researchers (it is seldom explicitly mentioned in later studies, although employed most recently by McCrory and Cooper 2007), efforts to improve the purely methodological aspects of the general IT paradigm have continued (Stough et al. 2001), evidently because at least one strategic approach to thwart the IT task is possible, unpredictable, and, likely to occur. Mackenzie and Bingham (1985), however, found that participants seemingly either did or did not use apparent motion cues, and that those <u>who did not</u> apparently could not learn or be trained to do so. Thus, an important issue would seem to be that of identifying users of apparent motion (or other strategies), or creating a highly complex mask from first principles which reinforces the basic premise of the methodology and task demands. Stough et al. (2001), through manipulations of mask type and deliberate attempts to <u>induce</u> strategy use in IT tasks were, like Nettelbeck (2001), claimants that the IT task is considerably more psychologically complex than first imagined by Vickers (1970).

Stough et al (2001) reported that the IT-IQ relationship, although weakened by those participants who claimed to employ apparent motion detection strategies, was still present – and that importantly, individuals with relatively higher IQs claimed to use this strategy. Although it is likely to be both valid and unfortunately somewhat unhelpful, it is also very possible that McCrory and Cooper’s (2007) statement that the IT-IQ relationship may also be “….just another high level task that intelligent people perform well…” is highly likely. In line with Kanazawa’s (2004) notion of *g* as a cognitive module for improvisation, the development and use of strategies for the specific requirements of the IT task (e.g. the apparent motion effects noted by Stough et al. and McKenzie and Bingham) may themselves be adjunct manifestations of higher IQ – i.e. an individual with a high IQ, in a less carefully developed IT methodology, may simply (and rapidly) develop a strategy (e.g. noting apparent motion) which significantly increases their chances of success, and this ability itself is a manifestation of higher IQ.

The nature of the IT task (i.e. a task with a controlled temporal progression through a series of short, easily segregated individual stimulus presentations), and its strong relationship with general intelligence has made it a good candidate for neuroimaging studies in an attempt to learn more about the neurological basis of intelligence, although to date, only two major studies (Deary et al. 2004 and Waiter et al. 2008, in press) and one explicitly titled pilot study – Deary et al. (2001) - have been performed. Results from Deary et al. (2004a) were complex, involving the supplementary motor area and anterior cingulate cortex – areas involved in “non-specific cognitive tasks”. Additionally, the inherent variations in SOA also appeared to affect regional activations in bilateral anterior insular regions, both of which showed large connectivity effects. Deary et al. (2004) suggest that based on other studies of neurological activity, activity in the anterior insulae may be related to processes of vision, attention, and the selective initiation and inhibition of action. These could be viewed as processes consistent with lower-level stimulus perception, as has previously been suspected in the IT task – although the supplementary motor area and anterior cingulate cortex are not heavily involved in such processes. Waiter et al. (2008) used older adults at least 60 years of age, who, based on IQ tests taken in 1936, showed cognitive abilities at least 0.5 standard deviations above the older test means, labelling such participants as “cognitive sustainers”. Comparisons with the younger sample used in Deary et al. (2004a) showed similarities in regional activation with these cognitive sustainers from the Aberdeen Birth Cohort, perhaps related to Zarahan et al.’s (2007) “compensatory re-organisation” hypothesis of cognitive aging.

The most recent developments in the IT paradigm have involved changes to the IT task. An IT variant known as the “Loop” task, whereby short sequences of stimuli were presented at varying SOAs rather than individual items, was used by Perry (1991) and Mundy (1992) in auditory and visual forms. In the auditory form, sequences of tones, buzzes and hisses were “masked” by a different tone, whilst the visual modality used letter sequences masked by asterisks on an LED grid. Perry (1991), however, found no correlations between existing IT results and those from the Loop task. Austin (2004 and 2005) used an emotional, or E-IT task, where participants were required to identify either a happy or sad emotional expression from a series of Ekman faces, in conjunction with symbol-IT and another novel word-inspection task (where emotional words, non-emotional words, and non-words were masked by other length- and letter-matched masks). McCrory and Cooper (2007) used a series of 3 tasks, one of which was entirely novel; a large coloured circle backward masked by a succession of other circles, with the task being to identify the first colour shown. In the cases of Austin and McCrory and Cooper, the non-standard IT figures generated significant correlations with Raven's APM, APM *Plus* and the MAB-II IQ measures, and, significant correlations were also obtained between the novel and typical IT tasks. It therefore remains that IT is strongly associated with a general intelligence factor, across a variety of studies, but that perhaps the traditional and solely behavioural IT task is reaching the limits of its usefulness. As McCrory and Cooper (2007), and Stough et al. (2001) suggest, new stimulus methodologies and modalities will be needed to advance this field of research, indicated by imaging work and the use of different target stimulus types.

Reaction Time

A very brief review of some aspects of reaction time (RT) and its associations with IQ and speeded mental processes is also warranted. The RT-IQ literature is otherwise large, and has been reviewed extensively by Jensen (1987) and Detterman (1987). Early research in the speed of apprehension and information processing focused on RT measurements, with RT itself divided into simple and choice variants. Simple RT is a literal measure of behavioural reflexive speed where participants are prompted to perform an unconditional action in response to the perception of a stimulus. In contrast, choice RT requires a considered response where individuals must first decide if a stimulus item fulfils pre-determined criteria for a response; in itself, choice RT can be divided into decision-time and response- or movement-time (Carroll 1980). Separate measurement of these elements can be accomplished by requiring a participant to lift a finger from a switch in order to press another switch, with the cognitive, decision-making elements measured by the interval between stimulus onset and the release of the first switch.

Behavioural RT from choice reaction time paradigms has historically been used as a dependent variable in a great many elementary cognitive tasks, or ECTs

(Carroll, 1976). Jensen (1987) and Deary (2000) provide a brief review of choice-RT paradigms, leading to the Hick Paradigm (1952). Merkel (1885) was among the first to use a choice-RT technique, noting that the relationship between individuals' mean RT and the number of choices presented (Merkel used up to ten choices) was a prominent "negatively accelerated increasing function of *n*" (Jensen 1987, where "*n*" refers to the number of choice items.). Almost 70 years later, Hick (1952) noted again that a logarithmic association was present between an individual's behavioural RT, and the number of choice alternatives with which they were presented during a visual task. Over the course of "thousands" of responses (Deary 2000), Hick suspected that the relative uniformity of RT responses was related to the manner in which the stimuli were initially apprehended; theorising that the process of apprehension occurred in small binary units he named "bits" (Neubauer and Fink 2005). When an individual was required to examine two stimuli and make a decision, they studied 1 "bit", while four choices involved 2 bits, and so on. Jensen (1987) reviewed Hick's work, and concluded that of 33 studies, results from the Hick Paradigm correlated at slightly less than -0.30 with psychometric intelligence; i.e. individuals who showed the most rapid RTs also tended to show higher intelligence scores. Vernon and Jensen (1984) found some (controversial) relationships between choice RT decision making and bit-intake rates of perception, consistent with this notion that the RT-IQ relationship, like the IT-IQ relationship, is a moderately strong negative correlation (approximately -0.30; Jensen and Vernon 1986).

Detterman (1987) reviewed several RT studies performed among mentally retarded populations, with the general finding that while mentally retarded populations show slower RT responses compared to intellectually "average" populations, mentally retarded groups also show much higher variability in responding. Although capable of showing RT responses as fast as those in non-retarded populations, mentally retarded individuals also tend to respond more slowly, more frequently than non-retarded populations. Lally and Nettelbeck (1977) have similarly shown slower IT values among mentally retarded populations. Some of this variability in mentally retarded populations may be accounted for by the well-known "speed-accuracy tradeoff", whereby it is commonly held that it is difficult to be both fast and accurate. Brewer and Smith (1984) found that intellectually normal individuals tended to show systematic variation in speed and accuracy in choice RT paradigms– building up the speed of responses until an error was made, followed by a reduction in speed until a suitable balance between the two could be found again. Detterman (1987) suggests that participants in RT-type methodologies "actively seek an optimum level of responding" which balances speed of completion with a presumably internal or personally acceptable error rate. In mentally retarded populations, this compensatory mechanism may operate more slowly, resulting in lengthier times being required to reach this optimum level, and considerable variation in responding throughout the test as a consequence.

Jensen (2005) stated that "chronometric" tests involving RT are methodologically important for two main reasons :

(i) High reliability : The often simple nature of RT testing means that increasing the number of trials to achieve a pre-determined reliability coefficient is usually not problematic for most RT methodologies.

(ii) Relative ease of replication and repetition : as an elementary cognitive task (ECT), there may or may not be a risk of participant habituation to stimulus items, depending on the task and stimuli involved, but otherwise many RT tasks can be precisely duplicated time after time.

Jensen also favours RT measures for what he perceived as a widespread tendency to place too little importance upon RT. As previously noted in regard to Gustafsson and Carroll, the sheer prevalence of speeded factors in the overall factor structure of intelligence from multi-task test batteries would indicate that the chronometry of mental abilities plays a low-level, but influential role; in the same way that IT can be considered a low-level correlate of mental speed, RT may also be so :

"….In a hierarchical factor analysis these speeded tests typically show up as rather small first-order factors; they have little variance in common with other tests…..least of all on the most general factor, psychometric *g*……This has resulted in a long held and strongly entrenched misconception….that mental speed is a minor factor in the abilities hierarchy and has little relevance to…..the *g* factor." (Jensen 2005, p32).

CHAPTER 4

Emotional Intelligence

The notion of emotional intelligence (hereafter EI) and its measurement as a psychometric concept is generally accredited to Salovey and Mayer (1990), and is regarded as a generally "newer" and popular area of psychological study. Broader work with the construct incorporates work by Goleman (1995), Bar-On (1997) and Schutte et al. (1998). Since 1990, over 800 studies have been conducted to identify and validate the core concepts of EI, while Landy (2005) states that the size of the population tested by the MSCEIT inventory alone numbers some 60,000 individuals. The terms "emotion" and "intelligence" still sit somewhat uneasily with each other in formal contemporary research, but the essential statement of EI as a concept is unambiguous and has proven intuitively appealing to many. Through either objective testing or self-report, EI attempts to measure an individual's emotional tendencies and sensitivities. These behaviours are broadly conceptualised as the individual's awareness of their own internal emotional experiences, the individual's perception of the emotional state of other individuals in the immediate world around them, and the manner in which these two states of awareness contribute to the individual's control of, and viewpoint on, the intra- and inter-personal events in their life.

The roots of emotional intelligence developed from older interests in social psychology, specifically the various capacities individuals manifest when required to work or interact in social groups. Thorndike (1920) is regarded as among the first formal proponent of social behaviour as an "intelligence" - and therefore an ability. Thorndike referred to this as "social" or "practical" intelligence, described as "…the ability….to act wisely in human relations..". The term "emotional intelligence" itself is not new, having been used by Leuner (1966), Payne (1986) and Greenspan (1989) in various contexts, and the issue of social and emotional functioning in society has remained topical since the 19th century. John Harlow's (1848, 1868) famous descriptions of his treatment of Phineas Gage clearly showed the social effects of what is now known as "acquired frontal lobe syndrome" after a traumatic brain injury (Bechara, Tranel and Damasio 2000). Although their purely intellectual functioning may remain largely intact (i.e. retention of vocabulary and varied comprehension abilities, simple reasoning and mathematical skills etc), individuals who suffer many forms of traumatic brain injuries often experience dramatic impairments in their decision-making processes and ability to socialise with others, which can radically and detrimentally affect their everyday lives. Observations of such individuals lead to the formation of Damasio's (1994) "somatic marker hypothesis", emphasising the role of internal somatic states.

In some cases, individuals may be impaired in their inter- and intra-personal emotional perceptions without overt physical pathologies - a condition known as alexithymia (Sifneos 1973, Nemiah et al 1976; Taylor 1984). Alexithymia is most obviously manifest as a limited ability to verbally express emotions; Reik (1952) provides an extreme example in Mayer and Geher (1996) of a female clinical patient unable to articulate her jealousy over an extra-marital lover's life in all but the most abstract (and unclear) terms. The condition may also include limited somatic experiences of emotional states (Parker et al. 2005), and a lack of empathy (Taylor 1987). Mayer, DiPaulo and Salovey (1990) suggested that an individual's sensitivity to emotional information was likely to be due to the possession of higher than normal manifestations of empathy and neuroticism, plus low scores on alexithymia measures (using other tests including the EPI-short version), thereby implying a factorial approach to the identification of emotional content – i.e. that sub-components of emotional behaviour could be identified and compiled into other measures. Participants' assessments of the emotional content of human faces, abstract designs, and colours showed correlations between measures of empathy and consensus judgements of the presence of an emotion in the images – an initial step to a conclusion that emotional sensitivity could be measured beyond simply "…attitudes and sentiments…" (Mayer, DiPaulo and Salovey 1990). Also implicit in this study is that some measures of emotional sensitivity were also associated with scores from other tests of personality, through the use of the EPQ-I measure.

Salovey and Mayer's original (1990) work in EI required a definition of emotion, and theirs was relatively uncontroversial – emotions are viewed as individuals' internal state(s) of being, with both mental and physiological components, which possess positive or negative connotations for the individual (i.e.

are subjectively pleasant or unpleasant) in response to internal or external events. Emotions can also serve as a shaping guide for an individual's eventual behaviours - essentially, individuals may evaluate their behaviours in terms of whether or not the results of those behaviours will result in enjoyable outcomes based on prior experience. Frijda (2004) similarly described one aspect of emotion as Mandler's (1984) "general sensitivity to goal interruption" - when an individual's intrinsic motivation towards a desired physical or mental state is affected by other events, the individual tends to experience internal mental and/or physical states as a consequence. Although Ekman et al. (1982) espoused the concept of a small subset of "basic emotions" (i.e. anger, fear, sadness, disgust, joy and surprise), the everyday definitions and ways of expressing these internal states are multitudinous and a simple definition of emotional experience remains complex. In common linguistic usage, for example, Roget's Thesaurus lists some 450 English synonyms associated with Ekman's 5 basic emotions, demonstrating that at the anecdotal level of experience, there are very disparate ways in which individuals can express these internal states to others. Emotional states can also vary in their intrinsic experience, both within and across individuals and circumstances, creating problems in the objective measurement of these states. In Ekman's (1999) opinion, "…..Not only can there be emotion without expression, there can be what appears to be expression without emotion….". There is, however, considerable contemporary agreement in the essential definition of emotion:

Barret (2007) : A psychological event producing intention from the inter-relation of oneself and the external environment.

Solomon (2007) : "Significant psychological phenomena" in response to events in the world.

Scherer (2007) : An experience of related and synchronous changes in e.g. cognition, motivation, and subjective feeling, evoked by "…the evaluation of an external or internal stimulus event as relevant to major concerns of the organism….".

Clarke (2007) : An "evolutionarily coded feeling" regarding one's present situation which can guide or modify behaviour.

Thayer (2007) : A subjective, cognitive state of awareness of contextually-mediated physiological arousal.

Three elements common to many of these theoretical definitions are :

(i) an innate physical sensation or feeling,

(ii) an associated simultaneous mental state,

(iii) often, but not always, the involvement of the external world in evoking or mediating both these effects.

Salovey and Mayers' notion that emotions may be reflected in objectively measurable practical abilities could be extremely useful across many domains including pure, occupational, and clinical research. In labelling EI as an "intelligence", Salovey and Mayer (1990) tacitly suggested that emotional behaviour and tendencies could be sub-divided into distinct, yet related and measurable abilities; in their own words, "a set of skills" (in general, Salovey, Mayer and Caruso favour an "ability"-based model of EI rather than self-report variants - to be discussed later). Mayer, Caruso and Salovey (1999) showed that these abilities could contribute to a formal psychometric factor structure for the functioning of mental processes in emotion in a similar manner as IQ measures of intellect – i.e. comprised of a positive manifold of multiple abilities, as well as possessing a superordinate "general" factor; two of the basic requirements for the definition of an intelligence.

Mayer and Salovey (1993) noted that their new construct had attracted controversy, but have persisted in naming and justifying EI as an "intelligence" despite some apparent reluctance and discomfort among their peers in labelling emotional phenomena as such (Salovey and Mayer 1993). Salovey and Grewal's (2005) assertion that EI addressed "a growing need in psychology for a framework to organize the study of individual differences in abilities related to emotion" would therefore seem to disagree with criticism Mayer, Salovey and Caruso's model received – by their own admission, EI as a concept was initially not well received :

"…We have been criticised for connecting emotion and intelligence, both in anonymous reviews of our initial articles and in a symposium…." (Mayer and Salovey 1993)

More recently, Mayer, Salovey and Caruso (2000) have described EI as a "zeitgeist", which has gained substantial public awareness through coverage in the popular media (Gibbs 1995; Goleman 1995a, Gibb-Clark 1996). EI nonetheless remains somewhat controversial as a concept, with research showing not only validity of the construct, but also overlaps with pre-existing psychometric phenomena, leading to questions regarding the usefulness of what could be considered as merely a newer label for previously un-explored <u>combinations</u> of existing, predefined individual traits. Although EI has quickly gained a foothold in the general public's awareness (i.e. advanced from a disputed concept in the world of academic research to popular "zeitgeist" in approximately 6 years), this is not necessarily to its benefit – the public at large does not possess the requisite research background to make an informed decision as to the overall value of the concept, no matter how great the intrinsic or intuitive appeal. Van Rooy and Viswesvaran (2004) are of the opinion that EI's primary popularisation occurred when it was related to dispositional approaches to workplace management and organisational psychology (Hough and Ones, 2001). Currently, issues in the definition and measurement of EI are still being investigated (Farrelly and Austin 2007).

Despite its status as a relatively new phenomenon in social and cognitive psychology, there are a large number of measurement tools for EI, differing in the theoretical approach adopted by the tester. Emotional intelligence is currently divided into two principal theoretical areas (Petrides and Furnham 2000, Austin, Saklofske and Egan 2005) known as "ability" and "trait" measures. Ability EI measures regard emotional intelligence as cognitive abilities which can be measured via objective testing in a manner similar to IQ testing – ability tests possess correct and incorrect responses which the subject of the test must identify. Trait EI measures view emotional intelligence as innate dispositional tendencies broadly more similar to personality measures; there are no objectively correct responses, and instead, responses constitute the individual's general psychological tendencies across situations and time. There is currently a wide variety of EI psychometric tests available; McEnrue and Groves (2006) list several inventories (the TMMS - Salovey et al. 1995; the EQ-i - Bar-On, 1997; the SREIT – Schutte et al. 1998; the EIQ - Dulewicz & Higgs, 1999b; the ECI-2 - Sala, 2002; the MSCEIT - Mayer et al.

2002), and three other self-report inventories (the WEIP-3 - Jordan et al. (2002); the WLEIS - Wong and Law (2002); and an un-named inventory by Tett et al. 2005). This list is not exhaustive – Perez, Pertrides and Furnham (2005) list a further thirteen separate EI measures. In contemporary research, however, only two predominate : the MSCEIT and SREIT.

The MSCEIT

The MSCEIT v.2 (Mayer-Salovey-Caruso Emotional Intelligence Inventory) is a modified application of Mayer and Salovey's (1997) "ability" model of EI. Version 2 of the MSCEIT was derived from the MEIS (Multifactor Emotional Intelligence Scale; Mayer, Salovey and Caruso 1997), and the MSCEIT version 1.1 (research version). The MSCEIT features approximately half the number of items of its predecessors (141 items vs. 392 and 292 items for the MEIS and MSCEIT v1.1). The MSCEIT and its predecessors are objective tests, and feature consensus and expert-scored "correct" responses throughout as a means of eliminating the inaccuracies of response often associated with self-report measures (Salovey and Grewal 2005). Consensus scores were provided by a sample of members of the International Society for Research in Emotion, and the MSCEIT was shown to display greater convergence between the expert and consensus responses than the MEIS in a sample of 2112 individuals (Mayer et al. 2003, Palmer et al. 2005). EI within this series of tests is defined as a set of 4 skills by Mayer, Salovey and Caruso (2000), and the MSCEIT assesses individuals across four factors (or "branches") :
(i) Perceiving Emotions : identifying emotional states in oneself and others' behaviours.
(ii) Facilitating Thought : emotions assist in reasoning and motivation.
(iii) Understanding Emotions : Comprehension of the sensations of, and shifts in the experience of emotional states.
(iv) Managing Emotions : control and regulation of emotions for positive intrapersonal gain.

These 4 four branches can also be conceptualised as a two-factor model, with branches (i) and (ii) comprising an "experiential" factor, and branches (iii) and (iv) comprising a "strategic" factor (Mayer, Salovey and Caruso 2002). Mayer, Salovey and Caruso (2000) state that emotion is one of at least three forms of “fundamental classes of mental operations”, and can motivate and regulate cognitive processes and behaviours by e.g. spurring behaviours such as flight during the experience of fear, or enhancing cognition through the maintenance of cheerful or happy moods, perhaps over lengthy periods of time. Emotions may also influence social processes by helping individuals to better understand interpersonal relationships in formal or informal settings (e.g. workplaces or friendships), and thus, emotion is seen to “work hand in hand” with intellectual intelligence. The MSCEIT items variously require test subjects to detect emotion in faces, liken emotions to physical sensations, judge how emotional states can be combined to form other states, and state which mood states should best accompany specified situations. A more detailed view of the items is discussed in Palmer et al. (2005).

Petrides and Furnham have been prolific commentators in the area of the factor structure of EI and its conceptualisation, stating that the plethora of testing instruments and relatively non-specific early definitions of the construct prior to 1997 by Mayer and Salovey caused researchers to “…overlook the fundamental difference between *typical* versus *maximal* performance…” (Perez, Petrides and Furnham 2005), resulting in a lack of distinction between “trait” and “ability” EI. Petrides and Furnham (2000a, 2000b and 2001) suggest that ability and trait EI are distinct constructs, measured in different ways. *Typical* performance is stated to be appropriately measured by self-report inventories, while *maximal* performance is more objectively assessed through test batteries with correct or incorrect responses. Several studies agree with this assessment; Zeidner et al.’s (2005) study of EI measurement in adolescent populations found patterns of responses to the MSCEIT and SREIT inventories resulting in interaction patterns similar to a double-dissociation. Gifted students scored more highly on the MSCEIT ability-based inventory, while non-gifted students scored more highly on the SREIT, with correlations between the MSCEIT and SREIT being cited as ”weak”. Brackett and Mayer (2003) and Keele and Bell (2008) reported similar correlations between the MSCEIT vs. EQ-i and SREIT tests, with actual correlation values cited by Mayer, Roberts and Barsade (2008) of approximately 0.19. O’Connor and Little (2003) have similarly found little convergence between the MSCEIT and the Bar-On EQ-i inventory, with each test showing no common correlations with other inventories (i.e. the MSCEIT showed correlations between the ACT college entrance inventory, whereas the EQ-i did not.). Petrides, Furnham and Mavroveli (2007) also state that the MSCEIT should have "moderate to strong" correlations with general intelligence, and that such a relationship is highly important for the MSCEIT's construct validity. According to Mayer, Roberts and Barsade (2008), this is so; MSCEIT scores correlate with verbal intelligence and SAT scores at .36 to .38, with the emotional understanding sub-scale showing the strongest association (Roberts et. al. 2007), and an overall finding that the MSCEIT is moderately related to verbal comprehension, specifically to crystallised intelligence, and emotional knowledge (MacCann et al. 2004, Farrelly and Austin 2007).

A primary criticism of the MSCEIT, however, is that much of the information on test construction and computation of scores is not available for scrutiny, and that at least three recent studies have found different factor structures underlying the test. Although Mayer et al. (2003) provides some information on the validation procedures, all of the actual MSCEIT scoring procedures are performed by the test providers and limited information is available regarding manual computation or analysis - independent assessments of the MSCEIT factor structure are therefore made more problematic than usual. Landy (2005) has noted the use of these "proprietary databases" as a hindrance to others' replication and validation of the scale. Palmer et al. (2005) conducted their own factor analysis of the MSCEIT v2.0, and found that a 3-factor model (omitting the Facilitation factor and subscales) was more appropriate than 4 factors, but also that overall reliabilities, means and S.D.s in an Australian population of N=450 were acceptably similar to those produced by the American test standardisation values produced by Mayer et al. (2003). Farrelly and Austin (2007) similarly found a different factor structure from that cited by the test authors, with only the Understanding and Managing factors being supported. Farrelly and Austin's model incorporated a different combination of sub-factors, however, rather than a more straightforwardly interpretable failure to reproduce the original four-factor structure; in their model, <u>different combinations</u> of sub-factors prevented replication of the Experiential and Strategic factors as described by the test's authors (Austin, however, acknowledges that the sample size in this study was likely insufficient for a full resolution of the factor structure of the MSCEIT, and that this was not a goal of the study in any case – Austin, personal communication). Keele and Bell (2008) also found a different 3-factor structure, which replicated Mayer et al.'s (1999a) Strategic factor, but found two "new" factors labelled "picture" (for heavy reliance on pictorial, visual items), and "perception" (reliant upon perception and appraisal items.). The inconsistent factorial validity of the MSCEIT is clearly an important, if not severe problem, but despite these issues, the MSCEIT currently is, and has been extensively used in the EI experimental literature.

The SREIT

The SREIT (Self Report Emotional Intelligence Inventory) has also been known as the Schutte Inventory, SEI, SSRI (Schutte Self Report Inventory), and EIS. It is a 33-item test by Shutte et al. (1998), intended to evaluate "trait" EI by Likert-scale self-report. Unlike the MSCEIT, the SREIT's popularity in research is likely due to its free availablity and openness to scrutiny. The SREIT also requires very little time to administer (approximately 5 minutes), although Schutte et al.'s source article gives no formal instructions or guidelines for its use. Schutte et al. (2001) state the SREIT is mainly appropriate as a quick, global measure of trait EI. Schutte et al.'s (1998) article states that only a single factor is present in the original inventory, but otherwise as a freely available inventory, the determination of the factor structure has been left entirely to the research community. As the SREIT is based upon Mayer and Salovey's (1990) model of EI, Perez, Petrides and Furnham (2005) are of the opinion that it does not provide a comprehensive measure of purely trait EI – i.e. because it is fundamentally based on an ability-type theoretical model rather than a dispositional or trait model. Thus far, the openness of the test has been the subject of several studies which variously found some agreement in a 3 or 4-factor structure (Petrides and Furnham 2000b; Saklofske, Austin and Minske 2003; Austin, Saklofske, Huang and McKenney 2004 (although this analysis used a modified version of the SREIT); Keele and Bell 2008). In common with the MSCEIT inventory, there is some (albeit less) disagreement over the factor structure of the SREIT, and in particular, that the SREIT factor structure differs from that stated by the test authors. There nonetheless appears to be slightly greater agreement over the factors present in the SREIT than the MSCEIT, perhaps due to the open nature of the inventory.

Much of the interest in EI as a new psychometric measure probably stems from considerable research agreement that an individual's ability to detect their own and other's emotional states is potentially valuable to the individual themselves across various real-world outcomes, particularly occupational and educational settings. The practical application of EI testing measures is heavily emphasised in the available literature, with a large number of various real-world outcomes for (mainly adults) either theorised to be, or having been found to vary in relation to EI. Across a variety of testing methods, EI has been shown to be related to :

(i) Job success and academic achievement.

In this realm, EI scores :

- predicted first year US college grades.
- were associated with greater adaptability and stress management.
- were higher among "gifted" students.
- were higher for therapists than clients.
- reduced the co-occurrence of classroom misbehaviour.
- were higher among students who competed their courses of study than those who did not.
- were associated with improved leadership abilities.
- were higher for individuals who expressed satisfaction with their job and career.

(Schutte et al. 1998; Druskat and Wolff 2001; Palmer et al. 2001 ; Parker et al. 2004; Parker et al. 2005 ; Zeidner et al. 2005, Parker et al. 2006, Petrides and Furnham 2004.)

(ii) Life satisfaction; physical and psychological health; social networking. Here, EI scores :

- were associated with quantity and satisfaction of social support.
- were positively correlated with an enhanced ability to recognise facial emotional expression.
- were positively correlated with the ability to manage moods.
- were positively associated with a willingness to seek help for personal problems and psychological illnesses.
- were more strongly associated with social network size than personality measures.
- were negatively associated with loneliness, depression, and alexithymia.
- were positively correlated with lowered anxiety.
- were negatively correlated with alcohol consumption in adults and adolescents.
- were negatively associated with tobacco use in adolescents.

(Schutte et al. 1998, Dawda and Hart 2000, Ciarrochi, Chan and Bajar 2001,Ciarrochi and Deane 2001, Trinidad and Johnson 2001, Lopes et al. 2003, Trinidad et al. 2004, Austin, Saklofske and Egan 2005, Bastian, Burns and Nettelbeck 2005, Extremera and Fernandez-Berrocal 2005.)

Typically, a large number of positive associations have been found between greater measured EI (across both ability and trait measures) and a greater sense of intrapersonal well-being or the presence of “healthy” lifestyle components. Negative associations are typically found between EI and behaviours or lifestyles likely to be detrimental (alcohol consumption, smoking, non-specific stress etc.). The presence of some psychological illnesses have also shown links with measured EI, including alexithymia, depression, and general life satisfaction. An abundance of experimental evidence shows that EI as a construct is potentially very valuable in real-world applications such as human resources management (McEnrue and Groves 2006), clinical therapies, and selection procedures for situations requiring e.g. team work in occupational settings, client-customer interactions, and broader situations involving everyday social interactions. Most recently, however, Keele and Bell (2008) have again raised the question of exactly how EI can be reliably stated to predict what it does if the various tests involved are not measuring what they claim to be, or, measuring concepts which differ depending on the way in which they are examined.

Criticisms of EI frequently centre on the validity of both the ability and trait scales in many dimensions, since they show notable overlaps with pre-existing constructs, and do not sit well with the multitude of predictive or lifestyle correlational findings. Perez, Petrides and Furnham (2005) have stated that the discriminant validity of EI is “beyond empirical doubt”, but this is apparently not so with several EI tests showing significant correlations with measures of personality, particularly the NEO-PI (usually trait-based tests) and some measures of intelligence (usually ability-based tests). Mayer, Salovey and Caruso (1990) themselves stated that higher EI would be theoretically associated with higher neuroticism, a component in Eysenck’s 3-factor P-E-N model of personality. McCrae (2000) noted that at the conceptual level, EI as measured by the Bar-On EQ-i scale should show relationships with some of the Big 5 personality variables, a potential problem for EI’s discriminant validity. Schulte et al. (2004), was among the first to draw together some of these critiques into a relatively short but otherwise problematic article reviewing overlaps between EI and other measurement instruments. Petrides and Furnham (2001) found correlations from -.29 to .35 between neuroticism, extraversion and conscientiousness in the NEO-PI and Bar-On EQ-i, while Schulte et al. themselves found moderate, but significant and shared associations between the Wonderlic Personnel Test, the MSCEIT, and the NEO-PI, leading them to title their study as “Emotional Intelligence : not much more than g and personality.”. Van der Zee et al. (2002) and Van der Zee and Wabeke (2004) have twice found NEO-PI scores to be significantly related to Bar-On EQ-i scores, with the EI measure found to be “…substantially related to Extraversion, Agreeableness, Emotional Stability, and Autonomy…”. Aside from personality variables, Mayer, Roberts and Barsade (2008) also noted correlations of .36 to .38 with crystallised intelligence, which they viewed as “moderate”; these correlations with IQ could, however, also be viewed as “relatively high” as well as being statistically significant, considering that the EI scores were produced by an entirely different scale which was not intended to evaluate general cognitive abilities. Van Rooy and Viswesveran (2004) similarly stated that the links between EI, personality and general mental abilities are "…. more highly correlated than many researchers would prefer….", and that the links with GMA were stronger with ability-based tests such as the MEIS. The links with GMA may be partially explained, however, as due to the otherwise all-pervasive nature of *g* – as a heavily influential factor in human intelligence, it is entirely possible that *g* is capable of influencing a wide variety of performance domains, perhaps including those outwith purely intellectual intelligence. The associations with *g* may be somewhat less of a problem for ability based tests, because objective testing will naturally employ problem-solving cognition in some form. Bastian, Burns and Nettelbeck (2005) stated that across several independent studies, ability EI is more strongly associated with other cognitive or intellectual measures (which can be rationalised to some degree), while trait EI is often associated with personality measures (a potentially more serious problem) (Dawda & Hart, 2000; Saklofske et al., 2003; Van Der Zee et al., 2002).

With regard to the predictive validity of EI, some of the associations found between EI and real-world issues have also been questioned. Van Rooy & Viswesvaran (2004), Barchard (2003) and Brackett & Mayer (2003) noted that the predictive abilities of EI in regard to some academic and employment success criteria were in general no better than that of other personality measures (although Van Rooy and Viswesveran also noted that EI was better than personality for some criterion measures, but that across six different EI measures, overall operational validity was highly variable.). Several other studies have also noted near-zero or otherwise non-significant relationships with EI and academic performance (Bastian, Burns and Nettelbeck 2005; O'Connor and Little 2003, and Newsome, Day and Catano 2000.). EI's associations with life-satisfaction and social network satisfaction, however, seem less contentious, with e.g. Palmer, Donaldson and Stough (2001) showing EI as able to account for 42.2% of the variance in the Satisfaction with Life Scale. The SREIT inventory has also been the subject of specific criticism by Charbonneau and Nicol (2002), who suggested problems of discriminant and convergent validity – i.e. the SREIT showed correlations with measures of social desirability, and a lack of correlation with peer nominations from an adolescent group, where positive correlations would be expected for high-EI individuals and measures of social popularity. EI, however, remains relatively less explored among adolescent groups, with the bulk of studies concentrating on adult populations. Additionally, three of Charbonneau and Nicol's other test materials were relatively uncommon scales (the Personality Research Form-E, the Interpersonal Reactivity Index, and a relatively obscure EI test known as the Weisinger Interpersonal Emotional Intelligence inventory.)

An adjunct problem with EI as a construct, and the MSCEIT scale in particular is that Mayer, Salovey and Caruso have been ardent proponents of both the concept of EI, and particularly the MSCEIT inventory; but as they are the test's authors, this is unsurprising. Since 1990, they have published more than 30 articles about EI, and more than 10 articles specifically regarding the MSCEIT inventory. Landy (2005) found this unpalatable from a scientific viewpoint; Mayer, Salovey and Caruso have an obviously implicit financial interest in the promotion and commercial success of their own test materials, but they do not make it easy for fellow researchers to examine the underlying science of their work. As the MSCEIT is a copyrighted test, perhaps the only threat to its continued usage (and of the use of other EI tests based upon its fundamental model such as the SREIT) would be investigations of its psychometric properties indicating important flaws. The MSCEIT cannot be copied or used illicitly by other individuals without civil legal penalties, and even if the underlying principles of the MSCEIT were found to be severely flawed by independent researchers, Mayer, Salovey and Caruso would nonetheless remain free to address any issues with updated materials. Nonetheless, specific details of scoring methods and their database of results remain undisclosed. Such reticience to allow independent scrutiny of the MSCEIT, perhaps justifiably, has lead some to wonder if Mayer, Salovey and Caruso deliberately refuse to release these details for this or similar reasons.

The MSCEIT inventory in particular, and therefore some of the fundamental issues in ability EI as a construct, also suffers from problems in underlying logical assumptions made by the test creators. Salovey and Grewal (2005) stated that the perception of emotions "makes all other processing possible", and therefore the ability to detect emotions in oneself and others would appear to be critical in the assessment of EI. It would seem logical, then, that a perceptual sub-factor would be vital not only in assessment, but in the fundamental ability to further assess EI in test subjects. Emotional perception, however, is never highlighted as a primary and elementary diagnostic criterion in EI inventories to evaluate whether the tested individual’s EI quotients actually can be appropriately assessed from first principles. Salovey and Grewal (2005) also stated that "laypeople and experts possess shared social knowledge about emotions", which could be also be interpreted as stating that EI testing does not test individual EI per se, but is actually a measure of social conformity, consensus or agreement. There is also an underlying issue of cross-cultural applicability of emotional detection, use and measurement implicit in consensus-scoring measures; MacCann et al. (2004) note that, for example, “…..(an) Australian undergraduate sample may have different connotations of ‘fear’ than (for example) a group of mostly male business executives in Tokyo, which in turn might influence relative shifts in category weights….”. Lastly, Salovey and Grewal seemingly contradict themselves by stating that self-report measures of EI are unreliable owing to overlaps with personality variables (Brackett and Mayer 2003), then by providing “diary self-report” measures by Lopes et al. (2004) as evidence for the usefulness of the MSCEIT. It seems that while self-report trait EI inventories themselves are considered unreliable measures, *diaries* detailing the diary-keeper’s interpretations of “success with the opposite sex” and the diary keeper’s perception of other individuals’ perceptions of *their own* “intelligence” and “friendliness” are apparently regarded as perfectly acceptable dependent measures – i.e. how the diary-keeper interpreted other individual’s reactions towards themselves. It would appear that when it is used to validate the MSCEIT, a diary is no longer a self-report measure, but a useful adjunct to ability-based testing.

Taken as a whole, EI testing using either trait or ability-based methods would appear to be somewhat contentious and generally difficult to accomplish. Although many studies have found apparently validating evidence of the usefulness of the EI, the construct remains somewhat ill-defined, and some of the measures used to assess these areas have been criticised at the level of quite fundamental conceptual issues – i.e. exactly what it is that various inventories are actually measuring. There is also the matter of known crossovers between existing measures of personality and intelligence, which could be interpreted as making EI less useful than other, more thoroughly validated measures, such as e.g. the NEO-PI. Petrides, Furnham, and Mavrovelli (2007) stated that :

"It has been pointed out that it is perfectly possible for trait EI and ability EI to "coexist" …...We would agree that our view of them as different constructs implies that the operationalization of one does not have implications for the operationalization of the other. Indeed, it is irrelevant for our purposes whether ability EI will ever be accepted into the mainstream taxonomies of human cognitive abilities……...Nevertheless, our prediction is that this construct will eventually find its place along the ever-growing number of pseudo-intelligences……on the fringes of scientific psychology."

This statement would appear to damn (EI) with faint praise. At least, although the life- and social-satisfaction elements of EI seem to be criticized considerably less often than other aspects such as academic and employment performance, some caution is warranted in interpreting the findings from various EI scales.

CHAPTER 5

Study 1

Piloting the behavioural emotional intelligence-IT task

Introduction and Research Aims

This initial study (study 1) was designed to test the basic methodology intended for future use in this series of studies. Throughout the present series of studies, Austin’s (2004) and (2005) emotional-IT (hereafter “E-IT”) task will be adapted to accommodate ERP acquisitions, with three main goals. ERPs acquired from these procedures will be examined for responses related to the emotional valency of the target stimuli, in an attempt to discover unique or specialised phenomena in the detection and classification of emotion at the level of brain electrophysiology. Secondly, the E-IT task will be investigated for effects related to the inspection-time task, in an attempt to further examine EI as a concept, and prospective links with intellectual intelligence. Lastly, the ERP data will be examined for effects related to intellectual differences among the participant samples.

A stimulus presentation program based on Austin’s (2004) emotional inspection time task was devised using E-Prime software, which required modification beyond the collection of behavioural responses for use in subsequent electrophysiological acquisitions. As well as a means to collect basic data on participant response rates and inspection times for the stimulus set, the present study was also an examination of stimulus presentation parameters. The main objectives of this study were :

(i) An assessment of the stimulus duration parameters to determine durations which were either too brief to discriminate the stimuli (resulting in unacceptably high participant error rates which would prevent future EEG averaging), or too lengthy, resulting in an excessively easy task with unsuitable demands. When presentation durations are brief, participants have great difficulty in apprehending the stimulus simply because they cannot visually detect it with accuracy. Some behavioural errors (i.e. pressing the wrong response key from that intended) can generate "accidentally" correct responses at rapid durations, but performance is otherwise poor at very brief durations. Thus, making the task too difficult or too simple could result in a failure to reproduce a typical inspection time curve (i.e. increasingly successful responses above chance levels as stimulus presentation durations increase). Monitoring of the difficulty of the task was therefore important, as a minimum of 70 to 100 correct responses would be required per participant to achieve a suitable grand average ERP in subsequent studies.

(ii) An examination and first test of the program's suitability for the collection of behavioural and EEG data. The E-Prime program was simply required to function properly and consistently outwith deliberate artificial testing, and only a large scale test using an actual participant population would evaluate this. The successful acquisition of EEG data also requires the use of several procedures transparent to the participants; primarily, the use of signalling triggers between the stimulus presentation and EEG acquisition PCs to start, stop, and flag events during the EEG recording.

The desired outcomes of the present study were the production of inspection time curves which could be later used in optimising the stimulus presentation durations for a second ERP-based study, and, a program capable of running without error through a gamut of genuine responses from actual participants.

As the stimuli were human faces, and thus quite different from the "traditional" inspection time stimuli of perceptually simple geometric shapes or lines, it could be expected that the mean inspection times for faces would be longer than those for geometric stimuli. Faces are more complex stimuli comprising more discrete elements, as well as stimuli with specific meanings and biological salience to humans. The procedures employed in the present study were intended to be kept as similar as possible to the forthcoming ERP studies, with the exception that an EEG acquisition would not be performed at this time. Unless severe problems were noted, the present task would be re-used with appropriate changes to the presentation durations should the current values result in excessively high or low accuracy levels.

The task employed here differed from Austin's (2004) emotional-IT task in that the emotional stimuli presented to participants differed within the same task, rather than being presented as two separate tasks. Austin's (2004) study featured three separate IT tasks using happy stimulus faces, sad stimulus faces, and a third task involving symbol discrimination without emotional aspects. It was expected that the participants' performance on this task would be broadly equivalent to that of the standard IT tests (e.g. Nettelbeck and Lally 1976, Longstreth et al. 1986, Smith 1986); specifically, a continuum of perceptual ability was expected to be present, with success rates at rapid presentation durations being close to or below chance, and rising to a plateau at lengthier durations.

Methods

Participants

40 participants were recruited, comprising 27 females and 13 males, with a mean age of 23.2 years (S.D. = 7.9 years). The majority of participants were university students, with 4 departmental staff also volunteering. Participants were not paid and were recruited from teaching groups, via e-mail, or opportunistically within the department. No selection criteria aside from normal or corrected-to-normal vision were required.

Materials

Nine photographs of human faces were chosen from the Stirling University PICS database, comprising the individuals' head against a neutral background. One of the female faces was intended for use as a masking stimulus, while the remaining eight photographs were intended for use as experimental stimuli. Two photographs of the two males and two females were used.

For each individual, one photograph was intended to show a happy facial expression, and the other a neutral facial expression. To verify the descriptions of the facial expressions, 20 male and 25 female raters (who were not later tested as subjects, mean age 38.5 years, s.d. = 13.5 years) examined each picture, stating the gender of each photographed individual and whether their facial expression was sad, happy or neutral. Where more than 20% of the raters disagreed within any of the rating categories, that photograph was discarded. One male stimulus face and the female mask face were discarded after rating. Two different photographs were selected from the Eckman and Freisen Facial Affect collection (Eckman and Friesen 1976) – one "stimulus" male showing both happy and neutral expressions, and a new neutral-expression female "mask" – to complete the set. Although the task in this instance was the identification of gender, these stimulus items were to be re-used in the next study in this series.

Each photograph was re-sized to 350 (h) x 275 (w) pixels and saved as a grey-scale bitmap image, subtending a visual angle of 9 degrees 31 minutes at 70cm distance from the screen. The images were presented using the E-Prime system on an IBM PC running Windows XP. During experimental trials, the vertical refresh rate of the monitor was 75Hz and the screen resolution was 1024x768. There were 256 stimulus presentations in total. This comprised each of the 8 face images being presented four times at eight duration intervals for a total of 32 presentations per face image.

The eight duration intervals in use were 20, 40, 60, 80, 100, 120, 140 and 160ms. Each target stimulus was immediately backward masked by the neutral female mask image for 500ms. The ordering of the stimulus items was randomised once and then invariant for all participants. Under Windows XP, E-Prime uses a timing system based on the refresh rate of the monitor to calculate all visual stimulus presentations :

> "…If the display duration is specified to be 200ms, and that value is not an exact multiple of the refresh rate, the duration will vary up to one refresh cycle less than or greater than the desired time…"
>
> (E-Prime User's Guide 2002, p. 82)

E-Prime therefore cannot display an image for any exact multiple of 10ms, except for durations of 50ms, 100ms, and 150ms when using a monitor capable of 160Hz refresh rates. The lowest achievable multiple has been calculated to be 6.5ms at 160Hz, which rises to approximately 13.3ms at 75Hz (Marshall, 2004). Thus, true millisecond accuracy is not possible and stimuli are presented in multiples of approximately 13.3 ms in the case of a 75hz refresh rate The relationship between refresh rate and presentation timing is a step-wise function and thus not easily characterised e.g. by a single equation (except for the 3 intervals here). To compensate for these timing difficulties, the stimulus durations were all reduced within the E-Prime presentation program by 5ms in order to better achieve the originally desired exposure time – e.g. a desired presentation of 40ms is achieved best by stipulating an actual presentation time of 35ms.

Desired	20	40	60	80	100	120	140	160
Requested	15	35	55	75	95	115	135	145
Actual	26.6	39.9	66.5	79.8	106.4	119.7	146.3	159.6

Prior to completion of the IT task, each participant also completed the original 33-item Schutte et al. emotional intelligence inventory, the SREIT (Schutte et al. 1998). Petrides and Furnham (2000) extracted four factors from this inventory named “optimism / mood regulation”, “appraisal of emotions”, “social skills” and “utilisation of emotions”. This inventory was also intended to be used in future studies.

Procedure

Participants completed the Schutte Self-Report Inventory (SREIT; Schutte et al. 1998) inventory prior to the IT task. Although the SREIT is freely available in the source article, there are no formal instructions for its use, and participants here were asked to:

“Please read each statement and think how well it applies to you personally. Then, circle one of the options on the right of the page from “1” if you strongly agree to “5” if you strongly disagree.”.

For the IT task, participants were informed that they were about to view human faces, and that their task was to identify the gender of the first (target) face. Although future task demands would require the identification of emotional expression, this task requirement was intended simply to ensure participants consciously attended to the stimuli. Participants were informed that they would always be shown two faces, that the target face would always be the first face shown, and that some of the target faces would be visible only very briefly. If they were unsure of a response, participants were instructed to guess as accurately as possible. It was emphasised that the accuracy of the response was important, and that the speed of their response itself was not measured. Participants performed 16 practice trials with stimulus items being shown at various exposure times ranging from 20ms to 120ms. Feedback was given after each trial. Upon completion of the practise trials, the experiment proper began.

Before initiating the main task, participants were informed there would be three slight differences from the practise trials, but that the essential task was unchanged. Firstly, there would no longer be any feedback after each response. Secondly, there would be periodic 10-second rest periods; these occurred after every 32 trials. Lastly, as the first stage of a series of experiments, participants were informed that a “Blink Now” instruction which appeared before each new trial began (required for a future ERP collection task) did not apply to them and could be ignored. The actual instructions were presented as 12-point black text on a white screen and are shown below :

“When the experiment starts you will see an asterisk in the center of the screen.
Look directly at the asterisk.

Next, a human face will be displayed briefly.
The first face will be covered up by a different face, then you will be asked to respond.

If the FIRST face you saw was MALE, press 1
If the FIRST face you saw was FEMALE, press 2

You should aim to be accurate rather than quick, so take as much time as you need to decide.

If you are not sure, guess.
There will NOT be any feedback during these trials.

Press spacebar to continue"

Each trial observed the following sequence :

1. A gaze-fixation symbol appeared in the centre of the screen (600ms).
2. The target face appeared in the same position.
3. The neutral mask face appeared in the same position (500ms).
4. The response prompt appeared :

" If the FIRST face you saw was MALE, press 1
If the FIRST face you saw was FEMALE, press 2"

5. The "Blink Now" prompt appeared.
6. New trial.

All testing took place in a computer laboratory cubicle. Upon completing both sections of the testing, participants were free to ask questions.

Results

Inspection time curves were plotted for each individual using their percentage of correct responses at each of the eight stimulus durations. The curves showed the characteristic IT-task shift from near-chance levels of response accuracy at very brief presentation durations to a ceiling effect at relatively longer presentation durations. Descriptive statistics for the individual presentation durations are shown in Table 1. The frequency distribution for the number of correct responses for presentation durations from 60 – 160msec were skewed owing to the high number of correct responses, and medians are provided for these values instead.

Table 1. Descriptive statistics for no. of correct responses at all presentation durations.

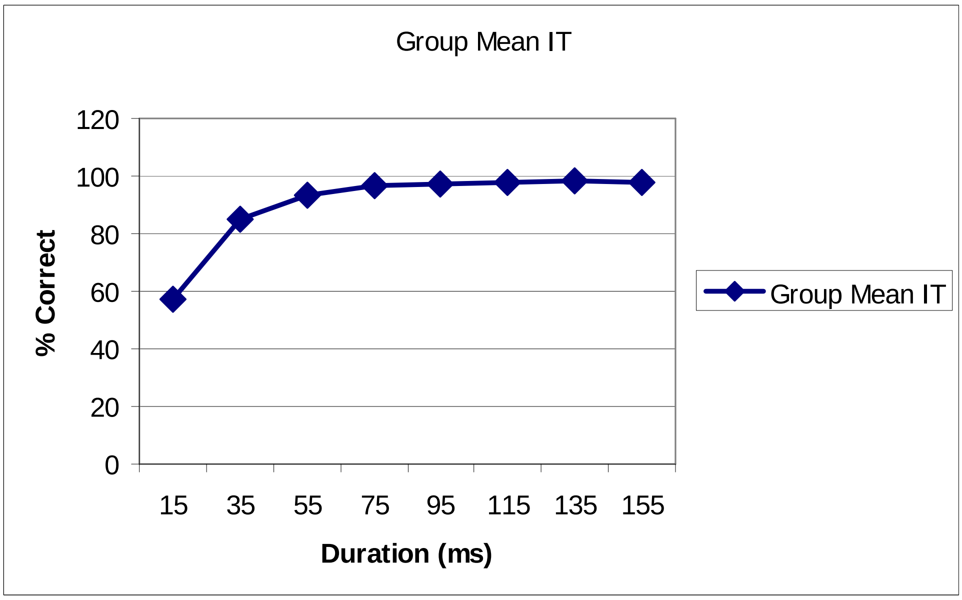
Duration (ms)	% Responses Correct	Mean No. Correct	S.D.
20	57.42	18.38	3.29
40	85.00	27.2	4.13
60	93.44	31*	4.36**
80	96.88	31*	4.36**
100	97.42	32*	4.36**
120	97.89	32*	4.36**
140	98.52	32*	4.36**
160	97.97	32*	4.36**

* Median value cited owing to non-homogenous distribution.

**Semi-Interquartile range

The inspection time value for the current sample was decided to be the minimum presentation at which 85% response accuracy was achieved. Table 1 shows that the mean value was likely to lie between 20-40ms. After 60ms, the presentation duration was sufficiently high as to permit 93-100% accuracy of responses. Between 20ms and 40ms, however, there was a sharp rise in the response accuracy. Chart 1 shows the obtained psychophysical curve. Importantly, however, the inspection time curve, and relationship with IQ was maintained despite the E-Prime timing discrepancy problem.

Chart 1. Plot of group mean percentage correct responses vs. presentation duration.



In order to produce the group mean inspection time (IT) value, the percentage correct data from all 40 participants was applied to a curve-fitting exercise using the logistic function [$a_1+(1-a_1)/(1+\exp^{(-a2*d+a3)})$] (Deary, Caryl and Gibson 1993). This produced a mean IT value for each subject, allowing the group mean IT to be calculated at 38.39ms (s.d. = 20.05). Austin's (2004) study did not report an IT value for participants, and results were instead expressed in terms of total correct responses.

A one-way ANOVA showed no gender differences to be present in the IT value (F(1, 38) = 0.018, p=N.S) despite a larger number of female participants. To ensure no gender effects were present, 13 females were randomly selected to match the population of males, and new descriptives computed, presented in Table 2.

Table 2. New descriptive statistics for gender-equivalent sample (N=26).

Duration (ms)	% Responses Correct	Mean No. Correct	S.D.
20	55.66	17.81	2.8
40	82.44	26.38	4.58
60	91.22	29.19	3.03
80	96.28	30.81	1.23
100	100.00	32*	4.21**
120	100.00	32*	4.21**
140	100.00	32*	4.21**
160	100.00	32*	4.21**

*Median value cited owing to non-homogenous distribution

**Semi-Interquartile range

The gender-matched sample produced a new mean IT value of 43.04ms (s.d. = 22.89ms), and Levene's test showed the new gender matched IT sample to be non-homogenous (Levene Statistic (8,17) = 5.039, p<0.002). A Mann-Whitney U test still showed no significant gender differences for IT within the equivalent gender sample, U=69, p= N.S. The IT value, therefore, did not vary significantly according to gender and showed that neither males nor females displayed advantageous responses to these stimuli.

The psychometric data from the SREIT was not analysed here, and was included as a procedure only to mimic the procedures of subsequent IT studies as far as possible.

Discussion

The present study achieved the principal aims in establishing the suitability of the IT task as a means of using human faces as stimulus items. Faces themselves are considered to be stimuli which involve “qualitatively different” processing from other types of stimuli (Kanwisher, McDermott and Chun 1997). However, according to Calder et al. (2001), “…there is still no detailed cognitive account of how we recognise facial expressions…”, and neither are there many studies (either empirical or purely cognitive) in the area of fundamental face perception other than two from some considerable time ago – e.g. Janik et al. (1978) and Bruce & Young (1986). The study of face perception therefore suffers from a lack of practical information regarding the actual process of face perception in an experimental or natural context – i.e. a breakdown of the behavioural act(s) of observing a face. There is also limited information on e.g. the visual features to which an individual attends when actively perceiving another person’s face in vivo, although Bentin et al. (1996) noted that ERP responses to human eyes tended to show preferential attention. It is therefore somewhat surprising that the facial gender identification IT obtained here is very close to the values obtained from studies using stimuli such as the traditional IT task line stimuli. Burns and Nettelbeck (2003) reported IT values of 64.9ms and 29.2ms for alphanumeric and geometric IT tasks, while Luciano et al. (2001) cited a minimum geometric IT value of 42.6ms in a population of 390 twin-sibling pairs. Given the differences between the face stimuli in use in the present study and the geometric stimuli employed in other types of IT tasks, the results here could be interpreted as arguing against Kanwisher et al.’s opinion – in terms of simple perceptual speed, identifying gender (from a facial stimulus) seems to be accomplished equally as quickly as the line-I.T. task despite the obvious differences between these stimulus types.

It is arguable that faces are biologically salient stimuli to human beings and that expressive faces are even more so (Campanella et al. 2002, Fox 2002), to the extent that angry faces are the easiest of all to detect (Hansen & Hansen 1988). Treisman (1986) suggested a two-stage model where the visual field is specifically scanned for “biologically relevant features” in a process known as “pre-attentive vision" followed by a more focused "attentive vision" where features are integrated (cited in Suslow et al. 2003). Previous studies have indicated that the processing of facial images involves specific areas of the extrastriate cortex which appear quite specific to un-altered images of faces, but not to scrambled faces or certain other objects (Ojemann et al. 1992, Allison et al. 1996.). Research detailed in the literature review of ERP and face responses shows that the evaluation of human faces is likely a near-automatic process carried out by the fusiform face areas of the brain, and therefore a rapid process facilitated by rapidly drawing an individual's attention to approximately face-like stimuli.

From the present study, it appears that successful human gender identification via exposure to a face image is possible (albeit with a small number of repeated stimuli and the concomitant susceptibility to practise effects) at relatively low presentation durations in the same manner as "traditional" IT-task geometric stimuli – i.e. at stimulus durations between 30-70ms. Austin (2004) used two different facial expressions in a similar paradigm in an emotional discrimination task, with two distinct IT tasks for each of the emotional valencies, rather than a single task incorporating both facial expressions. No information is available from Austin (2004) regarding inspection times themselves, as the primary dependent variable throughout was total correct identifications.

The obtained mean IT in the present study (38.39ms) seems fast when compared to IT measures from other studies using the traditional twin vertical lines instead of more visually complex human faces. Using the standard paired-lines IT task, Stough et al. (2001) obtained a mean IT of 33.5ms, O'Connor & Burns (2003) obtained 62.1ms using the same stimulus type, and Mackintosh & Bennett (2002) obtained a middling value of 37.97ms. Although Stough et al. (2001) state that the issue of IT as a measure of perceptual speed is still "unresolved", it appears that solely perceptual speed for relatively simpler discriminations (i.e. whether one line is longer or shorter than another) are approximately comparable to the identification of gender; lengthy appraisals are not required. Lee (1999), when taschistoscopically presenting pairs of familiar and un-familiar male and female faces with a PEST methodology, found substantially faster inspection times, ranging from 10.24ms to 12.48ms; females were also found to perform somewhat faster appraisals when viewing familiar faces, but this effect was inconsistent and slight. Whereas the simple human choice reaction time is often between 250-450ms across a variety of tasks, the perceptual appraisal of stimuli apparently occupies only 10-20% of the total time between exposure to the stimulus and the following behavioural act.

In the present study, unlike Austin (2004), participants were not questioned regarding the emotional state of the stimulus face. During debriefings, only one participant noted the differing expressions as an aside comment. Calder et al. (2001), using a purely computer-based principal components analysis technique, were able to state that when discerning gender, the hair-style of the individual was of relatively greater import than other features. When discerning facial expression, however, more visual components were required: eye width, jaw drop, the height of the corners of the mouth (raised or otherwise), and the extent of the narrowing of the eyes. Haxby, Hoffman and Bobbini (2000) have also suggested that different brain regions are also involved in making the distinction between facial expression and facial identity. For facial expression, the “changeable” muscles of the face produce the expression, and the superior temporal sulcus region is most involved in noting this. For facial identity, however, the invariant qualities of the face such as its shape and structure are processed by the fusiform gyrus. Calder et al. (2001) stated that there was also considerable overlap in the features used to identify gender and identity, involving mainly features of the face which “...change slowly over a number of years…” such as head size and nose shape. Again, the speed and accuracy with which this process is accomplished among human participants is quite impressive, given the various cognitive and neurological systems involved.

For the next study, the presentation durations at 140ms and 160ms will be removed and new durations at 25ms and 45ms will be introduced; the process of recognising facial gender is apparently quite rapid, requiring approximately only 50% of the maximum durations used here. A ceiling effect is very obvious in the present data-set after 60-80ms presentations, and at this point little is learned except that participants are able to respond correctly in 93-98% of trials at these presentation speeds. Accordingly, data collection points will be added at earlier presentation durations since the period of time needed to make such judgements approximately spans the region between 20-50ms. The value of the present study will be manifest in the next study involving an ERP acquisition concurrent with the task previously described. The near real-time data acquisition possible from ERP data will be facilitated by devoting more emphasis and actual data-points to the additional two presentation durations in the region prior to 60ms. From the data gathered in the present study, tentative new parameters can be set for a methodology involving EEG/ERP acquisitions.

CHAPTER 6

Study 2

Acquiring ERPs from the E-IT Task.

Introduction

To the best of my knowledge, the present study will describe the first ever application of ERP methodologies to an emotional IT task. Adjunct goals will also be accomplished; as the first application of the methodology, the precise nature of the resultant ERP activity is speculative, and the data will be examined with a view to improving subsequent studies as well as on the basis of emotionally-induced variation.

The results from the previous behavioural study provided the basis for modifications to the methodology for the present ERP acquisition. The E-Prime program worked reliably in presenting the stimuli, and the behavioural data obtained suggested that the methodology would benefit from additional presentations at the lower (or faster) end of the psychophysical curve. In the previous behavioural study, participants achieved success rates exceeding 90% after viewing stimuli for 60ms. As such, the plot of longer presentation durations plateaued and could likely be removed in favour of introducing newer and briefer durations to provide information on the ascending, or lower end, of the curve.

The task demands in the present study are slightly different from the previous behavioural task, now requiring participants to identify the emotional expression of each target stimulus. The nature of the methodology was also changed by the use of ERP acquisitions in this study. EEG acquisitions are generally regarded to be sensitive to voltage changes at the millisecond level; Fabiani, Gratton and Federmeier (2007) describe the temporal resolution of ERPs as “exquisite”. As this series of experiments will be focused on ERP responses, analyses of behavioural RT will not be emphasised, and instead differences in brain electrophysiological responses and inspection time will comprise the DVs under study. Thus, this study will decrease the emphasis on the participant’s behavioural responses except for their use in determining successfully identified trials. Decreased emphasis on behavioural responses in this manner will also require some replication of any phenomena in the present study, however, and subsequent studies will seek to verify these findings in turn.

As the first ERP acquisition using this task, the main research questions in the present study were :

(i) What is the nature of the resultant ERP from this task ? Caryl and Harper (1996) presented ERPs from IT tasks involving auditory pitch discrimination and a standard two-line IT task. While the auditory pitch task showed a P300 complex with N100 and P200 components, the visual IT task's ERP was generally less well defined.

(ii) Does the emotional valency of the stimulus classes result in statistically significant variations in the ERPs ? This question will be a core feature of subsequent studies.

The nature of the present task is such that a P300 complex with a facial N170 component (Bentin et al. 1996) is likely to be elicited. Several studies by Donchin (Donchin 1979, McCarthy and Donchin 1981, Donchin and Coles 1988a, 1988b) suggest that the P300 is likely to be involved in processes related to stimulus evaluation and context-sensitive updating of short-term memory – i.e. an appraisal of the environment at hand, with contextually relevant comparisons of what has occurred previously prior to a response selection. Much of the P300's ubiquity in psychophysiological studies is explained in this manner, as short-term memory involvement is a requirement of a vast number of commonly used experimental tasks and everyday activities. However, the question of ERP differences related to the emotional valency of the stimuli remains to be answered here.

Methods

Participants

46 participants were recruited, comprising 26 females (mean age = 25.96 years, S.D. = 4.84 years) and 20 males (mean age = 23.65 years, S.D. = 2.85 years). Participants were post- or under-graduate students recruited through the use of e-mail lists and notice-board announcements. Participants required English as a first language, possession of normal or corrected-to-normal vision, and an overall state of normal good health. For the EEG portion of the task, participants were required to have washed their hair on the day of the test, and refrained from using any hair-care products. Each participant was paid £10 for participation.

Materials

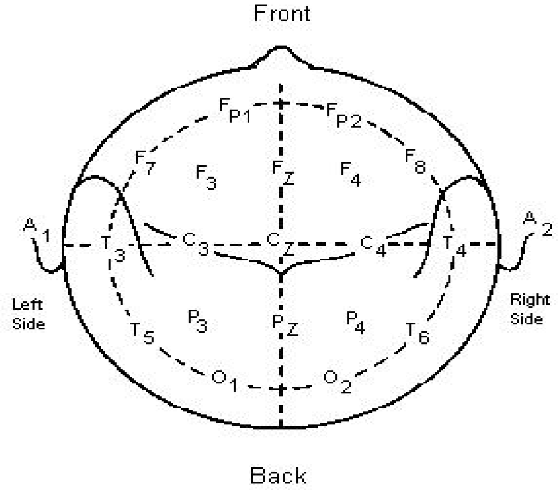
Three psychometric tests were employed – the 33-item SREIT (Schutte et al. 1998), the National Adult Reading Test (NART, Nelson and Willison (1991), NFER-Nelson Publishing Co. Ltd) and the Alice Heim 5 Group Test of Intelligence (AH-5, Heim (1968), NFER-Nelson Publishing Co. Ltd.).

The procedures of the E-Prime facial-IT task were slightly modified from those used previously in the facial gender identification task. The experimental task now required identifying stimulus emotion. Many of the alterations were methodological and neither apparent nor relevant to the participant. Following the results of the previous study, alterations were made to two of the stimulus presentation durations. The same 8 face stimuli used previously were presented 4 times at 8 presentation durations. The PC monitor displaying the stimuli was now set at a 100Hz refresh rate to maximise the accuracy of the presentation durations, which were now set at :

Desired	20	30	40	50	60	80	100	120
Requested	15	25	35	45	55	75	95	115
Actual	26.6	26.6	39.9	53.2	66.5	79.8	106.4	119.7

The longer stimulus durations at 140 and 160ms were removed in favour of two briefer durations at 30 and 60ms. The same 256 trials were presented from the behavioural study. An additional modification to the present study set the program to wait until the participant responded before displaying the next trial, and participants now set their own pace for this task, intended to minimise movement artefacts during the EEG recording. The program also flagged the beginning and end of each trial, and the stimulus class which was displayed, via a bit-setting output to the EEG software.

EEG recordings were accomplished using a Neuroscan NuAmps 7181 forty-channel amplifier and a Neuromedical Supplies forty-channel Quik-Cap sintered electrode cap. All sites were prepared using Neuromedical Supplies' Quik-Gel. Data was recorded via proprietary Scan v4.3 software suite at a sampling rate of 500Hz using linked and subtracted mastoid channels as a reference. Six scalp electrodes were used : F3, C3, P3, F4, C4 and P4. These placements are standard placements in the International 10-20 System (Jasper 1958), and illustrated below :



Electrodes with odd-numbers (F3, C3 etc.) are placed on the left of the scalp, and even-numbered electrodes are right-sided. Placements with a "z" (Fz, Cz, Pz etc.) are central, placed approximately above the central sulcus. Vertical EOG was monitored above and below the left eye using the FP1 site and one of the cap's auxilliary electrodes respectively. Impedances were maintained below 10Kohms (though frequently much lower), and the EEG data was band-pass filtered on-line between 0.1 to 30Hz. Averaging was performed off-line, and trials featuring incorrect responses were removed. The raw EEG traces were examined for deflections exceeding 45μV, and such activity was deemed to show movement and ocular artefacts. Trials exceeding this threshold on the raw EEG trace were also removed from subsequent averaging.

The parameters for each EEG acquisition featured a total recording time of approximately 2 seconds including the stimulus presentation time. The sub-divisions were as follows :

1. Trial begins.
2. Acquisition triggered.
3. Baseline period begins – 100ms.
4. Triggering pins reset.
5. Baseline continues - 100ms gap.
6. Asterisk fixation point displayed – 300ms.
7. Blank screen, EEG recording for 700ms
8. Stimulus presented (variable times up to 115ms) + stimulus class marker sent to acquisition software for averaging.
9. Neutral stimulus mask shown for 800ms.
10. Response prompt displayed.
11. Stimulus marker pins reset.
12. 500ms interval until next trial.

Procedure

Participants were briefly shown around the lab, and the EEG cap was fitted immediately, after which the participants completed the SREIT. As with the previous study, the SREIT instructed participants to:

"Please read each statement and think how well it applies to you personally. Then, circle one of the options on the right of the page from "1" if you strongly agree, up to "5" if you strongly disagree.".

Participants then completed the NART using the standard procedure, and were allowed to see their raw results while the rationale behind the NART was briefly explained. Approximately 10 minutes had now elapsed, allowing the conductance gel and impedance levels to settle. Each participant's impedance levels were measured along with a final check of the mastoid and EOG sites, and any additional electrode preparation was carried out on electrode sites showing unacceptably high resistance levels.

Participants then carried out a practise task using 10 trials with presentation durations of 80ms. The instructions for the practise task and the main experimental task were identical :

"When the experiment starts you will see an asterisk in the centre of the screen.
Look directly at the asterisk.
Next, a human face will be displayed briefly.
The first face will be covered up by a different face, then you will be asked to respond.
If the FIRST face you saw was HAPPY, press 1
If the FIRST face you saw was NEUTRAL, press 2
You should aim to be accurate rather than quick, so take as much time as you need to decide.
If you are not sure, guess.
There will NOT be any feedback during these trials.

Press spacebar to continue."

During the first practise trial, participants were instructed merely to watch and not make any response while the experimenter explained the response procedure. The response prompt for each trial paused the program and displayed the text :

“BLINK NOW
If the FIRST face you saw was HAPPY, press 1
If the FIRST face you saw was NEUTRAL, press 2”

Participants were shown their on-going EEG traces, and the interference generated by movement and blinking was demonstrated to them. Participants were notified that while the response prompt was shown on the screen, the next trial would not commence until they made their response, and if they needed to blink or otherwise move in the seat that they should wait until they saw the response prompt before doing so. Participants were also informed that in addition to any pauses they initiated by withholding a response, the program would automatically start and stop eight 10-second rest breaks. These periods were indicated by displaying “TAKE A BREAK” on the screen after every 32 trials.

Ten practise trials which used extremely brief presentations demonstrated the highest difficulty levels of the task, and participants were instructed not to be overly concerned if they found themselves unable to perceive the face accurately. In line with the original instructions, they were instructed to make their best guess instead. The participants were also shown the female face used for the neutral backward mask, and informed that while this face would be seen in every trial, it would never be the face to which they were required to respond.

The room lights were extinguished before each EEG session began. During the IT task, the experimenter sat silently behind the participant and monitored their EEG recording. During the first several trials, the experimenter coached the participant on their blink activity to ensure they waited for both the appropriate moment to answer, and the appropriate time to blink or move. Completion of the EEG task required approximately 25 minutes per participant.

After the removal of the electrodes and a short break to allow the participant to clean their hair, the participants completed the AH5 test using the standard procedure (two 20-minute sessions with standard examples). At the end of the testing procedure, participants were debriefed if they wished. Each participant was contacted via e-mail afterwards and notified of their NART and AH5 overall results if they desired.

Results

Psychometric Results

During the analysis, data from 3 female participants was discarded. For the IT task, one female participant failed to achieve the minimum 85% success level throughout the task. Although the EEG and psychometric data was available, the data file from the IT task for the other two female participants was corrupted and their behavioural responses (i.e. correct and incorrect answers) could not be discerned from the files. As the IT task was important for the later correlations with the psychometric data, these two participants were also excluded from further analysis. The remainder of the data was analysed among a population of 23 females and 20 males.

Descriptives

Descriptives are presented for the entire group's interval-level data in Table 1:

Table 1 – Overall descriptive statistics for parametric variables.

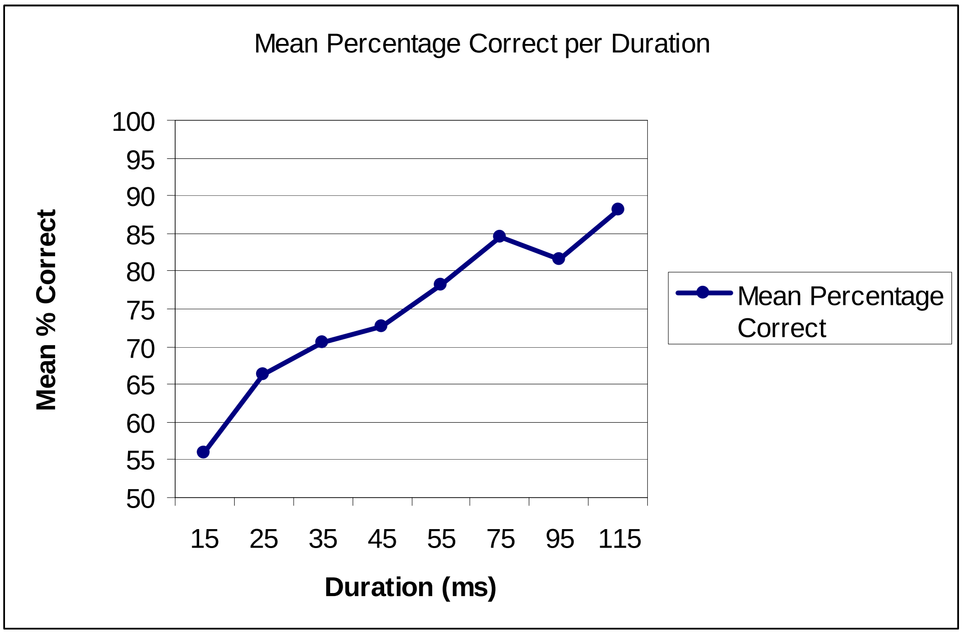
Variable	Mean	Std. Deviation
Inspection Time	121.60	64.88
NART Full IQ	119.14	3.15
NART Error Score	10.67	3.79
NART Verbal	119.18	3.49
NART Performance	117.06	2.46
AH5 Section1	17.56	5.44
AH5 Section2	22.07	5.19
AH5 Total	39.63	9.58
Total Correct Responses Per Participant	180.40	19.66

Emotional IT values (Kolmogorov-Smirnov Z=1.118), NART full estimated IQs (Z=0.89), AH5 total scores (Z=0.785), and the total number of correct answers from each participant (Z=0.571) all showed normal distributions indicating the applicability of parametric testing.

The IQ measures arising from the NART and AH5 tests showed the sample as a whole to be of above-average intelligence, with an approximate mean IQ of 119 points using the NART's estimation calculation. In contrast to the IT value, overall IQ appeared very homogenous.

The emotional identification task either relies upon quite different cognitive acts than the previous gender-identification task, or is generally more demanding, requiring longer examination of the stimuli for successful accomplishment. As with the previous study, the IT value for each participant was fitted using the model described by Deary, Caryl and Gibson (1993), resulting in a mean IT of 121.6 milliseconds. This is approximately 300% longer than IT measured during the previous study required to identify gender (38.39ms). Two female participants were able to achieve inspection times faster than 40ms overall, while four individuals (3 females and 1 male) required longer than 200ms. The SD for inspection time was quite large, however (~65ms), indicating considerable variation across the population.

Chart 1 : IT curve for mean correct responses.



The IT curve based on mean percentage correct responses was neither quite so smooth, nor as typical as that obtained during the previous gender identification study or a prototype curve produced by Vickers et al. (1972). Nonetheless, the obtained curve shows the expected progression from near-chance levels of success at very brief SOA durations (56.01%), up to high levels of success after 75ms (84.49 – 88.04%).

Descriptives are presented for the entire group's ordinal-level data in Table 2:

Table 2 : – Overall descriptive statistics for non-parametric variables.

Variable	Median	Interquartile Range	Reliability
Total EI	120.82	12	0.812
Appraisal of Emotions	31.26	9	0.748
Social Skills	48.23	7	0.723
Utilisation of Emotions	22.51	5	0.577
Mood Regulation	52.03	8	0.855

The sub-factors for the Schutte EI inventory were derived from Petrides and Furnham's (2000) analysis. Normality testing was not carried out on the non-parametric variables, and further comment upon the obtained descriptives is un-informative. As a non-objective test of individual tendencies (sample items include e.g. "Emotions are one of the things that make my life worth living.", or "Other people find it easy to confide in me."), there is no absolute answer and responses may vary considerably. Inferential tests were conducted on both the parametric and non-parametric variables to establish, firstly, implications for further testing.

(During testing of the SREIT, the scores were reversed to facilitate analyses (i.e. scores of 1 now signified strong disagreement, and 5 strong agreement.).

Inferential Tests

An ANOVA was conducted upon the IT and IQ scores between genders. There is little reason to suspect gender differences in IQ-related variables, and testing was carried out to establish the homogeneity of the population's results. No gender differences were revealed for overall IT value (F (1,42) = 0.013, p=N.S.), AH5 total score (F (1, 42) = 1.007, p=N.S.) nor NART full IQ scores (F (1,42)= 0.583, p=N.S.).

Mann-Whitney U tests were conducted upon the EI measures for the same reasons, yielding no effects for total EI score (U=68.5, p=N.S.), nor any of the sub-scale items: Mood Regulation (U=71, p=N.S.), Appraisal (U=79.5, p=N.S.), Social

Skills (U=58.5, p=N.S.) and Utilisation (U=69.5, p=N.S.). There is thus no reason to further analyse the data with respect to gender, and the following tests were carried out upon the population in its entirety. All reported NART scores are reduced to the overall NART IQ equivalent score. As NART PIQ and VIQ measures are arithmetical manipulations of the error score, correlation values were routinely identical within tests.

Table 3 : Summary of Significant Correlations for Inspection Time and IQ measures.

Pearson's Product Moment		NART Full IQ	AH5 Section2	AH5 Total	Total Correct
AH5 Section1	**r**	**0.363**			
	p=	**0.008***			
AH5 Section2	**r**	**0.335**			
	p=	**0.014***			
AH5 Total	**r**	**0.388**	**0.896**		
	p=	**0.005***	**0.001***		
TotCorr	**r**	**0.268**	0.102	0.173	0.151
	p=	**0.041***	0.258	0.134	0.166
Inspection Time (ms)	r		**-0.309**	**-0.274**	**-0.758**
	p=		**0.022***	**0.037***	**0.001***

Table 3 summarises the Pearson's correlations between the IT and IQ measures. The NART IQ and AH5 scores showed strongly significant correlations, thereby validating their measurement of IQ, albeit through different methods. AH5 total scores correlated significantly with the NART Full IQ estimate, NART Performance measure, and NART Verbal measure (r = 0.388, p<0.005 for all tests; identical results have been removed here) and negatively with the NART Error score (r = -0.388, p<0.005). Thus, as AH5 total score increased, so did the NART IQ measures, while NART error levels fell. The NART itself, however, was un-correlated with IT.

In turn, overall IT values correlated significantly and negatively (as expected) with the AH5 total score (Pearson's r = -0.274, p<0.037). A correlation of -0.274 is approximately in accordance with other studies using the method of constant stimuli. Nettelbeck and Lally (1976), Hulme and Turnbull (1983), Smith and Stanley (1983) and Nettelbeck (1985c) achieved correlations on 2-line IT tasks ranging from -0.12 to -0.41 among subject populations of 10, 65, 107 and 43 individuals in tasks of verbal and general intelligence

In the present study, as IQ scores rose, emotional IT values fell. Facial inspection times also correlated significantly and negatively with the total correct responses (Pearson's r = -0.758, p<0.001). Thus, as the number of correct responses rose, facial inspection times fell, reflecting that individuals who were more successful at the task also showed lower facial-IT times. The correlation between the AH5 section 2 scores and IT was also slightly stronger than that for AH5 total scores. From these findings, it appears that the test methodology is sound as an IT-type task - although there is little precedence for the IQ – emotional-I.T. relationship at this time.

Table 4 : Summary of Significant Correlations for Inspection Time and Emotional Intelligence. (two-tailed)

		TotalEI	Mood Regulation	Appraisal	Social Skills	Utilisation
Mood Regulation	rho	0.73				
	p	0.001				
Appraisal	rho	0.63	0.23			
	p	0.001	0.16			
Social Skills	rho	0.75	0.36	0.27		
	p	0.001	0.02	0.10		
Utilisation	rho	0.53	0.60	0.20	0.24	
	p	0.001	0.001	0.23	0.14	
Inspection_Time	rho	0.37	0.36	0.04	0.37	0.16
	p	0.02	0.03	0.82	0.02	0.32

Table 4 showed significant correlations between Inspection Time (milliseconds) and Total EI score (rho = 0.37, p<0.02), Inspection Time and Mood Regulation (rho = 0.36, p<0.03) and Inspection Time and Social Skills (rho = 0.37, p<0.02). As expected, there were various modest correlations among the sub-factors of the EI inventory itself. The primary implication from this data is that as overall total EI scores rose, so did participants' inspection times; i.e. individuals with relatively greater EI scores required longer stimulus presentations to make accurate judgements of the stimuli.

Table 5 : Summary of Significant Correlations for Emotional Intelligence and IQ.

		TotalEI	Mood Regulation	Appraisal	Social Skills	Utilisation	NART_IQ	AH5_1	AH5_2
Mood Regulation	rho	0.73							
	p	0.001							
Appraisal	rho	0.63	0.23						
	p	0.001	0.16						
Social Skills	rho	0.75	0.36	0.27					
	p	0.001	0.02	0.10					
Utilisation	rho	0.53	0.60	0.20	0.24				
	p	0.001	0.001	0.23	0.14				
NART_IQ	rho	-0.22	-0.39	-0.01	-0.13	-0.30			
	p	0.18	0.01	0.94	0.44	0.06			
AH5_1	rho	-0.36	-0.18	-0.38	-0.36	-0.22	0.32		
	p	0.02	0.28	0.02	0.02	0.18	0.04		
AH5_2	rho	-0.11	-0.08	0.03	-0.19	-0.23	0.40	0.64	
	p	0.51	0.62	0.85	0.24	0.17	0.01	0.00	
AH5_Tot	rho	-0.25	-0.16	-0.13	-0.31	-0.28	0.36	0.84	0.92
	p	0.13	0.34	0.42	0.05	0.09	0.03	0.00	0.00

Table 5 summarises the correlations between the EI factors and the IQ measures employed. AH5 section 1 scores were significantly correlated with Total EI scores, showing a modest negative relationship (rho = -0.36, p<0.02), NART IQ was significantly correlated with Mood Regulation scores (rho=-0.39, p<0.01) and Utilisation of Emotion Scores (rho = -0.30, p<0.06).

These results indicate that overall, as IQ rose, total EI values fell (irrespective of the significance levels achieved). When divided into the IQ-score sub-groups described in the ERP Data section (i.e. individuals with <36 and >46 points on the AH5 total scores), there were no significant differences between the high- and low-IQ scoring groups on any of the EI measures (Total EI U= 80.5, p=N.S., Mood Regulation U = 76.5, p=N.S., Appraisal of Emotions U = 86.5, p=N.S., Social Skills U= 82.5, p=N.S., and Utilisation of Emotions U = 77, p=N.S.).

ERP Results

ERP averages were computed for each subject's cumulative epochs for correct responses to happy- and neutral-face stimuli. Participant's AH5 total scores were used to approximately separate the upper and lower thirds of the group (16 individuals with less than 36 points, and 14 individuals with greater than 46 points). Grand average ERPs from these two groups of individuals were created for each stimulus type, resulting in four charts ((i) high- and (ii) low-IQ for happy-faces stimuli, and (iii) high- and (iv) low-IQ for neutral-face stimuli.).

Regions of interest for subsequent analysis were identified using global field power; a graphical representation of the standard deviation of the waveform from all recorded channels (Lehmann and Skrandies 1980). ERPs are considered to be an "almost synchronous" (Lehmann and Skrandies 1980) summation of dipolar changes in voltage from "sizeable" populations of neurons (Rugg and Coles 1995). Such synchronisation, summation of voltage changes, and physical orientation of neurons themselves are necessary in order for a "closed" electric field to be detected at the scalp. Rugg and Coles (1995) stated that ERP recordings undoubtedly capture only a small amount of overall brain activity, however, this synchronisation and summation of potentials fundamentally permits the use of ERPs as dependent measures – the field which is detected at the scalp is considered strongly related to the activity of the brain at the time of exposure to the target stimuli. When populations of neurones summate, the field at the scalp is "maximal", and can be used to describe the "occurrence times of evoked potential components" (Lehmann and Skrandies 1980) – i.e. the areas of the waveform showing the greatest field power, or as Lehmann and Skrandies (1980) describe it, "relief" or "hilliness" of the resultant ERP. When voltage changes are pronounced across the electrode montage, the obtained GFP value is similarly large, indicating a potential region of interest in the waveform.

Global Field Power

Global field power, as a measure of the root mean square of voltage differences across all electrodes at each recorded moment (or sample) in the epoch, is one of several measures in determining notable areas of change over time within the waveform which may vary according to experimental conditions and task demands – i.e. ERP deflections. Lehmann and Skrandies (1980) generated the formula :

$$GFP = \sqrt{\frac{1}{2n}\sum_{i=1}^{n}\sum_{j=1}^{n}(U_i - U_j)^2}$$

The computation of GFP using the above formula is a standard function of the EDIT 4.3 software. GFP plots were created from the grand average waveforms for the high- and low-IQ groups for each stimulus type. These four GFP plots were then overlaid, and areas where the waveforms showed concurrent peaks were highlighted as potential regions of interest. The beginning and end points of these concurrent peaks were defined as **the time-stamp in milliseconds after stimulus onset where all six waveforms converged or neared convergence prior to and after a major peak.**

Figure 1 shows the GPF plot for the present study :

Figure 1 : Global field power plot across conditions.

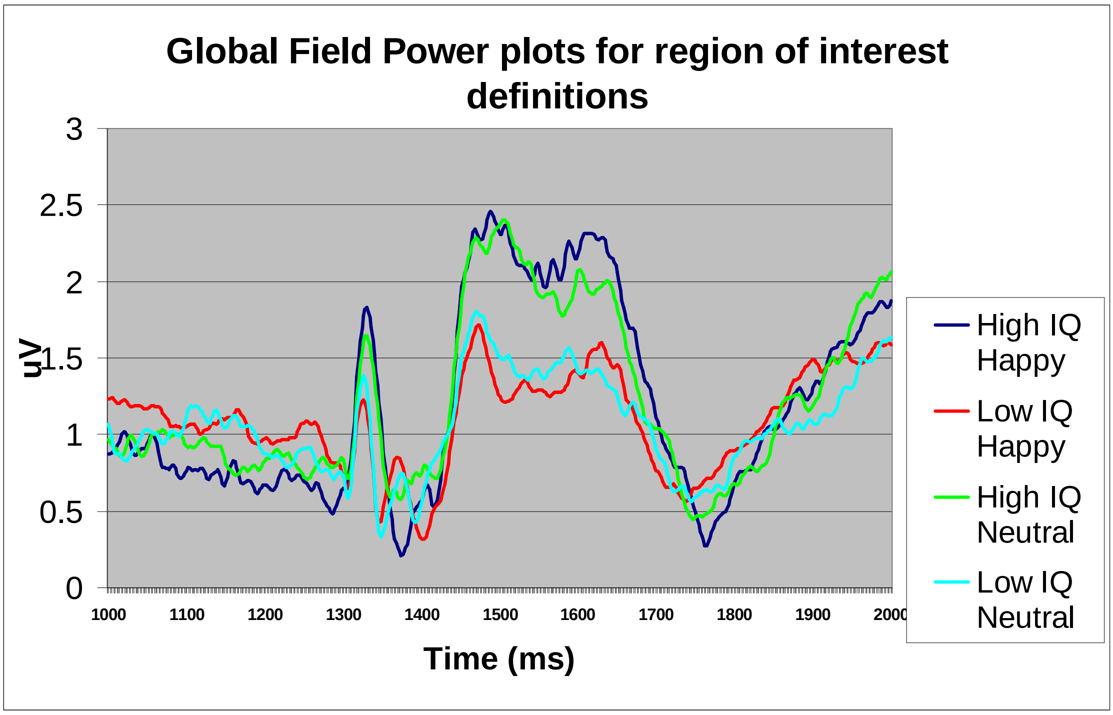
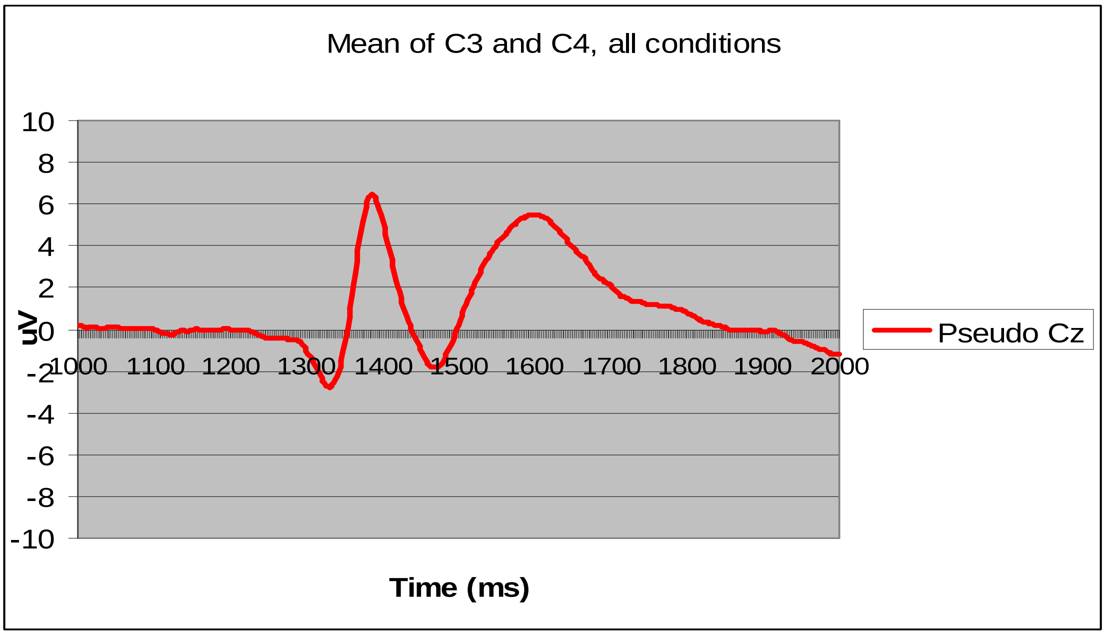


Figure 2 : Illustrative Grand Average ERP of Channels C3 and C4



From the GFP plot, peaks and troughs represent regions of maximal summation and change during the recorded epoch, and are therefore likely to represent deflections or components worthy of analysis. Figure 1 shows the GFP plot obtained from the present data set, whilst Figure 2 shows an exemplary ERP grand average for comparison. Major deflections in Figure 2 are also approximately concordant with GFP deflections in Figure 1.

For the happy-face stimuli, the first region of interest was deemed to be the region spanning 1304-1356ms. A second region of interest was deemed to span the region between 1416-1744ms.

For the neutral-face stimuli, two similar regions of interest were also found. The first region spanned 1308-1364ms. The second region of interest was defined as spanning 1434-1686ms. When all six waveforms were plotted concurrently, two overall regions of interest were defined as the points between **1306-1358ms**, and **1432-1732ms**.

Figures 3 and 4 show grand average ERPs from all participants across both conditions :

Figure 3 : Grand Average ERP, all participants, happy stimuli.

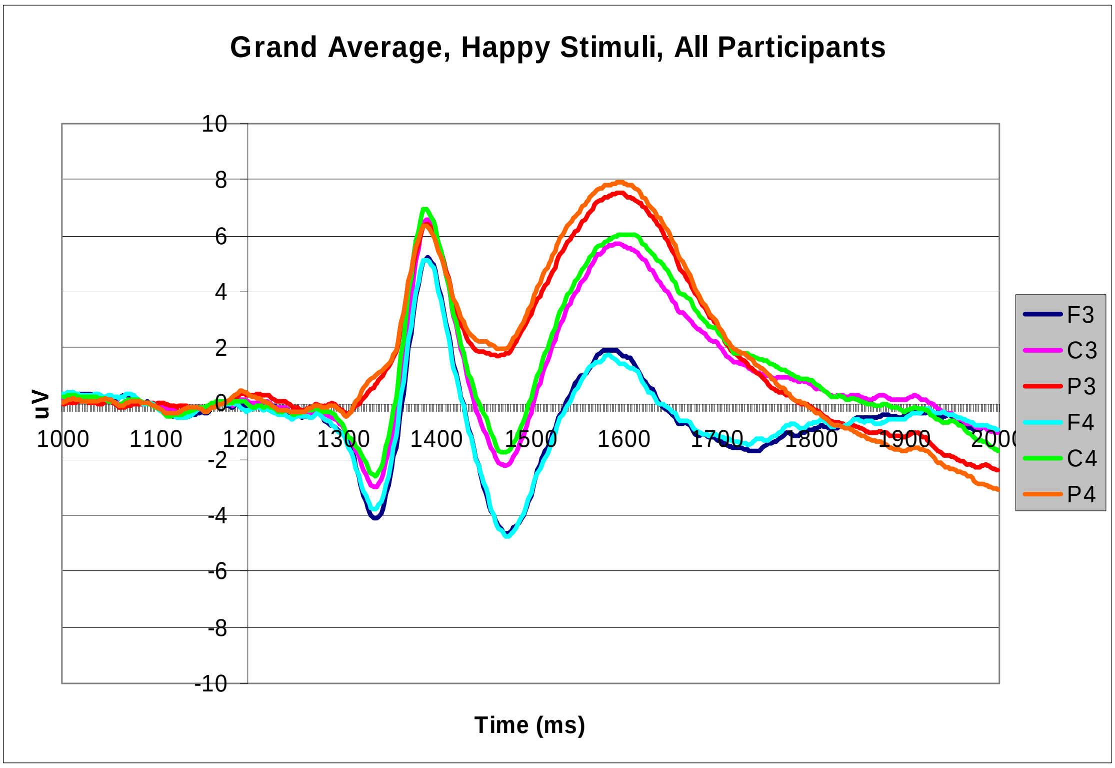
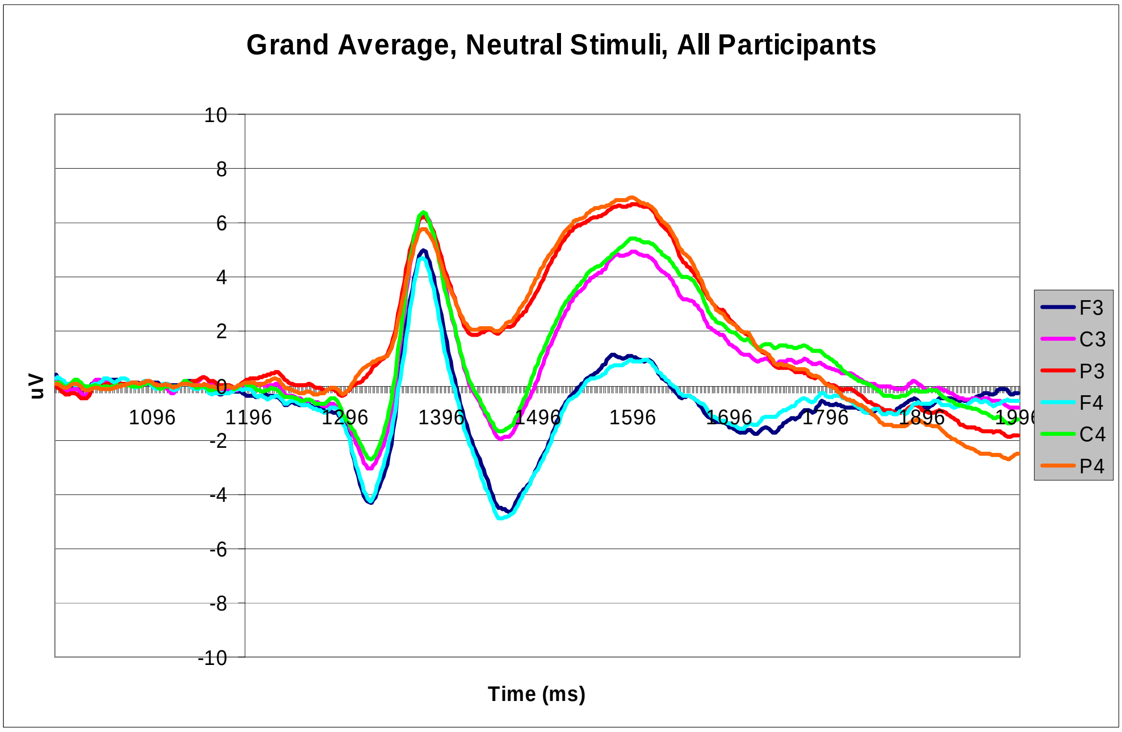


Figure 4 : Grand Average ERP, all participants, neutral stimuli.



As expected, both grand average ERPs displayed the prototypical morphology of a face-response ERP, including a late positive deflection typical of a P300. The negativity present in the region at approximately 260ms post-stimulus (1460ms) is likely to be the N170 response to the use of faces as stimulus items. The ERP amplitude is clearly differentiated at the 6 electrode locations, ascending in amplitude from the frontal sites, through the central locations, and achieving their largest values at the parietal sites. Prominent amplitude separations are present at approximately 1570ms, during the P300 region. Figures 5, 6 and 7 plot both emotional conditions in pairs.

Figure 5 : Grand average for frontal electrodes.

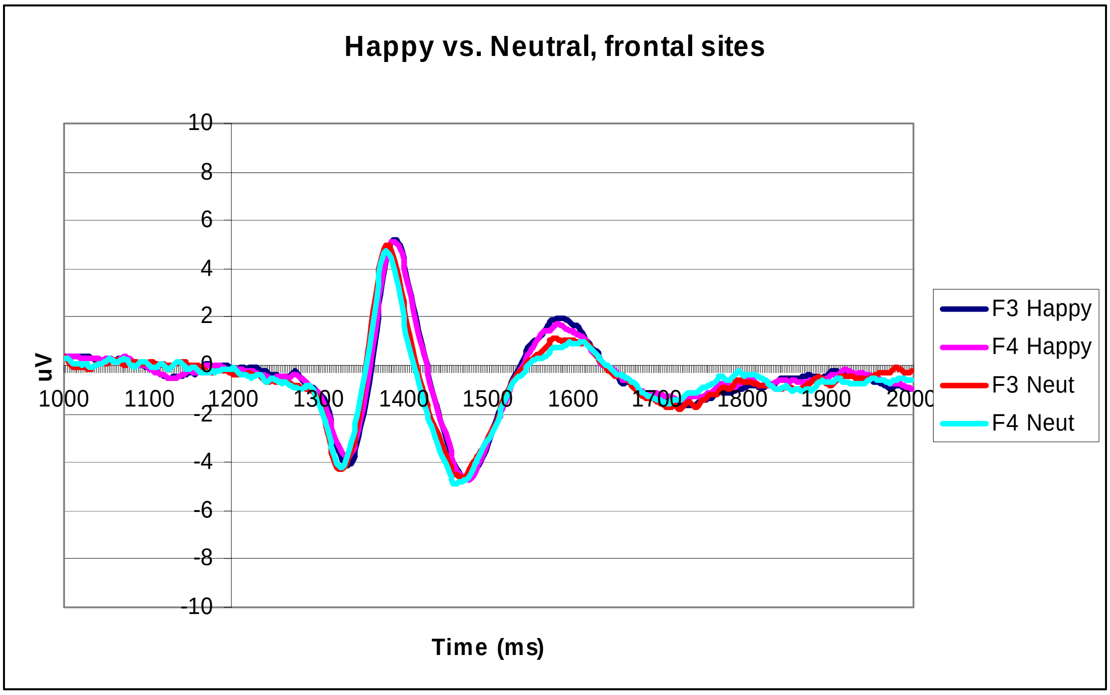


Figure 6 : Grand average for central sites.

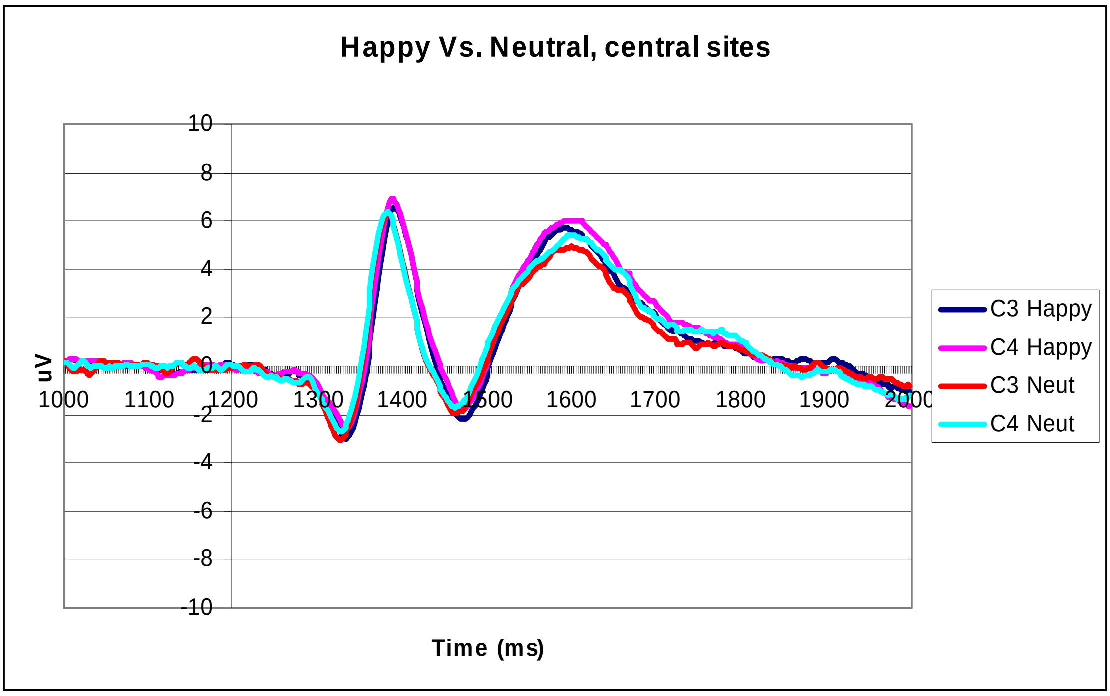
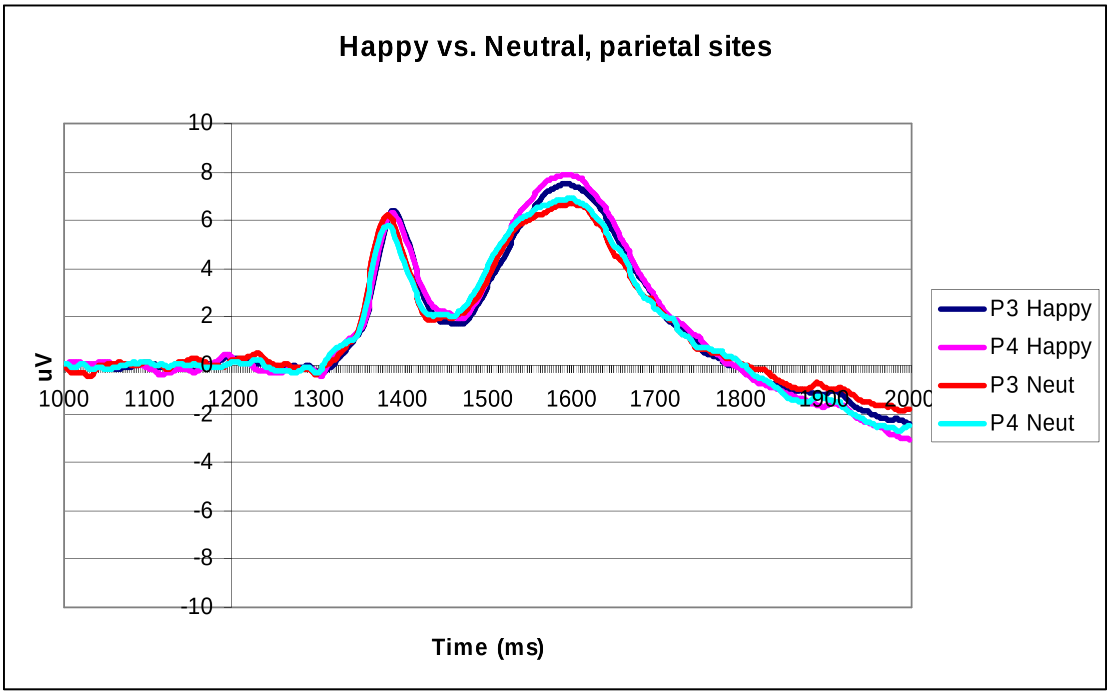


Figure 7 : Grand Average for parietal sites.



All of the waveforms were highly conformal within their scalp locations, with considerable overlap in the plots across both conditions; latency effects do not appear to be noteworthy at the level of visual inspection. Differences in amplitude, however, were prominent, and always reflected higher amplitudes for the happy conditions.

Statistical Analysis of ERP Data and Area Under The Curve

The ERP data was analysed using area under the curve (AUC), amplitude, and by gradient for a sub-group of 30 participants for the area described by both regions of interest. Area under the curve (using trapezoidal estimation) was chosen as it is able to represent both the duration and amplitude of electrical activity within the regions of interest by a single value, providing a more efficient means of analysis for this, and subsequent larger-scale studies (e.g. see Fabiani, Gratton and Federmeier 2007; precedence for AUC measures is also shown in Puce et al. 1999’s N170 face-ERP work.). Contemporary recommended methods of specifically latency analysis are highly cumbersome and subjective (and thereby no longer strictly objective), requiring individual scrutiny of all waveforms for values, making latency analyses unsuitable for studies featuring large participant populations and / or numbers of conditions. As AUC measures subsume duration and amplitude in a single measure, latency data is incorporated at the level of individual DVs across conditions, without requiring extensive attention to every individual's data.

Trapezoidal estimation of area under the curve in the present series of studies was calculated by applying the following formula to each amplitude value in sequence within the regions of interest :

$$[(a2-a1) * (b2+b1)/2]$$

-Where :
(i) a1 and a2 = x-axis values (time in ms)
(ii) b1 and b2 = y-axis values (amplitude of the wave in μV)

Within the present dataset, the difference between any two consecutive points on the x-axis was a constant 2ms (i.e. [a2-a1]), while the sum of any 2 consecutive points on the y-axis represented the cumulative amplitude of the wave over that time period (i.e. [b2+b1]). An example of a series of AUC calculations is provided :

=(2)*(I657+I656)/2
=(2)*(I658+I657)/2 etc.

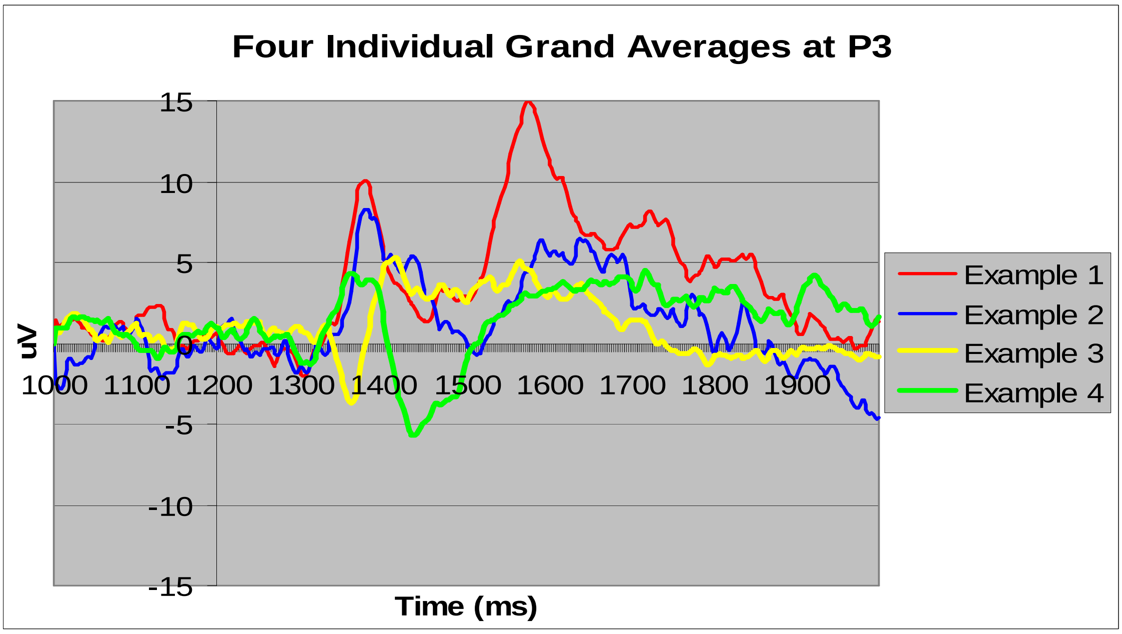
Essentially, the AUC was calculated in 2ms-long "strips" of wave amplitude, in a point-per-point manner for each data point (i.e. cell) within the regions of interest, representing the average height of the wave (or mid-point of a trapezium) at each time point.

The final DV for each individual was the sum of the area calculations within each region of interest, per electrode channel and condition. Depending on the specific variables under test, the obtained values for AUC could be, and frequently were large owing to these final summations, but importantly, they are as logically valid as any other transformation as a measure of individual differences. For example, a mean amplitude calculation would generate an "arbitrary" value representing the central tendency of the amplitude over an epoch, rather than e.g. a literal data-point corresponding to an actual value from an epoch. In this way, AUC is conceptually not dissimilar to mean amplitude, nor any other transformation producing an “arbitrary” summary variable – e.g. z-scores or percentages. AUC, however, subsumes measures of wave height, and onset time / component duration within the AUC calculation.

Although the typical unit of measurement for area under a curve is expressed as a squared value (e.g. “cm^2”), the calculation here creates a measure of units “μV x Time”. Thus, AUC is a signed value which can be either positive or negative depending on the summed polarities of the deflections within any region of interest. The possibility arises that the [(b2+b1)] amplitude calculation will varyingly add or subtract some combination of positive and negative values as a result of differing polarities between individuals’ amplitude values within the region of interest. However, because the final DV is no more or less artificial than any other transformation, the nature of the final value nonetheless remains a mathematically pre-defined reflection of individual differences in waveform amplitude over time. i.e. The magnitude of the AUC will be determined by a measure reflecting the sum of the deflections within an epoch.

Latency onset analyses were not conducted upon this dataset per se, although Luck (2005) states that AUC measures, although not directly comparable, can be used as a means of reducing latency “jitter” – i.e. individual trial-to-trial variability in latency onsets within individuals . A full latency analysis requires individual scrutiny of all participants’ individual grand average waveforms to determine values per region of interest and condition, where an amplitude analysis does not. In the present series of studies, this does not appear warranted from the highly overlapping nature of the group grand averages (figures 3–7). i.e. The grand average waveforms show prominent differences in wave amplitude, rather than obvious visual differences in onset timing. Latency analyses are also complicated by their inherently subjective nature, given that each waveform must be individually examined. Figure 8 illustrates the subjectivity in latency analysis of ERP waveforms.

Figure 8 : Sample individual averages, happy stimuli at P3 site.



Although the group grand average ERPs in the present study are clearly modulated, individual ERP averages typically show great variation. Figure 8 shows the grand average at the P3 site for four randomly selected participants. Example 1 shows prominent P100, N170 and P200 deflections, while Example 2 shows clear P100 and P300 deflections. Examples 3 and 4, however, show visually different deflections, neither of which show more than one obvious component (Example 4 shows a slight, and long P100 peak, while Example 3 shows an N100 instead). Importantly, however, all four of these individuals, contributed to the sample grand average waveforms shown in figures 3-7, which were clearly modulated overall. For any sample population, scrutiny of individual averages shows great variation literally due to individual differences, making the determination of component onset in individual grand averages highly problematic for the majority of the data-set. If a deflection or component intended for analysis is not obvious, then the moment in time at which it commenced is at best arguable, leading to inherent subjective error in the associated values. Amplitude analyses, however, do not suffer from this issue as (i) components may be determined from the population sample GFP plots rather than individual examination and (ii) amplitude analyses are inherently reductionist by popular and published convention, reducing the overall activity over time to a single mean value across the epoch of the deflection under examination.

The data was analysed firstly for significant differences in area under the curve from the grand average ERPs using a 4-way ANOVA consisting of Gender (2) x Electrode Location (3) x Emotional valency (2) x Hemisphere (2), and secondly for gradient effects using 30 individuals from the original 42 to contrast High- and Low-IQ sub-groups. Within these two sub-groups, the data from seven individuals featured missing electrode channels due to an excessive presence of artefacts. Both the F3 and F4 channels were removed from four individuals, the F3 channel alone was removed from two individuals, and the F4 channel alone removed from one individual. In order to retain the remaining data from these individuals, mean values were created based upon the entirety of the 30 individuals' data set (i.e. all high- and low-IQ individuals) for the F3 and F4 channels, and this mean values was inserted into the missing data as a replacement. The missing data, however, comprised less than 8 data points for all 7 individuals.

Area Under the Curve

Analysis of Region of Interest-1

The dependent variable here is expressed as μV x Time due to the use of area under the curve (AUC). Effect sizes are provided for significant post-hoc contrasts using the ES correlation for t-values, $r_{Y\lambda}$ or $r_{contrast.}$ This value is computed using $r_{contrast}$□= □$[t^2 / (t^2 + df)]$ (Field, 2005).

(i) A main effect of electrode location was present in region of interest-1 (F(2, 80) = 8.638, $p<0.0001$). Post-hoc testing of this effect revealed a difference in comparisons between all central and all parietal electrode sites.

t(44) = -6.423, $p<0.0001$
-49.135 Central vs. 65. 672 Parietal μV x Time.
($r_{contrast}$ = 0.69.)

(ii) An interaction effect of Emotion x Location x Gender was present in region of interest-1 (F(2,80) = 5.347, $p<0.007$). This effect was examined by performing an ANOVA using a 2 x 3 design within data from each gender, testing for differences between the front, central and parietal sites under both the happy and neutral stimulus conditions.

Within only the sub-group of the male participants, a marginal effect of emotional valency arose from this analysis ($F(1, 20) = 3.862$, $p<0.065$) and was not pursued further. However, a significant effect of Electrode Location was present ($F(2,40) = 7.874$, $p<0.001$).

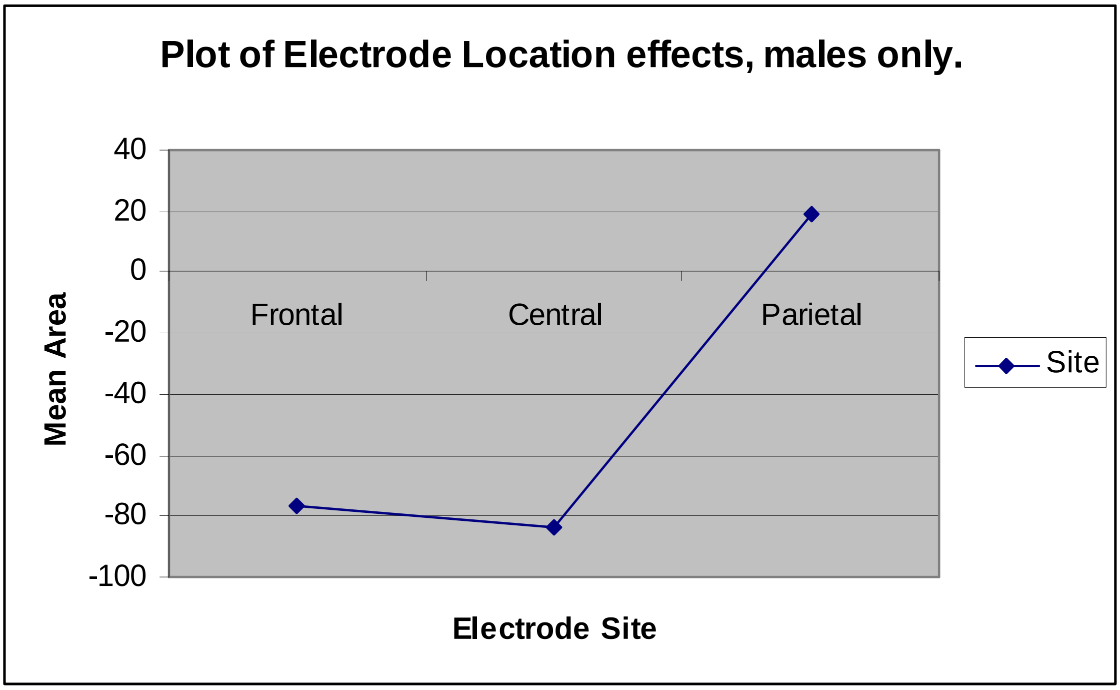
Post-hoc testing with the male participants showed that this effect was due to differences between the frontal and parietal sites :

$t(19)= -2.554$, $p<0.019$,
-76.732 Frontal vs. 18.681 Parietal μV x Time
($r_{contrast} = 0.5$)

Differences were also present between central and parietal sites :
$t(19)= -3.975$, $p<0.001$
-83.41 Central vs. 18.681 Parietal μV x Time
($r_{contrast} = -0.67$)

Figure 9 illustrates the difference in mean area under the curve for the 3 electrode locations.

Figure 9. Differences in AUC at all electrode locations, males only.



For female participants, an identical analysis was performed. A main effect of Electrode Location was present (F(2,40) = 3.891, p<0.029). As with the male participants, post-hoc testing showed the effect to involve the parietal electrode sites :

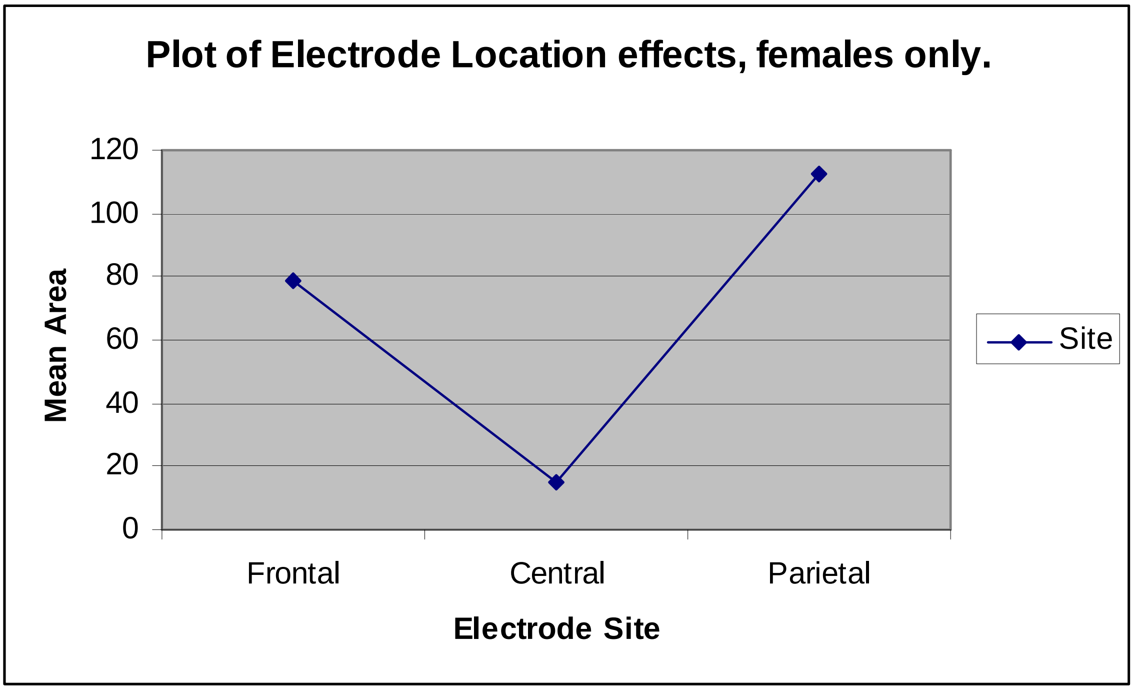
t(25) = -5.064, p<0.044

14.863 Central vs. 112.663 Parietal µV x Time

$r_{contrast} = 0.71$

As with male participants, the parietal sites for female participants evoked larger mean areas under the curve. Female participants, however, maintained a positive polarisation throughout region of interest-1 illustrated in Figure 5.

Figure 10 : Differences in mean AUC at all electrode locations, females only.



Additionally for female participants, an interaction of Emotion x Electrode Location was present (F(5, 100) = 3.561, $p<0.005$).

Post-hoc testing of this effect required multiple comparisons with a Bonferroni corrected significance level of $p<0.003$. Effects were again confined to the central and parietal sites :

Table 1 : Post-hoc comparisons for Emotion x Electrode Location interaction effect, females only.

Comparison	d.f.	t	Sig.	Mean Area	Effect Size ($r_{contrast}$)
Central, happy, vs. Parietal, happy.	25	-5.13	0.001	-21.832 105.603	0.71
Central, happy, vs. Parietal, neutral.	25	-4.808	0.001	-21.832 119.723	0.69
Central neutral vs. Parietal, happy.	25	-4.058	0.001	-7.894 105.603	0.63
Central, neutral, vs. Parietal, Neutral.	25	-4.850	0.001	-7.894 119.723	0.69

In all cases, mean AUC at the parietal sites were considerably larger than those at central electrode locations. These findings provide relatively little insight into the nature of the participant’s responses, however, and are more valuable in confirming the presence of the enhanced amplitudes towards the rear of the scalp which are characteristic of the presence of the P300 complex.

Analysis of Region of Interest-2

Two main effects and two interaction effects were present during this region of interest. AUC values for region of interest-2 were larger than those values in region of interest-1 due to a prominent and sustained late positivity spanning 1432-1732ms. Inter-regional differences were not compared for this reason; within AUC calculations, increases in a single dimension can result in large increases in overall area itself.

(i) An initial main effect of Emotion was present ($F(1,40) = 5.372, p<0.026$). Comparisons of all happy and all neutral stimuli across all electrodes showed a significant difference in the mean area under the curve represented by these conditions ($t(41) = 2.247, p<0.030, r_{contrast} = 0.33$). Happy stimuli evoked a significantly larger mean area under the curve than did neutral stimuli (1053.62 vs.

882.72 µV x Time), effectively differentiating between the emotional stimuli - a main aim of this series of studies. Specifically here, the presence of an emotional expression generated a larger and more sustained deflection than an absence of expression (a neutral expression.).

(ii) As with region of interest -1, a main effect of Electrode Location was also present during region of interest-2 – F(2,80) = 26.904, p<0.0001). Post-hoc testing of this effect found that the mean areas under the curve at the frontal, central and parietal electrode locations were all significantly different from each other. Table 2 shows that parietal sites evoked the greatest sustained amplitudes.

Table 2 : Post-hoc analysis of Electrode Location main effect.

Comparison	d.f.	t	Sig.	Mean Area	Effect Size ($r_{contrast}$)
Frontal vs. Central	44	-3.262	0.001	495.09 979.48	0.44
Frontal vs. Parietal	44	-5.65	0.0001	495.09 1429.96	0.64
Central vs. Parietal	44	-7.03	0.0001	495.09 1429.96	0.72

(iii) An interaction effect involving participant gender was present in region of interest-2. An effect of Emotion x Gender (F(1,40) = 3.639, p<0.064) was present. Within male participants, a significant difference was present in mean area between overall happy and neutral stimuli

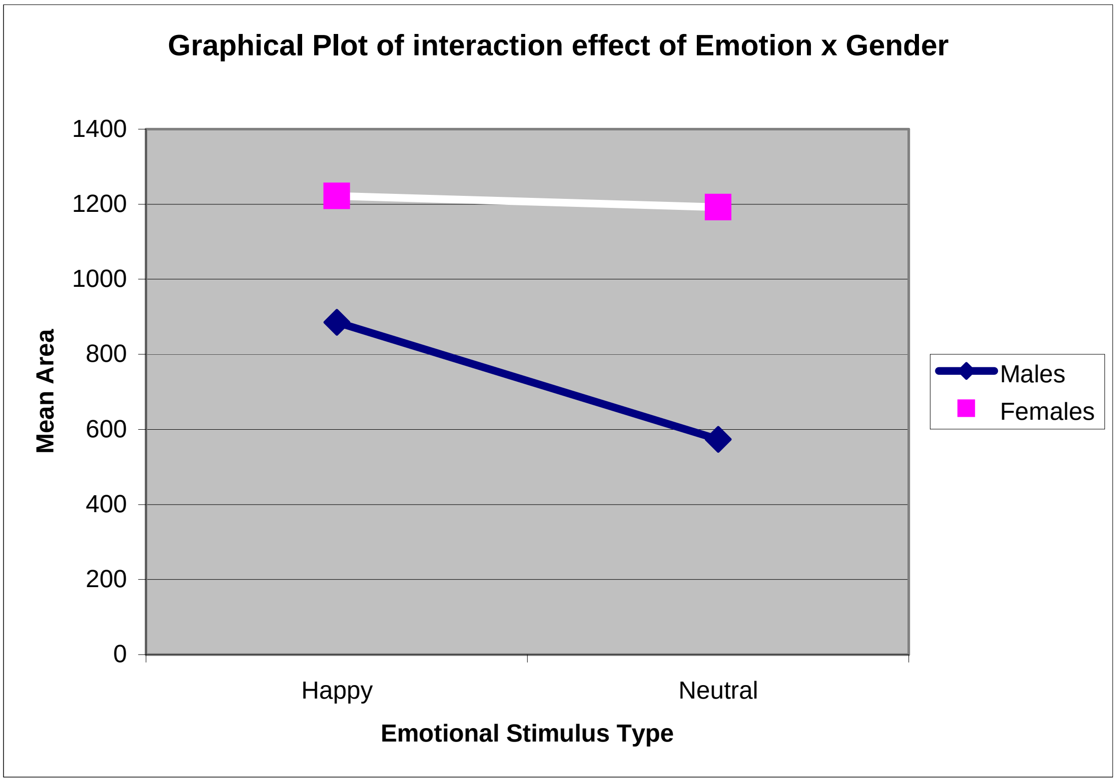
t(19)=2.591, p<0.017

885.07 Happy vs 573.51 Neutral µV x Time

$r_{contrast} = 0.51$

Female participants, however, did not show this effect (t(25) = 0.354, p = N.S.), although the mean area values for happy (1222.16 µV x Time) and neutral (1191.93 µV x Time) followed a similar pattern to that found in male participants. In both cases, mean area under the curve for happy stimuli was larger, as with the main effect of Emotion type, for happy-face stimuli. Female subjects showed a similarly larger overall mean area for happy stimuli, although this difference itself failed to achieve significance. Female participants did not display much differentiation between the emotional stimulus types in terms of differences in mean area. The effect is graphically plotted below in Figure 11 :

Figure 11 : Graphical plot of mean area values for male and female participants across emotional stimulus types in region of interest-2.



(iv) Lastly, an interaction effect of Electrode Location x Hemisphere was present (F(2,80) = 5.057, p<0.009). Post-hoc testing of left- and right-hemisphere electrode sites across the frontal, central and parietal locations revealed no significant differences (See Table 3) and were not pursued further.

Table 3 : Post-hoc analysis for Electrode Location x Hemisphere differences.

Comparison	d.f.	t	Sig.	$r_{contrast}$
Frontal, left vs. right	44	1.618	N.S	0.24
Central, left vs. right	44	-0.19	N.S	0.03
Parietal, left vs. right	44	-1.216	N.S	0.18

Gradient – IQ effects

Two gradient windows were identified using an alternative and simpler version of Caryl's (1994) rationale. Using the grand average for the C3 site, high- and low-IQ groups, happy and neutral stimuli, two windows spanning **1492-1548ms** and **1548-1608ms** were identified. Caryl (1994) adopted the technique of using "….the gradient of a straight regression line over a window…", Where the 32 ms boxcar window shifted in 2ms time-steps over the whole ERP. In the present study, this window was expanded to 56ms and 60ms in length, but confined to the region from where all concurrent plots crossed the X-axis, to the point where all four plots peaked and began to fall.

The gradient values of both regions of interest (1492-1548ms and 1548-1608ms) were analysed by Pearson's correlation for all participants, and employed only the High-IQ and Low-IQ groups (after e.g. Josiassen et al. 1988). Mean gradient values for the High and Low IQ groups are shown in Table 4.

Table 4 : Descriptive gradient values for High- and Low-IQ groups.

Value	Mean	S.D.
High-IQ, region 1 gradient	.0625	.0459
Low IQ, region 1 gradient	.0572	.0404
High-IQ, region 2 gradient	-.0175	.0241
Low-IQ, region 2 gradient	-.0029	.0485

Table 4 shows that gradient values within region of interest-1 and region of interest-2 for the High-IQ group were larger than equivalent values for the Low-IQ group. When analysing all high- and low-IQ participants, only window 2 showed an negative correlation between AH5 total scores and mean ERP gradient (Pearson's r = -0.317, p<0.044). Separate analyses of the high- and low-IQ groups yielded different findings.

Among the high-IQ group, effects were only present in gradient window 1 (1492-1548ms). Negative correlations with IQ were present here for overall mean gradient (r = -0.599, p<0.012), for happy stimuli (r = -0.512, p<0.031), and for neutral stimuli (r = -0.646, p<0.006).

Among the low-IQ group, correlations with IQ were only present in gradient window 2 (1548-1608ms). Negative correlations were present for overall mean gradient (r = -0.451, p<0.04), and happy stimuli (r = -0.488, p<0.027). No effects were present for the low-IQ group's exposure to neutral stimuli.

Examination of Incorrect Responses

A brief examination of the incorrect responses, via the lowest-scoring participants, was also conducted for interest. From the entire group, 10 individuals with the lowest number of correct responses were selected, and their areas under the curve for regions of interest-1 and -2 in response to happy and neutral stimuli for correct and incorrect responses were compared. These 10 individuals possessed at least 90 incorrect behavioural responses, or an error rate of approximately 35%. An examination of these low-scoring individuals, however, has an inherent theoretical problem for which it is difficult to compensate; specifically, the causes of incorrect responses are likely to be heterogeneous in origin, whilst the causes of correct responses are likely to be fewer in number. Some potential examples and explanations of errors are listed :

(i) A strictly behavioural error of physical movement - i.e. the wrong response key was pressed accidentally when the correct response was known to the participant.

(ii) A “genuine” error, where the perception of the stimulus itself was simply incorrect at a basic level; e.g. a happy face, for whatever reason, was mistaken for a neutral face, or vice versa.

(iii) A more persistent error related to the participant being in possession of an erroneous prototype or schema of the stimulus class. Although the stimulus faces were independently rated in the previous study for the presence of the expression they purportedly displayed, a small percentage of raters nonetheless disagreed with the majority. Some participants may also have possessed such an erroneous concept of the stimulus class, resulting in performance errors.

(iv) An error in perception related to the duration of the stimulus type; i.e. when the participant viewed the stimulus, it was fundamentally displayed at too brief an interval for a correct appraisal to be made.

There are likely to be other potential explanations for the presence of incorrect responses, and of the suggestions listed here, perhaps only item (iv) could be accounted for through the use of stimulus duration as a covariate in analyses. In short, however, the reasons for incorrect responses are numerous, while there are potentially fewer and simpler explanations as to why a participants’ response could be correct. Generally, correct answers are assumed across a wide variety of experimental methodologies to indicate that either the task demands were met appropriately, or, potentially, a guessed response was correct. i.e. Instead of pressing the incorrect response key, the participant accidentally pressed the key corresponding to the correct response. Such errors in the participant’s favour are equally difficult to compensate for, or identify.

Table 6. Analyses of area under the curve for correct vs. incorrect responses.

Analysis	Emotion
ROI-1, Happy	F(1,9)= 0.66, p=N.S.
ROI-1, Neutral	F(1,9)= 0.018, p=N.S.
ROI-2, Happy	F(1,9)= 0.002, p=N.S.
ROI-2, Neutral	F(1,9)= 0.133,p=N.S.

(Region of interest abbreviated to "R.O.I.")

Although main effects remained present between different electrode sites, more importantly, no significant differences were attributable to the emotional valency of the stimulus items when comparing waveforms from correct and incorrect responses. This data, however, is presented along with considerable caveats in its interpretation, and was not considered as an issue worthy of further exploration in subsequent studies. Here, essentially, no differential effects of the main stimulus manipulation can be detected.

Discussion

As an initial ERP acquisition during an emotional and facial-IT task, the present methodology has been successful in several regards. To the best of my knowledge, this study constitutes the first emotional inspection time task to feature a concurrent ERP recording, and successfully confirm the application of the methodology by replicating the expected negative relationship between IQ and IT. The task also generated an ERP commensurate with expectations, which showed statistical differentiation among the stimulus categories. In the case of region of interest-2, these differences were attributable to the emotional valency of the target stimuli. Effect sizes among post-hoc contrasts ranged from 0.27 to 0.72, indicating moderate to large effects (Field, 2005, Cohen 1992), and affirming the usefulness of a large subject population for an ERP study.

The behavioural and psychometric results of the task were successful in most respects, although difficult to directly equate with findings from Austin (2004) and (2005) owing to differences in the tested dependent variables. The tested population showed no gender differences across IT scores, AH5 scores, or SREIT measures, which simplified these analyses, although gender differences are sometimes present in EI studies (e.g. Austin 2005). In contrast to Study 1, the mean inspection time for this task was substantially longer; an increase from 38.39ms to 121.6ms when identifying facial expression versus gender. This potentially indicates differences in the rapid appraisal of gender and emotional expressions. As Austin's (2004) and (2005) studies concentrated on error rates rather than inspection times, there is no other information with which to compare this. Some information exists from a summary of ERP studies (Palermo and Rhodes 2007) regarding ERP latency responses to emotional faces, although these measures are not directly comparable to behavioural IT, and show considerable variation across studies.

The present psychometric findings showed several phenomena. The NART and AH5 showed significant associations with each other, and each test individually showed similar negative relationships to (albeit different) aspects of the SREIT scores. With regard to the typical findings from other IT studies, the task appears to have been broadly successful in this regard. Moderate negative correlations were present between individual inspection times and total correct responses, as well as negative correlations between IT and IQ measures. The population therefore showed the expected relationship between rapid apprehension and heightened IQ, broadly consistent with e.g. with Zhang, Caryl and Deary (1989a) and Caryl (1994). However, the negative associations between IQ and SREIT scores imply a different mechanism; as IQ rose, SREIT scores fell, or vice versa. Moderate positive correlations were present between overall EI and IT, and these two phenomena are not in accord with the notion of "speeded perception" implicit in non-emotional IT tasks.

Speeded perception of emotional stimuli was not involved in the expected manner here, as stimulus perception was slowed by higher SREIT trait scores. While the relationship present here between IT and EI here is neither illogical nor in accordance with precedence, it also does not imply superior rapid perceptual abilities for emotional stimuli among the higher-scoring EI group. Instead, an increasing SREIT score showed an overall tendency to require a longer period to make a judgement regarding the nature of the stimuli. Fittingly, increased SREIT scores were also associated with lowered IQ scores – as IQ scores rose, IT values and

SREIT scores fell. Possibly, an individual self-reporting higher EI traits requires or otherwise performs a more detailed examination of the stimuli before reaching a judgement, but, the examination of emotional stimuli was not associated with speeded perception or heightened intellect. Additional findings here also showed some results not found in Austin (2004); significant negative correlations were present between two sub-factors of the SREIT (mood regulation and utilisation of emotion) and NART full estimation IQ measures. These results are in accordance with the inter-correlations between the AH5 and NART measures.

The presence of the P300 complex in the ERP data is consistent with standard interpretations of the phenomenon. Polich and Kok (1995) broadly agree with Donchin’s interpretations, in stating that the P3 complex is known to be associated with “neuroelectric activity related to cognitive processes such as attention allocation and activation of immediate memory.”; in itself, this is a broad statement covering a multitude of cognitive processes, but importantly, task engagement is a pre-requisite. The P300 complex is an extremely prevalent phenomenon in cognitive ERP studies wherever stimulus identification and, importantly, the active performance of a task is required of the participant. Balconi and Pozzoli (2003) illustrated the phenomenon of the P300 in facial viewing in reverse, by showing ERPs recorded from a passive viewing of emotional human faces. When no task demands were required from the participants, while it is claimed that the N170 remained present, the ERP displayed a prominent lack of any consistent modulation, with only an isolated deflection being present at 230ms post-stimulus. In contrast, Pizzagalli et al. (2002) performed an apparently similar passive-viewing task using human faces as stimuli, and were able to evoke a P300 complex, despite there being no task required of participants at the time of viewing.

While there have been numerous past studies which have used human faces as stimulus items for ERP tasks, there do not appear to be any which are directly comparable to the present study, presenting some difficulties in interpreting the present, novel data. Palmero and Rhodes (2007) list 28 studies since 1999 which have used emotional human faces, of which 13 used ERP methodologies. Of these 13, only 1 study featured a primary comparison between emotional faces – Streit et al. (2000). Using 30 faces from the Eckman and Friesen facial affect set presented for 500ms each, participants were required to identify facial expressions. Streit et al. were also able to evoke a simple P300 complex, although the results presented focused on a discrimination between real and blurred human faces, rather than an overt discrimination between the emotional valency of the real faces. Palermo and Rhodes (2007) also state that differences were present between specific emotional valencies, although this information is not present in the Streit et al. source article. In that study, non-obscured faces evoked significantly higher amplitudes in the region spanning 180-300ms post-stimulus. Direct comparisons between the present study and Streit et al. are again problematic; in the present study, the presentation of the faces using the method of constant stimuli (MCS) makes the task substantially more difficult for participants, with half of the trials in the present study being presented at less than 50ms – less than one-tenth of Streit et al.'s constant 500ms stimulus presentation.

Visual inspection of the waveform obtained in the present study nonetheless showed deflections typical of the P300 complex; i.e. though the methodology was unique, the resultant ERP was not (morphologically) unique. The focus of the present analysis was not on face-specific components, but other statistical differences due to the emotional valency of the stimulus types; in region of interest-2, spanning the N170 to P300 components, statistical effects permitted a differentiation between happy and neutral stimuli, with larger and more sustained EEG activity present during exposure to the happy faces. Effect sizes between contrasts were also robust in this region. Perhaps importantly, however, this effect occurred when there was only a two-choice discrimination to be made in the task demands. At present, the effect related to the emotional valency of the face may be a confound of the nomenclature of the stimuli employed – i.e. while there is a main effect of emotional valence, it may also be simply another name for "stimulus discrimination between two categories which differed.".

Finally, the ERP data showed some effects similar to Zhang et al. (1989a)'s $P200_{T.}$ When sub-divided into high- and low-IQ groups, some gradient differences were apparent in regions of the ERP waveform per group. For the high-IQ group, gradient values were consistently higher, and significantly negatively correlated with AH5 score in a similar manner to the IQ-IT relationship, but only in the earlier gradient window (1492-1508ms). The relatively lower-IQ group showed gradient effects only in the second window (1548-1608ms), approximately 50ms later.

In summary, the initial ERP acquisition from this task has been successful in all regards. The expected phenomena from previous facial ERP and standard IT methodologies have been reproduced in most respects, although results were not “sweepingly” prevalent in all cases. Nonetheless, the task works well for the intended uses, and showed statistical effects related to the discrimination of emotional expression. The task will be modified for subsequent variations of the present study. The forthcoming study will examine a potential confound in the present methodology and its impact on the obtained data, with a view to increasing data collection in forthcoming studies. The current goal is to increase the number of emotional stimulus classes presented to further examine the discriminatory processes present, and to examine if the process of discerning emotional expressions can be characterised when the difficulty of the task is increased.

CHAPTER 7

Study 3

Comparison of EEG Waveforms arising from the use of face- and non-face masking techniques.

Introduction

The present study was intended to be a smaller-scale test of the previous methodology, with specific emphasis on the stimulus masking technique. In the previous study, and also in Austin (2004) and (2005), target stimuli were backward-masked by a neutral human face not in use as a target stimulus item. Although logical that the most appropriate image mask for a human face is another human face, the conventional line-IT task has shown methodological difficulties when using masking stimuli which were also other lines (Deary, 2000). The phenomenon of masking effects is compounded by the EEG/ERP methodology, which is highly sensitive to individual differences in participants' responses in ways which many other experimental methodologies, especially behavioural-only measures, are not – i.e. ERPs record "neural manifestations of specific psychological functions" (Fabiani, Gratton and Federmeier 2007, p85). The responses evoked from participants are therefore critically dependent upon all aspects of the stimuli and their manner of presentation, and otherwise small methodological changes may result in, at least, visual differences in grand average waveforms with concomitant statistical repercussions which may not be apparent in solely behavioural studies.

The present study has three principal aims :

(i) An evaluation of the effects of using neutral human faces or non-face images as backward-masks on grand average ERPs. The use of another human face as mask may generate an effect in itself which it may be desirable to avoid in future studies. Photographs of human face images naturally possess different contours and outlines which may generate a "contrast" effect when backward-masked, by rapidly adding or removing differences from an image, and in this way, make identification of salient features easier. In visual line-IT tasks, this phenomenon is known as "apparent motion", and is regarded as an influential confound in the inspection time methodology (Deary, 2000). The apparent motion effect is akin to the technique used in single-frame cartoon animation, where a sudden change in the shape or brightness of two successive, rapidly presented and visually similar images creates the illusion of movement in the target image. When apparent motion occurs, the backward masking technique serves the opposite purpose to its intention, and differences between the mask and stimulus become more obvious than intended. When apparent motion is easily noticeable by participants, the IT task fails to adequately measure inspection time itself (Mackenzie and Cumming 1986, Nettelbeck 1982, Egan 1994). Stough et al. (2001) suggested that IT as "a relatively pure measure of perceptual speed" still remains somewhat controversial as a concept, and the use of apparent motion cues in some situations may constitute a helpful strategy for participant success in IT tasks. Mackenzie and Bingham (1985) (in Stough et al. 2001) reported that the expected negative correlation between inspection time and IQ could be eradicated when apparent motion was perceived, whilst those who did not perceive apparent motion still manifest the expected inverse relationship between IT and IQ.

In the typical line-IT task, apparent motion cues can be minimised via the use of Evans and Nettelbeck's (1993) "flash mask"; a variant of the line mask with a "lightning-bolt" feature in the middle of each downward-pointing leg. Stough et al. (2001) reported that the standard mask still manifest apparent motion effects in their own study, whilst two alternative masks (a "flash" mask, and a third "lines" mask composed of multiple, dashed lines of varying lengths) both significantly reduced apparent motion. Apparent motion effects, however, were not completely eradicated no matter which method of masking was employed, and thus, the effectiveness of masking stimuli in IT tasks is highly important. An examination of the masking technique used is therefore worthwhile in variants of the IT task such as the present series of studies, although if the expected statistically inverse IT-IQ relationship is maintained, there is good reason to suspect that apparent motion effects have been attenuated. In the present study, the standard neutral-face mask type will be replaced by an alternative mask type, and any effects upon the ERP scrutinised.

(ii) A continuing examination of differences related to the emotional valency of stimuli. During the present study, participants will again be asked to identify the emotional expression from human faces. Although there will be slight methodological differences between this and other studies – principally, no variation in SOA between stimuli in the present study - there nonetheless exists an opportunity to collect emotional face-response ERPs from the participants.

(iii) An attempt to replicate the grand average waveform from the previous study, and any related statistical effects. Although the timing parameters to be employed in this study will no longer use varying SOAs, the task demands and other parameters are otherwise identical to the previous study – although this task is intended to be simpler and easier for participants. Although it is expected that the ERPs will vary in response to the masks in use simply due to a different stimulation of the participants, if the methodology is otherwise sound, the general morphology of the ERP should remain consistent with that obtained in the previous study.

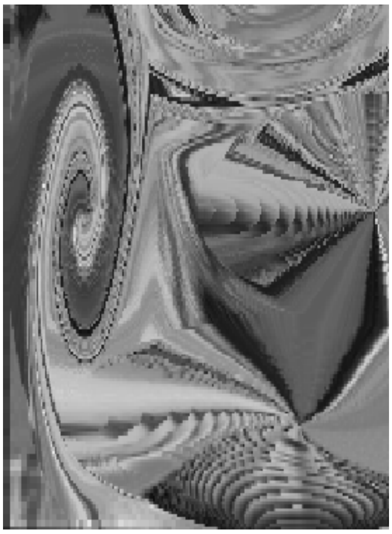
Methods

Participants

Five male (mean age = 26.4 years, S.D. = 3.6 years) and five female participants (mean age = 25.4 years, S.D. = 3.57 years) took part. The recruitment criteria for this study required all volunteers to be in a normal state of good health, and free from any conditions involving broken or sensitive skin on their scalp, face or forehead. Participants were required to have washed their hair either on the day of the test, or the night previously, and were asked to refrain from using any hair care products on the day of the test. No incentive payments were made to participants.

Materials

Thirty-two images of two male and two female individuals from Eckman and Friesen's Pictures of Facial Affect (1976) were rated by 13 males (mean age = 19.08 years) and 16 females (mean age = 21.44 years). These images individually showed emotional facial expressions of anger, disgust, happiness and sadness. When compared with Eckman and Friesen's original categorisations, the stimulus faces were reliably identified in accordance with the original categorisations; 90.74% of the items were identified "correctly", and the minimum no. of correct identifications was 73.21%. Three images of male human faces from were selected from the rated faces for use in the present study; two as stimulus items and one as a stimulus mask. The stimulus items featured the same male individual portraying a happy facial expression, and a sad facial expression. A single image of a different male face portraying a neutral facial expression was used as a mask. A "non-face mask" was then created by heavily distorting an image of the "stimulus" individual portraying a neutral facial expression, using the software utility Contort v.2.7 (www.graphicutils.com). This "non-face mask" was visually complex but unrecognisable as a human face, and as a distorted version of an existing stimulus, employed the same colour palette as the other stimulus items and mask (i.e. thereby controlling for stimulus luminance). This approach is similar to the non-face images employed by Kanwisher et al. 1997, although here, no attempt was made to preserve any individual facial features themselves. All stimuli, and both masks, were gray-scale images 350 x 275 pixels high (11.5cm x 8cm), subtending a visual angle of 9 degrees 31 minutes at 70cm distance from the screen. The stimuli and masks (for all studies) are presented in appendix 1**.** The presentation order of the stimuli was counter-balanced for quantities and then randomised. In total, participants viewed 64 faces with a happy expression followed by a neutral face mask, 64 sad faces with a neutral face mask, and identical numbers of happy and sad stimuli followed by the non-face mask. In total, 256 stimuli were presented, using an SOA of 80ms for all stimuli. The backward masks were presented on-screen for 500ms. The new non-face mask is presented below :



EEG recordings were accomplished using a Neuroscan NuAmps 7181 forty-channel amplifier and a Neuromedical Supplies forty-channel Quik-Cap sintered electrode cap. Data were recorded at a sampling rate of 500Hz, using linked and subtracted mastoid channels as a reference. Six scalp electrodes were used: F3, C3, P3, F4, C4 and P4. Vertical EOG was monitored between FP1 and an auxiliary electrode placed 2cm below the left eye. All sites were prepared using Neuromedical Supplies' Quik-Gel, and impedances were maintained below 10Kohms. The EEG recordings were band-pass filtered on-line between 0.1 to 30Hz. Raw EEG activity which exceeded 45µV on any channel was marked as containing artefacts and those trials were excluded from subsequent averaging. For each trial, the EEG recording epoch was 1980ms, with an initial 200ms baseline period.

Procedure

The EEG cap was fitted immediately, and impedances were monitored. Participants initially completed 10 practise trials, followed by the task proper. Each participant viewed the following instructions :

"When the experiment starts you will see an asterisk in the centre of the screen.
Look directly at the asterisk.

Next, a human face will be displayed briefly.
The first face will be covered up by a different image, then you will be asked to respond.

If the FIRST face you saw was HAPPY, press 1
If the FIRST face you saw was SAD, press 2
You should aim to be accurate rather than quick, so take as much time as you need to decide.

If you are not sure, guess.
There will NOT be any feedback during these trials.

Press spacebar to continue."

After each trial, the participant was prompted to respond with the following text :

"If the FIRST face you saw was HAPPY, press 1
If the FIRST face you saw was SAD, press 2"

Upon their response, another trial began. Participants were permitted to ask questions before commencing the full set of trials, and instructed that as far as possible, they should try not to blink or move in the seat wait until the response prompt was presented on-screen and the experiment paused. Once initiated, the stimulus presentation program presented a new trial only after the participant had responded, allowing them to determine the pace of the experiment. Every 32 trials, a 10-second rest break was automatically initiated, for a total of 8 breaks. Throughout the procedures, the experimenter was present in the room behind the subject and able to examine on-line averages as the trials progressed. For the first several trials, the experimenter examined the participants' pattern of blinking, and advised them if blinks were occurring at unsuitable moments. Each trial used the following sequence of events :

1 Trial begins.
2. Acquisition triggered.
3. Baseline period begins (100ms)
4. Blank screen (100ms)
5. Asterisk fixation point displayed (300ms)
6. Blank screen (700ms)
7. Stimulus presented (80ms)
8. Stimulus mask displayed (500ms)
9. Blank screen (200ms)
10. EEG recording ends.
11. Stimulus triggering reset.
12. "Respond Now" prompt displayed.
13. Subject's response triggers next trial.

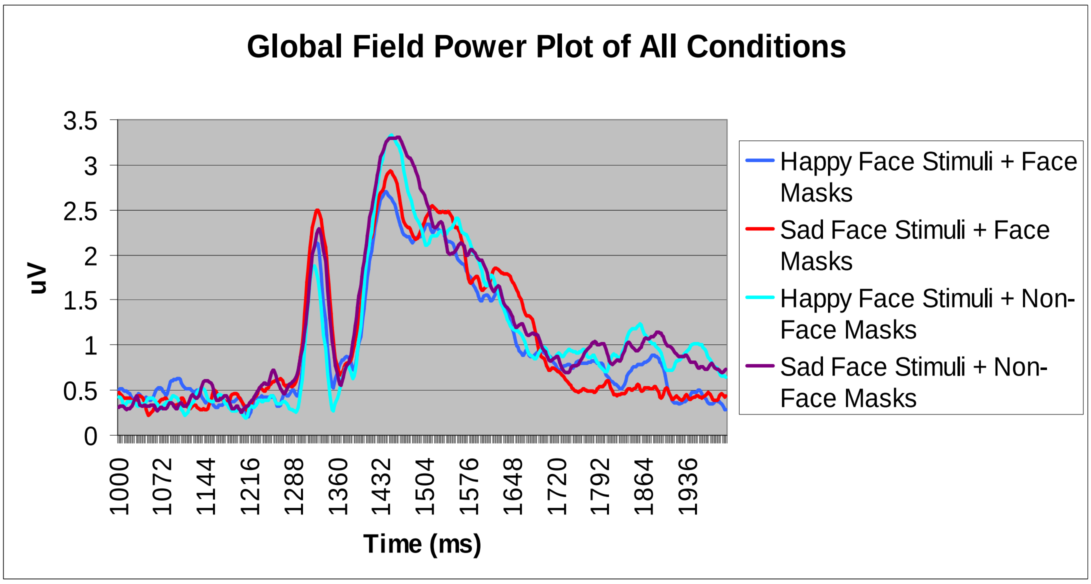
Results

As intended, all participants appeared to find the task very simple, with no participant obtaining less than 244 hits, a mean no. correct of 251.8, and an equivalent success rate of 95.3%. The extremely low participant error rate and "blink-reduction coaching" deliberately maximised the available ERP data and ensured that almost all trials were acceptable for analysis.

Data from all participants were screened for artefacts and errors in the manner described in the previous study, and grand average ERPs were produced for all participants with a baseline period of 200ms prior to stimulus presentation. Global field power (GFP) plots were produced and used to identify two regions of interest (Region of interest-1 and Region of interest-2) where GFP plots from all electrodes converged, rose to a peak, and converged again after the peak had subsided. For all analyses, the dependent variable under test was the area under the curve computed during each Region of interest (μV x Time). In all presented plots, the ERP baseline is present at 1000-1200ms.

Figure 1 illustrates the GFP plot for all conditions. Although in this instance the GFP plot itself resembles a grand average ERP, the GFP plot should not be mistaken as such.

Figure 1 :



Region of interest-1 was defined as the area spanning **1306-1376ms**.

Region of interest-2 was defined as the area spanning **1376-1696ms**.

Grand average ERPs are presented for all four experimental conditions in figures 2, 3, 4 and 5. Inspection of the waveforms shows that the main differences in morphology between the face-masked and non-face masked stimuli were present in the region beginning at approximately 1500ms. Both happy and sad face stimuli masked by another face showed a relatively flat region whose amplitudes did not exceed 6μV. For stimuli masked by the non-face image, however, a more prominent peak was present at approximately 1560ms. The contrast between the masking techniques is illustrated in figure 6.

Figure 2: Grand average for Happy stimuli with face masks.

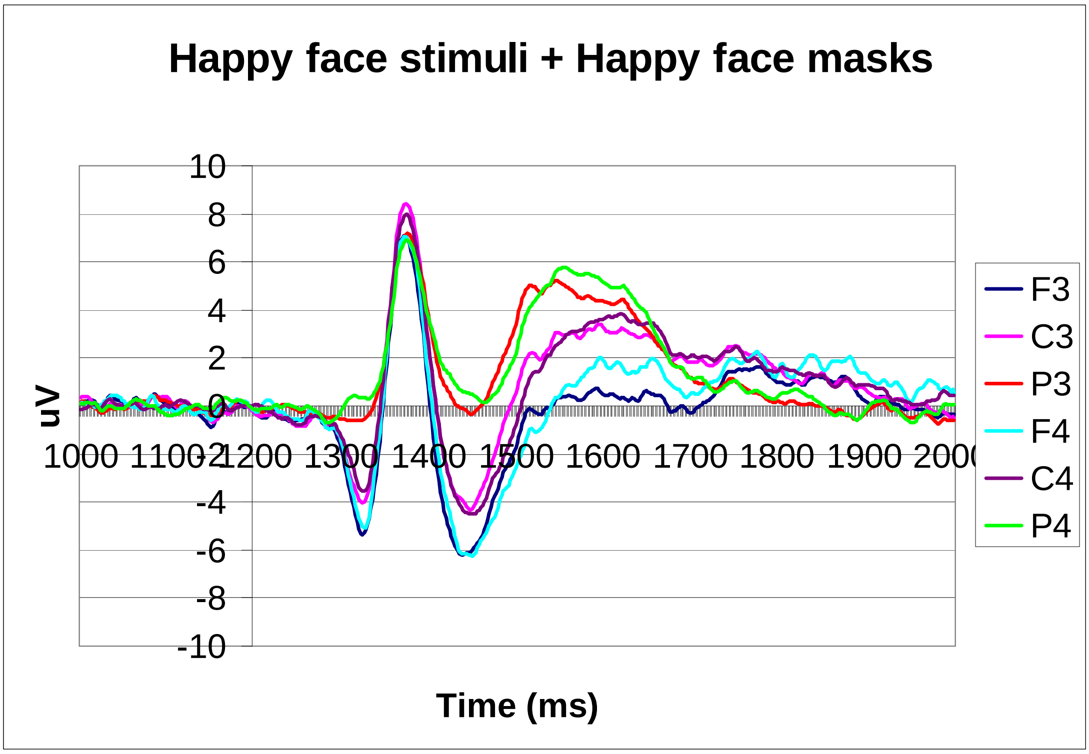


Figure 3: Grand average for Happy stimuli with non-face masks.

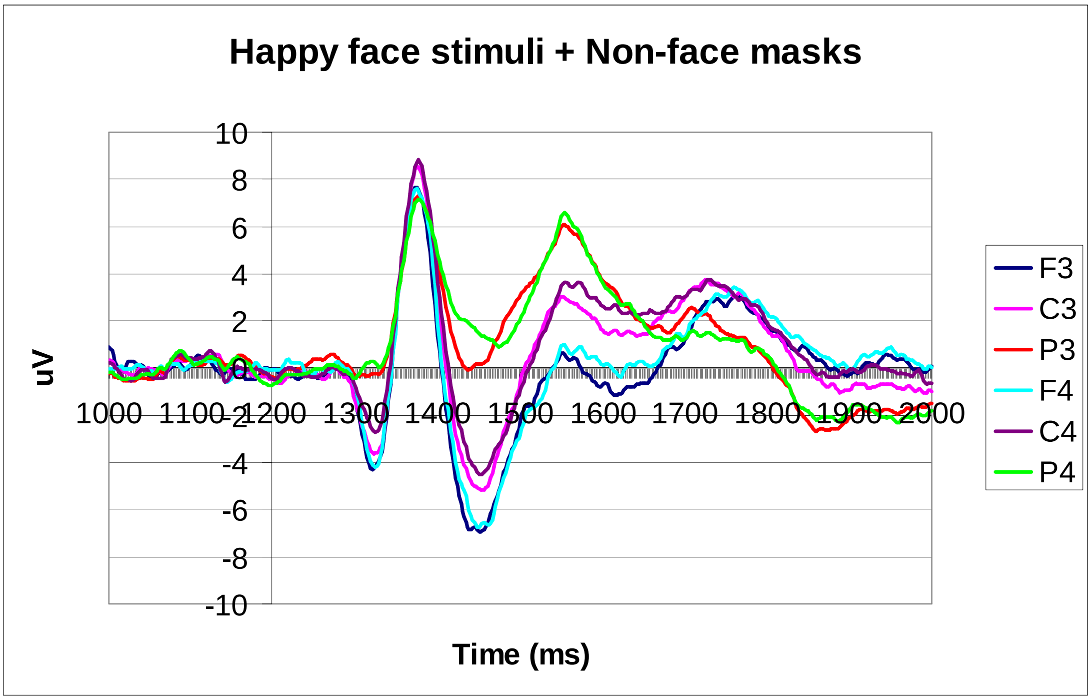


Figure 4: Grand average for Sad stimuli with face masks.

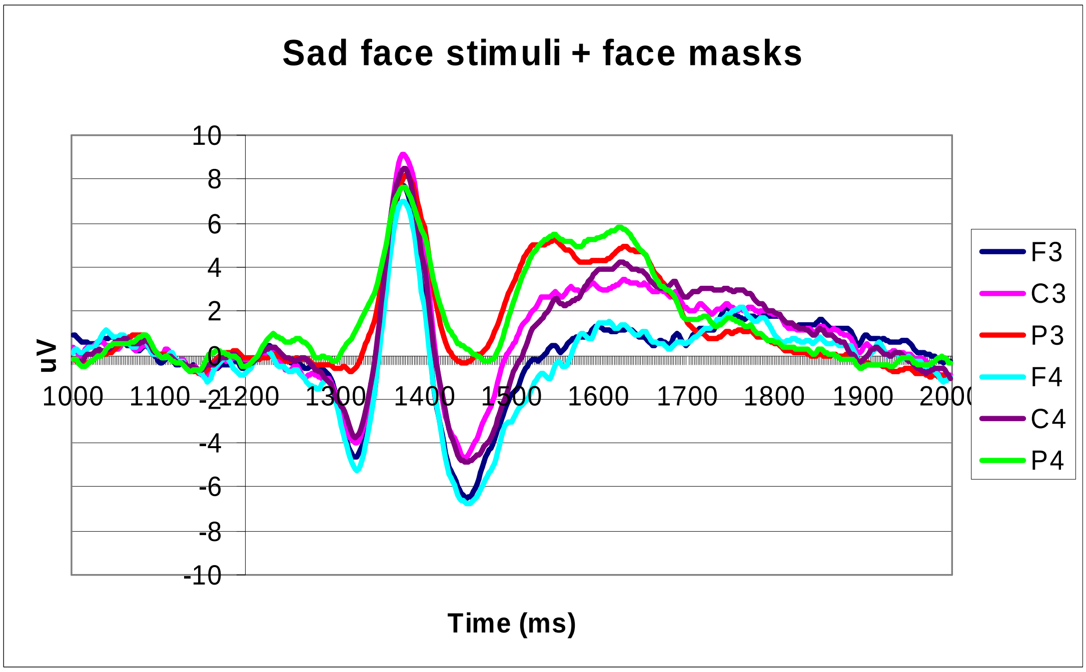
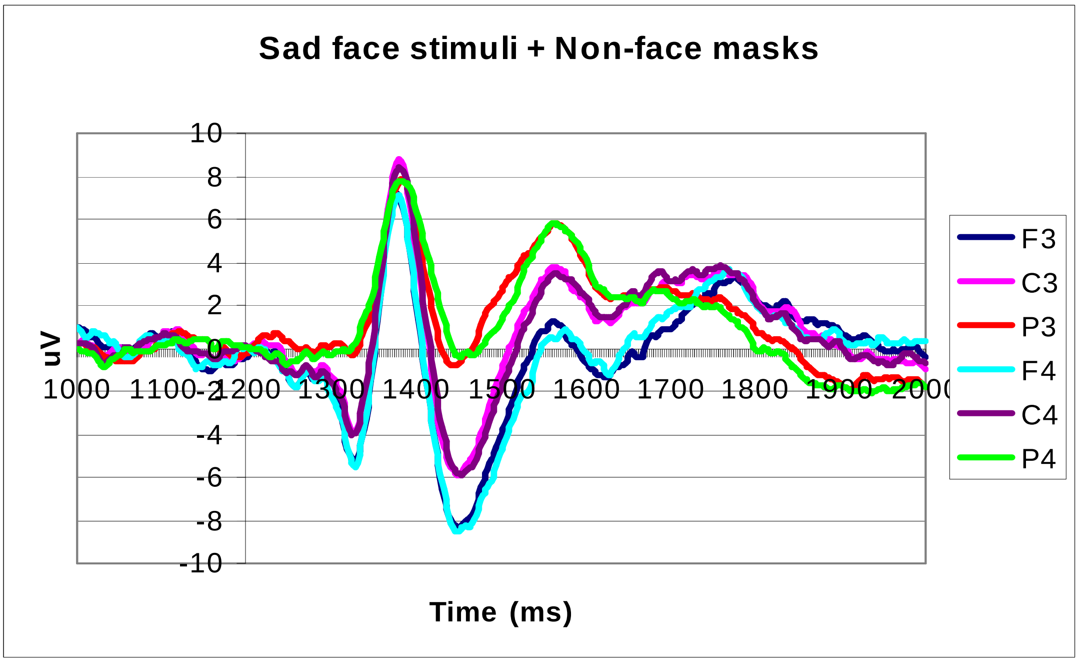


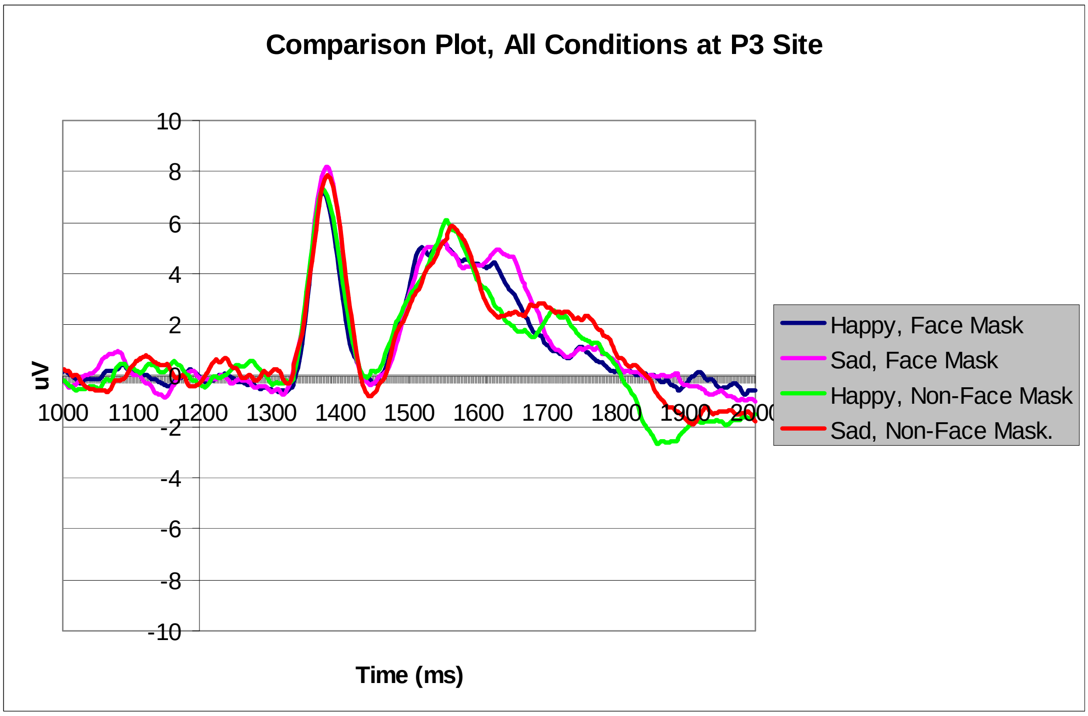
Figure 5: Grand average for Sad stimuli with non-face masks.



The waveform generated by this task again corresponded to a prototypical face-recognition waveform with a prominent P3 complex commencing at approximately 1500ms. Differences between the face-masked and non-face-masked waveforms were visually apparent, where the non-face-masked stimuli show a pronounced single peak at 1560ms, then a drop in voltage commencing at approximately 1580ms. In contrast, the face-masked stimuli showed a lowered-amplitude P300 with bifurcated peak, and did not show a voltage drop in the P300 region until approximately 100ms later, at approximately 1680-1690ms. As with the previous study, the parietal electrode sites consistently showed the largest amplitudes.

A comparison plot of all conditions at the P3 site is provided in figure 6 to illustrate the visual difference in waveforms.

Figure 6 : All conditions plotted at P3 electrode site.



The “plateau” region which contrasts the use of face and non-face masks is visually apparent in figure 6, spanning approximately 1500 – 1700ms.

The data was analysed by ANOVA, using Stimulus Type (happy and sad) x Masking type (face and non-face) x Rostral-Occipital Axis Position (F3 and F4 for frontal, C3 and C4 for central, and P3 and P4 for parietal sites), x Hemisphere (F3, C3, and P3 for left hemisphere, F4, C4 and P4 for right hemisphere) x Gender in a 2x2x3x2x2 design. Analyses for Region of interest-1 and Region of interest-2 were conducted separately, using area under the curve (μV x Time) as the dependent variable. Due to the smaller population size of this study (N=10), partial-eta^2 (ή^2) effect sizes were calculated for this study, as well as $r_{Y\lambda}$ (or $r_{contrast}$) values for post-hoc comparisons. The small scale of the present study also made a comprehensive amplitude analysis feasible, focusing on effects of mask type, emotional valency, and hemispheric lateralisation.

AUC Results for Region of interest-1

Two main effects were present in the early region of interest :

(i) A main effect of Rostral-Occipital Axis Position; F(2,16) = 5.399, p<0.016.

Post-hoc comparisons (chart 1) showed that parietal electrode sites displayed larger AUC than either frontal or central sites. This is consistent with the waveform effects noticed in the previous ERP study; waveform amplitude rose from the front to rear of the scalp, peaking at the parietal regions.

Chart 1 : Post-hoc comparisons for rostral-occipital axis position

Comparison	t	d.f.	Sig.	$r_{contrast}$	Mean μV x Time
Frontal vs. Parietal	-2.537	9	.032	0.646	-35.828 vs. 158.085
Central vs. Parietal	-2.502	9	.034	0.640	59.174 vs. 158.085

(ii) An interaction of Emotion x Rostral-Occipital Axis Position: F(2,16) = 8.247, p<0.003. Post-hoc comparisons of Happy vs. Sad stimuli within the frontal, central and parietal electrode sites revealed no further significant effects.

Effect sizes (ή^2) for results (i) and (ii) were moderate to large, at 0.403 and 0.508 respectively. The strict lack of a main effect of stimulus emotional valency here (F(1,8) = 0.077, p=N.S.) was reflected in the small effect size of ή^2=0.10.

AUC Results for Region of interest-2.

Again, two main effects were present in the early region of interest :

(i) A main effect of Rostral-Occipital Axis Position; $F(2,16) = 25.005$, $p<0.0001$. Again, shown in Chart 2, amplitudes and area under the curve peaked at the rear of the scalp.

Chart 2 : Post-hoc comparisons for rostral-occipital axis position.

Comparison	t	d.f.	Sig.	$r_{contrast}$	Mean μV x Time
Frontal vs. Central	-3.828	9	0.004	0.787	-477.188 vs. 360.936
Frontal vs. Parietal	-4.833	9	0.001	0.849	-477.188 vs. 968.618
Central vs. Parietal	-5.517	9	0.0001	0.878	360.936 vs. 968.618

(ii) A marginal main effect of Mask Type : $F(1,8) = 4.971$, $p<0.056$.
As a primary reason for conducting this study, any effect related to stimulus masking was examined fully. A comparison of all face- and non-face masked stimuli showed that face-masked trials evoked generally larger areas under the curve than non-face masked trials (385.188 μV x Time vs. 183.127 μV x Time). However, despite a moderate main effect size ($\acute{\eta}^2 = 0.383$), and a large effect of the paired contrast ($r_{contrast} = 0.572$), this difference was not statistically significant ($t(9) = -1.864$, p = N.S.).

Amplitude Analyses

In addition to AUC measures, a conventional mean amplitude analysis of both regions of interest was also conducted using the same 5-way ANOVA model. The results generated were identical to those of the AUC measures; principal findings comprised the same main effects of Rostral-occipital axis position ($F(2,16) = 6.651$, $p<0.014$), and an interaction of emotion x rostral-occipital axis position ($F(2,16) = 8.255$, $p< 0.003$) in region 1.

In region of interest-2, again, a marginal main effect of mask type ($F(1,8) = 5.016$, $p <0.055$), and a main effect of Rostral-occipital axis position ($F(2, 16) = 24.88$, $p<0.0001$) were repeated. As these effects were identical in overall impression to those in the original analyses, there was no point in pursuing them farther. The mean amplitude analyses showed one new, marginal effect of mask type x gender ($F(1,8) = 4.873$, $p<0.058$), but this result was not significant by the standard criteria, and the implications of the marginal main effect of mask type in the AUC analyses provide adequate justification for the forthcoming methodological considerations.

Discussion

Although not intended to be a purely investigative study, analyses of the data were not limited only to examination of the masking effects. With the primary difference in the methodology between the present and previous studies being a constant SOA of 80ms, instead of multiple durations, the data could still be examined for effects of emotional valency. Importantly and obviously, the face-recognition / P300 complex was present again here, lending face-validity to the methods and results from the previous study – the original waveform from the previous study can be replicated with a high level of concordance across studies, whether or not an inspection time methodology was applied with a similar stimulus set.

Within the data, face-masked stimuli evoked generally larger areas under the curve than non-face masked stimuli, and this phenomenon could be interpreted as confounding future examinations of emotional effects. Effectively, some differences in the waveforms (e.g. at least at the level of visual inspection) could be attributed to the manner in which the stimuli were masked, rather than the emotional nature of the stimuli. Statistical findings within the AUC data were relatively few, with only four effects emerging from a comprehensive initial analysis of variance. Of primary interest in the present study is the marginal effect of face masking in region of interest-2, where face-masked stimuli evoked larger AUC values than with the alternative mask type. Although the sample size in the present study was small, it is possible that a larger N would elevate this phenomenon to statistical significance. However, the possibility of apparent motion effects occurring should be reduced in the next study through continued use of the non-face mask. Effects among the rest of the dataset were intriguing. With participant error rates of less than 6%, and clearly modulated grand average ERPs generated as a result, there was a surprising lack of statistical variation arising from the emotional valency of stimuli. Hemispheric effects also failed to achieve statistical significance, despite some prior evidence of a right-hemisphere bias in the detection of negative facial expressions (Jansari, Tranel and Adolphs, 2001). Because participants accomplished the task with a consistently very high degree of success at the behavioural level, it is curious that the grand average ERPs varied so little; here, participants' behavioural success was not mirrored by detectable differences in brain electrophysiology. The mean amplitude analyses, although adding no other effects to the AUC methods, did strongly mirror the findings from the AUC measures, and therefore served as a useful validation of the AUC measure when compared with the standard ERP analysis techniques. Although amplitude analysis is common practise in ERP work, in this case, it did not provide any new information beyond that already present in the AUC analyses.

In summary, the use of different backward masking techniques did not radically alter the grand average waveform, and statistical effects were limited, but illustrative of a potential trend in larger scale studies. A main effect of mask type was not present at a significance level under p=0.05, and no further unequivocal results emerged – possibly a result of the reduced sample size in this study, although effect size estimates were nonetheless adequate in other areas. Although the grand average ERPs still resembled typical face-recognition waveforms (i.e. featuring P100, N170 and P300 deflections), fewer strictly conceptual confounds are likely to be present in future experimentation when non-face masks are used, despite slight visual differences in the grand average waveforms.

Additionally, at the behavioural and statistical level, the expected relationships between IT and IQ were maintained in the previous study irrespective of the possibility of apparent motion effects when using neutral face masks, and could be interpreted as showing an absence of the apparent motion phenomenon (or the use of a participant group who probably did not notice or use any apparent motion present). If apparent motion had been an influential factor in participants' performance, the inverse IT-IQ relationship should have been severely weakened or eradicated given the sample size, according to findings from Mackenzie and Bingham (1986). As this was not the case, the existing methodology is not likely to show farther confounds through the use of non-face masks in future studies. Finally, and importantly, the morphology of the grand average ERPs was maintained and reproduced within this study despite some changes to the stimulus presentation methods; the absence of varying SOAs still resulted in the evocation of an ERP showing discernible cognitive components.

CHAPTER 8

Study 4

Multiple-Choice Variants of the Emotional- and Conventional- I.T. Tasks

Findings from the Emotional Face-IT Task.

Introduction

The final experiment in this series is a key study, incorporating all methodological changes to date, and will collect a much larger data-set, comprising psychometrics and ERPs (from 3 separate EEG acquisitions) from N=50. This study will be analysed in two sections for easier comprehension.

-Section 1 will describe the experimental design and methods, then present and discuss results for ERP and psychometric findings for emotional effects.

-Section 2 will present results and discussion of ERP and psychometric findings for IQ effects.

The first ERP study allowed a general test of the program and SOA timings, as well as an early collection of emotional-recognition data. ERP study 2 examined the effects of stimulus masking upon ERPs. Having refined the methodology, the present study aimed to collect data from two blocks of face-IT tasks, separated by a modified four-choice line-IT task. In all 3 ERP tasks in the present study, a choice of four responses would be presented to participants, using an expanded electrode montage with the addition of Cz, O1 and O2. Using three ERP tasks, it would be possible to :

(i) Collect ERPs on two additional emotional expressions (anger and disgust) from two separate four-choice experimental tasks.

(ii) Examine ERPs from these two face-IT tasks for simple replicability of the waveform and internal consistency, and for similarities to the waveform obtained in ERP studies 1 and 2.

(iii) Examine data from a 4-choice, line-IT task for the presence of expected IT-related psychometric and electrophysiological phenomena, for comparison with data from both face-IT tasks.

The increase in the number of stimulus categories would serve both to slightly increase the general difficulty of the task, thereby better focusing participants' efforts, and emphasise differential ERP responses beyond the two-choice methods employed so far. In ERP study 1, happy face stimuli evoked larger deflections than neutral face stimuli, while ERP study 2's small participant population was likely to have been insufficient to detect emotional effects. By increasing both the participant sample over that in ERP study 2 and the number of stimulus categories over both studies 1 and 2, a more sensitive comparison of emotional recognition responses would be possible. In contrast to the previous studies, neutral facial expressions were not used, and the emphasis was placed upon four of the six basic emotional expressions – anger, disgust, sadness and happiness. It was expected that ERPs in response to all four emotional categories should generate statistically discernible differences among all categories, thereby segregating their recognition through electrophysiological responses.

Practical and theoretical comparisons of the present series of studies were problematic. Relatively low-level analyses of facial emotional expression in ERP methodologies remain surprisingly uncommon in the literature. Typically, ERP responses to emotional facial expressions are <u>not</u> examined for any characteristic phenomena related to the recognition or conveyance of emotional states. Rather, emotional faces are much more commonly used as a means of manipulating attention during another task; e.g. identifying other objects among emotional faces (Batty and Taylor 2003). Palermo and Rhodes (2007) listed 28 psychophysiological investigations of faces since 1999. Of these, 13 used scalp ERP, but only one of the 13 featured emotional identification as the primary task (Streit et al. 2000) – or, so say Palermo and Rhodes. Streit et al.'s participants were required to identify emotional faces from the Eckman set, and a primary comparison involved the identification of emotions from heavily blurred human faces, although the phenomena of the identification itself was not emphasised . Streit et al. did not report the presence of any effects in the ERPs (or their behavioural data) specific to the displayed emotions themselves, and overall, Streit et al.'s primary finding was that ERPs in response to normal emotional faces (non-blurred) versus blurred human faces resulted in differential ERP amplitudes around 240ms post-stimulus. Face-processing tasks are otherwise considered to occur quite rapidly, within 80ms after stimulus presentation (Palermo and Rhodes 2007).

Other studies in the area of emotional face recognition show similar general aims. The use, especially of fearful faces, as attentional manipulators within tasks are common, being noted as the “key” comparator in nine of Palermo and Rhodes’ 28 listed studies, and, seven of the 13 scalp ERP studies. It is later suggested by Palermo and Rhodes (2007) that attending to fearful facial expressions “may be completely mandatory under low attentional load conditions”, and is a feature of the involvement of the amygdala. As such, the emphasis on the use of fearful expressions in contemporary experimentation may be related much more to the enhanced likelihood of obtaining some statistical effects for comparison with other conditions (i.e. since fearful faces naturally draw attention very rapidly), rather than a strict interest in the ERP phenomena associated with face processing in general. An incidental, but profound consequence of this emphasis on fearful expressions is that there is relatively little to be learned of the perception of other expressions, except that in comparison to fearful faces, other expressions apparently evoke neither consistent reactions, nor much theoretical interest.

As a consequence of the emphasis on fearful faces, and the use of emotions as e.g. manipulators of attention, general information beyond the presence of the N170 in facial ERP responses has been examined in an inconsistent manner, and is confounded among various additional task demands – displaying or identifying faces is frequently a means to a different end, rather than a main goal itself. Guntekin and Basar (2007) similarly noted that diversity in the methods and results used to examine “emotional processing in the human brain” frequently generates varied results, leading a lack of common focus in this field of experimentation. Anecdotally, fear as a facial expression is more likely to be a relatively uncommon emotional expression for individuals to witness in most real-world, everyday events, and the use of the more commonly seen expressions of anger, disgust, sadness and happiness may lend a more natural element to the tasks in the present study.

The use of two face-IT tasks, each featuring different stimuli, should determine the replicability of findings between blocks. By placing a line-IT task between the face-IT tasks, three purposes would be served. Firstly, the four-choice line-IT task is more similar to standard two-choice IT tasks from past literature than the current face-IT tasks, and would permit new, novel analyses confirming (or not) the presence of IT-IQ psychometric correlations as seen in prior IT studies. Secondly, the 4-line IT task would serve as a suitable "distractor" when placed between the two face-IT tasks, re-directing participants' attention to a task that is broadly similar in intent, but different in practice from the demands of the face-IT tasks. In this way, the present study should be able to validate the face-IT methods by attempting to replicate results from each task within the same experimental session. Finally, line-IT tasks with four stimulus elements (i.e. 4 lines instead of 2) are uncommon and relatively novel, and should add information to the existing psychometric associations found in two-line IT studies to date.

The standard line-IT task has been the subject of many behavioural studies, but relatively few electrophysiological investigations, with perhaps only four ERP key studies. The most notable ERP finding associated with the line-IT task is Zhang et al.'s short $P200_T$ (1989) – a measure related to the gradient of the rising slope of the P200, or, the shift from the N150 to P200 component. The time-course of the $P200_T$ was positively correlated with participants' IQ, a result verified by Caryl (1994) and Morris and Alcorn (1995). However, the issue of brain electrophysiological differences and their relationship to intellectual functioning is highly complex, from which very limited theoretical conclusions can, and have been drawn. Zhang et al.'s short $P200_T$ is one such ERP correlate associated with higher IQ, while McGarry-Roberts et al. (1992) found that P300 amplitude was negatively associated with IQ as a trend – two quite different dependent measures, and with similarly different implications. Shagass et al. (1981), in a study comparing a psychiatric patient sample with healthy controls, concluded that the contribution of IQ to effects within evoked potentials was "demonstrable only by comparing extreme groups" and that "even then the magnitude of the effects is generally not large" (to facilitate these comparisons, Shagass and Josssiassen set a precedent by removing individuals with middling IQ scores from their distributions in some analyses, examining only those individuals with relatively high or low IQ scores). ERP component latency has been intensively studied (i.e. some 21 studies between 1965 and 1997 including Shagass et al. 1981), but findings here have not been easily replicable, nor pointed to definitive conclusions of the relationship between component onset and intellectual functioning.

Deary (2000) summarised evidence that latencies within the nervous system are related to intelligence, stating that there is tentative evidence that "….“smarter” people's brains apparently do run faster….", although Deary admits that this conclusion is difficult to sustain across different task methodologies, with e.g. ERP latency being difficult to directly relate to the overall, global functioning of the human nervous system. The general, and intuitively appealing notion that intelligence is in some way related to a simply faster form of cognitive activity has been expounded since the 19th century by Francis Galton (1883), and more recently and experimentally by Reed et al (2004) with nerve conduction velocity studies (NCV). Similarly to Shagass et al.'s conclusions, Reed et al.'s NCV work, although yielding positive results, showed relatively modest correlations between NCV itself and IQ. Although therefore likely to influence some aspect of human intellect, NCV alone is seemingly only one of possibly many unknown or un-measured contributors to an individual's intellectual abilities. Nettelbeck (2001) stated a similar opinion to Deary, in that he has "….long been skeptical about attempts to reduce intelligence to nothing more than mental speed as measured by IT.". Although Nettelbeck's comment is somewhat polarised in its implications, the reliability with which the IT-IQ correlation can be reproduced does cast doubt on Mackenzie and Bingham's (1985) suggestion that the IT-IQ relationship may reflect only by a single ability of enhanced "mental speed". If the IT-IQ relationship is due to such an ability, then this mental speed ability is perhaps either distributed in the same manner as IQ itself (i.e. normally across very large populations), or, mental speed is a reliable correlate of enhanced IQ in a way that is not yet fully understood. In short, after some 42 years, the evidence from a variety of studies on the matter of biological correlates or causal factors in human IQ remains equivocal and not easily replicated : no single enquiry or series of studies has shown a definitive and clearly interpretable explanation.

In the present study, analyses are expected to confirm the presence of existing psychometric relationships from line-IT tasks. It should be noted in the present study that the 4-line IT task employed here is not included as a primary means to an experimental goal; instead, it is intended to be an additional way of verifying the success of the IT procedure through the use of a relatively standard IT methodology, and for simple comparisons with face-IT waveforms and psychometric associations. In ERP study 1, negative correlations were present between AH5 section 2 scores and inspection times, and positive correlations between inspection times and Schutte Inventory (SREIT) total scores. It is therefore expected that similar patterns of correlations should emerge in the present study between both face- and line-IT if the SREIT's effectiveness is to be validated.

Methods

Participants

Fifty participants were recruited; 13 males (mean age = 22.46 years, s.d. = 4.27 years) and 37 females (mean age = 20.89 years, s.d. = 2.53 years). Participants were recruited via notices and e-mails across university departments, and were mainly students. The recruitment criteria were possession of unremarkable physical and psychological health, and English as a first language. Participants were required to attend the session with clean hair washed either that day or the previous evening, and free of any hair-care products. All volunteers were paid £7.

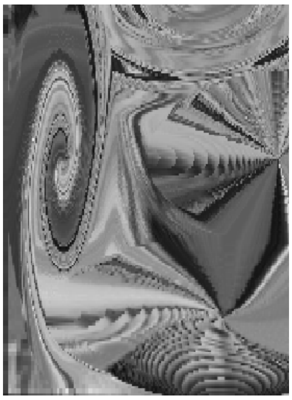
Materials

Participants were tested using the National Adult Reading Test (NART, Nelson and Willison, 1991), the Schutte Self-Report Inventory for emotional intelligence (SREIT, Schutte et al. 1998), and the 12-item short version of Raven's Advanced Progressive Matrices (hereafter Short APM, Arthur & Day 1994).

Three computer based inspection time tasks were employed. Two emotional IT tasks used two different male, and two different female faces displaying four emotional expressions (happiness, sadness, anger and disgust). The images were drawn from Eckman and Friesen's Pictures of Facial Affect (1976). The images of one male and one female were used in each task. Each stimulus item was a gray-scale image 350 x 275 pixels high (11.5cm x 8cm), subtending a visual angle of 9 degrees at 70cm distance from the screen. Each face-IT task used 192 stimulus presentations; 96 images of the male face, and 96 images of the female face. The facial expressions were displayed 6 times at 8 presentation durations -

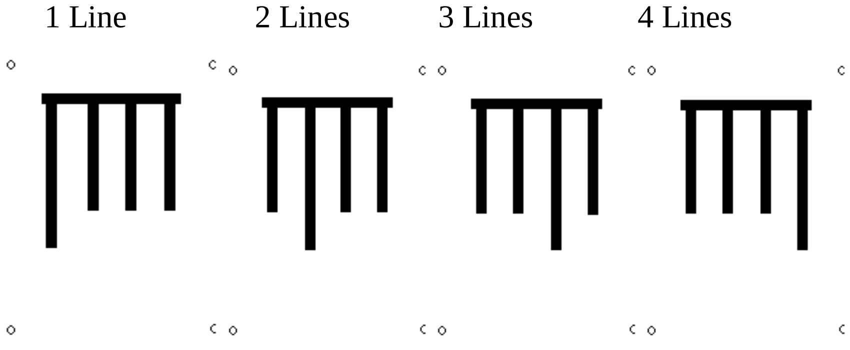
20, 30, 40, 50, 60, 80, 100, and 120ms

- for a total of 24 happy, 24 sad, 24 fearful and 24 disgusted expressions shown for each male and female face (i.e. 24 trials * 4 expressions * 2 genders = 192 trials). Stimuli were presented using a 100Hz CRT monitor, maximising the accuracy of SOAs. The order of stimuli was randomised, and all participants were shown the same sequence. The face stimuli were immediately masked after presentation by the same non-face image used in the previous study – a highly garbled and visually complex image of a face not in use as a stimulus item, but featuring the same colour palette as the other stimulus faces, and unrecognisable as a human face. The non-face mask stimulus is provided below :

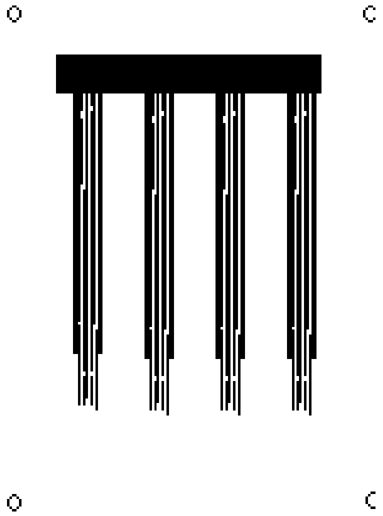


The third IT task was similar in structure, and used a 4-choice variant of the standard IT paradigm employing geometric figures.

The 4-line IT task stimuli are provided below (the dots visible in the corners of the image assisted in aligning the stimuli on-screen, and were otherwise irrelevant to the task) :



The 4-Line IT stimuli were backward-masked using the following image ::



In the 4-line IT paradigm, each geometric stimulus was presented 5 times at 10 durations –

10, 20, 30, 40, 50, 60, 70, 80, 100 and 120ms

Each of the 4 stimuli were therefore presented 50 times for a total of 200 trials (i.e. 5 presentations * 10 durations * 4 unique stimuli = 200 trials).

EEG Procedures

EEG was recorded using a Neuromedical Supplies forty-channel Quik-Cap sintered electrode cap and a NuAmp 7181 40-channel amplifier. EEG activity was monitored at F3, F4, Cz, C3, C4, P3, P4, O1 and O2. Linked and subtracted mastoid reference sites A1 and A2 were used, and a forehead-mounted ground. Vertical EOG was recorded using the FP1 site, and an additional electrode beneath the left eye. All sites were prepared using QuikGel, and impedances were maintained below 10KOhms. EEG was recorded at 500Hz, and filtered on-line between 0.1 and 30Hz. Artefacts were removed off-line. Where a deflection on the EOG trace exceeded +/- 50µV, that trial was removed from subsequent averaging. During the recordings, the previously established sequence of events was largely unchanged from those in previous studies :

1. Trial begins.
2. Acquisition triggered.
3. Baseline period began (100ms)
4. Triggering reset in software.
5. Baseline continued (100ms)
6. Asterisk fixation point displayed (300ms)
7. Gap – 700ms
8. Stimulus presented (One of 8 durations from 20 to 120ms.)
9. Stimulus mask displayed (720ms)
10. EEG recording ended.
11. “Respond Now” prompt displayed.
12. Stimulus triggering reset.
13. Subject’s response triggers next trial.

Each recording epoch lasted 2040ms, with only the stimulus duration varying across trials.

Procedure

Participants were fitted with the EEG cap before any other procedures, and the purpose of the electrodes and fitting procedures were explained. Participants then completed the SREIT and NART tests, after which the EEG recordings began. Eight practise trials (with SOAs of 95, 55, 35 and 25ms) were shown to illustrate the response procedures, the electrophysiological effects of moving and blinking were demonstrated to participants before beginning, and the importance of remaining motionless during the recording epochs was emphasised. Participants were tested firstly with a block of face stimuli, followed by the standard 4-line IT task, and concluded with the second block of face stimuli. The on-screen instructions to the participants were :

“When the experiment starts you will see an asterisk in the centre of the screen.
Look directly at the asterisk.
Next, a human face will be displayed briefly.
The first face will be covered up by a different image, then you will be asked to respond.
If the FIRST face you saw was ANGRY, press 1
If the FIRST face you saw was HAPPY, press 2
If the FIRST face you saw was SAD, press 3
If the FIRST face you saw was DISGUSTED, press 4
You should aim to be accurate rather than quick, so take as much time as you need to decide.
If you are not sure, guess.
There will NOT be any feedback during these trials.
Press spacebar to continue.”

After each trial, the participant was prompted to respond with the following text:

“If the FIRST face you saw was ANGRY, press 1
If the FIRST face you saw was HAPPY, press 2
If the FIRST face you saw was SAD, press 3
If the FIRST face you saw was DISGUSTED, press 4”

During the initial few trials, the experimenter examined the participant’s pattern of blinking, and where necessary, advised them if their blinks were present during the recording epochs. Rest breaks lasting 10 seconds were given every 32 trials, and after each stimulus presentation, the next trial was not triggered until the participant had responded. In this way, participants set their own pace, minimising the presence of electrophysiological artefacts.

Following the first block of faces, a similar procedure was employed for the geometric line stimulus task, including exemplary stimuli and on-screen instructions.

“When the experiment starts you will see a cue
(shown next) in the centre of the screen...
Then, one of the following
four line displays will be displayed briefly,
followed by a mask.
The line display will be covered up by the mask (shown next)
When the mask goes off you will respond on the keyboard,
identifying the position of the line.
Response: Press the key corresponding position of the longer line
Left = 1, 2, 3, 4 = Right

Be accurate rather than quick - take as much time as you need to decide.
If you are not sure, guess. There will NOT be any feedback during these trials.”

For all ERP tasks, the recording epoch began and ended prior to the subjects' behavioural response. Rest breaks for the geometric IT task were provided after every 40 stimuli. At the end of the geometric task, the subject was offered some de-caffeinated tea, coffee, or water and given a longer rest-break. After this, the second block of face E-IT stimuli was conducted, with identical instructions to those of the first block.

Throughout all of the EEG tasks, the experimenter sat silently behind the participant.

Results

Behavioural and Psychometric Findings

Data from three male and one female participant were removed from both the psychometric and EEG data sets owing to excessively high inspection times exceeding 1.5 standard deviations from the mean, reducing the overall data set to 46 participants. In the following section, only those effects pertaining to emotion will be examined and discussed. The subsequent chapter will examine effects and discussion related to IQ. Tables 6 and 7 in this section involve an un-avoidable cross-over of these topics in analysing links between IQ and EI scores.

Table 1 : Descriptive statistics for correct responses to emotional faces.

	Block 1	S.D.	Block 2	S.D.
Angry	37.59	5.96	30.39	9.6
Disgust	30.89	7.95	31.56	7.05
Happy	46.83	1.52	44.65	2.68
Sad	41.04	4.29	44.02	3.884

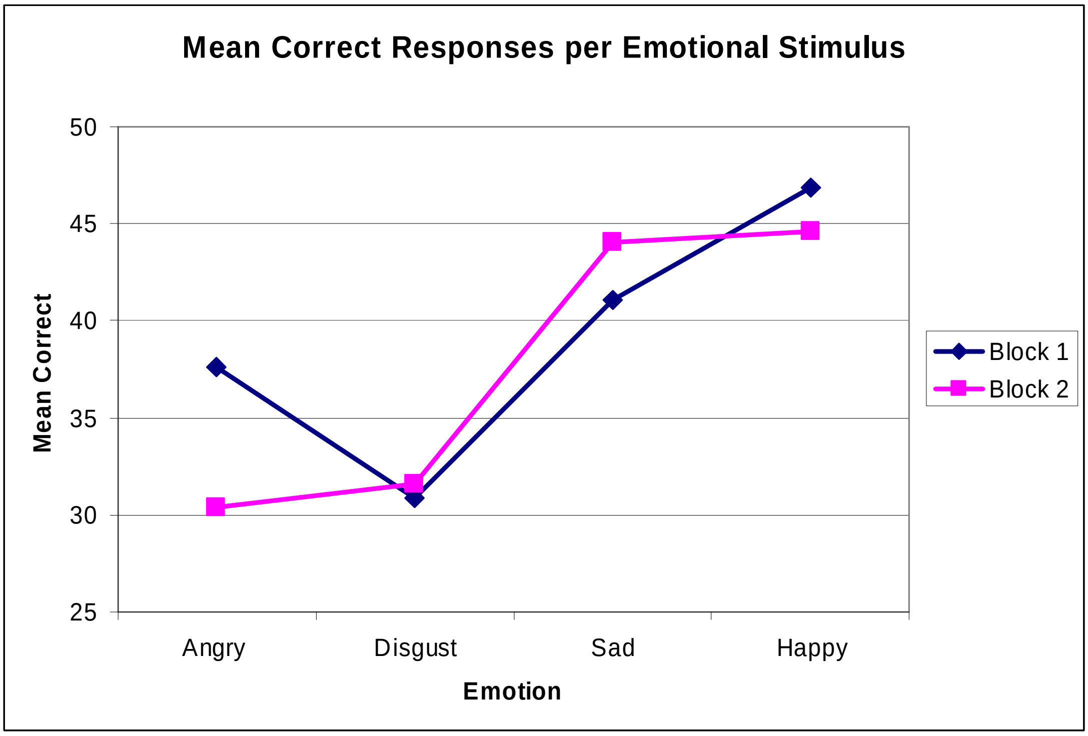
Post-hoc tests showed that 10 of 12 comparisons remained highly significant after Bonferroni correction.

Table 2 : Post-hoc tests for correct responses.

Block 1	T(d.f.=45)	Sig.	$r_{contrast}$
Angry vs. Disgust	5.54	0.001	0.64
Angry vs. Happy	-11.01	0.001	0.85
Angry vs. Sad	-3.89	0.001	0.50
Disgust vs. Happy	-14.26	0.001	0.90
Disgust vs. Sad	-8.32	0.001	0.78
Happy vs. Sad	8.76	0.001	0.79
Block 2 :			
Angry vs. Disgust	-0.87	N.S.	0.13
Angry vs. Happy	-10.50	0.001	0.84
Angry vs. Sad	-9.58	0.001	0.82
Disgust vs. Happy	-12.38	0.001	0.88
Disgust vs. Sad	-13.48	0.001	0.90
Happy vs. Sad	1.25	N.S.	0.18

There were significant differences in the response rates across almost all comparisons, but participants appeared able to make reliably correct responses across all stimulus types. Disgust was consistently the most difficult expression to discern. The discriminations between anger and disgust, and happiness and sadness became more problematic in block 2. Participant fatigue is suspected to have been influential in the second face-IT task; scores in several domains were noticeably lowered in comparison to block 1.

Figure 1 : Plot of correct responses per stimulus category for face-IT tasks.



Although strong behavioural effects are implied by the large number of strongly significant differences across stimulus classes, anger and disgust were more difficult for participants to identify, mainly in the second block of the face-IT task. Participants did not appear to show practise effects in identifying happy or angry faces between blocks, whose identification scores decreased during block 2.

These results were examined for gender effects, with a single effect being present. Total correct responses to “happy” face stimuli in Block 2 showed that **males made significantly fewer correct responses (mean = 43.10 correct) than did females**

(mean = 45.08) - F(1,44) = 4.32, p<0.04. This finding could be interpreted as congruent with the previous SREIT descriptive data, where females tended to show higher overall scores for EI. However, gender-related phenomena were not consistently present throughout the data set as a whole, and the actual difference between mean scores is very low.

Descriptive data are provided for the SREIT emotional intelligence inventory in table two. After exclusion of only 4 participants who failed to achieve valid inspection times, only 10 male participants remained in the sample. Descriptives are presented in Table 3 for these remaining 10 male participants, 10 randomly-selected female participants as a comparator for the males, all of the females collectively, and overall descriptives for N=46. Petrides and Furnham's (2000) analysis was again used to derive 4 factors (Mood regulation, Appraisal of emotions, Social skills, and Utilisation of emotions.).

Table 2. Descriptive statistics for SREIT score and factors.

	10 Males Median	S.-I. Range	10 Females Median	S.-I. Range	All Females, median	S.-I. Range	N=46 Median	S.-I. Range	Reliability *
Mood Regulation	50.0	4.75	54.5	6.75	53.0	9.5	51.5	9.25	0.74
Appraisal	33.5	4.75	34.5	8.25	34.0	5.0	34.0	5.0	0.76
Social Skills	48.5	7.0	50.5	6.0	50	7.75	50.0	8.0	0.71
Utilisation	22.5	7.75	23.5	4.25	23.5	4.0	23.0	4.25	0.76
Total EI	120.5	11.5	130.5	17	127.5	22.25	124.0	20.5	0.86

*Cronbach's Alpha

Generally, females scored more highly on all measures than did males, either as an entire group of 36, or a comparative sub-group of 10. (Reliability coefficients were computed using N=46.).

Data from the SREIT scale was examined by Friedman test. When comparing genders using N=46, or the N=20 sample of 10 males and 10 females, no significant differences in the above SREIT measures were evident. No overall gender differences were prevalent among this data.

Inspection Time and EI Correlations

As very few statistically significant gender differences were present, correlations with inspection time were performed using N=46.

Table 4 : Correlations : IT(ms) with EI.

		Utilisation of Emotions
IT Faces Block 2	Rho	0.31
	p	0.03
IT 4-Line	Rho	0.31
	p	0.03

Block 1 of the face-IT task showed no significant correlations with any of the EI factors. Only a single EI factor, utilisation of emotions, showed any correlation with inspection time. As IT values rose for faces block 2 and the 4-line task, so did participants' scores on the Utilisation of emotion factor of the SREIT.

Table 5 : Correlations : IT (total correct) with EI.

		Utilisation of Emotions
TotalHit1	Rho	-0.31
	p	0.03
TotalHit2	Rho	-0.35
	p	0.02

The pattern of correlations among IT and EI factors changed with the use of total correct responses. Now, block 1 of the face-I.T. tasks was significantly associated with EI, while the 4-line I.T. task was not. In general, phenomena related to the EI sub-scales and total scores were quite inconsistent.

Table 6 : Correlations : IQ measures and EI.

		Short APM ii	NART Errors	NART FIQ
Mood Regulation	Rho	**0.337**		
	p	**0.022**		
Appraisal	Rho			
	p			
Soc. Skill	Rho			
	p			
Utilise	Rho		-0.279	0.281
	p		0.060	0.059

Only one EI measure, Mood regulation, showed any association with the IQ measures employed (rho = 0.337, p<0.022), i.e. as Short APM scores rose, so does the individual's propensity to "regulate" long-term emotional states. As the Short APM relies heavily on participants' problem-solving abilities to create solutions, and Mood regulation as a self-reported trait implies the imposition of a mental state upon oneself, this correlation is logical.

The second factor from the SREIT, Utilisation of emotion, showed two small correlations which did not achieve significance. These associations were with the NART sub-scale measures, which have previously shown no other correlations with the IQ and IT measures. Utilisation of emotion, however, would appear to be another "active" or fluid cognitive process which requires positive responses to such questions as "I present myself in a way that makes a good impression on others" and "When my mood changes, I am able to come up with new ideas." – i.e. it is not a wholly passive process for the individual, with traits such as self-presentation to others requiring deliberate activity and effort. An individual's Utilisation of emotion implies similar processes to Mood regulation as a trait, in that some cognitive effort is required to evoke these traits and their concomitant behavioural manifestations. The NART, however, is a predominantly "crystallised" intelligence measure based upon participant vocabulary, and which relies heavily on pre-existing knowledge rather than more active, spontaneously creative cognition.

Table 7 : Subset of 30 hi- and low-APM scorers, re-run of original correlations, IQ and EI measures.

		Short APM ii	NART Errors	NART FIQ	NART VIQ	NART PIQ
Mood Regulation	rho	**0.41**				
	p	**0.01**				
Social Skills	rho	**0.38**				
	p	**0.02**				
Utilisation	rho		**-0.40**	**0.40**	**0.40**	**0.39**
	p		**0.01**	**0.01**	**0.01**	**0.02**
Total EI	rho	**0.31**				
	p	**0.05**				

Significant correlation effects were present primarily between Utilisation of emotions and NART scores. However, the significance levels were higher when using N=30. This slightly smaller and more intellectually diverse population (as reflected by APM scores) showed significant correlations between APM section (ii) scores and all EI factors except Utilisation of Emotion. The lack of association between Utilisation of emotion and APM scores is again unusual. The APM is very much a test of problem-solving cognition, yet the EI measure which would be most expected to be associated with the application of fluid cognitive ability (i.e. Utilisation of Emotions) was not statistically associated with APM scores. Additionally, the significant correlations between Utilisation of Emotions and NART scores were reproduced with the smaller sample size. These results, however, are generally not in accordance with Brand and Deary (1982), who noted that the IT effect is “less strong” when participants are possessed of normal or high-normal IQ, and stimuli are “comparatively complex” – i.e. words, or other stimuli beyond geometric line types. They do, however, indicate that conventional intelligence is able to affect SREIT scores.

ERP Analyses

Some technical difficulties were manifest when averaging the EEG data. In all cases, the ERP grand averages exclude the single female and 3 male participants previously excluded from the psychometric data who failed to achieve satisfactory inspection times. A further 6 participants were excluded due to missing data from electrode channels which could not be averaged due to other interference. In all, 40 participants possessed complete data from all electrode channels, and were the basis for the initial analyses of the ERP data.

Grand Average ERPs

Figures 2 – 19 on the following pages provide grand average ERP charts for all conditions at each electrode site.

Grand Average ERPs for Face data.

The grand average ERPs from all sites again showed distinctive and prototypical face-recognition complexes, including heightened activity in the N170-N200 region associated with the recognition of the presence of facial stimuli (Bentin et al. 1996, Puce et al. 1999). The waveforms in the present study showed increasing amplitude related to scalp location, with the highest amplitudes present at the rear of the skull (the P3 and P4 sites), again as expected from P300 phenomenology, as well as the associated N1 and P1 deflections (Fabiani, Gratton and Coles, 2000). The O1 and O2 sites showed very prominent early deflections, as would be expected from a task using visual stimuli. The occipital cortex apparently responded most quickly to the detection of visual information, with subsequent task-related cognitive acts likely based on discriminatory processes carried out upon this perceptual information. Despite the differences in behavioural response rates illustrated in tables 2, 3, and figure 5 previously, the waveforms across all categories show a high level of visual concordance. Where present, differences are manifest most obviously in amplitude variations.

Figure 2 : Grand ERP at F3, Faces Block 1

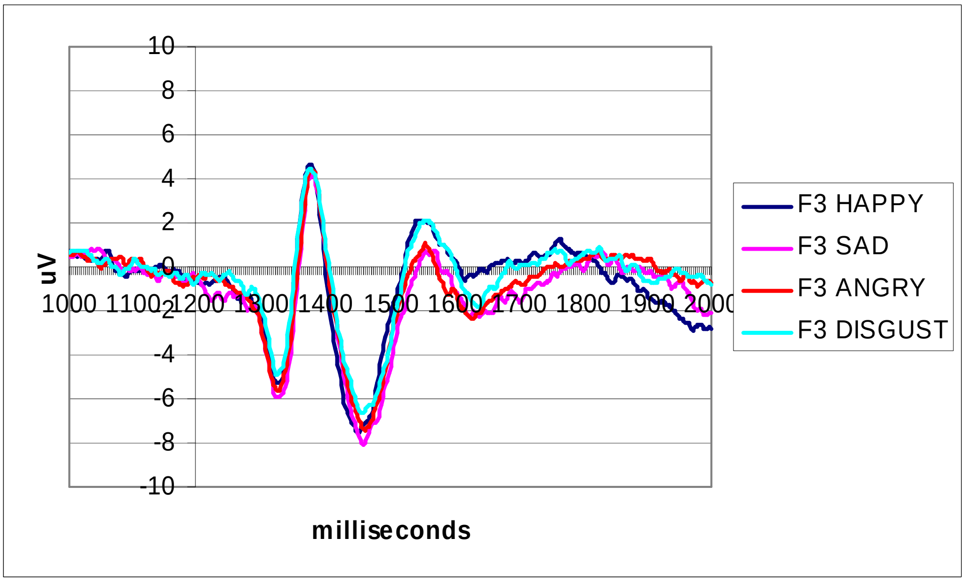
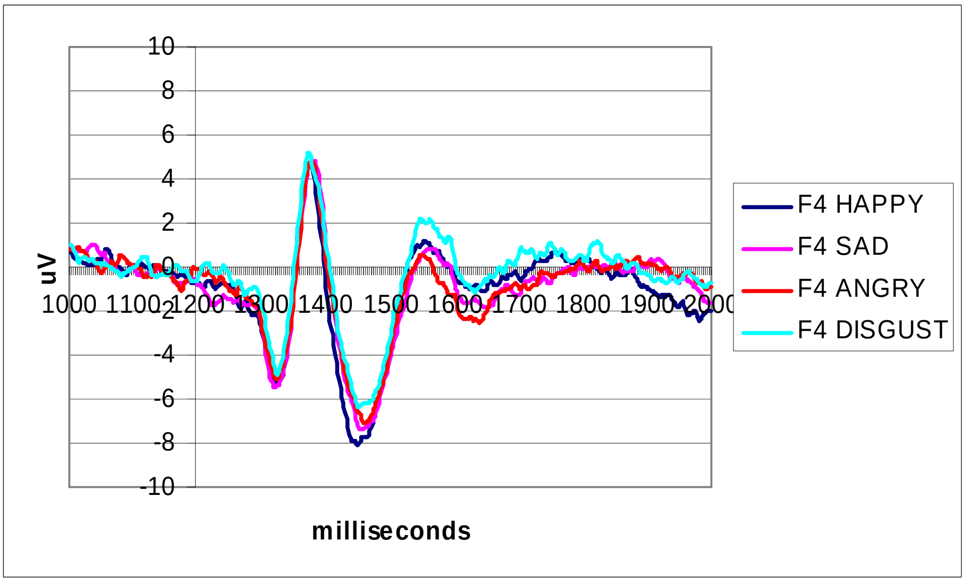


Figure 3: Grand ERP at F4, Faces Block 1



Although the general morphology of the P3 complex is present at the frontal sites, the amplitude of the N170 region was exaggerated, while the amplitude of the subsequent P300 region was noticeably attenuated. Also noteworthy was the differential amplitude of the waveform for happy stimuli at 1560ms. On the left of the scalp, happy and disgust were superimposed, while on the right of the scalp, they are prominently separated, with disgusted stimuli evoking a larger amplitude.

Figure 4: Grand ERP at C3, Faces Block 1

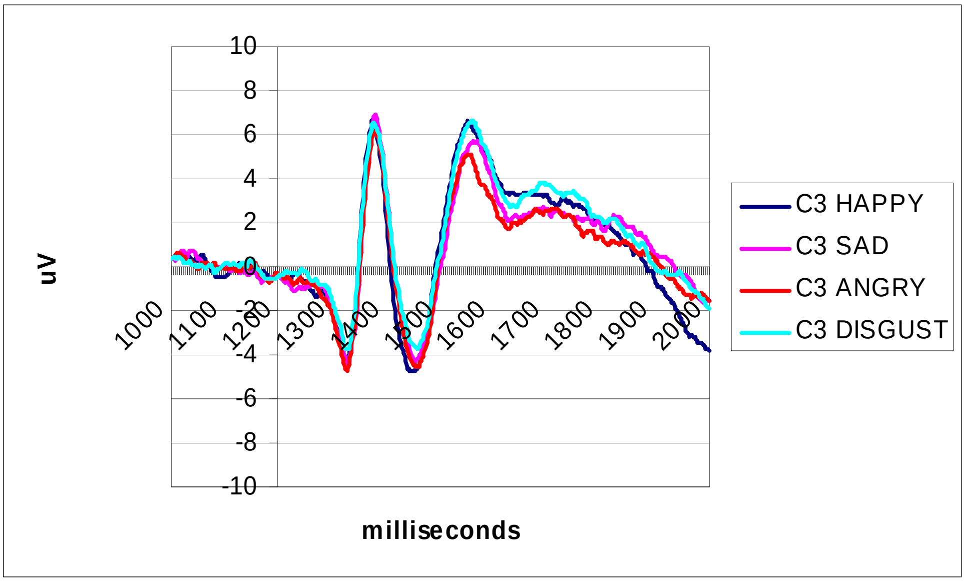


Figure 5: Grand ERP at C4, Faces Block 1

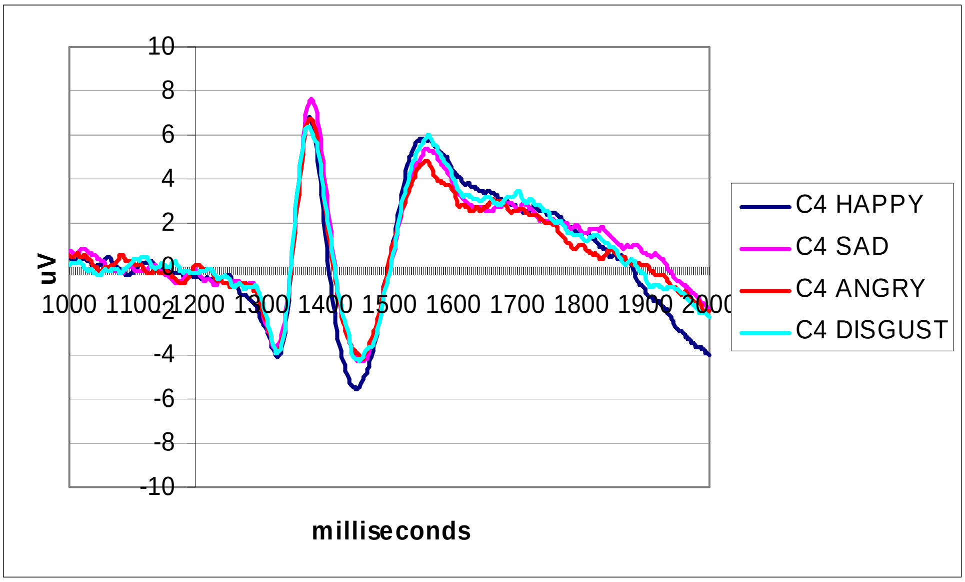
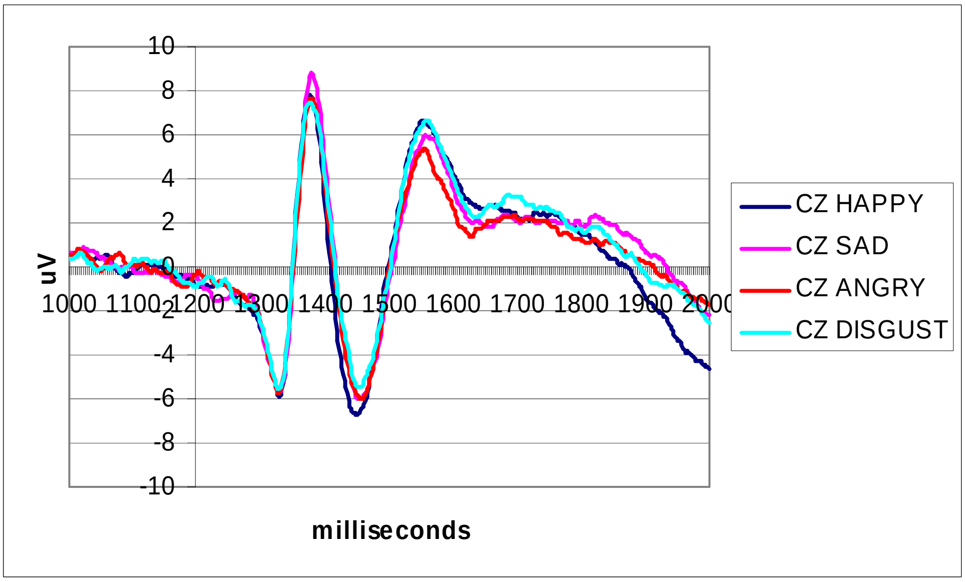


Figure 6: Grand ERP at Cz, , Faces Block 1



Sites F3, F4, C3, C4 and Cz showed similar deflections for N1, P1, and the N170 locations. The P3 region, however, became larger at the central electrode sites. Slight hemispheric differences were apparent, with the C3 site showing a pronounced negative deflection at approximately 1624ms (424ms post-stimulus), which was not mirrored at the C4 site.

Figure 7: Grand ERP at P3, Faces Block 1

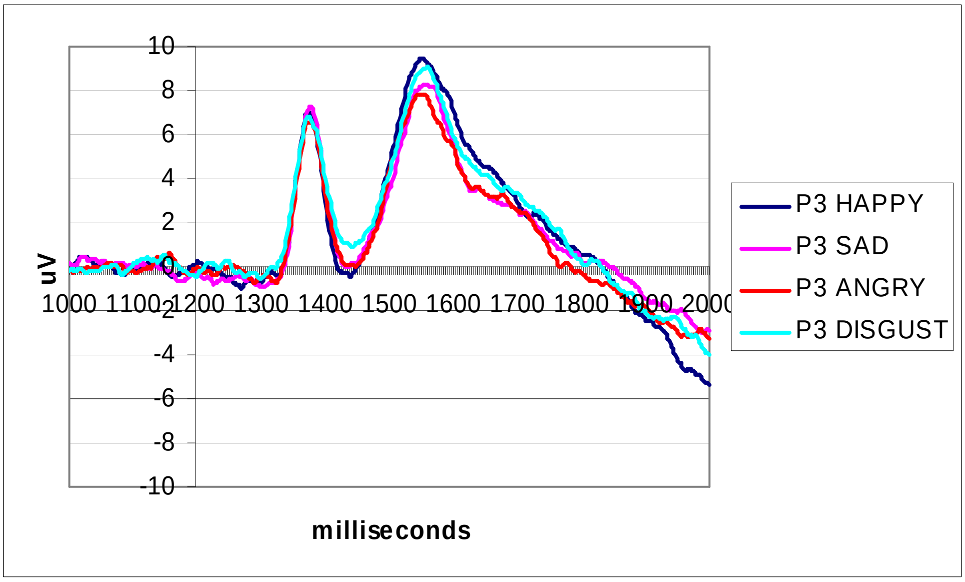
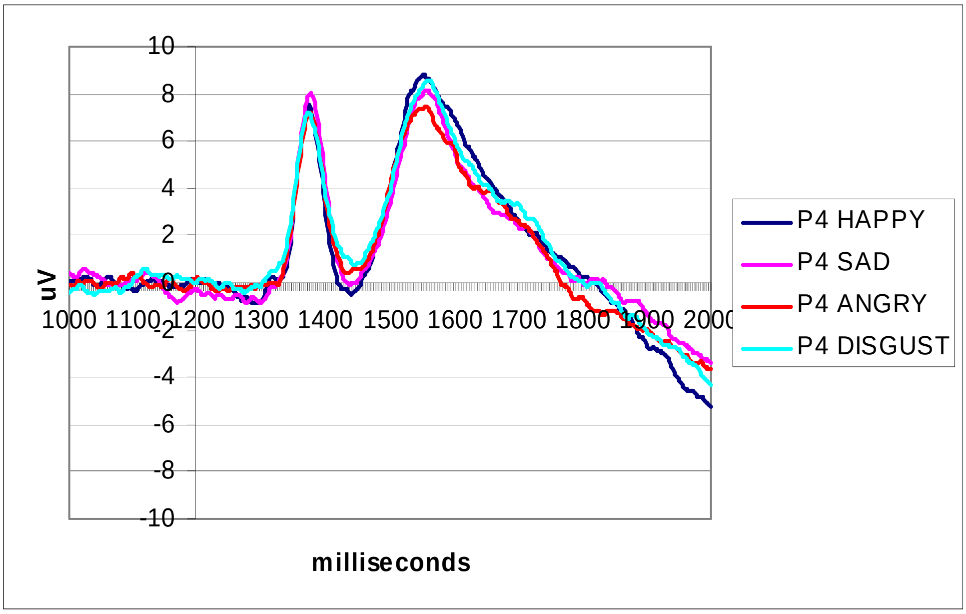


Figure 8: Grand ERP at P4, Faces Block 1



Parietal sites P3 and P4 showed a heightened P100 and P300 response, with the P300 response peaking in amplitude over all other scalp locations. Similar to the occipital sites, the P100 was also prominent at the parietal locations.

Figure 9: Grand ERP at O1, Faces Block 1

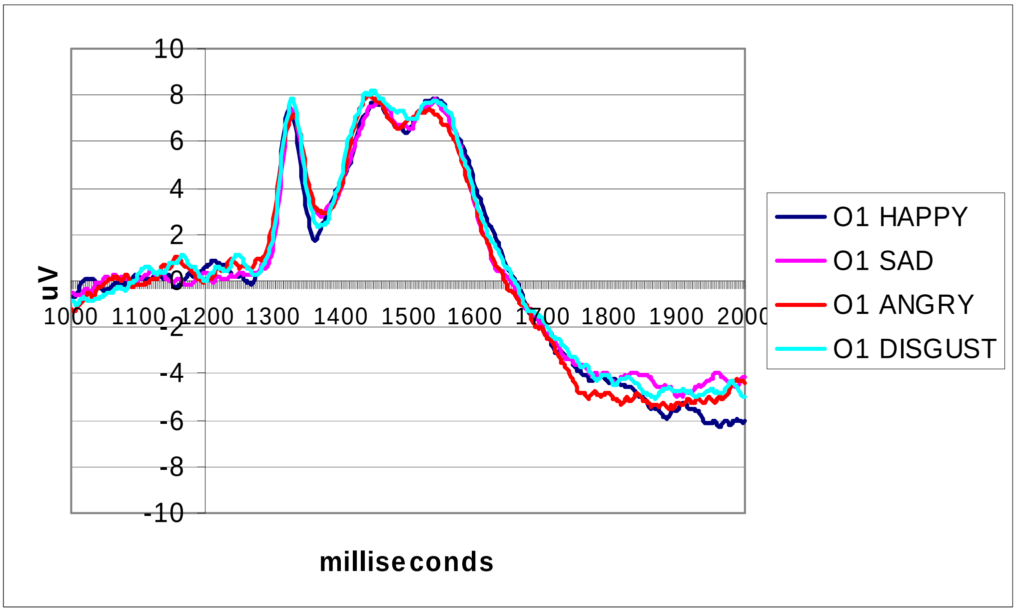
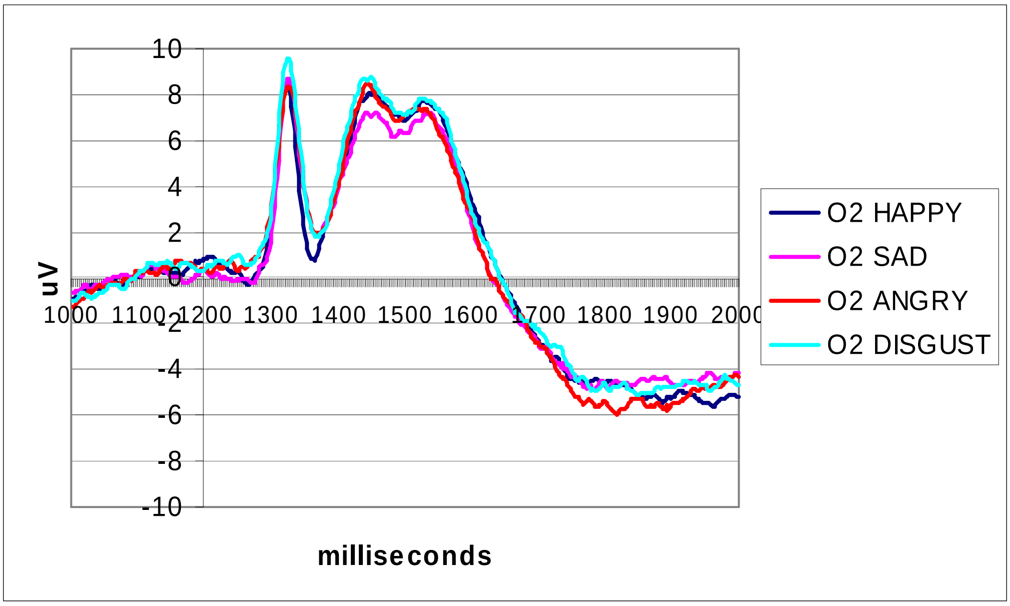


Figure 10 Grand ERP at O2, Faces Block 1



Sites O1 and O2 showed prominent and early P100 responses, most likely due to the visual nature of the task, occurring approximately 100ms prior to the P100 at other scalp locations. The N170 component was also prominent, but at the occipital sites, remained an entirely positive deflection throughout its presence.

Grand Average ERPs for Block 2 Face data.

Block 2 of the face stimuli showed another P3-complex with broadly similar deflections and patterns of amplitude variation to block 1.

Figure 11: Grand ERP at F3, Faces Block 2

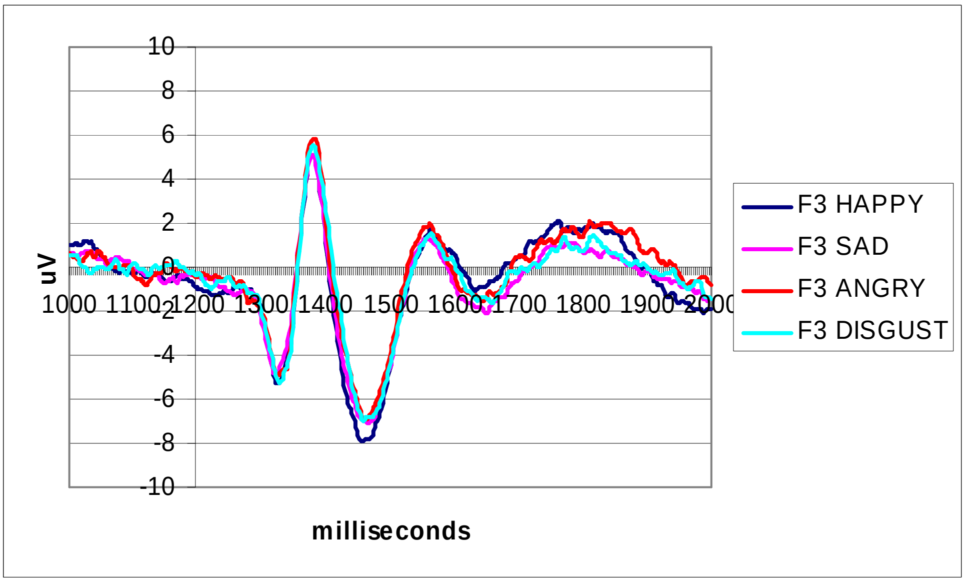


Figure 12: Grand ERP at F4, Faces Block 2

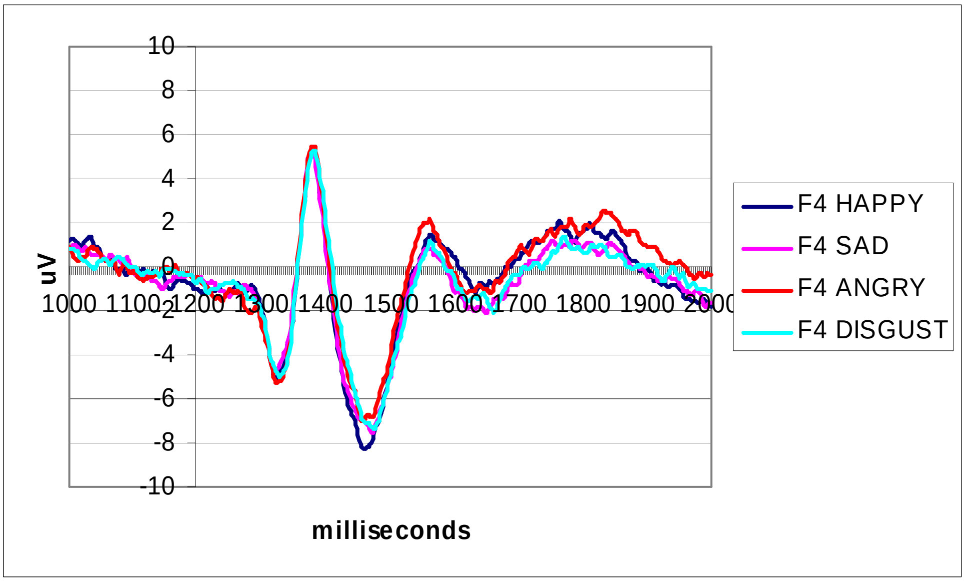


Figure 13: Grand ERP at C3, Faces Block 2

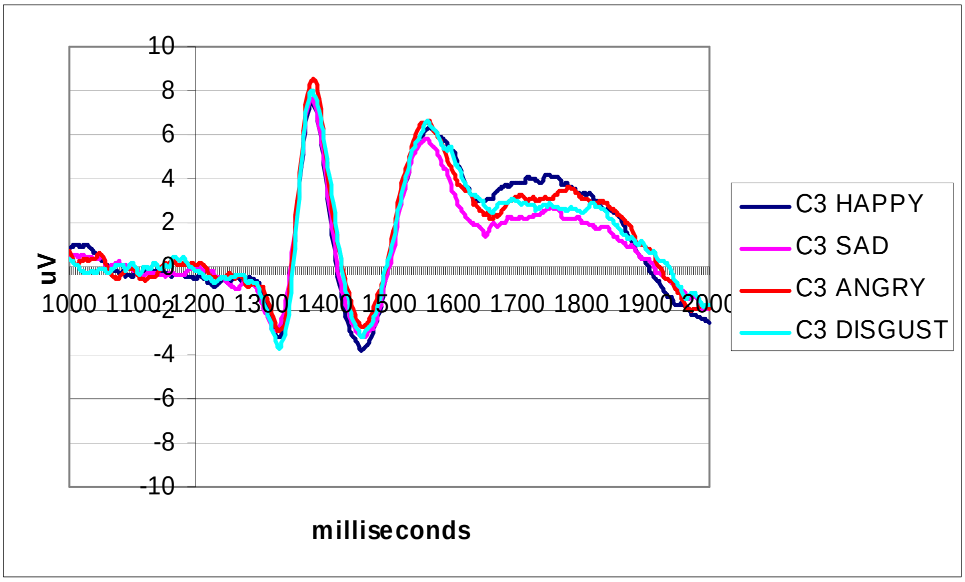
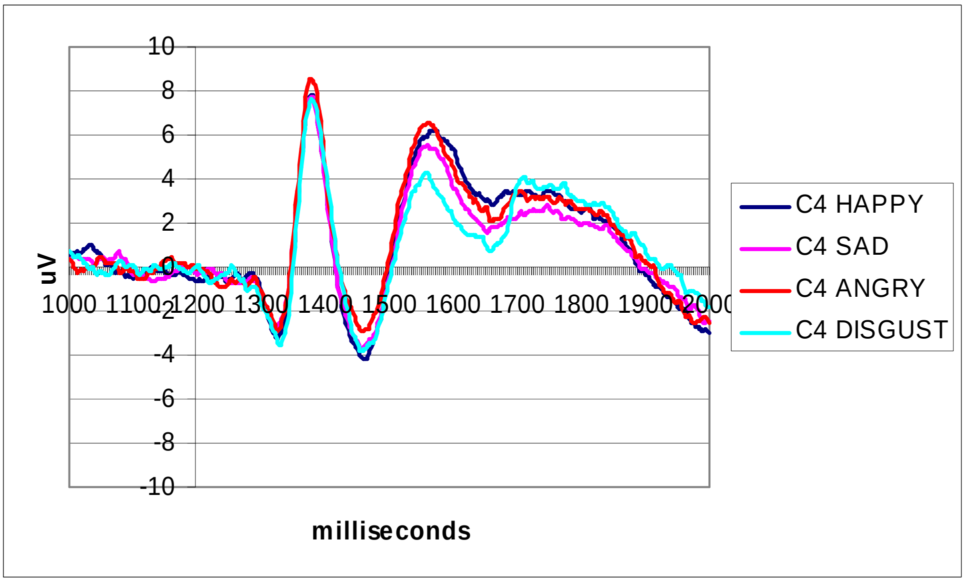
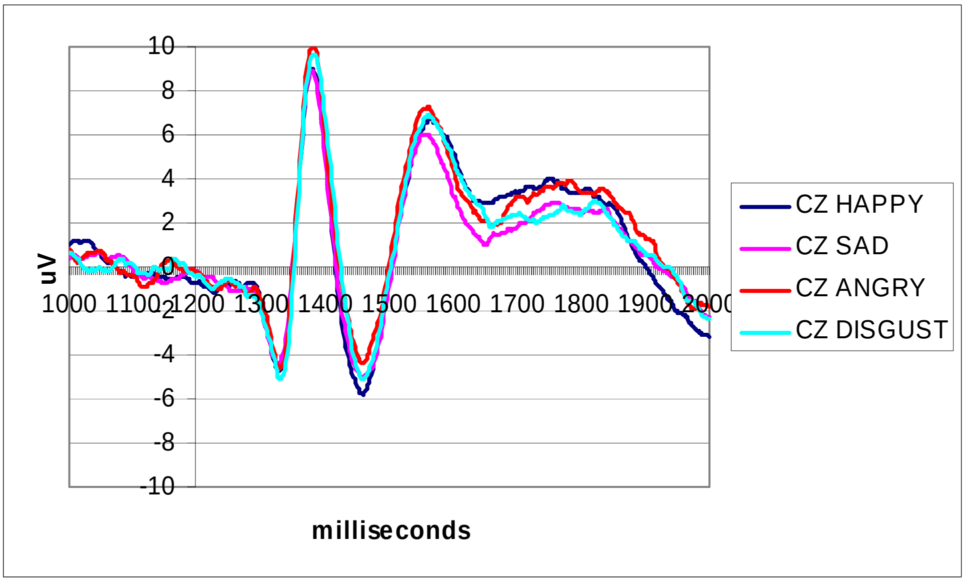


Figure 14: Grand ERP at C4, Faces Block 2



The waveform at site C4 for “disgusted” face stimuli shows a notable deviation from both previous block 1 waveform shapes, and the left-hemisphere C3-site during the P300 region. At approximately 360ms post-stimulus, the waveform fails to achieve the same amplitude as at the C3 site.

Figure 15: Grand ERP at Cz, Faces Block 2



At the Cz site, the pattern of responses for all stimuli was restored, with the waveform amplitude for disgust stimuli being no more distinctive than the other categories in general morphology.

Figure 16: Grand ERP at P3, Faces Block 2

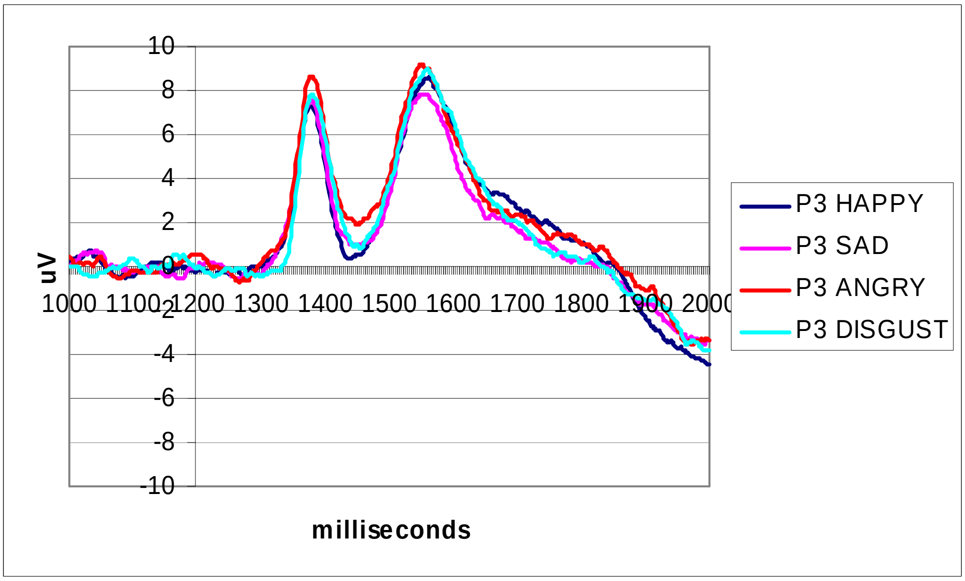
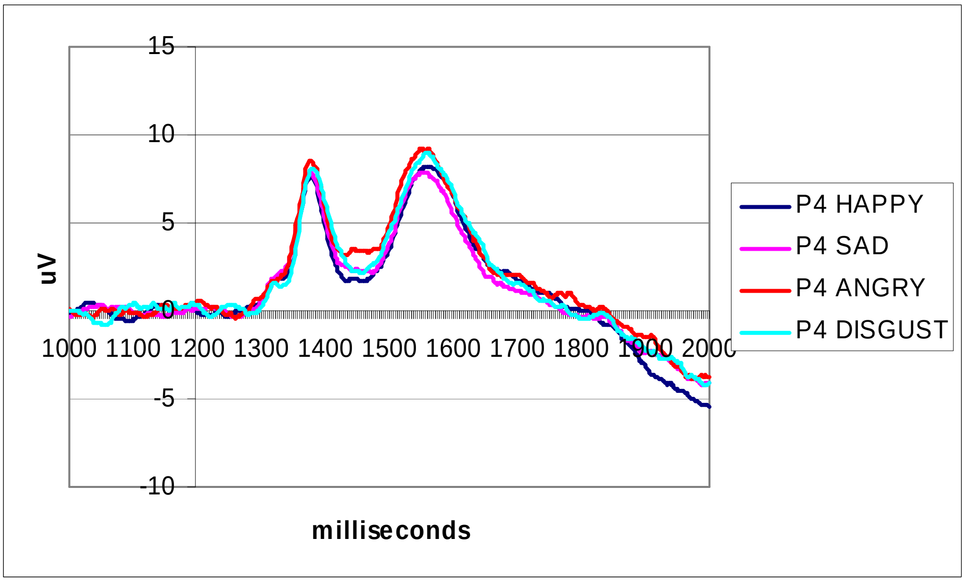


Figure 17: Grand ERP at P4, Faces Block 2



P300 Amplitudes at the parietal electrode sites were no longer quite so distinctive during the second face-IT task. Occipital sites O1 and O2 showed comparable deflections.

Figure 18: Grand ERP at O1, Faces Block 2

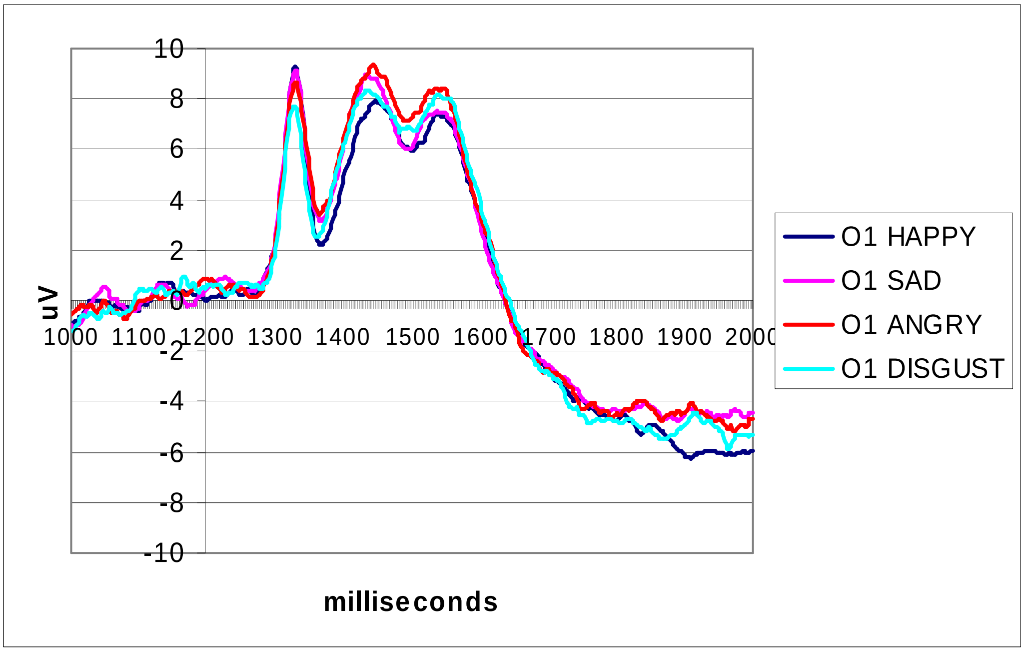
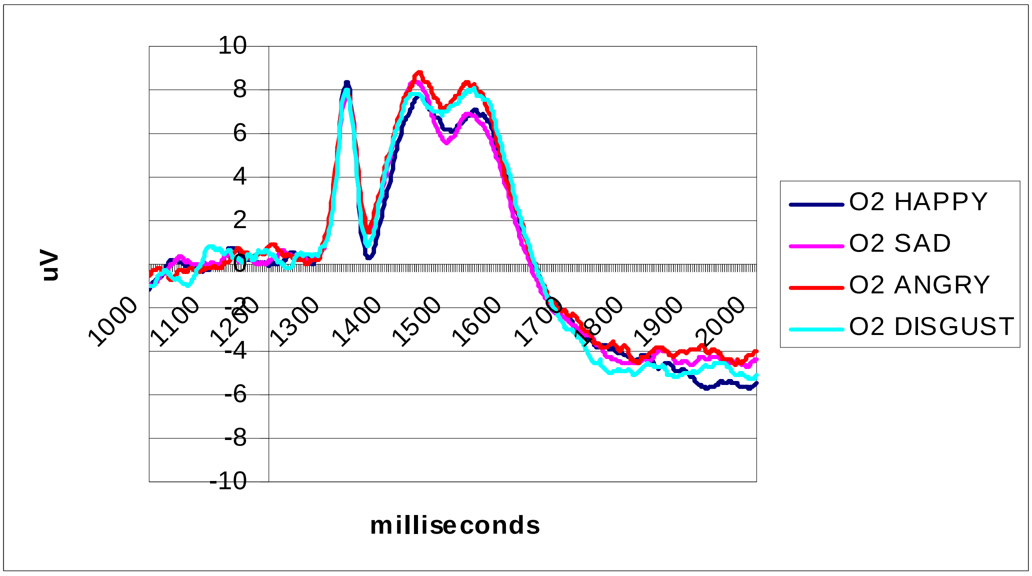


Figure 19: Grand ERP at O2, Faces Block 2



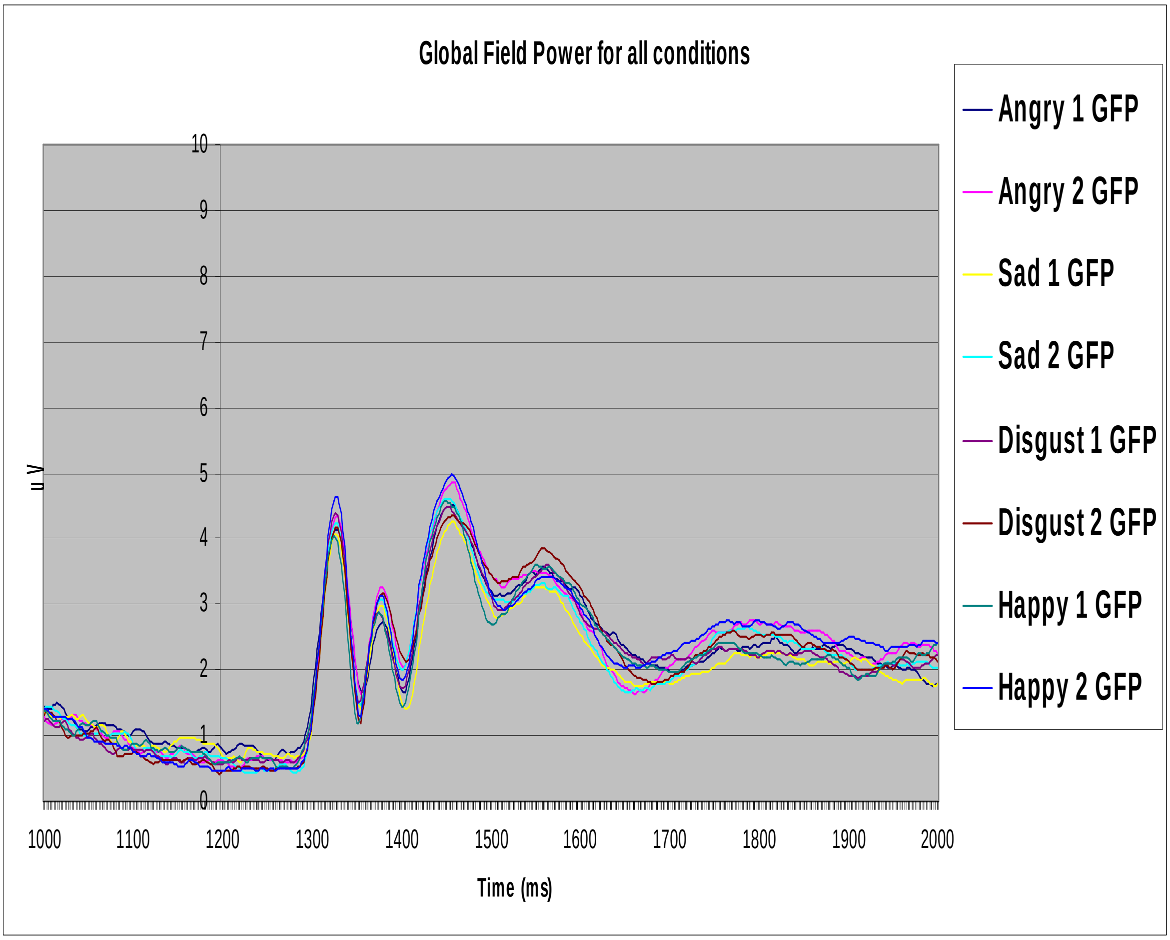
Unlike the first face-IT task, the P300 region during the second block of face stimuli showed higher amplitudes at the P100 region at O1, and a more pronounced N170 response at O2. The large initial P100 response was still present, and was also notably earlier at the parietal electrode sites than any frontal or central locations. The amplitude of the P3 region remained high, and was now bifurcated around 490ms post-stimulus.

The grand average ERPs generated in response to both facial E-IT tasks were again highly consistent in showing a P300-complex, even when separated by the demands of a different geometric-IT task.

ERP Analyses – Face-IT

Global field power (GFP) plots were again used to determine regions of interest for statistical analysis. The GFP plots from each grand average were plotted simultaneously, as shown in figure 32.

Figure 20 **:** Global field power plot for region of interest determination.



Major deflections and components in the grand average waveforms over time were extremely consistent across both blocks of face-IT stimuli, and all eight face-IT conditions, with no task showing a gross deviation from either the P3 complex or the GFP trends. In this study, four visually apparent regions of interest were extracted by determination of the start- and end-points of four major peaks in the global field power plot. The pre-IT stimulus baseline period comprised 1000ms to 1200ms, immediately after which stimulus onset occurred; subtraction of 1200 from the stated values provides the post-stimulus onset time. The regions of interest were defined as follows, and coincide with previously established component windows (e.g. Smith et al. (2003) for the P1 region, Bentin et al. (1996) for the N170.).

- Region of interest..-1 comprised the period 1280ms to 1352ms.
- Region of interest..-2 comprised the period 1352ms to 1402ms.
- Region of interest..-3 comprised the period 1402ms to 1530ms.
- Region of interest..-4 comprised the period 1530ms to 1702ms.

Results

An initial 5- way ANOVA was conducted upon each block using the design Emotion (4) x Rostral-Occipital Axis Position (4) x Hemisphere (2) x Region of Interest (4) x Gender for each block of face presentations using area under the curve. An individual repeated-measures ANOVA was also performed on each block of face stimuli using mean amplitude over each region of interest at the Cz electrode site. At the Cz site only, data from two additional participants was available for block 2 of the face-stimuli, resulting in N=40 for block 1, and N=42 in block 2.

The term "Rostral-Occipital Axis Position" refers to four locations on the scalp subsuming nine electrode locations - Frontal (F3 and F4), Central (C3, C4 and Cz), Parietal (P3 and P4) and Occipital (O1 and O2).

Due to the cumbersome nature of and difficulties associated with the interpretation of interaction effects of a 5-way analysis, only main effects (where present), and limited interaction effects were fully examined.

Results for Block 1 Faces

1. Rostral-Occipital Axis Position showed significant variation (F(3,114) = 56.782, p<0.0001).

Post-hoc t-tests (after Bonferroni correction with a new alpha level of 0.0083) showed all comparisons of electrode regions to be significantly different from each other, except for Parietal vs. Occipital. Table 8 presents these test values.

Table 8 : Post-hoc tests for electrode locations.

Comparison	T (df = 39)	Sig.	Mean Area (µV x Time)
Frontal vs. Central	-11.511	0.0001	-170.245 vs. 141.236
Frontal vs. Parietal	-13.045	0.0001	-170.245 vs. 399.097
Frontal vs. Occipital	-9.622	0.0001	-170.245 vs. 446.218
Central vs. Parietal	10.775	0.0001	141.236 vs. 399.097
Central vs. Occipital	5.577	0.0001	141.236 vs. 446.218
Parietal vs. Occipital	-1.215	0.0232 N.S. after correction	399.097 vs. 446.218

Mean activity in the frontal regions was consistently of a lower magnitude than all other regions on the scalp, with activity peaking at the parietal and occipital regions at the rear of the skull. Strong statistical effects related to inter-electrode differences are (again) unsurprising and commonly found in brain electrophysiology, but serve more to validate the nature of the observed ERP by confirming a rising magnitude of responses from the anterior to posterior scalp regions, or the presence of specific waveform sub-components. Although the presence of inter-electrode effects helps to confirm the presence of the P3 complex, inter-electrode differences in this case provide little insight into the nature of task-related cognition, except that two large regions at the rear of the skull appear more heavily involved in these processes; likely areas of the occipital and parietal lobes. The attenuated responses at the frontal regions to emotional faces are, however, similar in morphology to the findings of Eimer, Holmes and McGlone (2003).

2. Region of Interest : A main effect of Region of interest. was present (F(3,114) = 16.656, $p<0.0001$.

Caution must be used in the interpretation of all specifically *inter-*regional differences. As the dependent variable here was the area under the curve, extending the time epoch also increased the magnitude of the area under the curve by summation. A truly valid comparison would require that all epochs for all regions of interest be kept identical, however this would inevitably create difficulties in the definition of regions of interest per se, as the regions of interest themselves are variously defined by morphological, mathematical, or statistical variation in the grand average ERPs. To some extent this phenomenon is a problem for any analysis involving e.g. the standard mean amplitudes or latencies. An alteration to the epoch length of the region of interest inevitably impacts the value of central tendency for the whole epoch, and any subsequent mathematical manipulation of other values within that epoch.

For analyses involving any *intra*-regional effects, the length of the epoch remained constant across comparisons. Figures 21 and 22 below illustrate this rise in area per epoch and region of interest. As the length of the epoch rose, so did the area under the curve (except for region of interest-3 in each case.).

Figures 21 and 22 : Relationship of area magnitude to epoch length for face-IT tasks.

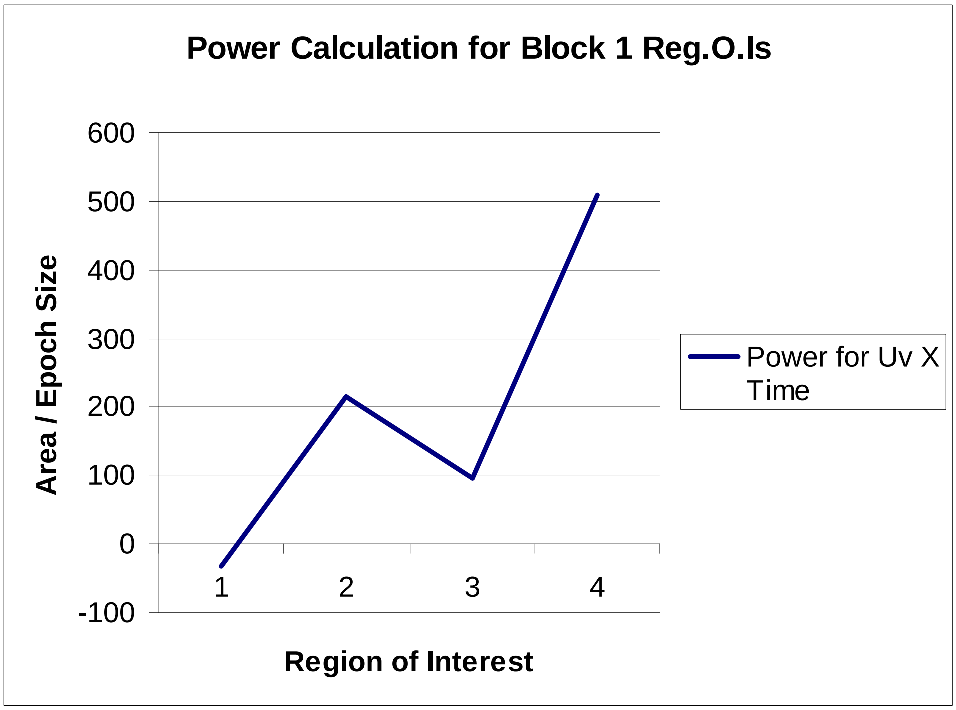


Figure 22.

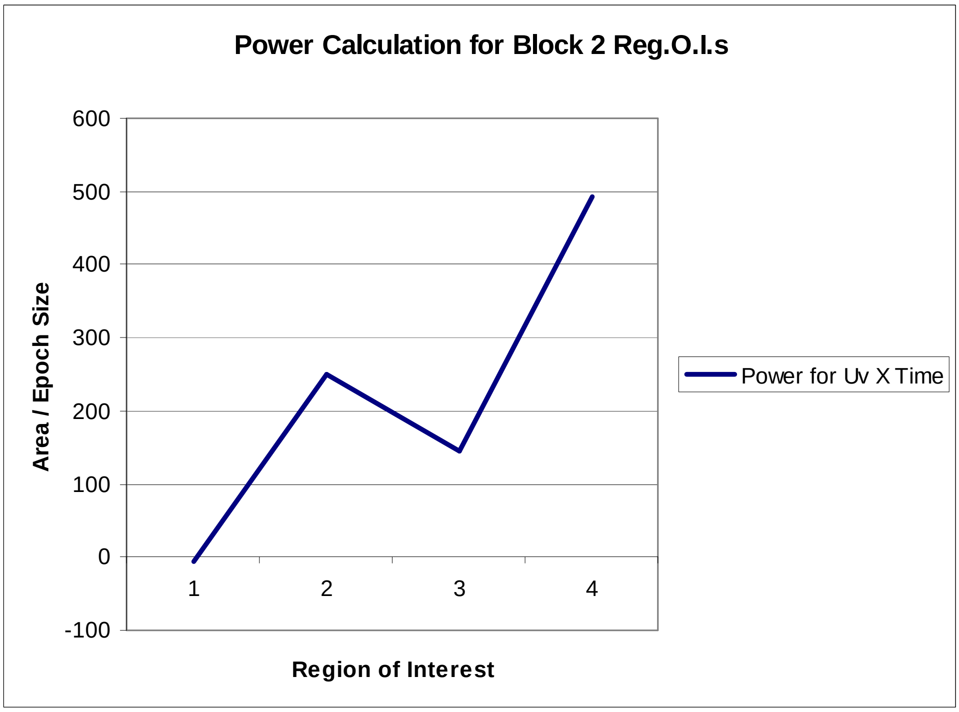


Table 9 : Post-hoc tests for regions of interest, block 1.

Comparison Regions	T (df = 39)	Sig.	Uncorrected Mean Area (µV x Time)	Corrected Mean Area
1 vs. 2	-12.540	0.0001	-31.894 vs. 215.165	-0.443 vs 4.303
1 vs. 3	-2.584	0.014 N.S. after correction	-31.894 vs. 96.548	-0.443 vs. 0.754
1 vs. 4	-8.494	0.0001	-31.894 vs.508.559	-0.443 vs 2.957
2 vs. 3	2.209	0.033 N.S. after correction	215.165 vs. 96.548	4.303 vs 0.754
2 vs. 4	-4.233	0.0001	215.165 vs. 508.559	4.303 vs 2.957
3 vs. 4	-6.061	0.0001	96.548 vs. 508.559	0.754 vs2.957

To compensate for differences in the magnitude of time epoch, corrected values showing the power of the effect are also presented in Table 10 (i.e. the uncorrected mean area divided by the epoch length in milliseconds). In this comparison, region of interest -2 (1352ms to 1402ms) and -4 (1530ms to 1702ms) showed the greatest activity, although significant differences were present between several combinations of regions. Regions of interest -2 and -4 occur at the time windows respectively corresponding to the N170-N200 and the P300 components.

Activity in region of interest-2 is most likely indicative of the N170 component present during the detection of facial stimuli, while activity during region of interest-4 is likely to be memory-updating processes consistent with a task-based discrimination of the stimuli during the P300 region. The distinctive waveform of the P300 complex makes inter-regional differences both likely and of limited usefulness except in terms of the confirmation of the presence of certain cognitive phenomena. The P3 complex is classically associated with several cognitive acts, including the contextual updating of short-term memory, and the novelty and recognition of target stimuli (e.g. Courchesne et al. 1975), and it can be inferred from the simple presence of the P3 complex itself that cognition of these forms was (again) likely to have been present. This is further supported by the repeated presence of the P3 complex across the two previous experiments in the present series. The presence of effects at regions of interest-2 and -4 further validates the task and outcome - participants viewed the stimuli, then made accurate judgements of the stimulus faces, simultaneously producing memory-related electrophysiological responses.

3. An interaction of Emotion x Hemisphere was present (F(3,114) = 8.812, $p<0.0001$.). No further effects of emotional valency (F(3,117) = 2.077, p=N.S.) or hemispheric location (F(1,39) = 0.608, p=N.S.) were present in post-hoc testing.

4. An interaction of Emotion x Hemisphere x Region of interest. (F(9, 342) = 5.087, $p<0.0001$). Post-hoc tests of this effect comprised four, 2-way ANOVAs for Emotion x Hemisphere within each region of interest. Regions of interest -1 and -4 showed different effects here.

Region 1 : A main effect of hemispheric lateralisation was present, F(1,39) = 4.283, $p<0.045$. Greater activity overall was present in the left hemisphere (mean = -17.0452 µV x Time) than the right hemisphere (mean = 3.0986 µV x Time) for region of interest-1 (t(39)= -2.07, $p<0.045$, $r_{contrast} = 0.31$).

Region 4 : A main effect of emotional recognition was present, F(3, 117) = 3.231, $p<0.025$.

Table 10 : Post-hoc comparisons for emotional valency.

Comparison	T (df = 39)	Sig.	Mean Area (µV x Time)	$r_{contrast}$
Disgust vs. Anger	2.071	.045	555.358 v.s. 400.698	0.31
Disgust vs. Sadness	1.832	N.S.	555.358 v.s. 445.1110	0.28
Disgust vs. Happiness	-0.169	N.S.	555.358 v.s. 567.954	0.027
Anger vs. Sadness	-0.796	N.S.	400.698 v.s. 445.111	0.12
Anger vs. Happiness	-2.564	.014	400.698 v.s. 567.954	0.37
Sad vs. Happiness	-2.233	.031	445.111 v.s. 567.954	0.33

Comparisons between pairs 1, 5 and 6 did not remain statistically significant after Bonferroni corrections, with a new significance level of $p<0.0083$, and effect size estimates were uniformly low. At best, a marginal effect of emotional valency was present in region of interest- 4, all of which were negated after corrections for multiple comparisons. Prior to correction, the recognition of disgusted and happy faces evoked the greatest activity. The emotional recognition aspects of this task appear to be somewhat weak, and possibly relied more on recognition of the stimulus items practised over time, without specific affective responses to the emotion being displayed. Nevertheless, there was an effect of emotional valency present among the data, a main aim of both the present study, and the series of studies presented. Occurring relatively late in the acquisition in region of interest -4, at 500ms post-stimulus, this effect would be consistent with the notion that the processes involved here were discriminatory and associated with deliberate cognition, rather than early and endogenous perceptual processes. Given the nature of ERPs as relatively spatially indistinct, stochastic processes occurring over very brief periods of time, it was felt that a highly stringent correction to the significance levels was warranted here.

5. Interaction of Rostral-Occipital Axis Position x Hemisphere ($F(3,114) = 7.344$, $p<0.0001$). Post-hoc-testing of this effect yielded a persistent effect of electrode position, which has already been addressed previously as a main effect in point **1** previously**.** No hemispheric effects were present ($F(1,39) = 0.608$, p = N.S), nor further interactions.

Component Amplitude Analyses

In line with conventional analysis of ERP data, regional amplitudes and latencies were specifically analysed for emotional effects at the Cz site.

For amplitude values, the mean voltage at Cz over the entirety of each region of interest was calculated for each condition. The use of mean amplitude over the region is generally agreed to most accurately represent amplitude measures by reducing the possibility of defining a peak in which may or may not represent an instance of individual noise in the waveform from each participant.

Rigourous latency analyses were problematic for this data-set and were not pursued. In addition to practical difficulties, however, IQ-mediated differences in ERP are not generally manifest as differences in component onset. Zhang, Caryl and Deary (1989a and 1989b) did not find differences in amplitude or latency in populations with differential inspection time values (as noted, a well-documented, moderate to strong associate of higher IQ). Rhodes, Dustman and Beck (1969), Davis (1971), Shagass (1972), and Dustman and Beck (1972) all failed to replicate Ertl's (1969) reduced vertex potential (VEP) latency association with high-IQ – or "Ertl Effect" . Ertl's general experimental methods, from electrode placement to definition of peak(s) for measurement have been criticised, as have his criteria for statistical significance and analytical methods by Callaway (1975). Josiassen et al. (1988) noted that Davis's (1971) finding was that "….there were no consistent relationships between IQ and VEP latency…." . Callaway (1975) states that for visually evoked potentials, latency differences attributable to IQ differences are manifest only if either the task is sufficiently difficult to adequately distinguish high and low-IQ scorers on its own merit, or, if the participant is given no instructions and left to ascertain the task demands through "…..his own more habitual cognitive mode….", and that "There have been replications and failures to replicate", leading to an a non-conclusion in this field. Caryl (1994) noted that where effects were related to intelligence (specifically correlations), these effects were present within an epoch, rather than due to differential onset latencies between components. Given the inconsistency reported through these and other studies, and the practical differences in accomplishing latency analyses using contemporary methods, latency effects were not pursued.

Computation of latency effects remains complex and subjective; two main techniques exist for the analysis of component latency effects, resulting either in a relatively simple analysis with limited resolving capability, or an in-depth analysis at the expense of objectivity. Contemporary practise in examining component latency effects requires the individual scrutiny of each participant's individual grand average. For each region and electrode site, the initial ascending or descending phase of each component must be identified in turn, a peak identified, then a point in the deflection corresponding to a pre-determined percentage of the maximum peak, assuming that e.g. at a point corresponding to 40% of the maximum, the deflection is underway to a peak.

It is extremely problematic to automate this procedure based on scrutiny of the group average, since individual variation in each participants' averages alter the maxima and minima of the magnitude of components. A considerably greater problem, however, is that not all individuals clearly manifest all components, requiring a subjective judgement for each identification. Attempting to discern the maxima and minima from the group grand averages frequently results in attempting to find values in individual analyses which do not exist, thereby requiring individual scrutiny of all waveforms for components. With N=46, and four distinct conditions, such an analysis was both insufficiently objective, and highly impractical. In any case, visual scrutiny of the grand average waveforms (e.g. figures 1-23), and global field power plots shows the main variation in responses to be differentiated by amplitude variations, rather than apparent onset delays.

Cz Amplitude analyses for Block 1 Faces

A significant effect of emotion was present in amplitude variations only in region of interest– 4; (F(3,117) = 15.064, p<0.0001). Four post-hoc comparisons showed significant effects, all of which remained significant after Bonferroni correction :

Table 11 : Amplitude effects of emotional valency at Cz site, region of interest -4.

Comparison	T (df = 39)	Sig.	µV	$r_{contrast}$
Disgust vs. Anger	-3.114	.003	4.672 vs. 3.532	0.44
Disgust vs. Sadness	-2.876	.006	4.672 vs. 3.662	0.41
Disgust vs. Happiness	.098	N.S.	4.672 vs. 4.640	0.16
Anger vs. Sadness	-0.427	N.S.	3.532 vs. 3.662	0.06
Anger vs. Happiness	-3.062	.004	3.532 vs. 4.640	0.44
Sadness vs. Happiness	-2.789	.008	3.662 vs. 4.640	0.40

Similar to the results from the AUC measurements, results here did not reveal that every emotional category differed strongly from every other, but, again, disgust and happiness evoked significantly larger deflections than all other stimulus types. Although somewhat consistent with the results from the AUC analysis, the amplitude comparison effects were generally robust, both in terms of the alpha levels and effect sizes.

Results for Block 2 Faces

Many of the findings from block 1 were repeated in block 2; in particular, effects due to electrode locations continued to be prevalent :

1. Rostral-Occipital Axis Position : As with block 1, a main effect of electrode location was present ($F(3,114) = 66.320, p<0.0001$).

Post-hoc tests of this result are presented in Table 12. As with Block 1 results, all regions differed significantly from each other (after correction for multiple comparisons) except for comparisons between the Parietal and Occipital locations.

Table 12 : Post-hoc tests for electrode locations.

Comparison	T (df = 39)	Sig.	Mean Area (µV x Time)	$r_{contrast}$
Frontal vs. Central	-12.231	0.0001	-161.958 vs. 202.972	0.89
Frontal vs. Parietal	-14.064	0.0001	-161.958 vs. 427.337	0.91
Frontal vs. Occipital	-10.480	0.0001	-161.958 vs. 437.878	0.85
Central vs. Parietal	-10.056	0.0001	202.972 vs. 427.337	0.84
Central vs. Occipital	-5.171	0.0001	202.972 vs. 437.878	0.63
Parietal vs. Occipital	-0.332	n.s.	427.337 vs. 437.878	0.05

Again, electrodes positioned at the rear of the scalp showed larger and more sustained activity than did frontal or central regions, further validating the presence of the P3 complex.

2. Region of Interest : Another main effect of region of interest was present in block 2 (F(3,114) = 16.5, p<0.0001. Post hoc test results are presented in table 13.

Table 13 : Post-hoc tests for block 2 regions of interest.

Comparison Regions	T (df = 39)	Sig.	Mean Area (µV x Time)	Corrected Mean Area	$r_{contrast}$
1 vs. 2	-13.228	0.0001	-5.019 vs. 249.752	-0.07 vs. 4.995	0.90
1 vs. 3	-3.125	0.003	-5.019 vs. 146.022	-0.07 vs. 1.141	0.44
1 vs. 4	-9.249	0.0001	-5.019 vs. 492.669	-0.07 vs. 2.864	0.82
2 vs. 3	1.987	N.S.	249.752 vs. 146.022	4.995 vs. 1.141	0.30
2 vs. 4	-4.248	0.0001	249.752 vs. 492.669	4.995 vs. 2.864	0.56
3 vs. 4	-5.514	0.0001	146.022 vs. 492.669	1.141 vs. 2.864	0.66

Here, all regions of interest except -2 and -3 differ significantly from each other, showing significant variation in the early and late components, but not during the N170 to N200 region of the waveform. The previous cautions in interpreting the similar results in Block 1 of the face-IT task also apply here.

3. Interaction of Emotion x Hemisphere (F(3,114) = 3.794, p<0.012. Again, similar to block 1, post-hoc tests yielded no subsequent effects of emotion (F(1,117) = 1.603, p = N.S.) or hemispheric location (F(1,39) = 1.337, p = N.S.).

1. Interaction of Rostral-Occipital Axis Position x Hemisphere (F(3,114) = 7.464, p<0.0001).
   Persistent effects related to electrode position were again present (F(3,117) = 99.643, p<0.0001), but no other effects of hemispheric laterality (F(1,39) = 1.337, p=N.S.), nor any interaction of these variables (F(3,117) = 1.669, p = N.S.). Further tests of the effect of location have again already been addressed in the analysis of the main effect of electrode location for block 2.

In contrast to Block 1, no further effects of emotional valency were present in Block 2 when using AUC as the dependent variable. The initial greater left-hemisphere activity found in region of interest -1 was not repeated during the AUC analyses.

Cz Amplitude analyses for Block 2 Faces.

Two significant effects of emotion were present in amplitude variations in region of interest – 3 (F(3, 123) = 4.105, p<0.008), and region of interest-4 (F(3,123) = 6.204, p<0.017) at the Cz electrode site. For block 2 faces at CZ only, analyses of amplitude permitted the inclusion of data from an additional 3 individuals owing to fewer artefact-related data exclusions.

Four post-hoc comparisons showed significant effects, all of which remained significant after Bonferroni correction :

Table 14 : Amplitude effects of emotional valency at Cz site, Region of interest- 3

Comparison	T (df = 41)	Sig.	µV	$r_{contrast}$
Disgust vs. Anger	-0.508	N.S.	-.523 vs. -.711	0.08
Disgust vs. Sadness	-2.274	.028	-.523 vs. -1.195	0.33
Disgust vs. Happiness	3.170	.003	-.523 vs. -1.576	0.44
Anger vs. Sadness	1.304	N.S.	-.711 vs. -1.195	0.20
Anger vs. Happiness	2.592	.013	-.711 vs. -1.576	0.37
Sadness vs. Happiness	1.346	N.S.	-1.196 vs. -1.576	0.20

Table 15 : Amplitude effects of emotional valency at Cz site, Region of interest- 4

Comparison	T (df = 41)	Sig.	µV	$r_{contrast}$
Disgust vs. Anger	-1.579	N.S.	4.379 vs. 3.829	0.23
Disgust vs. Sadness	-3.067	.004	4.379 vs. 3.427	0.43
Disgust vs. Happiness	-0.465	N.S.	4.379 vs. 4.521	0.07
Anger vs. Sadness	1.112	N.S.	3.829 vs. 3.427	0.17
Anger vs. Happiness	-1.725	N.S.	3.829 vs. 4.521	0.26
Sadness vs. Happiness	-3.870	.0001	3.427 vs. 4.521	0.51

Although the amplitude analyses of emotional valency revealed several significant differences in block 2 of the faces, the AUC analyses did not, likely attributable to the greater effect size and resolving capability associated with solely amplitude based analyses. The main effects of emotional valency in block 2 predominantly distinguished between effects related to sadness and happiness, but similarly to block 1, every stimulus category did not differ from every other. One more effect was present in region of interest-3, with comparable effect sizes throughout. In contrast to Block 1, sadness and happiness in block 2 were very prominently distinguished in region of interest-4.

Discussion

The performance of the participants and the effectiveness of the task methodology were highly acceptable. Although apparently somewhat fatigued by the end of the session, participants were able to reliably make accurate judgements about the nature of the stimuli (either identifying the facial expressions or the length of the lines) at varying presentation speeds in a logical manner. When presentation speeds were rapid, participants had difficulty in making accurate decisions regarding the stimuli, and vice versa. Behavioural error rates were low, and the obtained ERPs were highly characteristic of both previous phenomena in memory and discriminatory cognition (i.e. the presence of the P3 complex), and also in terms of the replicability of the results of the previous studies presented here. It is thus quite certain that participants had little difficulty in understanding the task, performing it, and in so doing, reliably identifying the stimuli. Additionally, participants manifest related and expected phenomena, e.g. the negative correlation between P300 onset times and IQ scores, and the IT-IQ relationship (presented in chapter 9, study 5.).

Psychometric Findings

Findings from the psychometric and electrophysiological data were somewhat unusual in this study. The population appeared to be extremely homogenous, with very few gender based-differences in the psychometric data. Gender-related differences were not prevalent among the ERP data either, where e.g. Orozco and Ehlers (1998) found that female subjects showed larger and longer-lasting P450 components to happy and sad emotional faces, such phenomena were absent in the present study. The findings of the present study were different in some respects from the findings of Austin (2004), and Austin (2005), the closest analogous (behavioural) studies upon which this series were based. Austin’s (2004) findings did not show any effects or trends involving the NART, where the present study showed a weak trend between Utilisation of emotion and NART scores, which was amplified and achieved significance after segregation of the population into two extreme-scoring groups. As discussed previously, however, the explanation of this trend is problematic owing to the apparent dichotomy of a crystallised intelligence measure (i.e. a test primarily of previously stored knowledge) showing potential links with an active process of intrapersonal cognition; within the literature, ability-based tests of EI are more associated with crystallised and verbal intelligence than self-report measures (MacCann et al. 2004, Farrelly and Austin 2007). Only one significant correlation between an EI and IQ measure (i.e. Mood regulation and APM scores) was obtained in the present study. Although precedent exists for the use of Raven's Matrices as a correlate of inspection time (Deary 1980, Olson and Marshuetz 1998; Morris and Alcorn 1995, Bates and Sheiles 2003, and Vickers, Pietsch and Hemingway 1995.), the use of Raven's Short-APM was relatively less successful where the use of the AH5 battery in study 2 yielded two stronger associations. In contrast to Austin (2005), where effects pertained to interpersonal factors from the modified SREIT, in the present study, the correlation was with an *intra*personal factor (i.e. Utilisation of emotions). The most notable difference between these IT studies, however, was only in the participant population's relative ages between the present study (mean age = 21.7 years) and Austin's (2004) and (2005) studies, where the mean ages were 32.7 and 51.3 years respectively, which may have resulted in these inconsistent effects.

Austin's general approach has been validated by the present study, however, in showing associations with established measures of intellect (Raven's Standard Progressive Matrices *Plus* and in the present study with APM Short Version) and self-report EI measures (the standard SREIT, a modified version of the SREIT and the Bar-on EQ-i:S). Total correct responses and inspection times were positively correlated with utilisation of emotions, while mood regulation was positively correlated with Short APM section 2 scores. When the sample population was reduced to N=30, these correlations became stronger. In contrast, Bastian, Burns and Nettelbeck (2005) found "Self-report EI measures were moderately correlated with personality, but their correlations with cognitive abilities were generally near-zero.". In the present study, this has not proven to be the case, even allowing for the artifice of the creation of high- and low-IQ groups, and a slight, if not entirely explicable relationship was present between EI and IQ. Even if such a relationship was not entirely explicable, the participants' intellect did impinge upon the tested relationships to some degree. Van Rooy and Viswesveran's (2004) meta-analysis found modest correlations between EI and general mental ability (0.22), although they reported that ".....EI and GMA tend to be orthogonal constructs that denote different competencies….." – a somewhat contradictory statement given their finding of correlations. Their analysis of other studies, however, featured a substantial proportion of self-report measures of EI rather than e.g. solely ability-based tests, which would tend to undermine their essential conclusion of orthogonality – i.e. they did find relationships among the tested variables, but not through the use of only ability-based measurements, which they claim arose from "different competencies".

The present study did not reproduce gender-related differences in EI. Women have self-reported higher scores across several domains in the SREIT, even if these scores do not always reach statistical significance (e.g. Ciarrochi et al. 2001, Schutte et al. 1998, Austin 2005, Van Rooy, Alonso and Viswesveran 2005). While the present study featured a weak gender - related trend, it failed to achieve statistical significance.

Three interpretations of the present study's phenomena are considered likely.

(i) The present study's population may have shown only a very weak manifestation of the expected SREIT gender-related traits, and simply failed to display differences which the E.I. literature has previously noted. The tested population was otherwise quite homogenous with regard to other variables under test (e.g. IQ, and most ERP regions of interest.), and it is similarly possible that this homogeneity was also reflected in the EI self report scores.

(ii) It is possible that the SREIT test used here was simply non-discriminatory for gender effects; a combination of these two potential causes is strongly suspected.

(iii) It may also be the case that the present study's sample size (N=46) was insufficient to reveal these effects, and it could be argued that EI effects as measured by the SREIT self-report are somewhat weak, requiring considerably larger sample sizes to achieve statistical prominence. If this is so, it is questionable that such inter- or intra-personal traits would be broadly noticeable across individuals' behaviour in any ecologically meaningful way in everyday behaviour.

The relevance of "real-life" behaviours and life-events are heavily emphasised in the EI literature; it has been noted that e.g. EI traits (although measured by other tests) correlate with "satisfaction with social support" (Ciarrochi et al. 2001), and life satisfaction (Palmer, Dodgson and Stough 2002). If the SREIT is to be used further, it should, in principle, be able to demonstrate effects which verify these basic tenets of EI as a viable construct, perhaps without resorting to very large participant sample sizes, or verification from other established test. As a simple critique, Schulte, Ree and Carreta (2004) titled their article "E.I. : not much more than *g* and personality". Using the MSCEIT "ability" EI measure, the NEO-PI, and the Wonderlic Personnel Test, several statistically significant associations were noted between all three measures, leading Schulte et al. to "question the uniqueness of EI as a construct". It could therefore be interpreted that EI is either actually not fundamentally unique as a construct, sharing many trait measurements (in some form) with existing personality inventories such as the NEO-PI, or that at least, existing measures of EI feature an unavoidable, and considerable, overlap with pre-existing psychometric tests to the extent that distinctions or definitions of measurement are problematic. It also appears that EI, as a psychometric construct, is difficult to measure accurately, and is perhaps of limited usefulness given its apparently poor discriminant validity and poor definition as a construct given the overlaps with established personality inventories. As such, the general utility of trait EI can legitimately be called into question, as it may not truly measure anything that is unique or unprecedented.

ERP Findings

The continued presence of the P300 complex was highly important in the present series of studies by validating many aspects of the methodology, although the continued presence of the P300-type complex alone says much about the processes involved in this task. The successful performance of the participants, coupled with the continued presence of a ubiquitous ERP waveform, reinforces the success and applicability of the task as a whole. The inspection time methodology was useful in facilitating the EEG acquisition; by combining fixed presentation durations (where a stimulus is either shown long enough to be correctly recognised or not) and ERP methodology, where reliance on participant behavioural RT is effectively lowered in importance. Additionally, the lack of time limits on participants' responses helped to minimise the presence of muscular and ocular artefacts within the recording; a useful benefit of the procedure.

The inconsistent effects of emotional recognition in the ERPs involved differential effects of the recognition of all four emotional states. It seems that the emotional expressions did not evoke ERP responses that could be reliably, and statistically, differentiated between all stimulus classes either within or between the face-IT tasks. Although differences in wave amplitude were present (and with some consistency across Studies 2 and 4 with happy stimuli evoking larger amplitudes and areas in two of three cases), the characteristics of the obtained waveforms were not strongly characteristic or different from those recorded in many other cognitive studies – there does not appears to be any particularly unique psychophysiological attribute which can be associated with the detection of emotional stimuli and which segregates the detection of such information. The N170, for example, is specific to faces, and not to facial expressions, and did not vary in the present study.

This raises a question previously asked by Smith et al. (2003) on the nature of emotional cognition – "Zajonc (1980) postulated that affective processing was separable from cognitive processing.". The data from the present series of studies indicate that this is indeed the case, given the presence of brain electrophysiological responses absolutely characteristic of cognitive processes involved in memory-related comparisons (the P3 complex), yet, responses which did not differ in terms related to the emotional valency of the stimuli in a novel or remarkable way. Effect sizes for emotional valency were low to moderate in most cases, and, <u>all</u> of the four emotional valencies presented to participants did not differ from each other in consistent ways based on each experiment in the present series – in this final study, effects were strongest when featuring angry and disgusted emotional states. As can be seen from visual inspection of the grand ERPs, when overlaid, the grand averages from all emotional conditions were again highly conformal. The behavioural data, however, presents a different overall pattern from the electrophysiological data : participants were able to successfully identify and differentiate the stimuli with great reliability, but, their ERP responses did not always show statistically discernible differences.

It is therefore likely that the visual recognition of an emotional face is only one of several “requirements” to evoke responses in the viewer, and the initial appraisal of facial expression is purely cognitive and quite separate from further affective responses within the viewer. Given the repeated presence of the P300 complex, it is likely that the associated cognitive acts were strongly associated with discriminations based upon memory of the stimuli encountered to that point, initially based upon prototypical concepts of the stimulus classes held by participants. As participants were not given feedback on their performance, and yet were able to perform highly above chance levels, they obviously possessed suitable mental templates for comparison with the stimulus items – i.e. their archetypes of emotional displays were congruent with those from the Eckman set. Because the stimulus faces were also highly unlikely to have any broader association or meaning for any of the participants, purely <u>discriminatory</u>, rather than <u>specialised affective</u> responses are plausible. Ohman (2002) and Vuilleumier (2002) suggest that there are advantages to the individual in rapidly detecting threatening or dangerous facial expressions, and the present data supports this to some degree – emotions such as disgust and anger showed more frequent statistical differences in post-hoc comparisons.

An additional and considerable difficulty in interpreting these results is the difficulty in finding other studies with analogous results or methodologies. Carretie and Iglesias (1995) highlighted this inconsistency :

"Secondly, components after the 300th millisecond……….are supposed to reflect the affective processing of neutral and emotional facial expressions. However, previous results are contradictory. While in some studies the neutral faces evoked lower amplitudes than emotional ones (Carretie and Iglesias, 1991; 1993; Laurian et al., 1991), in others they evoked the highest (Vanderploeg et al., 1987).”.

Statistically significant ERP responses to emotional stimuli are seemingly neither highly consistent in their nature, nor always easily replicable, and, their manifestation may vary considerably according to the precise and specific details of the stimuli and method of presentation involved. Perhaps these responses are more "straightforward" cognitive processes involving initially the detection of visual differences which are eventually passed to increasingly complex cognitive systems for further analysis, potentially culminating in the visceral emotional experiences, but beginning with an initial and simple discriminatory process. It seems clear, however, that emotional responses to visually presented stimuli of this nature (i.e. unfamiliar human faces) are not strongly characteristic or otherwise unique to these stimuli, even within the present series of studies.

Smith et al. (2003) noted that :

"a growing body of literature is documenting an *attention bias* toward negative information. That is, our attention is automatically drawn to negative information more strongly than it is automatically drawn to positive information.".

Such a statement does not define how attention could or should be measured; a clearly important aspect of investigations of emotion. E.g. does slower behavioural RT, or more rapid behavioural RT, or enhanced ERP component amplitude or lowered ERP component latency imply a greater "amount" of attention being devoted to the analysis of a stimulus ? The notion of negative emotional information being more salient during such studies is somewhat consistent with the present study's findings, as significant comparisons were present generally when "negative" faces (sad, disgusted or angry) were compared to happy. Smith et al. also referenced Hansen and Hansen (1988), in whose study "participants were faster at picking the angry face out of a happy grid than vice versa, suggesting that their attention was automatically drawn to the angry faces. ". Related to Smith et al's earlier reference to Zajonc's question of the cognitive interpretation and seperability of emotion and cognition, Hansen and Hansen's finding could also be interpreted as stating that participants were simply better at rapidly finding the item in a grid which was different from the others; a response more cognitive than affective.

Eimer & Holmes (2007), and Eimer, Holmes and McGlone (2003) found that when emotional faces were presented alongside non-emotional faces, upside-down emotional faces, or neutral objects (houses), the obtained ERPs showed larger positive amplitudes for the emotional faces in contrast to the other stimuli presented simultaneously. Additionally, these effects were manifest from an early stage ("within 120ms") in the ERP. Eimer and Holmes (2007) stated that these effects were likely to be specific to emotional faces rather than simple discrimination, because responses to inverted faces were attenuated, rather than completely absent. While their 2003 study featured some similarities with the present experiments in the discrimination of emotional faces, their methods were nonetheless different. Participants were always provided with emotional and neutral stimuli simultaneously during each trial, and the stimuli were presented at a fixed duration of 300ms. The present study's methodology differed in three major aspects which may have influenced results:

(i) The stimulus presentations ranged from extremely brief to relatively longer periods, but which nonetheless comprised, at most, 40% of the 300ms presentations used by Eimer, Holmes and McGlone (2003).

(ii) As only a single stimulus was presented within each trial , participants in the present study were never required to make discriminations between two stimulus items during trials, but rather discriminate from 4 options from previous experience.

(iii) The present study used a moderately large sample size for an ERP study (N=46), with 192 stimulus presentations. In contrast, Eimer, Holmes McGlone used a small participant population (N=15) coupled with a very large number of trials (1,920 trials).

Their obtained ERPs were also morphologically different from those in the present study. Although again broadly conforming to a P3-type complex with an N170 component, the P3 regions themselves were seldom prominent. Eimer, Holmes and McGlone interpreted their data in terms of a theory of specific emotional mechanisms proposed by Adolphs (2002) (and also Adolphs, Tranel and Damasio 2003) as not having been strictly correct, as their ERP responses to all stimulus types were broadly very similar. Eimer and Holmes (2007) chose to re-interpret their findings with specific reference to the presence of the N170 component as relevant to the structural, then perceptual and affective encoding of face stimuli. Although Pizzagalli et al. (2002) found that the N170 was modulated in response to "liked" and "disliked" faces, there is also evidence that the N170 is invariant to all but the simple presence of a face-like stimulus (e.g. Halgren et al. 2000, Eimer and Holmes 2002, and Herrmann et al. 2002) except when explicitly compared with a non-face stimulus, which substantially diminishes the usefulness of the N170 as a dependent measure. It is also questionable as to the extent to which claims of the resolution of facial structural encoding can be made of Eimer, Holmes and McGlones' (2003) data from the methodology employed, both in terms of the task demands, and the ability of ERP data to resolve e.g. detailed structural activation over time. The methodology of Eimer, Holmes and McGlones' task was never initially intended to examine face-encoding procedures, by e.g. selectively presenting whole faces versus gradiated face elements for scrutiny and response evaluation, or other variations related to specifically structural aspects of human faces, which makes their claims difficult to substantiate. Eimer and Holmes' (2007) interpretation and conclusion, however, would seem similar to the present study's, in that "it is clear that the question of whether or not different emotional facial expressions give rise to specific ERP effects is far from settled.".

Other, more recent behavioural studies have been conducted of emotional facial phenomena. Olson and Marshuetz (2005) found that facial attractiveness could be assessed accurately using a behavioural study of forward and backward masking, but with extremely brief, tachistoscopic-level stimulus presentations of 13ms. Facial attractiveness, however, is a different phenomenon from the detection of emotional expression, and Olson and Marshuetz's findings remain to be replicated. Although their subject population were stated to be consciously unaware of the qualities of the stimuli they viewed, Olsen and Marschutz were nonetheless of the opinion that "….attractiveness is assessed rapidly and from small slivers of visual information….".

In terms of broader spatial localisation effects, the hemispheric lateralisation effect in block 1 of the faces task was different to that shown by Jansari et al. (2000), who found significantly greater accuracy in discrimination when stimuli were presented to the left visual field / right hemisphere. In contrast, block one of the present study found greater brain electrical activity in the left hemisphere using a central stimulus presentation. Carretie and Iglesias (1995) also failed to find a right-hemisphere superiority. Jansari et al.'s study, however, was purely behavioural, and quite different from the present study in several ways. Jansari et al. interpreted these results with reference to a right-hemisphere superiority, although their methods did not include any measures of brain activity beyond correctness of response as a wholly behavioural-cognitive task. Additionally, participants were not time-limited in making their decisions, and a proprietary stimulus set was created via the use of software morphing of images from the Eckman set between a neutral and target emotional expression. Jansari et al.'s subject population was both markedly older than the present participants (mean age of 41-45 vs. 20-22 years), and possessed of lower NART IQ estimate scores (104-106 vs. 117 combined mean for both genders). This constitutes a clear example of the differential discrepancies in results arising from different experimental methodologies, and highlights the difficulties in further experimentation; in many cases, slight differences to the methodology result in markedly different effects which are both difficult to directly compare to previous work, and build upon in future.

As the present study was not a precise replication of other studies, it is difficult to comment further, and generalise across other studies, given that differences in the specifics of the task methodology, from Carretie and Iglesias' brief review, apparently result in varied outcomes. The inconsistent effects of emotional valency could be related to the relatively brief exposure times employed here, although this raises the questions of how, or if, longer presentation durations would alter the outcomes – participants were otherwise highly successful in identifying the emotions displayed, and in Eimer, Holmes and McGlone's (2003) study, presentation durations of 300ms still failed to evoke emotional responses within the ERPs. As can be seen from reference to Study 3, presentations of 80ms still result in extremely high success rates in stimulus identification, with no participant scoring less than 95% correct. Carretie & Iglesias (1995) used 100ms presentations, but their task required participants to rate the faces they viewed on "arousal" and "valency", and only 1 facial expression (happiness) was employed.

While specific mechanisms or neural circuits may well exist for the processing of affective information, given the universality of appropriate emotional experience among the psychologically healthy population, it remains questionable whether the present study's methods were appropriate to reveal them, or indeed, those of other studies referenced here (e.g. Eimer Holmes & McGlone 2003). The findings of the present series of studies do, however, imply that as a process of appraisal and discrimination, the recognition of emotional states is a cognitively penetrable behavioural act, if one that is not possessed of powerful effects.

CHAPTER 9

Study 5

Multiple-Choice Variants of the Emotional- and Conventional- I.T. Tasks : Findings from the 4-Line IT Task and Intelligence

Introduction

This section contains separate analyses of behavioural, psychometric and electrophysiological effects related to IQ from the previous study. The experimental procedures are unchanged, and described in the previous study.

Results

Effects for IQ

Psychometric and Behavioural Results.

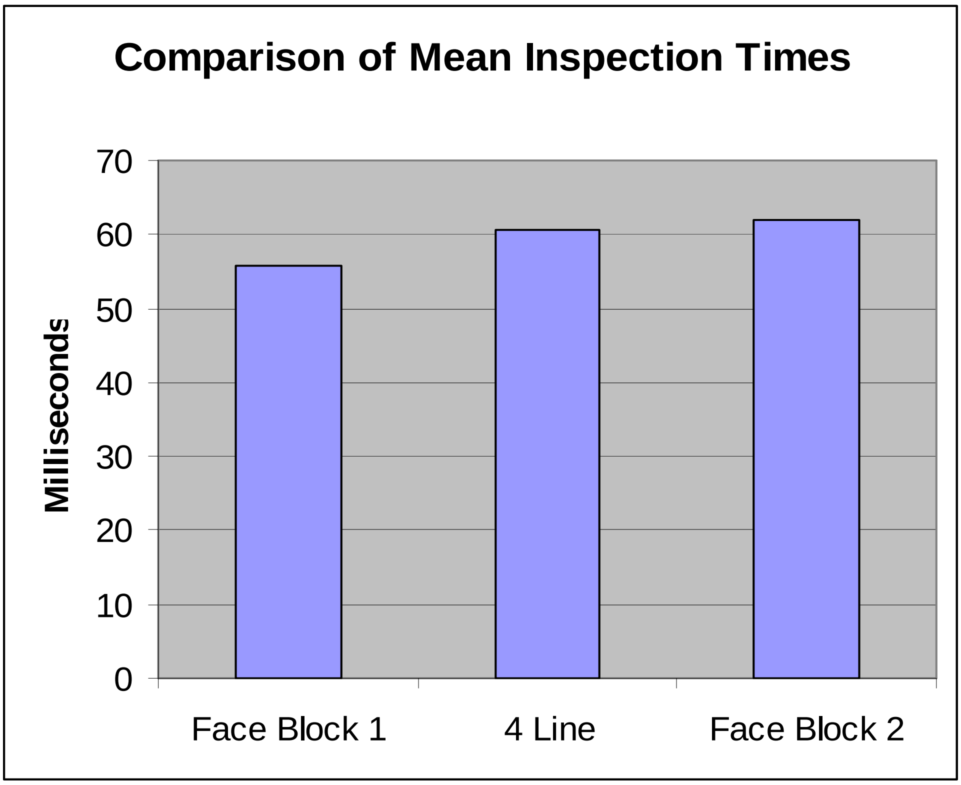
Means, standard deviations and normality-test results for interval-level psychometric and behavioural data are presented in table 1.

Table 1 : Descriptive statistics and results of normality testing for interval data.

Measure	Mean	Std. Dev	Kolmogorov-Smirnov Z	Sig.
Short APM Section 1 Score	5.50	0.66	2.46	0.01
Short APM Section 2 Score	8.67	2.01	1.18	0.12
NART Errors	13.15	4.33	0.55	0.92
NART Full-scale IQ	117.08	3.59	0.55	0.92
NART Verbal IQ	116.90	3.98	0.55	0.92
NART Performance IQ	115.50	2.80	0.51	0.96
IT Block 1 Faces (ms)	55.68	23.83	1.25	0.09
IT Block 2 Faces (ms)	61.82	32.45	1.13	0.16
IT 4 Line (ms)	60.70	18.29	0.76	0.60
Correct Block 1 Faces	156.35	14.01	0.95	0.33
Incorrect Block 1 Faces	35.65	14.01	0.95	0.33
Correct Block 2 Faces	150.72	16.85	0.66	0.78
Incorrect Block 2 Faces	41.28	16.85	0.66	0.78
Correct for 4 Line	139.07	15.66	0.65	0.79
Incorrect for 4 Line.	60.93	15.66	0.65	0.79

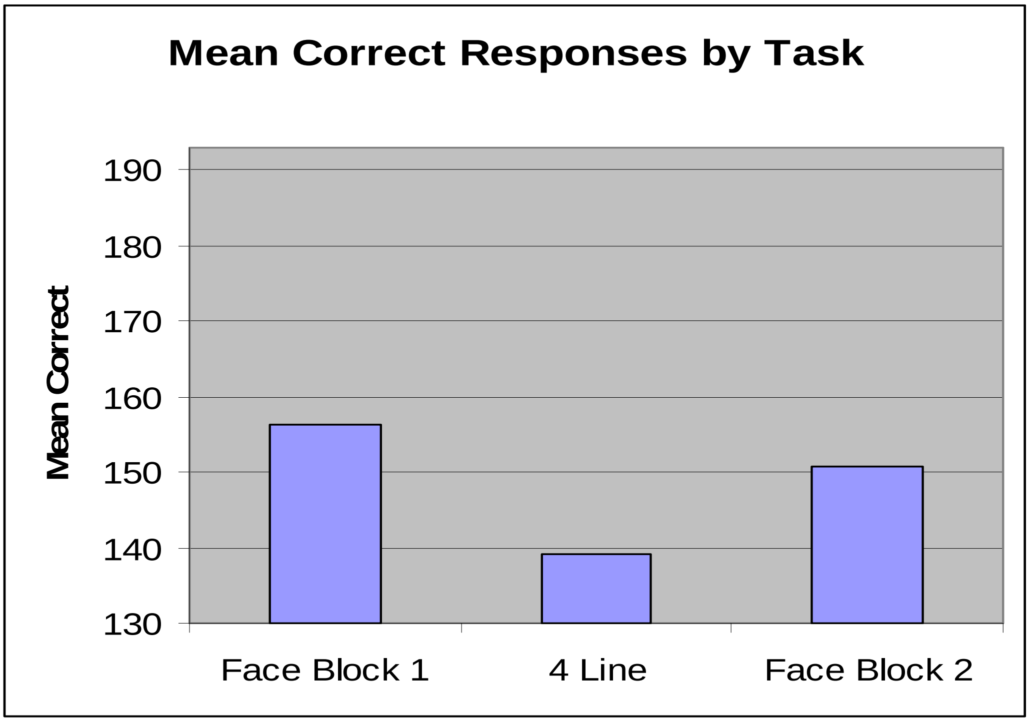
Only Short APM section 1 scores showed a skewed distribution (z= 2.46, p<0.01). However, although recorded, the first section of the Short APM is intended to familiarise participants with the test procedures and does not contribute to the final result drawn from Short APM section 2. The remainder of the interval level data was appropriately suited for parametric analyses.

Chart 1 : Graph of mean inspection times.



Inspection times for all three tasks were very similar despite a relatively higher error rate for the 4-Line task. Block 1 of the face tasks differed by only 6-7ms from the other two tasks. Participant performance in the IT tasks is presented in chart 2.

Chart 2 : Mean performance for IT tasks.



Mean correct responses for blocks 1 and 2 of the emotional faces show comparable difficulty. The 4-line IT task, however, appears to be considerably harder, with the largest number of errors.

Group IT curves for all three tasks are provided in Figures 1, 2 and 3. Figure 4 overlays the curves for all of the IT tasks for comparison. In block 1 of the face-IT tasks, the 85% success rate was achieved quickly, and the overlay plot (figure 4) shows the trends to be extremely similar. In block 2, however, participants required slightly longer to achieve an 85% hit rate. Again, this may be a result of participants' fatigue.

Figure 1 : IT curve for Faces Block 1.

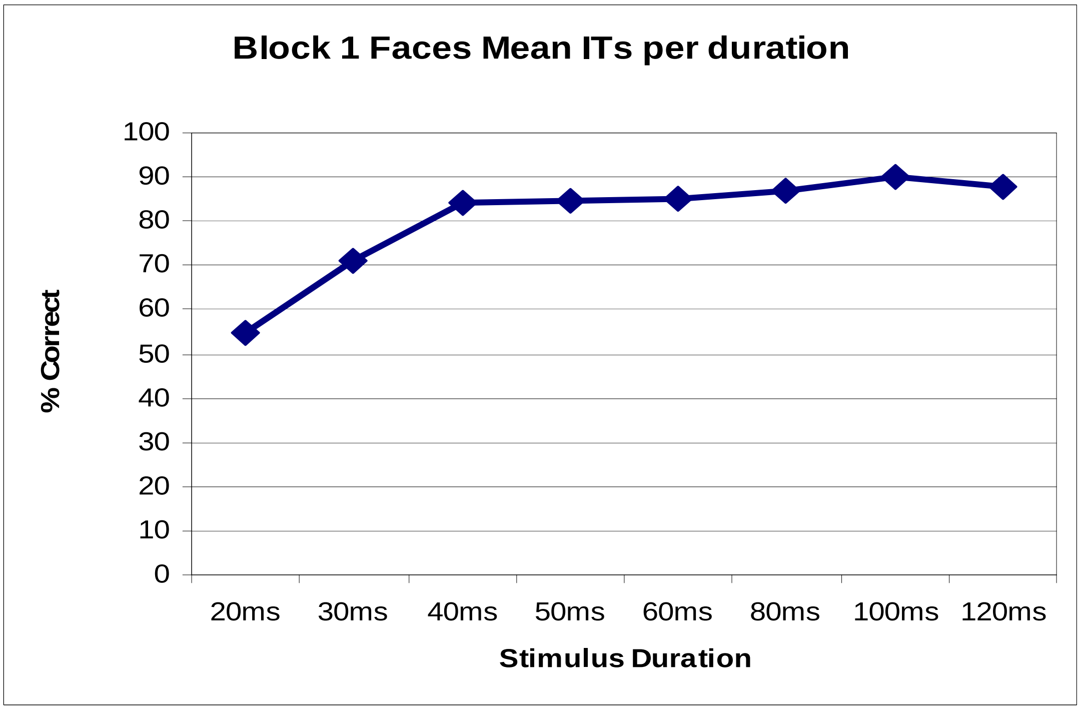
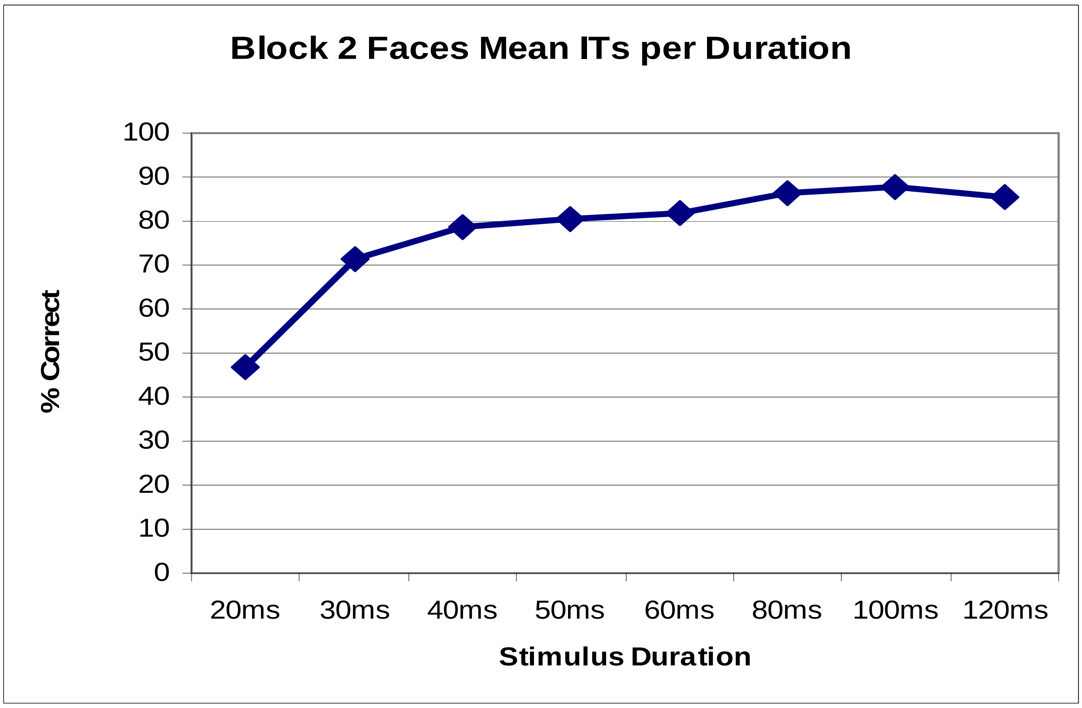


Figure 2 : IT curve for Faces Block 2



Both face-IT tasks showed a moderately high, early success rate which plateaued after presentation durations of approximately 40ms. Success rates at stimulus durations below 40ms, however, were above chance levels (i.e. 25%), indicating that these tasks were only moderately difficult.

Figure 3 : IT curve for 4-Line Stimuli.

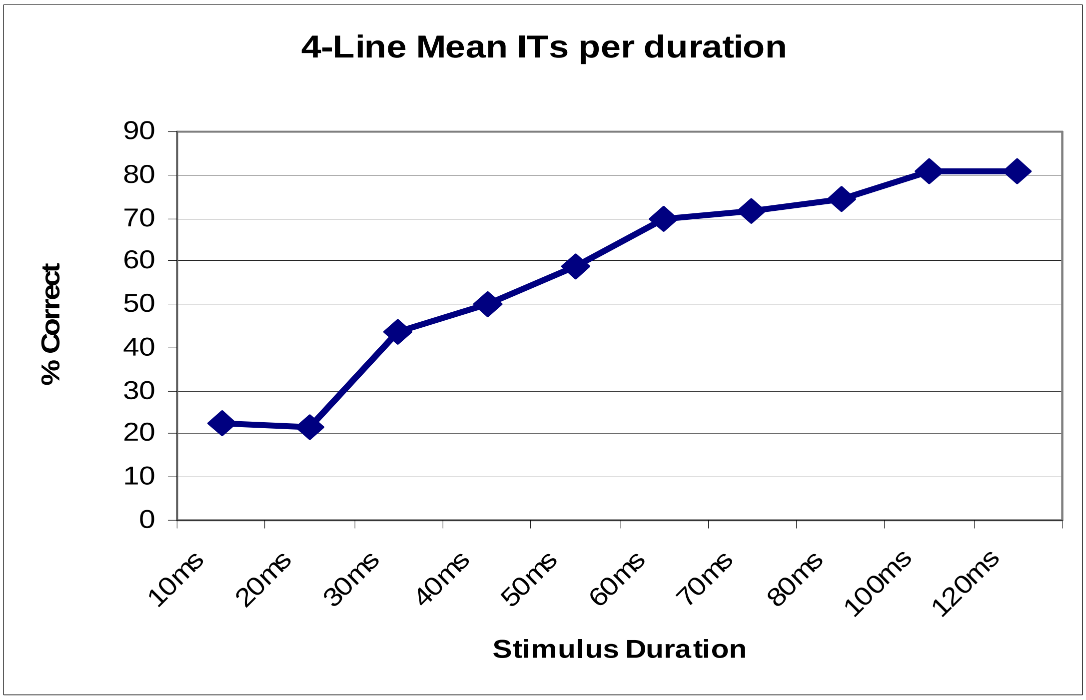
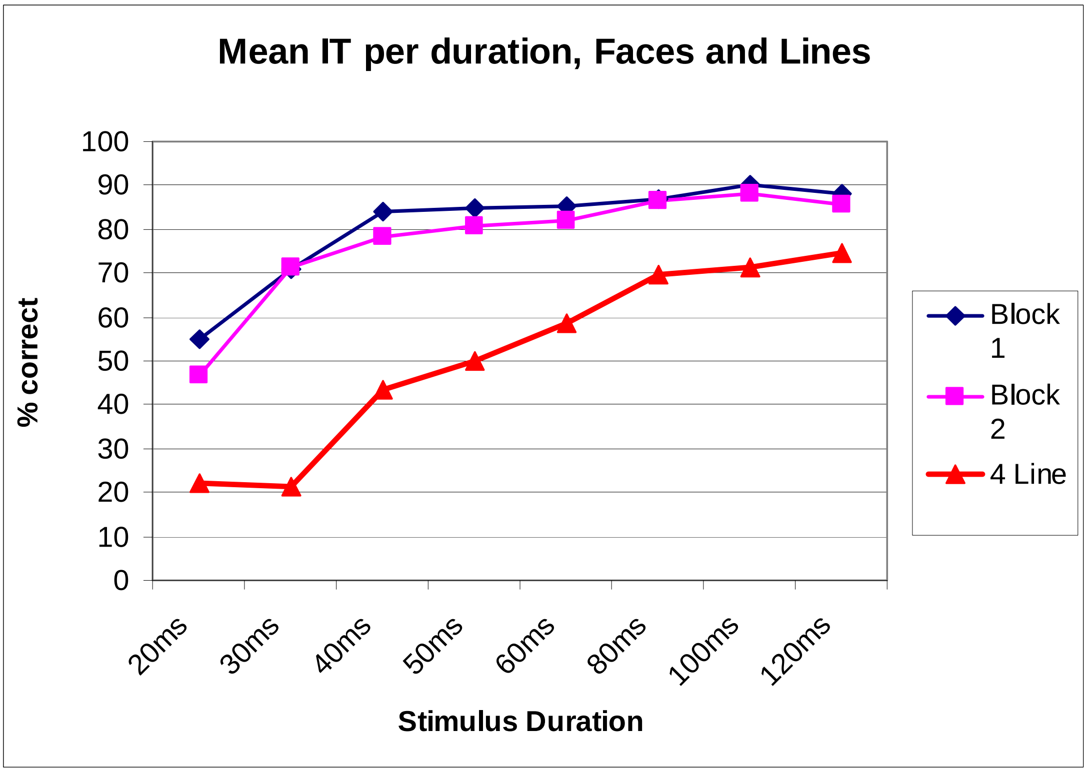


Figure 4 : All IT values overlaid.



The 4-Line IT task showed an expected inspection time curve (e.g. Deary et al. 2001). Correct responses occurred slightly below chance levels up to approximately 35ms durations, with a mean maximum hit rate of 80% not being achieved throughout the entire task. The 4-Line task was clearly much more difficult to complete than either face-IT task, and showed the lowest scores for mean correct responses, at 69.5%.

The data presented in Table 1 was assessed for gender differences in two stages. As with the SREIT inventory data, all 46 participants were tested, then a gender matched sample of 10 males and 10 females. No gender effects related to IQ were present for N=46 (the full sample). For N=20 (i.e. the 10 remaining males, and a random sample of 10 females), two significant results were present here.

(i) The 4-line IT task showed that **mean inspection times for males (53.82ms) were significantly faster than females (69.02ms),** F(1,18) = 5.581, p<0.030.

(ii) These participants also showed the same pattern of accuracy results for the left-most stimulus in the 4-Line IT task. **Males made significantly more correct responses (mean = 34.3) than did the 10 randomly-selected females (mean = 27.4) – F(1,18) = 7.645, p<0.013.**

High- and Low-IQ Groups

Following Josiassen et al. (1988) and Shagass et al. (1981), 30 participants were selected based on their Short APM score to explore any potential differences that may be related to variance in intellect. Seventeen individuals scored 10-12 (mean = 10.5 points), and thirteen participants scored 4-7 (mean = 6.5 points), comprising the upper and lower thirds of the population’s Short APM scores. The correlation analyses were re-run using the subset of high- and low-Short APM scorers. Statistical differences here were obviously somewhat artificial, induced by the segregation of the sample, but these effects demonstrate that such a segregation was possible within the sample. Statistics here are provided only for confirmation of these differences. Three effects were present :

2. Short APM score (part 2) –

Mean Short APM scores differed significantly between the high- (10.65 points) and low-scoring groups (6.62 points).
(F(1,28) = 108.295, p<0.0001.)

3. Inspection time for block 1 face-IT –

The high-scoring group showed a mean IT value 14.24ms faster than the low-scoring group (45.94ms vs. 60.18ms).
(F(1,28) = 5.246, p<0.030.)

4. Total correct responses for block 1 face-IT –

The high-scoring Short APM group achieved significantly more correct answers than the low-scoring group (162.18 vs. 152).
(F(1,28) = 7.431, p<0.011.)

These results provide evidence in support of the basic tenets of the inspection time paradigm and methodology - the performance of the high-scoring Short APM group was superior in matters of perceptual speed and accuracy, resulting in significantly faster IT values, greater scores for spatial reasoning tasks, and overall correct responses. These effects are not comprehensive across all tasks, however – the higher-scoring group (i.e. Short APM scores) did not out-perform the low-scoring group across all other measures. It should also be considered that any effects present in the group could be considered as “artificial”, in that specific sub-sets of the population have been selected due to the relative differences in IQ scores.

Inspection Time and IQ Correlations

As with the IT and EI correlations, all 46 participants' data were used here owing to an overall absence of gender-based differences.

Significant correlations among intra-test items are omitted here as these associations are related to test reliability, and otherwise irrelevant to the analysis. Significant correlations with inspection time were also rare using this test battery, as shown in Table 2.

Table 2 : Correlations : IT(ms) with IQ measures.

		Short APM ii	IT Block 1
IT Block 1 Faces	r	**-0.37**	
	p	**0.01**	
IT Block 2 Faces	r		**0.50**
	p		**0.001**
IT 4 Line	r		**0.36**
	p		**0.01**

Some significant inter-correlations were present between the IT tasks, although:

(i) Only the first face-IT task showed the expected negative correlation with IQ measures – specifically, Short APM section 2 scores (r= -0.37, p<0.01). The NART showed no significant associations with any other tests.

(ii) All three IT tasks did not show significant concordance with each other – only block 1 of the face-IT task was significantly related to both other IT tasks, and a single IQ measure.

Table 3 shows correlations between total accuracy rates for the inspection time tasks and IQ measures.

Table 3 : Correlations : Total correct responses and IQ measures.

		Short APM ii	Total Hits1
Total Hits Faces 1	r	**0.405**	
	p	**0.005**	
Total Hits Faces 2	r		**0.533**
	p		**0.000**
Total Hits 4 Line	r		**0.304**
	p		**0.040**

Both total correct responses and IT values show the pattern of results. As a relatively more blunt correlation within IT tasks (i.e. instead of correlations with actual inspection times), again only the first face-IT task showed positive associations with Short APM section 2 scores and total correct responses to the faces (r = 0.405, p<0.005), and similarly, only the first block of the face-IT tasks shows relationships with the other tasks.

These correlations were conducted again using the high- and low-IQ populations mentioned previously.

Table 4 : Subset of 30 high and low Short APM scorers; re-run of initial correlations for IQ and IT.

		Short APM ii	IT Block 1
IT Block 1	r	**-0.49**	
	p	**0.001**	
IT Block 2	r		**0.48**
	p		**0.001**

Using the subset of participants, fewer associations were present than when using the whole population. Again, Short APM section (ii) scores correlated significantly and negatively only with IT scores for Block 1 of the faces task (r = -0.49, p<0.001) – as Short APM scores rose, IT values decreased, indicating more rapid perception.

Table 5 : Sub-set of 30 hi- and low APM scorers, correlations of IQ and total hits.

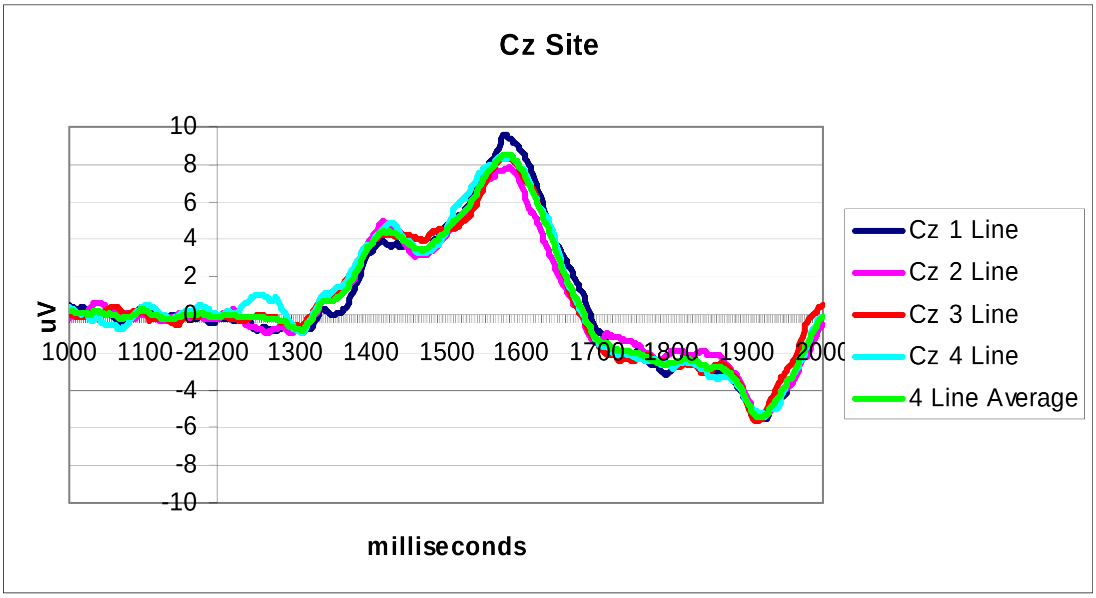
		APM ii	TotalHit1
TotalHit1	r	**0.55**	
	p	**0.001**	
TotalHit2	r		**0.58**
	p		**0.001**

A similar pattern was present again; only Block 1 of the faces task showed any significant associations with IQ (r = 0.55, p<0.001), although the correlation was marginally stronger than that associated with actual inspection times in milliseconds.

Grand Average ERPs for 4-Line Stimuli.

Grand average ERPs are presented for the 4-Line stimuli in Figures 5-13. Each ERP in figures 5-13 is an average of all four line-images at each electrode site. Unlike the facial stimuli, there is little reason to evaluate ERP responses to the individual line stimuli, as each stimulus possesses no heightened significance outwith the task demands – i.e. they are merely lines which are placed in different locations and which do not immediately resemble any other stimulus form. The grand average ERP for the CZ site is presented in figure 5 to illustrate the similarity among the individual 4-line plots and the averaged plot of all conditions. Thereafter, all plots feature only the averaged condition.

Figure 5: Grand Average for Cz site, all conditions + average of all conditions.



As shown, when grand ERPs for each stimulus type were averaged, the general morphology of the ERP was closely maintained in comparison to a plot of each individual stimulus line.

Figure 6: Grand Average for F3, Geometric stimuli.

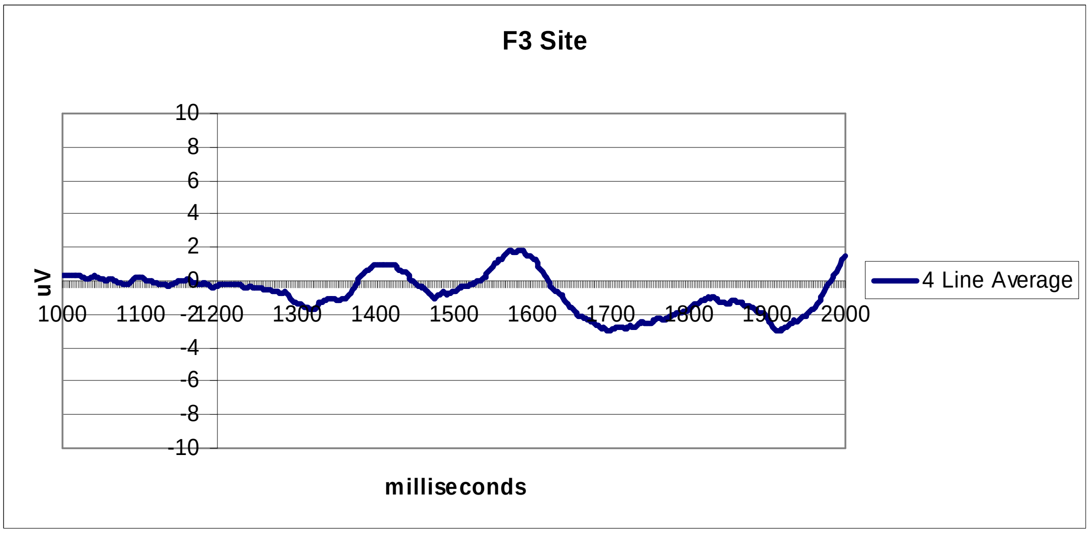
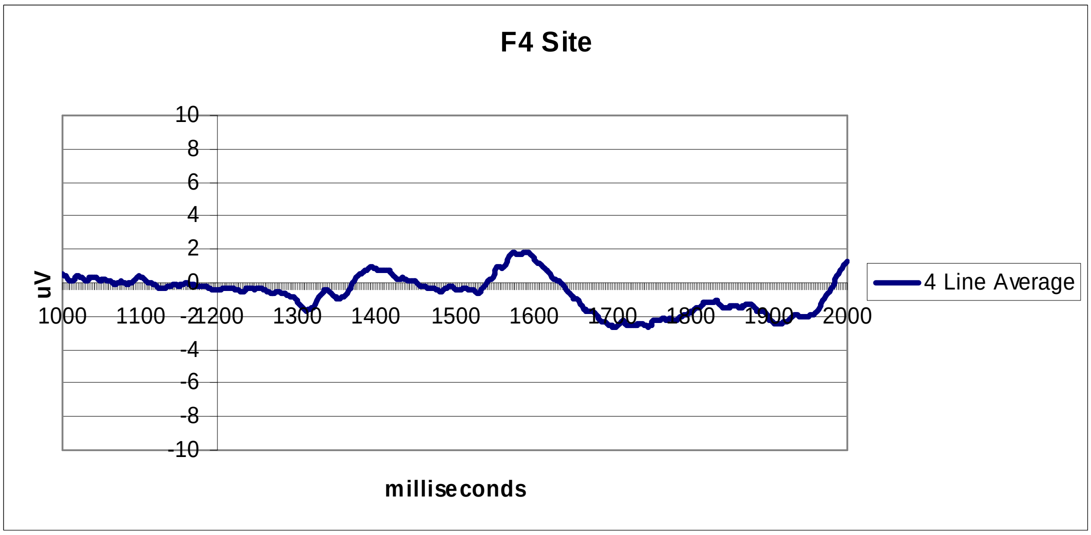


Figure 7: Grand Average for F4, Geometric stimuli.



The waveforms recorded at the frontal sites were heavily attenuated in comparison to all other scalp locations; the general amplitude was lower, and the P300 region was always negatively polarised. As expected, the N170 deflection was now characteristically absent.

Figure 8: Grand Average for C3, Geometric stimuli.

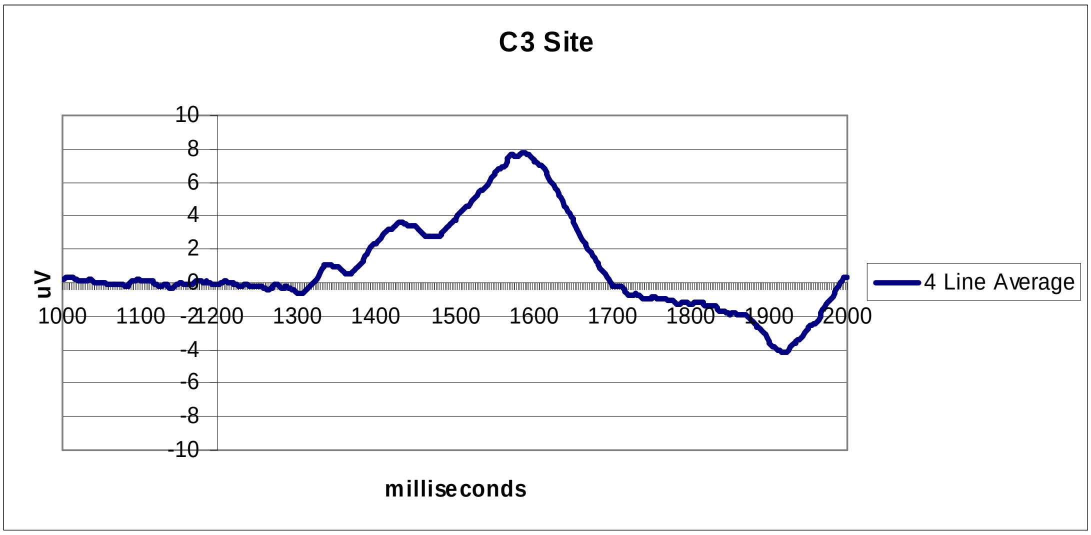
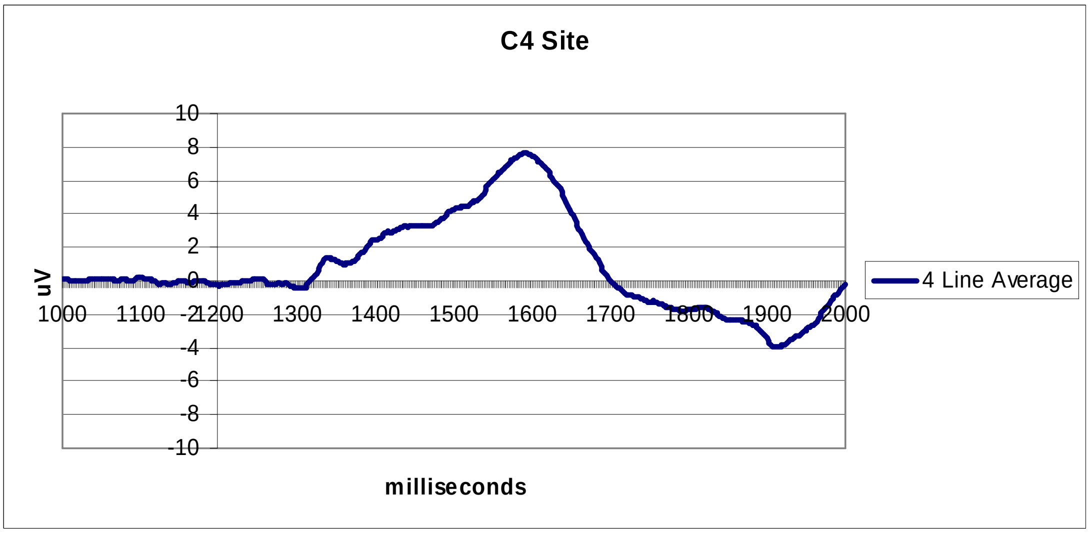


Figure 9:. Grand Average for C4, Geometric stimuli.



The candidate components of the waveform at the central electrode sites were difficult to differentiate. Only a prominent P300 complex remained, with sites C3 and Cz (figures 5 and 8) showing what appeared to be a heavily attenuated P100 at approximately 1400 milliseconds (200ms post-stimulus).

Figure 10: Grand Average for P3, Geometric stimuli.

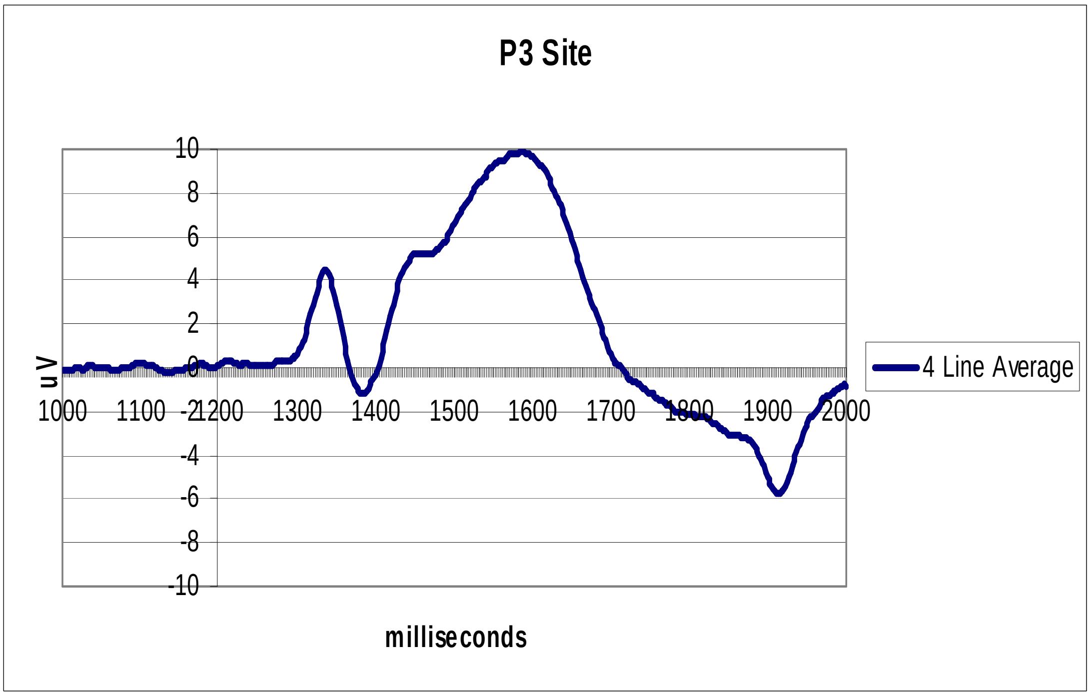
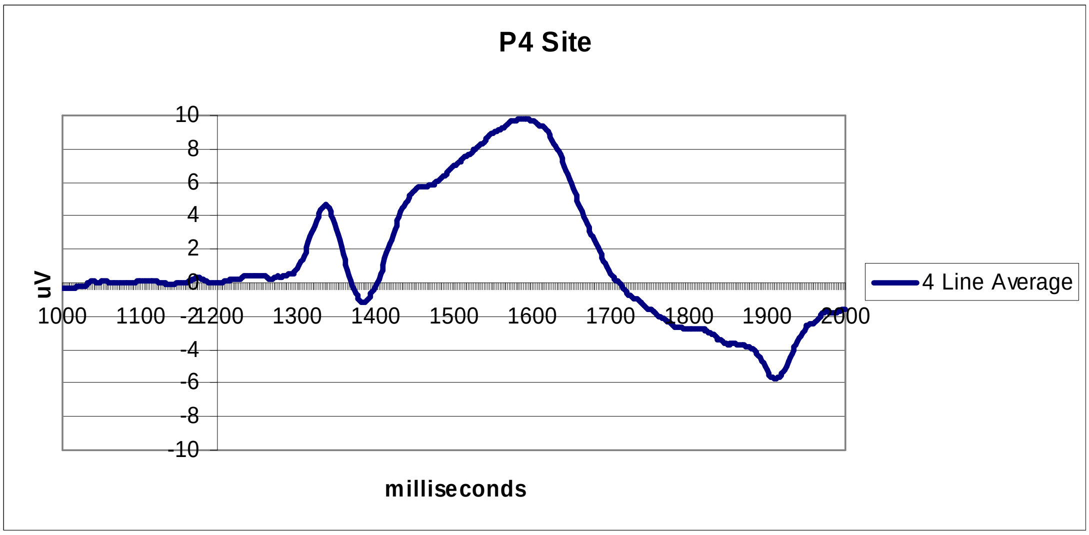


Figure 11: Grand Average for P4, Geometric stimuli.



Parietal electrode sites showed a slightly more differentiated P3 complex, now with an initial P100, a small N200, and P300 components.

Figure 12: Grand Average for O1, Geometric stimuli.

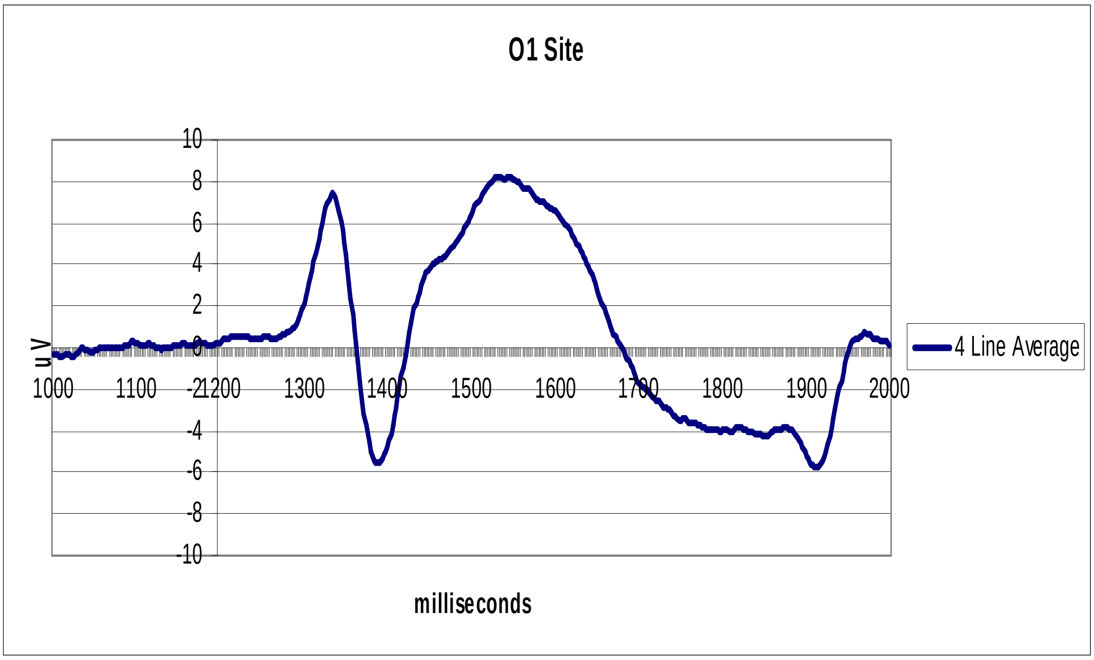
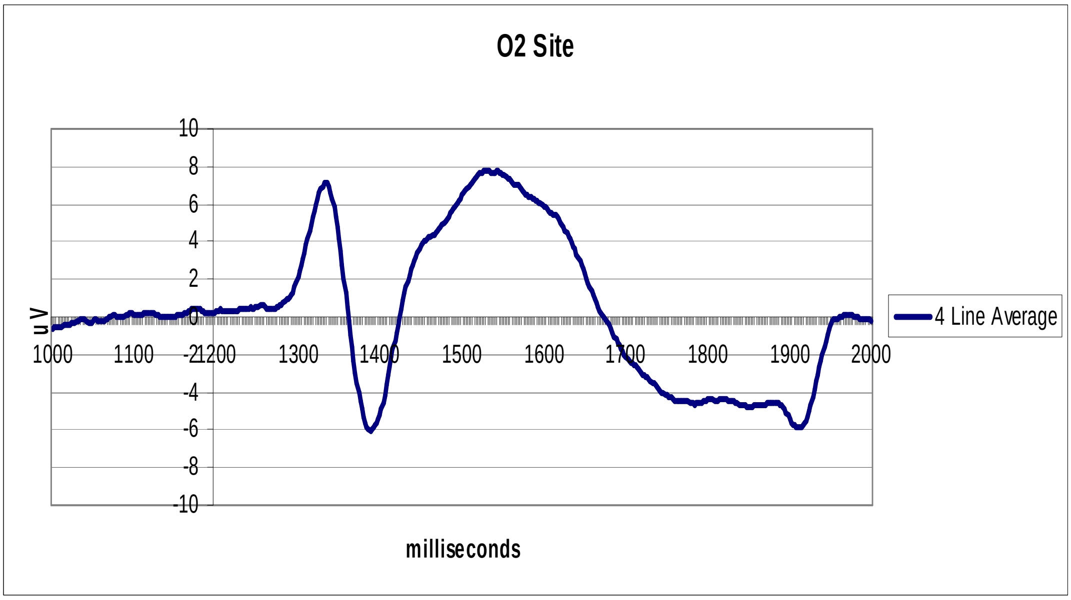


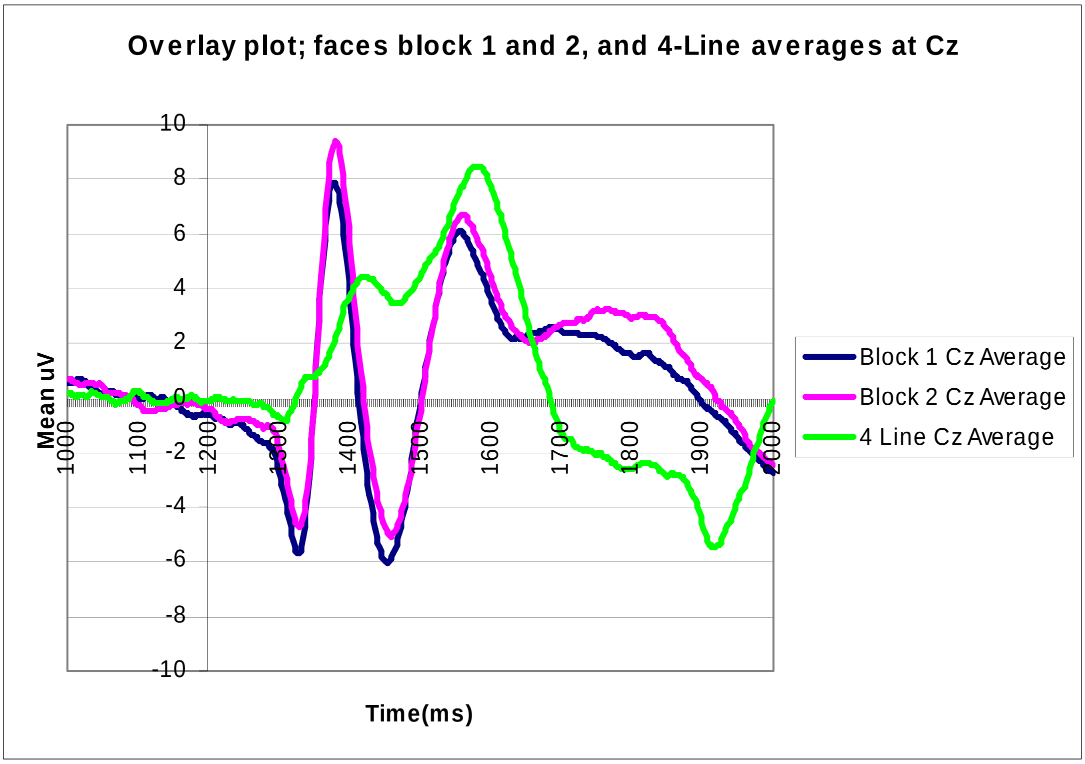
Figure 13: Grand Average for O2, Geometric stimuli.



Occipital sites O1 and O2 showed the most clearly differentiated waveforms with three recognisable components present (P100, N200 and P300). As with the face-IT tasks, there was a prominent P100 peak, easily discernible from the waveforms from the other electrode sites, followed by a large P300 component. In part, the relatively poor definition of ERP components here may be due to a higher error rate (30.5%) within the 4-Line task, combined with apparently more difficult task demands. Mean error rates for the face-IT tasks were both lower, at 18.56% and 21.5% for blocks 1 and 2 respectively.

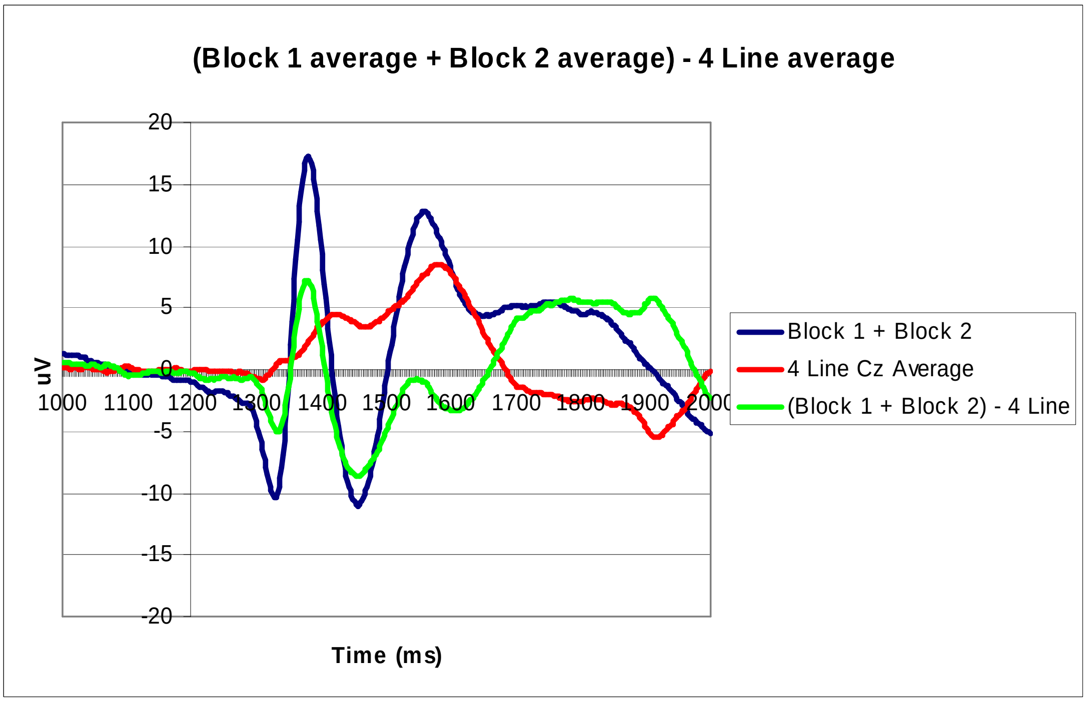
Differences between the face-IT and Line-IT tasks are shown in Figures 14 and 15. Three new averages of all four facial expressions, and all four line conditions were created for all IT tasks at the Cz electrode site. In Figure 14, these plots were overlaid :

Figure 14 : Overlay plot of all conditions for each task.



Both face tasks showed a similar morphology, whilst the 4-Line task was visually very different. The P100 and P200 components both show sustained and higher amplitudes than the P300 region in the 4-Line tasks, while the P100, N170, P200 and P300 are sharply defined in the face-IT tasks.

Figure 15 : Subtraction plot of face- and line-IT tasks



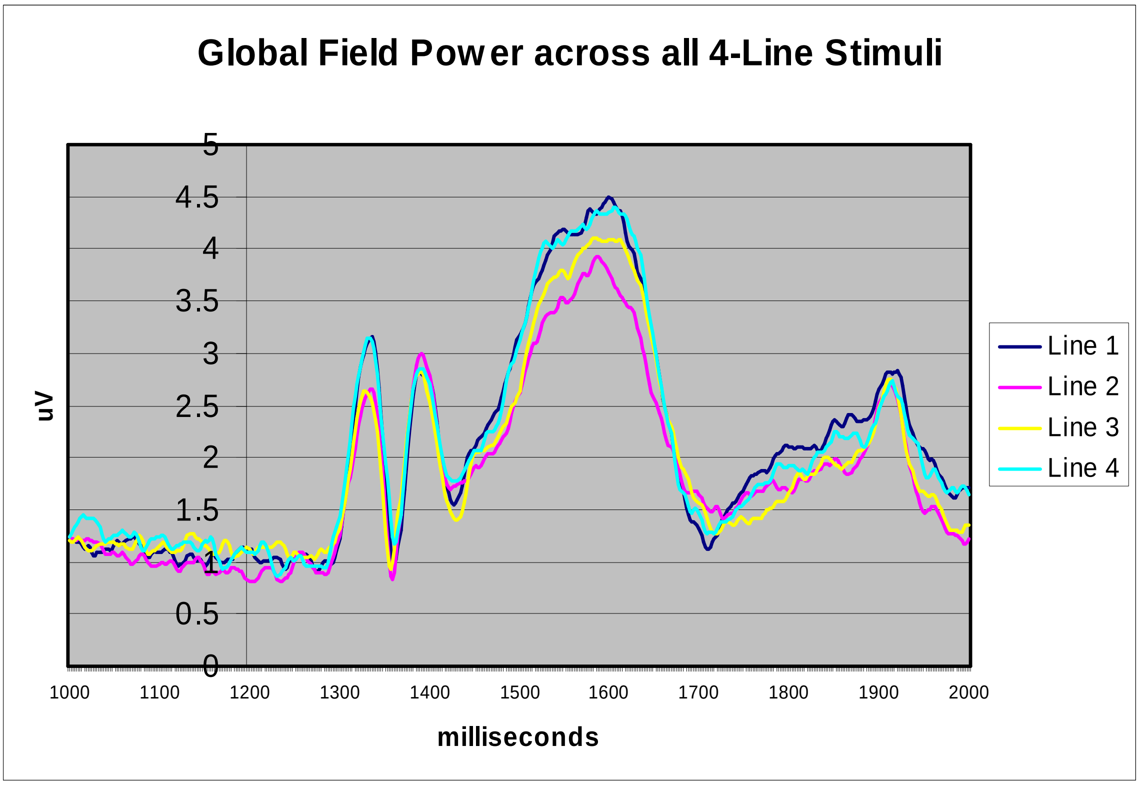
In figure 15, the averages for both face tasks have been summed, and the 4-line Cz average subtracted from that summation. The areas which differ are illustrated by the subtraction waveform. The 4-Line waveform was simpler than those from the face-IT tasks, with a notably later P100, and attenuated N200 and P300 components. The single most prominent peak for the 4-line task was a P200 deflection at approximately 1590ms. Combined with the lower behavioural success rate for the 4-Line stimuli, the attenuated P300 region is in accordance with Kok and Loren de Jong (1980); when stimulus discriminations are generally difficult, P300 amplitude is reduced – and in this instance, quite markedly.

Analysis of the 4-Line IT ERP Data.

Lengthy and explicit comparisons of the 4-line data with the face-stimuli data were considered to be of limited usefulness owing to the different natures of each task; human faces are obviously very different from geometric vertical line-stimuli, and aside from a visual IT methodology, the tasks differed in the specifics of their demands. For this reason, the 4-Line IT data was deemed to be of greater use as a means to a profile for a more “classic” line – I.T. paradigm, and for subsequent analyses within this line-I.T. data rather than comparisons between the face- and 4-line datasets. The analysis of this data-set will therefore be constrained to supplementary information regarding the success or otherwise of the IT procedures; i.e. do the relatively high- and low-IQ groups show electrophysiological differences which might be related to intellectual differences.

As with the data from the face-stimuli, regions of interest within the ERP data were defined in the 4-line data using the global field power plot provided in figure 16. The baseline period comprised 1000-1200ms, and subtraction of 1200ms from the stated values provides the post-stimulus onset time of the epoch. The original four participants with outlier IT values were again excluded from this analysis (3 males and 1 female), as well as a further two participants (2 females) due to technical difficulties with the EEG acquisition.

Figure 16**:** Global field power plots for a line-stimuli ERP data.



The GFP plot shows a clear visual difference in the variations between the facial and line stimuli; most notably, a strong region of pronounced differential activity in the P300 region of the waveform commencing at approximately 230ms post-stimulus.

Here, 3 regions of interest were defined as spanning the following epochs :

Region of interest -1 : 1282ms to 1362ms
Region of interest -2 : 1362ms to 1432ms
Region of interest-3 : 1432ms to 1734ms.

Within the 4-line data, 30 participants were selected based on their APM scores. Seventeen individuals scored 10-12, and thirteen participants scored 7-4, comprising the upper and lower thirds of the population's scores. Area under the curve was calculated for all three regions of interest and stimulus classes (1-, 2-, 3- and 4-line stimuli), and examined via a 4 x 2 ANOVA comprising all line stimuli x IQ group. No effects were present for ERP area under the curve for either IQ group (F(1,28) = 0.187, p = N.S.), or line stimulus type (F(3,84) = 0.203, p= N.S.).

Table 6 : Correlations between P300 Amplitude for the averaged line condition at Cz and IQ measures in the 4-Line IT task.

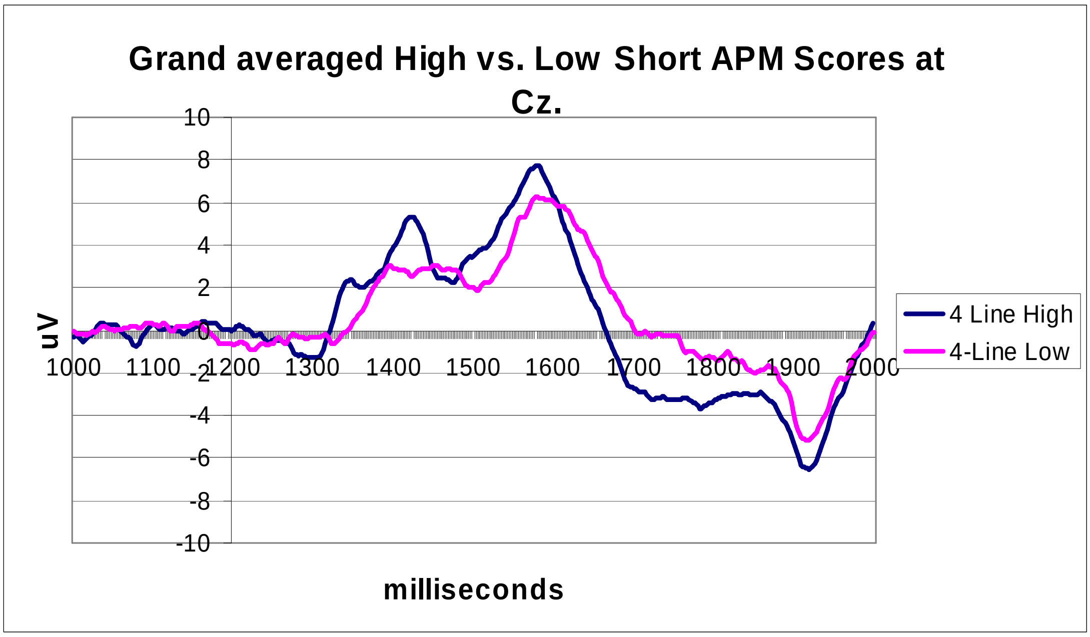
		APMi	APMii	NART Full IQ
Cz All Lines	r	0.011	-0.042	-0.139
	p	0.945	0.793	0.387

Within this subject group, the creation of a more extreme IQ-based sample did not result in significant differences in brain electrical activity. An additional analysis investigating McGarry-Roberts et al.'s (1992) correlation between P300 amplitude and IQ measures was also performed, with no statistically significant results.

ERP Data from High- and Low-scoring IQ Groups

Grand Average ERPs were computed for 18 individuals with the highest and lowest Short APM scores (9 individuals from each group, with scores ranging from 4-7 in the low group, and 10-12 in the high group), and are presented in figures 17, 18 and 19. The following plots present data from the Cz site only.

Figure 17 : Grand average ERP for 4-Line Geometric data.



Within the 4-line task, the two groups differentiated themselves primarily in terms of peak amplitude at three component regions (at approximately 240ms, 400ms, and 500ms post-stimulus), although the ERP morphologies retained the overall characteristics of the P300 complex.

Figure 18 : Grand average ERP at Cz for face-IT task, Block 1.

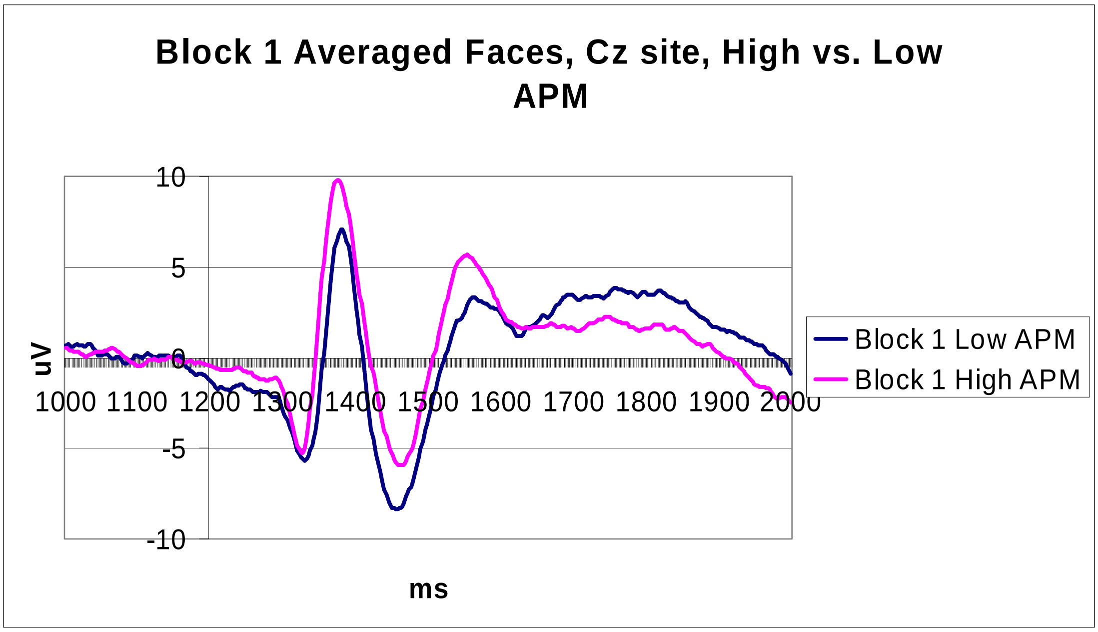
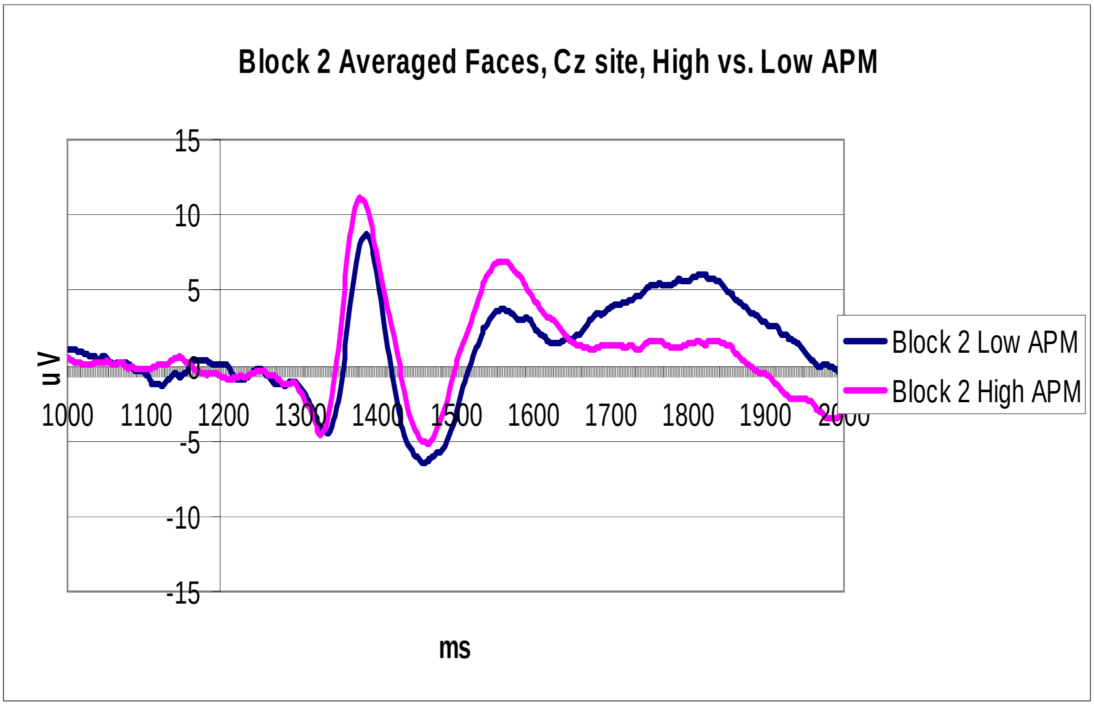


Figure 19 : Grand Average ERP at Cz for face-IT task, Block 2.

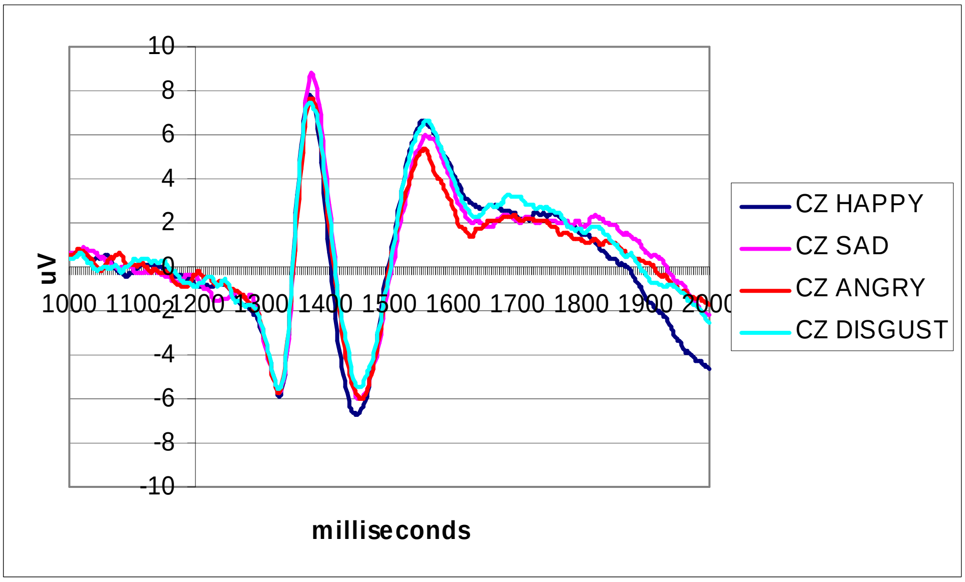


Within the face-IT tasks, again, differentiation took the form of visually-apparent amplitude-based differences, rather than e.g. the slope-based analyses (short P200$_T$)

used in Caryl, Golding and Hall (1995) and Caryl (1994). Exploring differences between the high- and low-APM groups, a mean amplitude value at 1800ms was created (i.e. the mean of all four geometric stimuli and the mean of all four emotional face categories). The amplitude at 1800ms was chosen due to the apparent peak of the Cz-site's P300 region at that time in both face-IT tasks.
Although the participants differentiated themselves on Short APM scores across a narrow range, these new mean amplitude values were not strikingly different per IQ group. Statistical tests of these values yielded only one significant difference between Short-APM groups in Block 2 of the face-IT tasks (F(1,16)=6.806, p<0.019). Here, the mean peak amplitude across conditions was significantly higher for the low-scoring group (1.79μV vs. 6.05μV).

A limited examination of latency effects for the P300 at Cz were performed, after Caryl's (1994) correlation of P300 latency and IQ. The P300 onset was defined as the largest peak within 1450 – 1650ms post-stimulus from the grand average, not individual averages; these latency values will be necessarily simple due to the practical difficulties in obtaining precise latency values from each participant's average per condition, discussed previously. (copies of figures 6 and 15 contain the face-IT task grand average at Cz for reference, and these figures are duplicated below for reference). Correlations of Short-APM scores and P300 latencies across stimulus categories showed results broadly consistent with Caryl (1994); modest negative correlations were present between IQ measures and P300 latencies, as shown in Table 7. This analysis, however, does not fully account for individual variations in the onset times of individual averages, but reduced the determination of onset times to a manageable level.

Copy of Figure 6, Study 4 :. Grand ERP at Cz, Faces Block 1



Copy of Figure 15, Study 4. Grand ERP at Cz, Faces Block 2

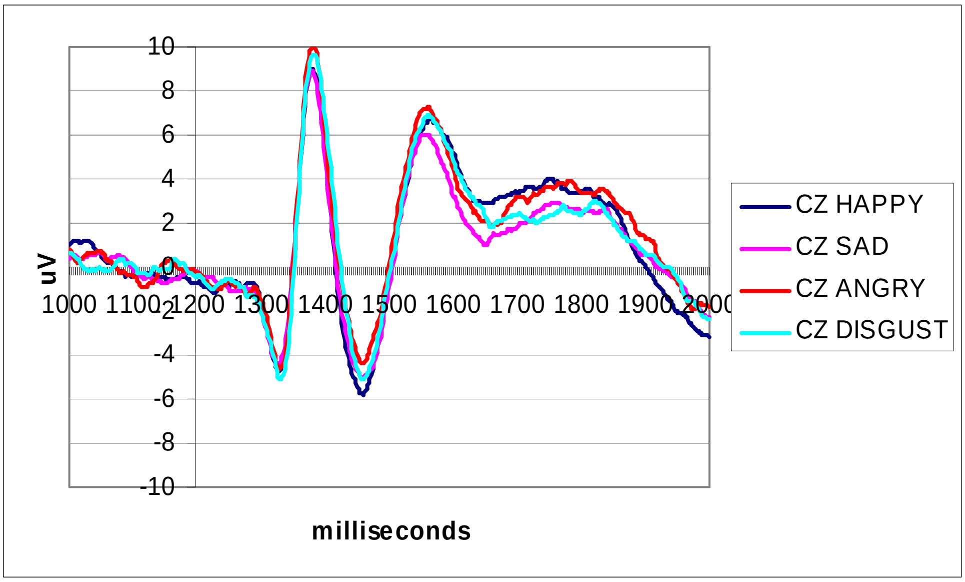


Table 7 : P300 Latency Onsets and IQ Correlation

(Pearson)		Block 1 Short-APM(ii)	Block 2 Short-APM(ii)
Sad			
	r	-.251	-.303
	p	n.s.	0.025
Happy			
	r	-.248	-.308
	p	n.s.	0.024
Angry			
	r	-.265	-.208
	p	0.047	n.s.
Disgust			
	r	-.236	-.282
	p	n.s.	0.035

Correlations here were modest, and more prevalent in the second block of stimuli, but again confirmed the applicability of the methods; as participant IQs rose, P300 onset times were reduced. This is similar to, and consistent with Caryl's (1994) findings of r = -.27 with AH5 scores.

Although statistically correlated with IQ, the P300 onset was uniform in both blocks of the face-IT task, with neither block 1 (F(3,120) = 0.563, p=N.S.) nor block 2 (F(3,123) = 2.335, p=N.S.) showing significant differences in P300 latency in any emotional stimulus category. This is consistent with the effects of the emotional valency present in region of interest-4 in block 1 of the face-IT task. As the latency of the P300 complex did not differ between either blocks or individuals, by elimination, variations in area under the curve were most likely caused by differential amplitude effects than by latency differences, resulting in some effects of emotional recognition.

Moving-Boxcar Gradient Analyses

Lastly, a more extensive gradient based-examination of the line-I.T. data was conducted according to Caryl (1994). A 16-sample (32ms) moving boxcar gradient window was computed for individuals' grand average ERP at all electrode sites, and across all face- and line-IT conditions, and correlated with the participants' Short-APM score and inspection time value. For this calculation, the 9 highest-scoring individuals (Short APM section 2 scores = >10) and the 8 lowest-scoring individuals

(Short APM section 2 scores = 4 – 7) were used. The gradient window overlapped as it progressed through the duration of the ERP as whole, separately correlating every participant's ERP gradient over a 32ms segment with every participant's IQ, and then their IT in the following manner :

Window 1 : Compute Gradient for 0ms (1st sample) to 32ms – Correlate with IQ, then IT.

Window 2 : Gradient for 2ms (2nd sample) to 34ms – Correlation with IQ, then IT.

Window 3 : Gradient for 4ms (3rd sample) to 36ms – Correlation with IQ, then IT.

- and so on, throughout the entirety of each grand ERP's 500 samples.

The correlation coefficients were plotted against time and averaged across N=17, showing the change in gradient per window over the epoch of the grand average ERP. Data from the Cz site only is presented in figures 23-28; all other electrode sites showed near-identical patterns, and no visually apparent differences

Figure 23 : Gradient and IQ correlation over ERP Epoch at Cz Site, Block 1 Faces.

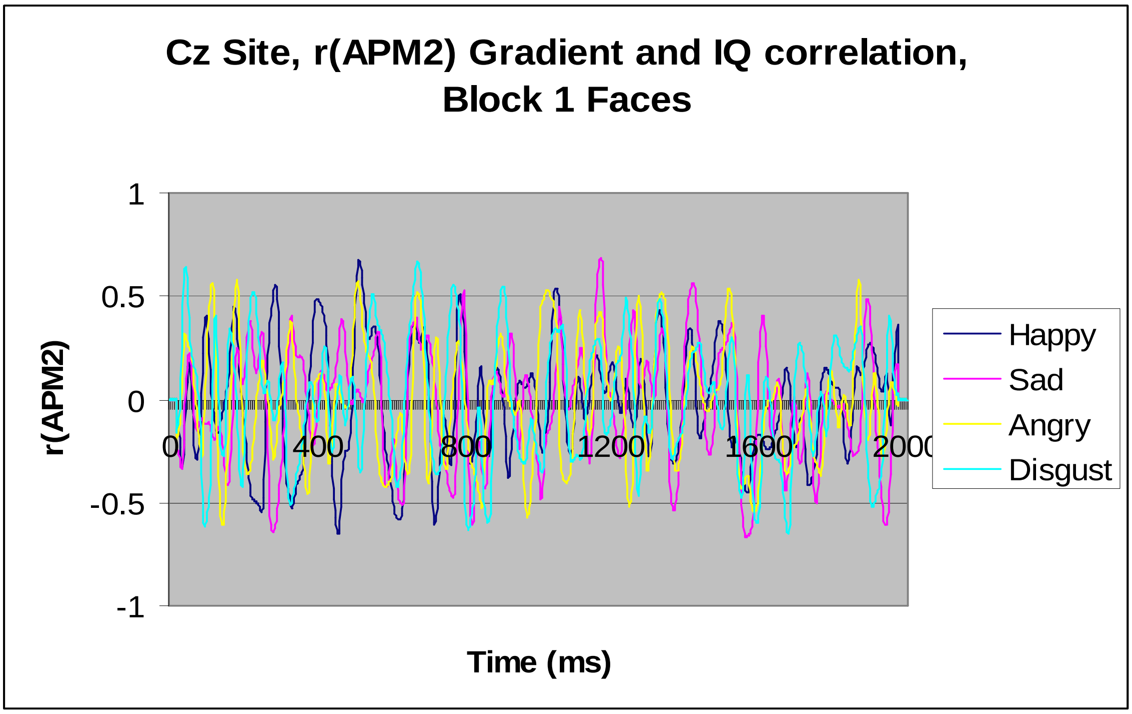


Figure 24 : Gradient and IQ correlation over ERP Epoch at Cz Site, Block 2 Faces.

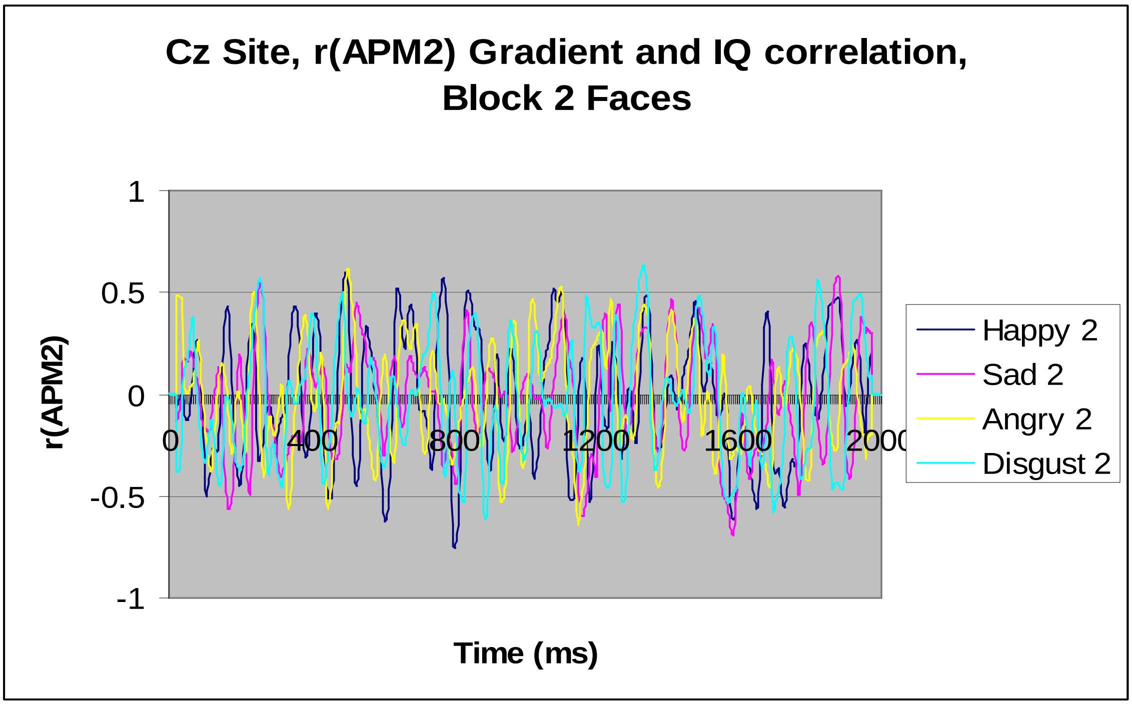


Figure 25: Gradient and IQ correlation over ERP Epoch at Cz Site, 4 Lines task.

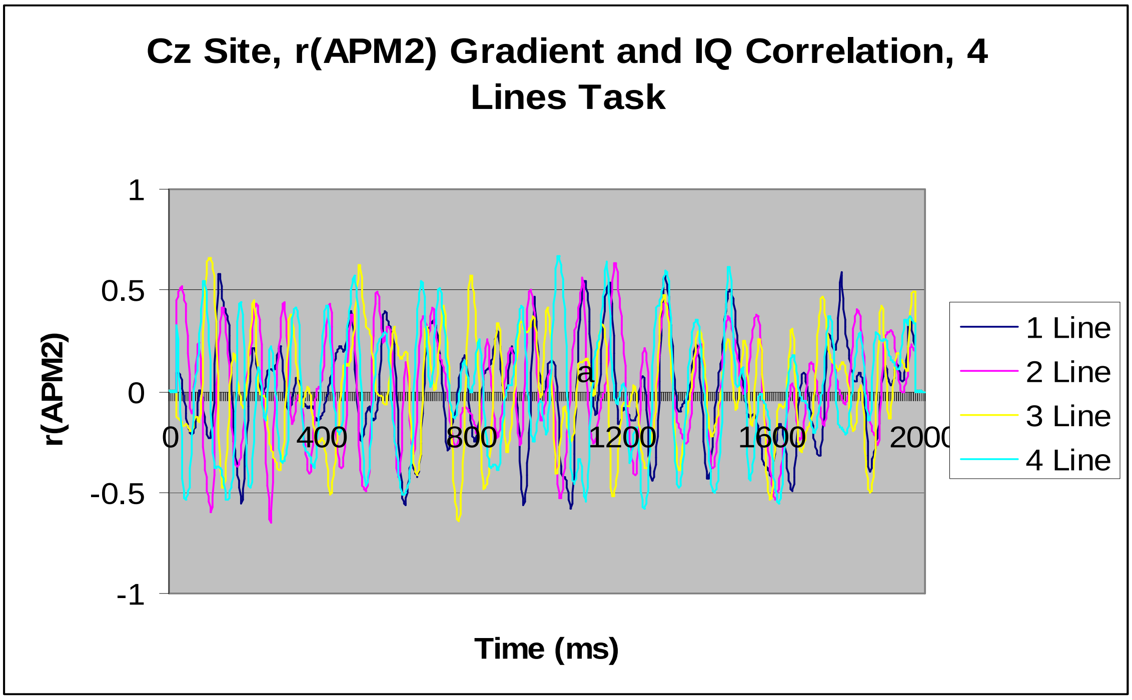
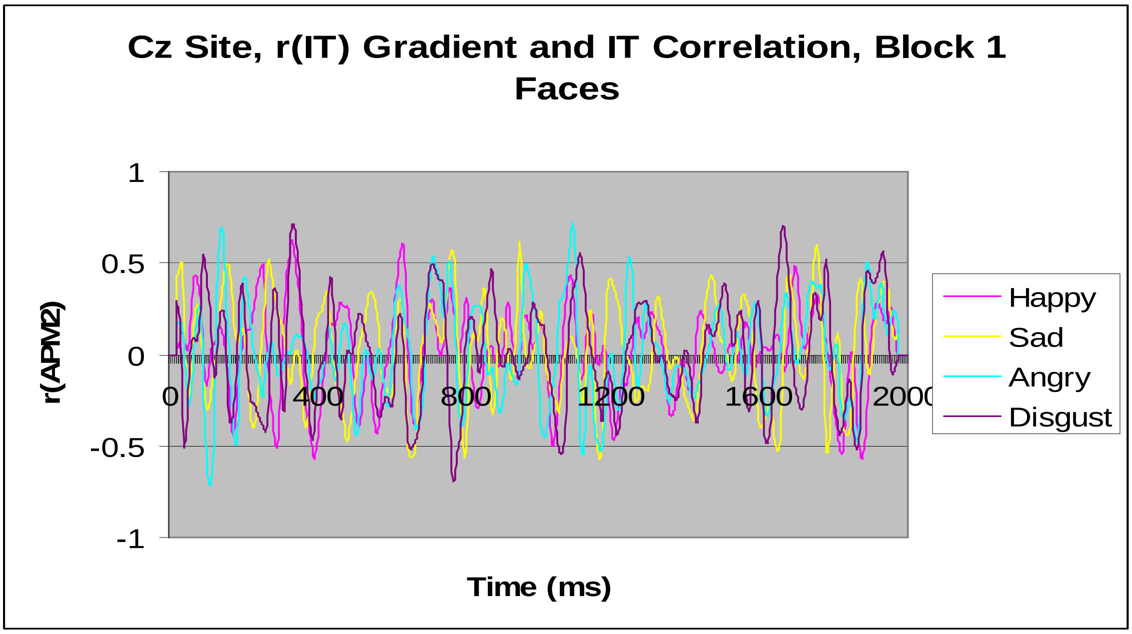


Figure 26 : Gradient and IT correlation over ERP Epoch at Cz Site, Block 1 Faces.



<u>Figure 27</u> : Gradient and IT correlation over ERP Epoch at Cz Site, Block 2 Faces.

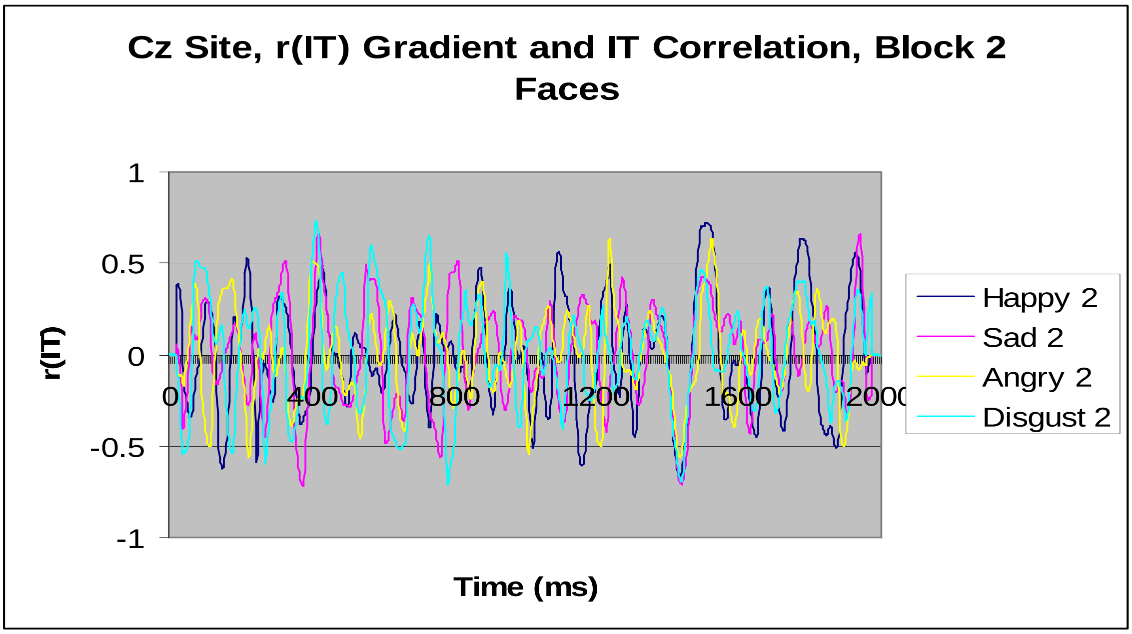
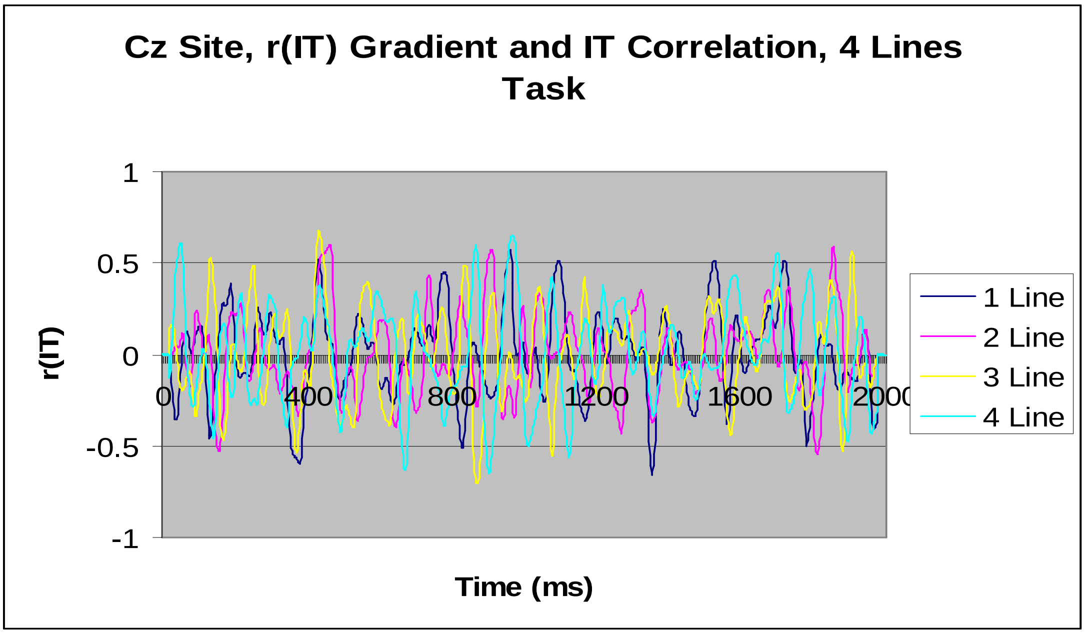


Figure 28 : Gradient and IT correlation over ERP Epoch at Cz Site, 4 Lines task.



Visual inspection of the gradient correlation windows showed an approximate regular periodicity of 8-12Hz throughout the wave, most likely a reflection of alpha-wave activity during testing. However, no specific or obvious activity in any of the gradient windows was visually apparent in figures 23-28 (or from any other electrode site), and thus no potential ERP gradient changes specifically associated with task performance, or concurrent with ERP components were found. Ideally, a region of relatively high activity (i.e. a peak) would be more visually prominent amongst other instances of generally lowered activity, indicating a larger correlation co-efficient for a specific epoch within the ERP wave. As shown, this did not occur in any obvious or meaningful way.

Discussion

The data shows showed the participant sample (N=46) was possessed of above-average IQ scores, with NART-estimated mean IQ scores of 117.08. Additionally, the mean inspection time (i.e. the presentation duration at which 85% of responses were correctly identified) values for the recognition of facial emotional expression were substantially faster (55.68ms in block 1 and 61.82ms in block 2) than that recorded in ERP study 2 (121.6ms). The 4-line IT task showed comparable scores to the face-identification tasks in terms of total correct responses and IT values. These values are shown graphically in chart 1, in the same order the tasks were conducted, with the first IT task (Block 1 faces) showing a marginally faster IT. Actual differences, however, were small (<7ms.). A recurring theme of participant fatigue is suspected to be present among the IQ-related data – participants' responses slowed, or participants made slightly more errors as the task progressed.

Performance on the face-IT tasks also dropped over time, rather than improving due to practice, and was likely due to tiredness among the participants. Performing all three ERP tasks in succession required approximately 60 minutes, with the additional increasing discomfort of wearing the EEG cap. This may also account for the increased mean IT value for Block 2 faces shown in chart 1; the second face-IT task was not substantially more difficult than the first, yet IT values and total correct responses showed noticeably lower successes and longer ITs. In contrast, the 4-Line geometric IT task simply appeared to be very difficult, resulting in higher ITs and lower mean correct responses.

The production of the expected IQ-IT correlations in this study proved more troublesome. Although precedent exists for using the full Raven's APM as an IQ correlate in the IT literature (e.g. Bates and Shieles 2003, Burns et al. 1999), the use of the Short Version APM was not wholly successful in the present study – correlations between IT, IQ and total correct responses were present only in the first face-IT task, and not in the 4 Line IT task. In the present study, the Short APM was used rather than the full battery for simple reasons of practicality; the conduct of the entire experimental procedure required up to 120 minutes, while a full APM battery (or other full IQ battery) would have required at least another 40 minutes. Recruitment, use of available funds to pay participants, and total sample sizes would have been adversely affected by the extra time; an experimental test battery lasting approximately 3 hours would undoubtedly not have been so attractive to participants in exchange for £7, and would likely have resulted in the use of a lowered sample size.

More generally, the possibility of participants' Short APM scores being adversely affected by fatigue is again a likely potential cause for the absence of effects in the second block of the fact-IT tasks. By the time the Short APM was conducted, participants had completed the NART, the SREIT, and 3 separate EEG acquisition tasks (including EEG electrode placement) totalling some 80 minutes; a demanding test battery. The APM test battery alone is quite demanding of participants, and the Short APM slightly more so since it is apparent to participants that in order to finish the battery, they must complete each item in less than 90 seconds. With these practicalities and difficulties in mind, however, the participant samples comprising N=46 and N=30 still showed the anticipated negative IT-IQ relationship within the first face-IT task – as IQ and total correct responses rose, IT fell. This was highlighted by the high-IQ group, whose Short APM scores were significantly higher than the low-IQ group, and whose IT values were significantly faster than the low-IQ group.

Among the ERP data for the 4-Line task, the single most prominent peak was a P200 component occurring at approximately 1590ms. Combined with the lower behavioural success rate for the 4-Line stimuli, the attenuated P300 region is in accordance with Kok and Loren de Jong (1980); P300 amplitude is reduced when task demands or stimulus perception are made difficult – and in this instance, quite markedly so (Table 15.). Anecdotally, participants themselves claimed to find the 4 Line task particularly difficult, and this was confirmed by their behavioural results. Overall among the line-stimuli data, while ERPs showed some visual differences, statistical comparisons did not differentiate IQ groups, nor those groups' identification of any line stimulus type.

McGarry-Roberts et al.'s (1992) relationship between P300 amplitude and IQ measures was also not found in this data in any of the three ERP tasks, nor Caryl's (1994) 100-200ms peak correlations with either IT or IQ scores. In Figures 23-28, constantly varying gradients were apparent throughout the time-course of the entire waveform, rather than at any particular moment in time. Figures 23-25 (i.e. gradient and IQ correlations) were particularly muddled, with rapid and highly-overlapping gradient shifts occurring throughout the wave. In contrast, slightly less activity overall is visible in Figures 26-28 – the gradient – IT correlations, although both the IQ and IT correlation plots were extremely “noisy”. Caryl’s (1994) findings were generally not repeated here, although a possible explanation is the difference in IQ measures. As noted previously, the presence of positive correlations in the present study between IT and IQ measures were somewhat inconsistent, perhaps due to the use of an abbreviated IQ test battery. Caryl (1994) employed a full Alice Heim 5 IQ battery, which, when used in ERP study 1 in the present series, resulted in stronger and more prevalent associations with IT measures than the Short APM used in the present study. Again, although practical and generally considered to be a useful measure of “g”, the Short APM did not generate robust effects when used in this manner.

CHAPTER 10

CONCLUSIONS

A brief summary of the present series of studies is presented :

Study 1

Study 1 (N=40) served as a pilot study, evaluating the practicalities and difficulty scaling of the E-IT task for later ERP testing. Using human faces in contrast to the traditional pi-figure, and in this study examining the participants' ability to discern gender rather than emotional expression), Austin's (2004, 2005) face E-IT task generated a psychophysical curve with an early, and sustained plateau of correct responses, although participants seemed to find this initial variant extremely easy. No gender differences were observed during this study.

Study 2

Study 2 (N=46) modified the E-IT task to accommodate the first large-scale ERP acquisitions in response to this task, and also to examine the task's ability to discriminate between emotions in the stimulus faces from ERPs. Changes were made to the presentation durations to make the task more demanding, with participants required to discriminate between a happy and neutral facial expression. Participants possessed above-average IQs, and gender differences among the sample were again found to be absent in IQ and EI measures. The expected negative IT-IQ correlations were present (e.g. Nettelbeck 1987). Self-report EI scores, however, were found to be marginally positively correlated with IT, and negatively correlated with IQ – speeded apprehension does not appear to be a component of emotional intelligence as measured by the SREIT inventory. ERP findings from this study revealed the presence of a wave complex comprising 4 prominent deflections, including P100, N170 and P300 components; the presence of the P300 component was confirmed by the rise of amplitude from the front to the rear of the scalp. This ERP morphology is extremely common in the cognitive ERP literature, and was interpreted as further indicating the success of the task in evoking directed cognition. Effects due to differences in emotional expression of the face stimuli in these data were weakly present only among males in the earlier region of interest (around the P100 region), but more strongly among the whole sample during the N170 to P300 region. Happy facial expressions generated larger areas under the curve than did neutral expressions. Some correlations between ERP gradient and participant IQ were present when the sample was divided into high- and low-IQ groups; gradients were larger (steeper), and occurred earlier among the high-IQ group. The high- and low-IQ split was conducted after prior studies by Josiassen et al. (1988) and Shagass et al. (1981), who found that differences in IQ as reflected by ERP were subtle, and frequently masked by normal variance shown by literally averagely intelligent individuals. By removing participants scoring in the middle of the IQ range within a study, the normal extremities of the IQ range are obviously made more apparent, but importantly, e.g. the IT-IQ correlation is maintained, demonstrating that the relationship between stimulus presentation times and participant intellect is not a spurious finding, and that therefore the high- and low-IQ split does not notably affect IQ-related phenomena. The association of gradient measures with IQ is perhaps the only robust relationship discovered so far in the ERP-IQ literature (Zhang et al. 1989a,b; Caryl et al. 1994, Morris et al. 1995), although these four studies present relatively isolated findings – there has not been much attempt to replicate these results.

Study 3

This study (N=10) re-evaluated the facial E-IT masking techniques. The ERP acquisitions in use in the present series of studies are sensitive to individual differences in different ways from behavioural tasks, and potential confounds in ERP components between stimuli and the backward mask were possible. As the target stimuli were presented for very brief periods of time (not more than 120ms), while the backward mask was presented for several hundred milliseconds (up to 800ms across studies), the possibility arose that ERP responses would be evoked by the mask to a greater extent than by the emotional faces. Without explicit segregation and testing of mask types, it would not be possible to distinguish deflections due to the stimulus face from those due to the backward mask. A new, non-face mask was created and presented in a non-IT emotional identification task to a small participant group to examine electrophysiological effects between mask types. The ERP waveforms generated in Study 2 were replicated in overall morphology, as were inter-electrode effects. Effects arising from the masks, however, resulted in visually obvious differences in the waveforms, but these effects were not statistically significant (using area under the curve as the D.V.), and no differences attributable to stimulus emotional expression were observed. The newer, non-face mask was used throughout the rest of the studies to avoid any future confounds.

Study 4

Studies 4 and 5 (N=50) involved separate analyses of data on responses to faces and to line-IT stimuli collected in a single session involving three E-IT tasks and three psychometric scales. Study 4 examined effects related to EI and stimulus emotion from two face-IT tasks. Inspection times in this study were approximately 50-60ms faster than in Study 2, demonstrating the limitations of comparisons with IT values across studies. Correlations between participant IT and SREIT scores were not prominent, with only two of the three IT tasks showing any relationship at all, and only with a single EI factor (utilisation of emotions) in terms of either IT or total correct responses. A different EI factor, mood regulation, showed positive correlations with IQ (Short APM), but again, relationships were neither strong nor prevalent, with only one IQ measure showing significant results. Results were consistent with findings from study 2, however, in that the relationships remained positively correlated, indicating a lack of any speeded cognitive factors. These correlations were strengthened in an analysis that compared high- and low-scoring groups, generating correlations with more sub-factors of the SREIT, and could indicate that intellect is influential in SREIT scores among extreme-scoring groups (precedence for the high- and low-IQ group split is referenced previously, see Josiassen et al., Shagass et al, and Zhang et al.). ERP waveforms here replicated the morphology of the waveforms found previously in Studies 2 and 3, and waveform amplitude variations across emotional categories were visually apparent. Effects of stimulus emotional expression were much more prevalent than in previous studies. In the first block of the face-IT task, comparisons between disgust vs. happiness, and anger vs. sadness were not statistically significant, but other comparisons remained so after stringent statistical correction. The number of comparisons between emotional categories that reached statistical significance was reduced in the second block of the face-IT task 2, where participant fatigue was suspected to have been influential.

Study 5

Study 5 examined effects related to IQ in the 4-choice IT task in Study 4. Participants found the 4-Line IT task substantially more difficult than either of the face-IT tasks. Although direct statistical comparisons between the face- and 4-line IT tasks are inappropriate owing to the fundamentally different tasks involved, visual examinations of the IT curve and ERP responses were possible. Phenomena related to IT remained consistent – when divided into high- and low-IQ groups, the higher-IQ group scored more highly and showed more rapid ITs – a finding consistent with the IT-IQ relationships demonstrated previously by the whole population sample. Males showed significantly better performances in terms of IT and total correct. The Short APM IQ test used in this study generated few significant associations with IT when the literature shows that the full version is generally more effective (Bates and Shieles 2003, Burns et al. 1999, Morris and Alcorn 1995). Pronounced differences were present in the ERP waveforms between the face-IT and 4-line IT tasks; the 4-line task generated markedly fewer visible ERP components across electrode sites, with only anterior sites showing clearly defined ERPs. Limited effects related to IQ were present among the ERP data, including a tendency to show shorter latency onsets in the P300 region with increasing IQ. A larger-scale analysis attempted to replicate Caryl's (1994) gradient-based correlations with IQ, but found no effects.

Inspection Time Findings

Throughout the present series of studies, the face-IT task consistently showed correlations between the AH5, NART, and Raven's Short APM measures of IQ and either inspection times, or total number of correct responses, and these correlations provided evidence of the basic methodological success of the tasks throughout. The established literature on inspection time shows it to be a robust phenomenon in human cognition, and one which is strongly linked to G_{fluid} (e.g. Sheppard 2008) but one which as yet lacks a comprehensive explanation of the underlying mechanisms. The IT-IQ relationship has been variously regarded as an index of human perceptual intake abilities (Vickers 1970), a speeded perceptual-cognitive phenomenon arising from core intellectual abilities such as *g (*Nettelbeck 1994, 2001, Vickers and Smith 1986, Kranzler and Jensen 1989), and as a task at which intelligent individuals quickly develop successful strategies (Deary at al. 2001, McCrory and Cooper 2007). The inter-relation of all these explanations within the basic IT methodology, however, creates great difficulty in separating these phenomena from each other, resulting in no simple or entirely convincing explanation of the basis of the IT-IQ correlation. As noted by Mackenzie and Bingham (1985) and Stough et al. (2001), the ad-hoc development of cognitive strategies by participants can weaken (but usually not entirely eradicate) the IT-IQ correlation, which could be interpreted as being inextricably linked with general intellectual ability. Because the IT-IQ correlation can be reduced by deliberate cognitive activity, it is therefore potentially not solely an index of innate, biological ability, as e.g. speeded neural transmission would be a lower-level function of the nervous system which could not be consciously controlled. The alternative theory that the IT-IQ relationship is due to innate limitations in individual rates of visual apprehension is popularly regarded as insufficient. Studies of nerve conduction velocity (NCV), nerve myelination, and ERP latency (Reed et al. 2004; Haier 1993; Shucard and Horn 1972) could be interpreted as lending some, if inconsistent evidence to the notion of speeded perceptual apprehension at the physiological level. Although the inconsistency of NCV and ERP component effects is problematic, they have nonetheless been seen to vary in the manner of individual differences, and in the case of NCV, due to gender differences. It may be the case that some interaction between certain very low-level physiological phenomena and an individual’s core, general intellectual capacities dictates their relative success or failure at the IT task. As an argument, however, this notion is open to the criticism that low-level nervous physiology and core intellect are capable of influencing almost every other psychological phenomenon in existence, and this argument potentially says everything and nothing. Future directions for the IT task have centred upon the use of newer stimulus forms, including the main stimuli themselves (e.g. McRory and Cooper’s 2007 coloured circle variants) and mask types (e.g. Evans and Nettelbeck’s (1993) “flash mask” with the lightning-bolt feature), but it remains unclear as to how the use of alternative stimuli without modification to the task would reveal anything fundamentally new - essentially, psychology needs a different method of examining the processes of rapid apprehension where the task, and intellectual and biological individual differences are less tightly intertwined.

The IT task methodology both within the literature and in the present series of studies nonetheless works very reliably with various stimulus forms, whether they are geometric figures, human faces, coloured geometric shapes or auditory sounds; the present series of studies have shown it to be highly robust through the use of newer stimulus forms and various different measures of IQ. Within the present series of experiments, the primary use of the IT task was as a vehicle for the acquisition of ERPs.

Emotional Intelligence Findings

Findings from the SREIT throughout the present series of studies tended to show the presence of effects related to Utilisation of Emotions (Study 2) or Utilisation of Emotion and Mood Regulation (Study 4). The pattern of results was inconsistent, however, in that the findings in Study 4 varied markedly when the high- and low-IQ split was performed. Both of these factors were consistently found to be correlated with IQ measures known to measure *g*. Previous literature in the EI field suggests that some correlations with personality variables and trait EI are expected (Dawda & Hart, 2000; Saklofske et al., 2003; Van Der Zee et al., 2002), but measures of trait EI showing significant associations with IQ are unexpected (rather, ability-based EI tests such as the MSCEIT are expected to correlate with intellectual ability; Mayer, Roberts and Barsade 2008; Roberts et al. 2007). Correlations between EI and IQ in the present series of studies were also more numerous when the participant group was divided into high- and low-scoring groups in Study 4. Although this division could be interpreted as potentially skewing other results related to IQ, a true and discriminant EI test should be only minimally affected unless trait EI and IQ are more closely related than previously thought. There are potentially several explanations for this occurrence; a substantial involvement of IQ in the SREIT's underlying constructs; the existence of more serious flaws in the discriminant validity of the SREIT; the use of a sample which was insufficiently large for a full examination of this inventory (or perhaps biased towards the presence of above-average intelligence), or (and perhaps least likely) a new and valid association between high-IQ and trait emotional intelligence. Correlations with the SREIT and IT, however, were logically consistent, showing that individuals with longer emotional inspection times also tended to have higher total EI scores. This does not sit entirely well, however, with the fact that the population samples employed here were of above-average intelligence, attaining NART Full-Scale IQ estimates of 119 and 117, and such participants would concomitantly be expected to (and actually did) show generally lower, rather than higher inspection times.

This combination of logical associations with emotional IT, and consistent negative correlations with IQ would seem to point mainly towards the SREIT as either an inadequate psychometric instrument, or some other problem within the distinct participant samples involved here. In considering these options, it would seem that SREIT is both unreliable and non-discriminatory as a test of “emotional” intelligence, due both to an incomplete definition of the trait itself, and apparently weak discriminant validity in the SREIT.

ERP Findings

ERP findings from the present series of studies showed a high replicability in overall wave morphology – the P100, N170 (or N200) and P300 components were present in all cases. In the case of the present series of studies, the basis of the emotional discrimination between the Ekman faces is based around internal prototypical expressions held by the participants themselves - i.e. although emotional facial expressions are naturally idiosyncratic to some degree, the prototypical expressions held by observers of these expressions obviously allows the expressions to be unambiguously identified. Although the participants were not primed to identify the stimulus faces, task performances across studies were typically highly successful and beyond chance levels.

Although effects of stimulus-face emotion were quite pronounced in Study 4, the waveforms showed that the morphology is neither particularly distinctive nor unique throughout the present series of studies, and the pattern of components is potentially indicative of many other cognitive tasks from the ERP literature. In this sense, the task of identifying emotions in human faces appears to be little different from any other task which involves discrimination between other forms of stimuli. Differences between the waveforms evoked by the geometric 4-Line IT task and the face-IT task are presented in Study 5 in subtraction and overlay plots, and despite obvious visual differences in some components when overlaid, in isolation, the overall pattern of deflections is broadly very similar – a P100→N200→P300 complex arises from each task - and also in the non-IT methodology used in Study 3. From the present series of studies, the discrimination of happy stimulus faces tended to evoke larger amplitudes and areas under the curve than did any other emotional categories in both Studies 2 and 4 (face-IT task 1). Study 4 showed a continuum of increasing amplitudes and area measures from (smallest) Anger→Sadness→Disgust→Happiness (largest). This pattern was not wholly consistent, however, as during Study 4's second face-IT task, the pattern changed to Sadness→Anger→Disgust→Happiness (i.e. Sadness evoked larger amplitudes than Anger).

From these results, it would seem that classification of stimulus-face emotional expressions using ERPs is not possible without prior knowledge of the stimulus categories. Without this knowledge, all that can be stated from the ERP data is that participants were awake, alert, and able to discern some differences between the stimulus categories, but that the brain electrical activity underlying their responses does not reveal anything except variants of the ubiquitous P100→N200→P300 complex. As stated, the task of detecting stimulus differences makes the emotional face-IT not dissimilar to many other tasks used in cognitive electrophysiology, and implies the use of similar cognitive evaluation processes across many forms of stimuli. The inconsistent (and mainly absent) electrophysiological findings related to individuals' IQ would indicate that either the present task methodology is inadequate to reveal IQ-related differences (although Caryl (1994) also used IT methodologies), or that the goal of understanding IQ-related differences remains resistant to detection with ERP methods. The previous literature in this field shows highly equivocal results, and the concept of IQ-based differences in ERP may be something of a pipe-dream.

These difficulties, caveats and general findings could be interpreted as reducing the usefulness of ERP work in further studies across many different domains, as ERP techniques are time-consuming to implement and subsequently analyse, and which are also extremely likely to reveal an already familiar pattern of responses (i.e. a P1→N2→P3 wave complex) than anything truly novel. This researcher also feels that this lack of genuine novelty in the evoked potential literature indicates that ERP as an investigative technique is now reaching the limits of its usefulness. What may be more salient as a finding is the fact that the P1→N2→P3 complex is so readily replicable, and so prevalent among the ERP literature as a whole. Clearly, this pattern of brain electrical responses constitutes a fundamental aspect of the brain's normal functioning across various circumstances, and its links with e.g. the updating of short-term memory (Courchesne et al. 1975) probably has implications for moment-to-moment cognition; the P300 can be likened to an electrophysiological reflection of moment-to-moment snapshots of sensory input, where short-term memory components are continually evaluated for new, contextually salient features in the environment.

It would appear this pattern of ERP activity is common among individuals who are normally healthy, awake and alert to their surroundings. Further work in ERP responses to stimulus habituation may be much more informative than the typical gamut of cognitive experimentation involving the detection of differences. Researchers may have more to learn about how brain electrical activity reflects either similarity, or possibly boredom, than how the brain detects novelty.

References

Adolphs, R. (2002). Recognizing emotion from facial expressions:
Psychological and neurological mechanisms. Behavioural Cognitive
Neuroscience Review 1, p21-61.

Adolphs, R., Jansari, A., and Tranel, D. (2001). Hemispheric perception of emotional valence from facial expressions. Neuropsychology 15(4), p516-524.

Adolphs, R., Tranel, D., & Damasio, A. R. (2003). Dissociable
neural systems for recognizing emotions. Brain & Cognition 52, p61-
69.

Adrian, E.D. (1935). The Origin of the Berger Rhythm. Brain 58, p323–51.

Allison, T., McCarthy, G., Nobre, A., Puce, A. and Belger, A. (1994c).
Human Extrastriate Visual Cortex and the Perception of Faces,
Words, Numbers, and Colors. Cerebral Cortex 5, p544-554.

Allison, T., Ginter, H., McCarthy, G., Nobre, A.C., Puce, A., and Belger, A. (1994). Face recognition in human extrastriate cortex. J Neurophysiol 71, p821-825.

Allison, T., Puce, A., Spenser, D.D., and McCarthy, G. (1999). Electrophysiological Studies of Human Face Perception I : Potentials generated in occipitotemporal cortex by face and non-face stimuli. Cerebral Cortex 9, p415 – 430.

Anderson, M. (2005). Marrying intelligence and cognition : a developmental view. In Sternberg, R.J. and Pretz, J.E. (eds) In Cognition and Intelligence : Identifying the mechanisms of the mind (Chapter 14, p268-87). Cambridge University Press, Cambridge, UK.

Arthur, W., and Day, D.V. (1994). Development of a short form for the Raven Advanced Progressive Matrices Test. Educational and Psychological Measurement 54 (2), 394-403.

Austin, E. J. (2004). An investigation of the relationship between trait emotional intelligence and emotional task performance. Personality and Individual Differences 36, p1855-1864.

Austin, E.J. (2005). Emotional intelligence and emotional information processing. Personality and Individual Differences 39, p403-414.

Austin, E.J., Saklofske, D.H., and Egan, V. (2005). Personality, well-being and health correlates of trait emotional intelligence. Personality and Individual Differences 38, p547-558.

Austin, E.J., Saklofske, D.H., Huang, S.H.S., and McKenney, D. (2004). Measurement of trait emotional intelligence : testing and cross-validating a modified version of Schutte et al.'s (1998) measure. Personality and Individual Differences 36, p555-562.

Balconi, M., and Pozzoli, U. (2003). Face-selective processing and the effect of pleasant and unpleasant emotional expressions on ERP correlates. International Journal of Psychophysiology 49, p67-74.

Barchard, K. A. (2003). Does emotional intelligence assist in prediction of academic success? Educational and Psychological Measurement 63, p840–858.

Bar-On R. (1997). BarOn Emotional Quotient Inventory: Technical Manual. Toronto: Multi-Health Systems.

Bar-On, R. (2002). Bar-On EQ-i:S technical manual. Toronto: Multi-Health Systems.

Barrett, L.F. (2007). What is an emotion ? In Bard, K. and Cornelius, R. (eds). The Emotion Researcher (International Society for Research on Emotion newsletter) 22 (1-2). Harmon & Castella Printing, Inc. Poughkeepsie, New York.

Barret, S.E., Rugg, M.D. and Perrett, D.I. (1988). Event related potentials and the matching of familiar and unfamiliar faces. Neuropsychologia 1, p105-117.

Barrett, P.T. and Eysenck, H.J., (1992b). Brain electrical potentials and intelligence. In Gale, A. and Eysenck, H.J. (eds). Handbook of individual differences : Biological Perspectives (p255-285). Wiley, NY,.

Barrett, P.T. and Eysenck, H.J., (1994). The relationship between evoked potential component amplitude, latency, contour length, variability, zero-crossings and psychometric intelligence. Personality and Individual Differences 16, p3–32.

Bastian, V.A., Burns, N.R., and Nettelbeck, T. (2005). Emotional intelligence predicts life skills, but not as well as personality and cognitive abilities. Personality and Individual Differences 39, P1135-1145.

Bates, T., Stough, C., Mangan, G. and Pellett, O. (1995) Intelligence and complexity of the averaged evoked potential : an attentional theory Intelligence 20, p27-39.

Bates, T., and Eysenck, H.J. (1993). String length, attention, and intelligence : focused attention reverses the string length-IQ relationship. Personality and Individual Differences 15, p363-371.

Bates, T.C., and Eysenck, H.J. (1993). Intelligence, inspection time and decision time. Intelligence 17, p523-531.

Bates, T.C., and Shieles, A. (2003). Crystallized intelligence as a product of speed and drive for experience: the relationship of inspection time and openness to g and Gc. Intelligence 31, p275-287.

Batt, R., Nettelbeck, T., and Cooper, C.J. (1999). Event related potential correlates of intelligence. Personality and Individual Differences 27, p639-658.

Batty, M., and Taylor, M.J. (2003). Early processing of six basic facial emotional expressions. Cognitive Brain Research, 17(3), p613-620.

Bechara, A., Tranel, D. and Damasio, A..R. (2000). Poor Judgement in Spite of High Intellect. In The Handbook of Emotional Intelligence : Theory, Development, Assessment and Application at Home, School, and in the Workplace, p.192-214. Jossey-Bass Inc., San Francisco, California.

Begleiter, H., Porjesz, B., and Wang, W. (1995). Event-related potentials differentiate priming and recognition to familiar and unfamiliar faces. Electroencephalography and Clinical Neurophysiology 94, p41-49.

Bennett, W. F. (1968). Human perception: a network theory approach. Nature 220 p1147-1148.

Bentin, S., Allison, T., Puce, A., Perez, A., and McCarthy, G. (1996). Electrophysiological studies of face perception in humans. Journal of Cognitive Neuroscience 8, p551-565.

Bentin, S., Deouell, L.Y., & Soroker,N. (1999). Selective visual streaming in face recognition: Evidence from developmental prosopagnosia. Neuroreport 10, p823–827.

Berger, H. (1929). Uber das Elektrenkephalogramm das Menchen. Archiv fur Psychiatrie 87, p527-570.

Blinkhorn, S. F. & Hendrickson, D. E. (1982). Averaged evoked responses and psychometric intelligence. Nature 295, p596-597.

Bodamer, J. (1947). Die-Prosop-agnosie. Arch. Psychiatr. Nervenkrankh, 179, 6–54. English translation by Ellis, H.D., Florence, M., 1990. Cogn. Neuropsychol 7, p81–105.

Boomsma, D.I., van-Baal, G., and Caroline, M. (1998)
Genetic influences on childhood IQ in 5- and 7-year-old Dutch twins.
Developmental Neuropsychology 14(1), p115-126.

Brackett M, Mayer JD. 2003. Convergent, discriminant, and incremental validity of competing measures of emotional intelligence. Personal. Soc. Psychol. Bull. 29, p1147–58.

Brand, C. R. and Deary, I.J. (1982). Intelligence and inspection Time. In A Model of lntelligence (Eysenck H. J. (Ed.). Springer, New York.

Brewer, N., and Smith, G.A. (1984). How normal and retarded individuals monitor and regulate speed and accuracy of responding in serial choice tasks. Journal of Experimental Psychology : General 113, p71-93.

Bruce, V. and Young, A. (1986). Understanding face recognition. British Journal of Psychology 77 (3), p305-327.

Bruce, V., Green, P.R., and Georgeson, M.A. (1996). Visual Perception – Physiology, Psychology and Ecology (3rd Edition). Psychology Press Ltd., East Sussex.

Burns, N. R., Nettelbeck, T., & Cooper, C. (1999). Inspection correlates with general speed of processing but not with fluid ability. Intelligence 27, p37–44.

Burns, N.R. and Nettelbeck, T. (2003). Inspection time in the structure of cognitive abilities: Where does IT fit ? Intelligence (31), p237-255.

Burns, N.R., Nettelbeck, T., and Cooper, C.J. (1996). The string measure of the ERP : what does it measure ? International Journal of Psychophysiology 27, p43-53.

Burns, N.R., Nettelbeck, T., and Cooper, C.J. (2000). Event-related potential correlates of some human cognitive ability constructs. Personality and Individual Differences 29, p157-168.

Burns, N.R., Nettelbeck, T., White, M., 1998. Testing the interpretation of inspection time as a measure of speed of sensory processing. Personality and Individual Differences 24, p25– 39.

Calder, A.J., Burton, M., Miller, P., Young, A.W., and Akamatsu, S. (2001). A principal component analysis of facial expressions. Vision Research 41, p1179-1208.

Callaway, E. (1973). Correlations between average evoked potentials and measures of intelligence. Arch. Gen. Psychiatr. 29, p553-558.

Callaway, E. (1975). Brain electrical potentials and individual psychological differences. New York, Raven Press.

Campanella, S., Gaspard, G., Debatisse, D., Bruyer, R., Crommelinck, M. and Guerit, J.-M. (2002). Discrimination of emotional facial expressions in a visual oddball task : an ERP study. Biological Psychology 59, p171-186.

Carmel, D., Bentin, S. (2002). Domain specificity versus expertise: factors influencing distinct processing of faces. Cognition 83, p1-29.

Carretie, L. and Iglesias, J. (1995). An ERP study on the specificity of facial expression processing. International Journal of Psychophysiology 19, p183-192

Carrol. J.B. (1976). Psychometric tests as cognitive tasks : A new "structure of intellect.". In Resnick L. (editor) The Nature of Intelligence (p27-56). Earlbaum Hillsdale, N.J.

Carroll, J.B. (1980). Individual difference relations in psychometric and experimental cognitive tasks. Chapel Hill, NC. L.L. Thurstone Psychometric Laboratory, University of North Carolina.

Carroll, J.B. (1993). Human cognitive abilities : a survey of factor analytic studies. Cambridge, UK; Cambridge University Press.

Caryl, P.G. (1994). Early event-related potentials correlate with inspection time and intelligence. Intelligence 18, p15-46.

Caryl, P.G., and Harper, A (1996). Event related potentials in elementary cognitive tasks reflect task difficulty and task threshold. Intelligence 22, p1-22.

Caryl, P.G., Deary, I.J., Jensen, A.R., Neubauer, A.C., and Vickers, D. (1999). Information processing approaches to intelligence : Progress and prospects. (chapter 10, p 181-219) Mervielde, I., Deary, I.J., De Fruyt, F. and Ostendorf, F. (editors). Personality Psychology in Europe (Vol.7.). Tilburg University Press.

Caryl, P.G., Golding, S.J.J., and Hall, B.J.D. (1995). Interrelationships among auditory and visual cognitive tasks : an event-related potential (ERP) study. Intelligence 21, p297-326.

Chalke, F. and Ertl, J. (1965). Evoked potentials and intelligence. Life Sciences 4, p1319-1322.

Chapman, R. M., McCrary, J. W. & Chapman, J. A. (1978). Short-term memory: The 'storage' component of the human response predicts recall. Science 202, p121I-1214.

Charbonneau, D., and Nicol, A. A. M. (2002). Emotional intelligence and leadership in adolescents. Personality and Individual Differences 33, p1101-1113.

Ciarrochi, J. V., & Deane, F. P. (2001). Emotional competence and willingness to seekhelp from professional and nonprofessional sources. British Journal of Guidance and Counselling 29, p233–246.

Ciarrochi, J., Chan, A. Y. C., & Bajgar, J. (2001). Measuring emotional intelligence in adolescents. Personality and Individual Differences 31, p1105–1119.

Clarke, G. (2007). What is an emotion ? In Bard, K. and Cornelius, R. (eds). The Emotion Researcher (International Society for Research on Emotion newsletter) 22 (1-2). Harmon & Castella Printing, Inc. Poughkeepsie, New York.

Clark VP, Keil K, Maisog JM, Courtney S, Ungerleider LG, Haxby JV (1996) Functional magnetic resonance imaging of human visual cortex during face matching: a comparison with positron emission tomography. NeuroImage 4, p1–15.

Cohen, J. (1992). A power primer. Psychological Bulletin 112 (1), 155-159. cortex. Proc Natl Acad Sci USA 88, p1621–1625.

Courchesne, E., Hillyard, S.A., and Galambos, R. Stimulus novelty, task relevance, and the visual evoked potential in man. Electroencephalogr. Clin. Neurophysiol. 39 (1975) p131-141.

Crawford, C.B. (1974). A canonical correlation analysis of cortical evoked response and intelligence test data. Canadian Journal of Psychology 28, p319-332.

Crawford, J. R., Deary, I. J., Allan, K. M., & Gustafsson, J. (1998). Evaluating competing models of the relationship between inspection time and psychometric intelligence. Intelligence 26, p27−42.

Crawford, J.R., Allan, K.M., Stephen, D.W., Parker, D.M., and Besson, J.A.O. (1989). The Weschler Adult Intelligence Scale- Revised (WAIS-R) : factor structure in a UK sample. Personality and Individual Differences 10, p1209-1212.

Crommelinck, M., and Guerit, J. M. (1999). Spatio-temporal localization of the Damasio, A.R., Damasio, H., and Van Hoesen, G.W. (1982). Prosopagnosia : Anatomic basis and behavioural mechanisms. Neurology 32, p331-341.

Crommelinck, M., and Guerit, J. M. (1999). Spatio-temporal localization of the face inversion ef-fect: An event-related potentials study. Biological Psychology 50(3), p173-189.

Daruna, J.H., and Karrer, R. (1984). Event-related potential correlates of intelligence and personality. Ann. NY. Acad Sci. 245, p565-569.

Davis, F.B. (1971). The measurement of mental capacity through evoked potential recording. Educa Rec Res Bull 1.

Dawda, D., & Hart, S. D. (2000). Assessing emotional intelligence: reliability and validity of the Bar-On Emotional Quotient Inventory (EQ-i) in university students. Personality and Individual Differences 28, p797–812.

Deary, I.J. (1980). How general is the mental speed factor in “general” intelligence ? An attempt to extend inspection time to the auditory modality. BSc (Med Sci) honours thesis, University of Edinburgh.

Deary, I.J. (1986). Inspection time: Discovery or rediscovery? Personality and Individual Differences 7, p625-631.

Deary, I.J. (1992). Auditory Inspection Time and Intelligence. Thesis, PhD University of Edinburgh.

Deary, I.J. (2000). Looking Down on Human Intelligence. Oxford Psychology Series no.34, Oxford University Press. Oxford, UK.

Deary, I.J. and Caryl, P.G. (1997). Neuroscience and human intelligence differences. Trends in Neuroscience 20 (8), p365-371.

Deary, I.J., and Caryl, P.G. (1993). Intelligence, EEG, and Evoked Potentials. In Vernon, P.A. (editor) Biological Approaches to the Study of Human Intelligence. Ablex Publishing Corporation, Norwood : New Jersey.

Deary, I.J., Caryl, P.G., and McLullich, A.J. (2000). Wetware. In Deary, I.J. Looking Down on Human Intelligence. Oxford University Press, Oxford, UK.

Deary, I.J., Caryl, P.G., and Gibson, G.J. (1993). Nonstationarity and the measurement of psychophysical response in a visual inspection-time task. Perception 22, p1245-1256.

Deary, I.J., Simonotto, E., Marshall, A., Marshall, I., Goddard, N. and Wardlaw, J.M.. (2001). The functional anatomy of inspection time: a pilot fMRI study. Intelligence 29, p497-510.

Deary, I.J., Simonotto, E., Meyer, M., Marshall, A., Marshall, I., Goddard, N., and Wardlaw, J. (2004a). The functional anatomy of inspection time: An event-related fMRI study. Neuroimage 22, p1466-1479.

Desimone R (1991) Face-selective cells in the temporal cortex of monkeys. Special issue: face perception. J Cognit Neurosci 3, p1– 8.

Detterman, D. (1987). What does reaction time tell us about intelligence ? In Vernon, P.A. (editor) Speed of Information Processing and Intelligence (chapter 5, p177-200). Ablex Publishing Corporation, Norwood, New Jersey.

Developmental Neuropsychology 14(1), p115-126.

Donchin, E. (1979). Event-related brain potentials : A tool in the study of human information processing. In H. Begleiter (Ed), Evoked Potentials and Behaviour (pp.13-75). New York, Plenum Press.

Donchin, E. and Coles, M.G.H. (1988a). Is the P300 component a manifestation of context updating ? Behavioural and Brain Sciences 11, p354-356.

Donchin, E. and Coles, M.G.H. (1988b). On the conceptual foundations of cognitive psychophysiology : a reply to comments. Behavioural and Brain Sciences 11, p406-417.

Druskat, V., & Wolff, S. (2001). Group emotional intelligence and its influence on group effectiveness. In C. Cherniss & D. Goleman (Eds.), The emotionally intelligent workplace: How to select for, measure, and improve emotional intelligence in individuals, groups, and organizations (pp. 132–155). San Francisco: Jossey-Bass.

Dulewicz, V., & Higgs, M. (1999b). Emotional intelligence questionnaire and users' guide. London: ASE/NFER Nelson.

Dustman, R.E., and Beck, E.C. (1972). Relationship of intelligence to visually evoked processes. Electroencephalography and Clinical Neurophysiology 33, p254-262.

Eckman, P. and Friesen, W.V. (1976). Pictures of Facial Affect. Consulting Psychologists Press, Palo Alto, California.

Egan, V. (1994). Intelligence, inspection time and cognitive strategies. British Journal of Psychology 85 (3), p305-15.

Egan, V. (1986). Intelligence and Inspection Time : Do high-IQ subjects use cognitive strategies ? Personality and Individual Differences 7(5), p695-700.

Egan, V. and Deary, I.J. (1992). Are Specific Inspection Time Strategies Prevented by Concurrent Tasks? Intelligence 16, p151-167.

Egan, V., Chiswick, C., Naidu, K., Rimmington, J.E. and Best, J.J.K. (1994). Size isn't everything : a study of brain volume intelligence, and auditory evoked potentials. Personality and Individual Differences 17, p357-367.

Eimer, M. (2000c). The face-specific N170 component reflects late stages in the structural encoding of faces. Neuroreport 11(10), p2319-2324.

Eimer, M. (1998) Does the face-specific N170 component reflect the activity of a specialized eye processor? Neuroreport 9(13), p2945-2948.

Eimer, M. (2000b). Attentional modulations of event-related brain potentials sensitive to faces. Cognitive Neuropsychology 17(1/2/3), p103-116.

Eimer, M., & Holmes, A. (2007). Event-related brain potential correlates of emotional face processing. Neuropsychologia 45, p15–31.

Eimer, M., Holmes, A., & McGlone, F. (2003). The role of spatial attention in the processing of facial expression: An ERP study of rapid brain responses to six basic emotions. Cognitive, Affective, and Behavioral Neuroscience 3, p97–110.

Eimer,M., & Holmes, A. (2002). An ERP study on the time course of emotional face processing. Neuroreport 13, p427–431.

Ekman and Friesen, 1976 P. Ekman and W. Friesen, Pictures of facial affect, Consulting Psychologists Press, Palo Alto, CA (1976).

Ekman, P. (1999). Basic Emotions. In T. Dalgleish and T. Power (Eds.) The Handbook of Cognition and Emotion Pp. 45-60. Sussex, U.K.: John Wiley & Sons, Ltd.

Ekman, P., Friesen, W. V., & Ellsworth, P. (1982). What emotion categories or dimensions can observers judge from facial behavior? In P. Ekman (Ed.), Emotion in the human face (p.39-55). New York: Cambridge University Press.

Ertl, J.P. (1969). Evoked potentials, neural efficiency and IQ. In S.D. Proctor (Ed). International Symposium on Biocybernetics of the Central Nervous System. New York; Little, Brown & Company.

Ertl, J. (1969). Neural efficiency and human intelligence, Final report, US Office of Education Project No. 9-0105.

Ertl, J. (1971). Fourier analysis of evoked potentials and human intelligence. Nature 230, p525-526.

Ertl, J., and Schafer, E.W.P. (1969). Brain response correlates of psychometric intelligence. Nature 223, p421-422.

Espay, A., and Jacobs, D.H. (2008). Frontal Lobe Syndromes. eMedicine, January 2008. http://www.emedicine.com/NEURO/topic436.htm

Everhart, J.P., China, C.L., and Auger, R.A. (1974). Measures of EEG and verbal intelligence : an inverse relationship. Physiological Psychology 2, p374-378.

Extremera, N., and Fernandez-Berrocal, P. (2005). Perceived emotional intelligence and life satisfaction : Predictive and incremental validity using the Trait Meta-Mood Scale. Personality and Individual Differences 39, p937-948.

Fabiani, M., Gratton, G., and Coles, M.G.H. (2000). Event-related brain potentials. In J.T. Cacioppo, L. G. Tassinary, and G. Berntson (Eds.) Handbook of Psychophysiology (pp. 53-84). New York: Cambridge University Press.

Fabiani, M., Gratton, G., and Federmeier, K.D. (2007). Event-related potentials : Methods, theory and applications. In Cacioppo, J.T., Tassinary, L.G., and Berntson, G.G. (editors) Handbook of Psychophysiology (p85-120). Cambridge University Press, New York.

Fabiani, M., Gratton, G., and Federmeier, K.D. (2007). Event-related potentials : Methods, Theory, and Applications. In Cacioppo, J.T., Tassinary, L.G., and Berntson, G.G. (Eds). Handbook of Psychophysiology (3rd Edition). Cambridge University Press, New York.

Farrelly, D., and Austin, E.J. (2007). Ability EI as an intelligence? Associations of the MSCEIT with performance on emotion processing and social tasks and with cognitive ability. Cognition and Emotion 21(5), p1043-1063.

Field, A. (2005). Discovering Statistics Using SPSS. Sage Publications Ltd., London.

Fox, E. (2002). Processing emotional facial expressions : The role of anxiety and awareness. Cognitive, Affective and Behavioural Neuroscience 2(1), p52-63.

Frijda, N.H. (2004). The psychologist’s point of view. In Lewis, M. and Haviland-Jones, J.M. (eds) Handbook of Emot-ions (2nd Edition) Pp. 59-73. The Guildford Press, Guildford Publications, New York.

Galton, F. (1833). Enquiries into Human Faculty. London: Dent.

Galton, F. (1883). Inquiries into human faculty and its development. London, Macmillan.

Gasser, T., Jennen-Steinmetz, C., and Verleger, R. (1987). EEG coherence at rest and during a visual task in two groups of children. Electroencephalography and Clinical Neurophysiology 67, p151-158.

Genetic influences on childhood IQ in 5- and 7-year-old Dutch twins.
Giannitrapani, D. (1969). EEG average frequencies and intelligence. Electroencephalography and Clincal Neurophysiology 27, p480-486.

Gibb-Clark, M. (1996). Do you have the emotional smarts? The Globe and Mail, (15 August).

Gibbs, N. (1995). The EQ Factor. Time 146, p60-68.

Gilbert, D.G., Johnson, S., Gilbert, B., and McColloch, M.A. (1991). Event-related potential correlates of IQ. Personality and Individual Differences 12, p1183-1184.

Goddard, N., and Wardlaw, J.M. (2001). The functional anatomy of inspection time: a pilot fMRI study. Intelligence 29, p497-510.

Goffeuax, V., Jemel, B., Jacques, C., Rossion, B., and Schyns, P.G. (2003). ERP evidence for task modulations on face perceptual processing at different spatial angles. Cognitive Science 27, p313-325.

Goleman D. 1995. Emotional Intelligence. New York: Bantam

Goleman, D. (1995a). Why your emotional intelligence quotient can matter more than IQ. USA Weekend, September 10th, p4-8.

Gottfredson, L. S. (1997). Why g matters: The complexity of everyday life. Intelligence 24, p79–132.

Greenspan, S.I. (1989). Emotional Intelligence. In Field, K., Cohler, B.J., and Wool, G. (eds). Learning and Education : Psychoanalytic Perspectives, p209-243. Madison, CT : International Universities Press.

Grill-Spector, K., Sayres, R., and Ress, D. (2006) High-resolution imaging reveals highly selective nonface clusters in the fusiform face area. Nature Neuroscience 9 (9), p1177 – 1185.

Gross, C.G., Bender, D.B., and Rocha-Miranda. C.E. (1969). Visual receptive fields of neurons in inferotemporal cortex of the monkey. Science 166, p1303-1306.

Guntekin, B. and Basar, E. (2007). Emotional expressions are differentiated with brain oscillations. International Journal of Psychophysiology 64 (1), p91-100.

Gustafsson, J.E. (1984). A unifying model for the structure of mental abilities. Intelligence 8, p179-203.

Haier, R.J. (1993). Cerebral glucose metabolism and intelligence. In Vernon, P.A.. (editor) Biological approaches to the study of human intelligence (p317-332). Norwood, NJ; Ablex.

Haier, R.J., Robinson, D.L., Braden, W., and Williams, D. (1983). Electrical potentials of the cerebral cortex and psychometric intelligence. Personality and Individual Differences 4, p591-599.

Halgren, E., Raij, T., Marinkovic, K., Jousmaki, V.,&Hari, R. (2000). Cognitive response profile of the human fusiform face area as determined by MEG. Cerebral Cortex 10(1), p69–81.

Hansell, N.K., Wright, M.J., Luciano, M., Geffen,G.M., Geffen,L.B., Martin, N.G. (2005). Genetic covariation between event-related potential (ERP) and behavioral non-ERP measures of working-memory, processing speed, and IQ. Behavior Genetics 35(6), p695-706.

Hansen, C.H. and Hansen, R.D. (1988). Finding the face in the crowd : An anger superiority effect. Journal of Personality and Social Psychology 54, p917-924.

Harlow, J. (1848). The passage of an iron bar through the head. Boston Medical and Surgical Journal 39, p389-393,

Harlow, J. (1868). Recovery from the passage of an iron bar through the head. Publications of the Massachussets Medical Society 2, p327-347.

Hautecoeur, P., Debruyne, P., Forzy, G., Gallois, P., Hache, J.-C., & Dereux, J.-F. (1993). Potentiels evoques visuels et reconnaissance des visage : Influences de la celebrite et de l'expression emotionelle. Revue Neurologique (Paris) 149, p207-212.

Haxby JV, Grady CL, Horwitz B, Ungerleider LG, Mishkin M, Carson RE, Herscovitch P, Schapiro MB, Rapoport SI (1991) Dissociation of spatial and object visual processing pathways in human extrastriate cortex. Proc Natl Acad Sci USA 88, p1621–1625.

Haxby JV, Horwitz B, Ungerleider LG, Maisog JM, Pietrini P, Grady CL (1994) The functional organization of human extrastriate cortex: a PET-rCBF study of selective attention to faces and locations. J Neurosci 14, p6336–6353.

Haxby, J.V., Hoffman, E.A., and Bobbini, M.I. (2000). The distributed human neural system for face perception. Trends in Cognitive Sciences 4(6), p223-233.

Heim, 1968. A. Heim In: (Rev. ed.),Manual for the AH5 Group Test of High Grade Intelligence, NFER-Nelson, Windsor, United Kingdom (1968).

Hendrickson, D.E. (1982b). The biological basis of intelligence Part II : Measurement. In Eysenck, H.J. (editor) A Model for Intelligence, p197-228. New York, Springer-Verlag.

Hendrickson, D.E. and Hendrickson, A.E. (1980) The biological basis of individual differences in intelligence. Personality and Individual Differences 1, p3-33.

Herrmann, M.J., Aranda, D., Ellgring, H.,Mueller, T.J., Strikd, W.K., Heidricha, A., and Fallgattera, A.J. (2002). Face-specific event-related potential in humans is independent from facial expression. International Journal of Psychophysiology 45, p241-244.

Hick, W.E. (1952). On the rate of gain of information. Quarterly Journal of Experimental Pyschology 4, p11-26.

Hillyard, S.A., Hink, R.F., Schwent, V.L., and Picton, T.W. (1973). Electrical signs of selective attention in the human brain. Science 182, p177-180.

Holmes, A, Winston, J.S., and Eimer, M. (2005). The role of spatial frequency information for ERP components sensitive to faces and emotional facial expression. Cognitive Brain Research 25, p508 – 520.

Horn, J. L. (1967). Intelligence: Why it grows, why it declines. Transaction, p23-31.

Horn, J. L., & Cattell, R. B. (1966a). Refinement and test of the theory of fluid and crystallized general intelligences. Journal of Educational Psychology 57, p253-270.

Hough, L. M., & Ones, D. S. (2001). The structure, measurement, validity, and use of personality variables in industrial, work, and organizational psychology. In N. Anderson, D. S. Ones, H. K. Sinangil, & C. Viswesvaran (Eds.), Handbook of industrial, work and organizational psychology: Personnel psychology (pp. 233–277). Thousand Oaks, CA: Sage.

Hulme, C., and Turnbull, J. (1983). Intelligence and inspection time in normal and mentally retarded subjects. British Journal of Psychology 74, 365-370.
Human Extrastriate Visual Cortex and the Perception of Faces,

humans. Neuroscience Letters 278, p13–16.

Ikebuchi, E., Nakagome, K., Tugawa, R., Asada, Y. (1996). What infleences social skills in patients with schizophrenia? Preliminary study using the role play test, WAIS-R and event-related potential. Schizophrenia Research 22(2), p143-150.

Janik, S.W, Wellens, A.R., Goldberg, M.L., and Dell'Osso, L.F. (1978). Eyes as the center of focus in the visual examination of human faces. Perceptual and Motor Skills 47(3, Pt 1), p857-858

Jansari, A., Tranel, D. and Adolphs, R. (2000). A valence-specific lateral bias for discriminating emotional facial expressions in free field. Emotion 14(3), p341-353.

Jasper H.H.(1958). The 10–20 electrode system of the International Federation. Electroenceph. clin. Neurophysiol.10, p370–375.

Jensen, A.R. (1987). Individual differences in the Hick Paradigm. In Vernon, P.A. (editor) Speed of Information Processing and Intelligence (chapter 4, p101-175). Ablex Publishing Corporation, Norwood, New Jersey.

Jensen, A.R. (2005). Mental chronometry and the unification of differential psychology. In . In Sternberg, R.J. and Pretz, J.E. (eds) In Cognition and Intelligence : Identifying the mechanisms of the mind (p26-50). Cambridge University Press, Cambridge, UK.

Jensen, A.R., and Vernon, P.A. (1986). Jensen’s reaction time studies : a reply to Longstreth. Intelligence 10, p153-179.

Jordan, P., Ashkanasy, N., Hartel, C., & Hooper, G. (2002). Workgroup emotional intelligence: Scale development and relationship to team process effectiveness and goal focus. Human Resources Management Review 12, p195–214.

Josiassen, R.C., Shagass, C., Roemer, R.A., and Slepner, S. (1988). Evoked potential correlates of intelligence in non-patient subjects. Biological Psychology 27, p207-225.

Kanazawa, S. (2004). General intelligence as a domain-specific adaptation. Psychological Review 111(2), p512-523.

Kanwisher, N., McDermott, J. and Chun M.M. (1997). The fusiform face area : a module in human extrastriate cortex specialised for face perception. The Journal of Neuroscience 17 (11), p4302-4311.

Keele, S.M., and Bell, R. C. (2008). The factorial validity of emotional intelligence : An unresolved issue. Personality and Individual Differences 44, p487-500.

Knott, J.R., Friedman, H., and Bardsley, R. (1942). Some eectroencephalographic correlates of intelligence in eight-year and twelve-year old children. Journal of Experimental Psychology 30, p380-391.

Kranzler, J.H., and Jensen, A.R. (1989). Inspection time and intelligence : a meta analysis. Intelligence 13, p329-47.

Kreezer, G. and Smith, F.W. (1950). The relation of the alpha rhythm of the EEG and intelligence level in the nondifferentiated familial type of mental deficiency. Journal of Psychology 29, p47-51.

Lally, M., and Nettelbeck, T. (1977). Intelligence, reaction time and inspection time. American Journal of Mental Deficiency 82, p273-281.

Landy, F.J. (2005). Some historical and scientific issues related to research on emotional intelligence. Journal of Organisational Behaviour 26, p411-424.

Lee, K. (1999). Unpublished Honours Thesis. University of Edinburgh.

Lehmann, D., & Skrandies, W. (1986). Segmentation of EEG potential fields. Electroencephalography and Clinical Neurophysiology 38, p27–32.

Lehmann, D., and Skrandies, W. (1980). Reference-free identification of components of checkerboard-evoked multichannel potential fields. Electroencephalography and Clinical Neurophysiology 48, p609-621.

Leuner, B. (1966). Emotional Intelligence and Emancipation. Praxis der Kinderpsychologie und kinderpsychiatry 15, p196-203.

Levy, P. (1992). Inspection Time and its relation to intelligence : issues of measurement and meaning. Personality and Individual Differences 13 (9), p987-1002.

Lindholm, E., and Koriath, J.J. (1985). Analysis of multiple event-related potential components in a tone discrimination task. International Journal of Psychophysiology 3, p121-129.

Longstreth, L.E., Walsh, D.A., Alcorn, M.B., Szeszulski, P.A., and Manis, F.R. (1986). Backward Masking, IQ, SAT and Reaction Time : Interrelationships and Theory. Personality and individual Differences 7(5), p643-651.

Lopes, P. N., Salovey, P., & Straus, R. (2003). Emotional intelligence, personality and the perceived quality of social relationships. Personality and Individual Differences 35, p641–658.

Lopes, P.N., Brackett, M.A., Nezlek, J.B., Schulz, A., Sellin, I., & Salovey, P. (2004). Emotional intelligence and social interaction. Personality and Social Psychology Bulletin 30, p1018–1034.

Luciano, M., Smith, G.A., Wright, M.J., Geffen, G.M., Geffen, L.B., and Martin, N.G. (2001). On the heritability of inspection time and its covariance with IQ: a twin study. Intelligence (29), p443-457.

Luck, S.J. (2005). An introduction to the event-related potential technique. Cambridge, Mass.; London MIT Press.

MacCann, C., Roberts, R. D., Matthews, G., & Zeidner, M. (2004). Consensus scoring and empirical option weighting of performance-based emotional intelligence (EI) tests. Personality and Individual Differences 36, p645-662.

Mackenzie, B., & Bingham, E. (1985). IQ, inspection time and response strategies in a university sample. Australian Journal of Psychology 37, p257-268.

Mackintosh, N.J. and Bennett, E.S. (2002). IT, IQ and perceptual speed. Personality and individual differences 32, p685-693.

Mackintosh, N.J., and Bennet, E.S. (2002). IT, IQ, and perceptual speed. Personality and Individual Differences 32, p685-693.

Malach R, Reppas JB, Benson RB, Kwong KK, Jiang H, Kennedy WA,
Mandler, J. M. (1984). Stories, scripts, and scenes: Aspects of schema theory. Hillsdale, NJ: Lawrence Erlbaum.

Malach R, Reppas JB, Benson RB, Kwong KK, Jiang H, Kennedy WA, Ledden PJ, Brady TJ, Rosen BR, Tootell RBH (1995) Object-related activity revealed by functional magnetic resonance imaging in human occipital cortex. Proc Nat Acad Sci USA 92, p8135– 8138.

Marshall, A. (2004). Characterisation of inter-stimuli interval with E-Prime experiment generator. Unpublished internal memorandum. University of Edinburgh School of Philosophy, Psychology and Language Sciences.

Mayer, J. D., Caruso, D. R., & Salovey, P. (1999). Emotional intelligence meets traditional standards for an intelligence. Intelligence 27, p267–298.

Mayer, J. D., Salovey, P., Caruso, D. R., & Sitarenios, G. (2003). Measuring emotional intelligence with the MSCEIT V2.0. Emotion 3, p97–105.

Mayer, J., Salovey, P., & Caruso, D. (2002). MSCEIT user's manual. Toronto: Multi-Health Systems.

Mayer, J.D. and Geher, G. (1996). Emotional intelligence and the identification of emotion. Intelligence 22, p89-113.

Mayer, J.D. and Salovey, P. (1993). The intelligence of emotional intelligence. Intelligence 17, p433-442.

Mayer, J.D., Roberts, R.D., and Barsade, S.G. (2008). Human Abilities : Emotional Intelligence. Annual Review of Pyschology 59, p507-536.

Mayer, J.D., Salovey, P. and Caruso, D.R. (1997). Emotional Intelligence Test. Needham, MA : Virtual Knowledge.

Mayer, J.D., Salovey, P., and Caruso, D.R. (2000). Emotional Intelligence as Zeitgeist, as Personality, and as a Mental Ability. In Bar-On, R. and Parker, J.D.A. (2000) (eds). The Handbook of Emotional Intelligence : Theory, Development, Assessment and Application at Home, School, and in the Workplace Pp.92-118. Jossey-Bass Inc., San Francisco, California.

Mayer, J.D., Salovey, P., and Caruso, D.R. (2000). Models of Emotional Intelligence. In Sternberg, R. (editor). Handbook of Intelligence. Cambridge UK, Cambridge University Press.

McCarthy, G., Puce, A., Belger, A., and Allison, T. (1999). Electrophysiological Studies of Human Face Perception II : Response properties of face-specific potentials generated in occipitotemporal cortex. Cerebral Cortex 9, p431 – 444.

McEnrue, M.P., and Groves, K. (2006). Choosing among tests of emotional intelligence : what is the evidence ? Human Resources Development Quarterly 17(1), p9-42.

McGarry-Roberts, P.A., Stelmack, R.M., and Campbell, K.B. (1992). Intelligence, reaction time and event-related potentials. Intelligence 16, p289-313.

McKenzie, B., and Cumming, S. (1986). How fragile is the relationship between inspection time and intelligence : the effects of apparent motion cues and previous experience. Personality and Individual Differences 7(5), p721-729.

McRorie, M. and Cooper, C. (2004). Synaptic transmission correlates of general mental ability. Intelligence 32, p263-275.

McRory. C. and Cooper, C (2007). Overlap between visual inspection time tasks and general intelligence. Learning and Individual Differences 17, p187-192.

Merkel, J. (1885). Die zeitlichen Verhaltnisse der Willensthatigkeit. Philosophische Studien 2, p73-127.

Miller, E.M. (1994). Intelligence and brain myelination : a hypothesis. Personality and Individual Differences 17, p803-832.

Miller, G. (2000). How to keep our metatheories adaptive: Beyond Cosmides, Tooby, and Lakatos. Psychological Inquiry 11, p42–46.

Mischel W (1973) Towards a cognitive social learning reconceptualisation of personality. Psychol. Rev. 80, p253-293.

Mogg K, Bradley B. Orienting of attention to threatening facial expressions presented under conditions of restricted awareness. Cognition and Emotion 13, p713–740.

Morris, G.L. and Alcorn, M.B. (1995). Raven's progressive matrices and inspection time : P200 slope correlates. Personality and Individual Differences 18 (1), p81-87.

Mundy, K.J.M. (1992). Evoked responses as produced by the Loop Task. Unpublished Honours Thesis, University of Edinburgh.

Mundy-Castle, A.C. (1958). Electrophysiological correlates of intelligence. Journal of Personality 26, p184-199.

Mundy-Castle, A.C., and Nelson, G.K. (1960). Intelligence, personality, and brain rhythms in a socially isolated community. Nature 185, p484-485.

Nelson, H. & Willison, J. R. (1991) National Adult Reading Test (NART): Test Manual (2nd edn). Windsor: NFER-Nelson.

Nemiah, J. C., Freyberger, H., & Sifneos, P. E. (1976). Alexithymia: A view of the psychosomatic process. In O. W. Hill, Modern trends in psychosomatic medicine Vol. 3 (p. 430-439). London: Butterworths.

Nettelbeck, T. (1973). Individual differences in noise and associated perceptual indices of performance. Perception 2, p11-21.

Nettelbeck, T. (1982). Inspection time : an index for intelligence ? Quarterly Journal for Experimental Psychology 34(A), 299-312.

Nettelbeck, T. (1985c, June). Inspection time and IQ. Paper presented at the second meeting of the International Society for the Study of Individual Differences, Sant Feliu de Guixols, Catalonia, Spain.

Nettelbeck, T. (1987). Inspection Time and Intelligence. In Vernon, P.A. (editor) Speed of Information Processing and Intelligence (chapter 9, p295-346). Ablex Publishing Corporation, Norwood, New Jersey.

Nettelbeck, 1994. T. Nettelbeck, Speediness. In: R.J. Sternberg, Editor, Encyclopedia of human intelligence, Macmillan, New York (1994), p. 1014–1019.
Nettelbeck, T. & Wilson, C. (1994). Childhood changes in speed of information processing and mental age: A brief report. British Journal of Developmental Psychology12, p277-280.

Nettelbeck, T. (2001). Correlation between inspection time and psychometric abilities : A personal interpretation. Intelligence 29, p459-474.

Nettelbeck, T. and Kirby, N.H. (1983a). Measurement of timed performance and intelligence. Intelligence 7, p39-52

Nettelbeck, T., and Lally, M (1976). Inspection time and measured intelligence. British Journal of Psychology 67, p17-22.

Neubauer, A. C., and Fink, A. Basic information processing and the psychophysiology of intelligence. In Sternberg, R.J. and Pretz, J.E. (eds) In Cognition and Intelligence : Identifying the mechanisms of the mind (Chapter 4, p68-87). Cambridge University Press, Cambridge, UK.

Newsome, S., Day, A. L., & Catano, V. M. (2000). Assessing the predictive validity of emotional intelligence Personality and Individual Differences 29, p1005–1016.

Niedermeyer, E (1993). Sleep and EEG. In Niedermeyer, E. and Lopez da Silva, F. (eds.) Electroencephalography : Basic Principles, Clinical Applications, and Related Fields (3rd ed) p153-166. Baltimore, William and Wilkins.

Nunez, P. L. and Srinivasan, R. (2006). Electric Fields of The Brain : The Neurophysics of EEG (2^{nd} Edition). Oxford University Press; New York.

O'Connor, R.M., and Little, I.S. (2003). Revisiting the predictive validity of emotional intelligence: self-report versus ability-based measures. Personality and Individual Differences 35, p1893-1902.

O'Connor, T.A., and Burns, N.R. (2003). Inspection time and general speed of processing. Personality and Individual Differences 35, p713-724.

Öhman A, Flykt A, Esteves F. (2001a). Emotion drives attention: Detecting the snake in the grass. Journal of Experimental Psychology: General 130, p466–478.

Öhman A, Mineka SM. (2001) Fear, phobias, and preparedness: Toward an evolved module of fear and fear learning. Psychological Review 108, p483–522.

Öhman, A. (2002). Automaticity and the amygdala: Nonconscious responses to emotional faces. Current Directions in Psychological Science 11, p62–66.

Ojemann, J.G., Ojemann, G.A., and Lettich, E. (1992). Neuronal activity related to faces and matching in human right nondominant temporal cortex. Brain 115, p1-13.

Olsen, H., Bjorkman, C., Haag, K. and Juslin, P. (1998). Auditory inspection time : on the importance of selecting the appropriate sensory continuum. Personality and Individual Differences 25, p627-634

Olson, I.R., and Marchuetz, C. (2005). Facial attractiveness is appraised in a glance. Emotion 5(4), p498-502.

Orozco, S. and Ehlers, C.L. (1998). Gender differences in electrophysiological responses to facial stimuli. Biological Psychiatry 44, p281-289.

Osborne, R.T(1969). Psychometric correlates of the visual evoked potential. Acta Psychologica 29, p303-308.

P. (2004). Emotional intelligence and social interaction. Personality and Social Psychology Bulletin 30, p1018–1034.

Palermo, R., and Rhodes G. (2007). Are you always on my mind ? A review of how face perception and attention interact. Neuropsychologia 45, p75-92.

Palmer, B., Donaldson, C., & Stough, C. (2002). Emotional intelligence and life satisfaction. Personality and Individual Differences 33, p1091–1100.

Palmer, B.R., Gignac, G., Manocha, R., and Stough, C. (2005). A psychometric evaluation of the Mayer-Saolvey-Caruso Emotional Intelligence Test Version 2.0. Intelligence 33 (3), p285-305.

Palmer, B.R., Walls, M., Burgess, Z., & Stough, C. (2001). Emotional intelligence and effective leadership. Leadership & Organisational Development Journal 22, p5–10.

Parker, J. D. A., Duffy, J., Wood, L. M., Bond, B. J., & Hogan, M. J. (2005). Academic achievement and emotional intelligence: Predicting the successful transition from high school to university. Journal of First-Year Experience and Students in Transition 17, p7-78.

Parker, J. D. A., Summerfeldt, L. J., Hogan, M. J., & Majeski, S. A. (2004). Emotional intelligence and academic success: examining the transition from high school to university. Personality and Individual Differences 36, p163–172.

Parker, J.D.A., Austin, E.J., Hogan, M.J., Wood, L.M., and Bond, B.J. (2005). Alexithymia and academic success: examining the transition from high school to university. Personality and Individual Differences 38, p. 1257–1267.

Parker, J.D.A., Hogan, M.J., Eastabrook, J.M., Oke, A., and Wood, L.M. (2006). Emotional intelligence and student retention : predicting the successful transition from high school to university. Personality and Individual Differences 41(7), p1329-1336.

Payne, W.L. (1986). A study of emotions : Developing emotional intelligence, self-integration, relating to fear, pain and desire. Dissertation Abstracts International 47, p203.

Perez, J.C., Petrides, K.V., Furnham, A. (2005). Measuring Trait Emotional Intelligence. In Schulze, R., and Roberts, R.D. (eds). Emotional Intelligence : An international handbook. Hogrefe and Huber Publishers, Gottingen, Germany.

Perini, G.I., Colombo, G., Armani, M., Pellegrini, A., Ermani, M., Miotti, M. and Angelini, C. (1989). Intellectual impairment and cognitive evoked potentials in myotonic dystrophy. J. Nerv. Ment. Dis. 177, p750-754.

Perrett, D.I., Rolls, E.T., and Caan, W. (1982). Visual neurones responsive to faces in the monkey temporal cortex. Exp. Brain Res. 47, p329-342.

Perrett, D.I. et al. (1985) Visual cells in the temporal cortex sensitive
to face view and gaze direction. Proc. R. Soc. London Ser. B 223,
p293–317.

Perry, A. (1991). The effect of the repeated presentation of multi-letter sequences on perception. Unpublished Thesis, University of Edinburgh.
PET-rCBF study of selective attention to faces and locations.

Petrides, K. V., & Furnham, A. (2006). The role of trait emotional intelligence in a gender-specific model of organizational variables. Journal of Applied Social Psychology 36, p552–569.

Petrides, K. V., Furnham, A. & Mavroveli, S. (2007). Trait emotional intelligence: Moving forward in the field of EI. In G. Matthews, M. Zeidner, & R. Roberts, R. (Eds.). Emotional intelligence: Knowns and unknowns (Series in Affective Science). Oxford: Oxford University Press.

Petrides, K.V, and Furnham, A. (2000). On the dimensional structure of emotional intelligence. Personality and Individual Differences 29, p313-320.

Petrides, K.V., and Furnham, A., (2000a). Gender differences in measured and self-estimated trait emotional intelligence. Sex Roles 42, p449-461.

Petrides, K.V., and Furnham, A., (2001). Trait emotional intelligence : Psychometric investigation with reference to established trait taxonomies. European Journal of Personality 15, p425-448.

Petrides, K.V., Frederickson, N., and Furnham, A. (2004) The role of trait emotional intelligence in academic performance and deviant behavior at school. Personality and Individual Differences 36, p277–293.

Pizzagalli, D. A., Lehmann, D., Hendrick, A. M., Regard, M., Pascual-Marqui, R. D.,& Davidson, R. J. (2002). Affective judgments of faces modulate early activity (160 ms) within the fusiform gyri. NeuroImage 16, p663–677.

Polich, J., and Kok, A. (1995). Cognitive and biological determinants of P300: an integrative review. Biological Psychology 41(2), p103-146.

Puce, A., Allison, T., and McCarthy, G. (1999). Electrophysiological Studies of Human Face Perception III : Effects of top-down processing on face specific potentials. Cerebral Cortex 9, p445 – 458.

Puce, A., Allison, T., Gore, J. C. & McCarthy, G. (1995). Face sensitive regions in human extrastriate cortex studied by functional MRI. J. Neurophysiol. 74, p1192–1199.

Reed, T.E. and Jensen, A.R. (1992). Conduction velocity in a brain nerve pathway of normal adults correlates with intelligence level. Intelligence 16, p259–272.

Reed, T.E., Vernon, P.A, and Johnson, A.M. (2004). Sex difference in brain nerve conduction velocity in normal humans. Neuropsychologia 42, p1709-1714.

Reed, T.E., Vernon, P.A., and Johnson, A.M. (2004). Confirmation of correlation between brain nerve conduction velocity and intelligence level in normal adults. Intelligence 32 (6), p563-572.

Reik, T. (1952). Listening with the third ear : the inner experiences of a psychoanalyst. New York, Farrer, Straus.

Renault, B., Signoret, J.-L., Debruille, B., Breton, F., and Bolger, F. (1989). Brain potentials reveal covert facial recognition in prosopagnosia. Neuropsychologia 27, p905-912.

Rhodes, L..E., Dustman, R.E. and Beck E.C. (1969) The visual evoked response] a comparison of bright and dull children. Electroencephalography and Clinical Neurophysiology 2, p364-372.

Roberts RD, Schulze R, O’Brien K, MacCann C, Reid J, Maul A. 2006. Exploring the validity of the Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT) with established emotions measures. Emotion 6, p663–69.

Robinson, D.L., 1993. The EEG and intelligence: an appraisal of methods and theories. Personality and Individual Differences 15, p695–716.

Rodriguez, E., Lachaux, G.N., Martinerie, J., Renault, B. and Varela, F.L. (1999). Perception’s shadow : long-distance synchronisation of human brain activity. Nature 397, p430-433.

Rodriguez, M., Prieto, B., Bernal, J., Marosi, E., Yanez, G., Harmony, T., Silva-Pereyra, J., Fernandez, T., Fernandez-Bouzas, A., Rodriguez, H., Luviano, L., and Guerrero, V. (2006). Language event-related potentials in poor readers. In Randall, S.V. (editor) Learning disabilities (New Research). (pp. 187-217). Hauppauge, NY.

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Rossion, B., Delvenne, J. F., Debatisse, D., Goffaux, V., Bruyer, R., Crommelinck, M., and Guerit, J. M. (1999). Spatio-temporal localization of the face inversion effect: An event-related potentials study. Biological Psychology, 50(3), p173-189.

Rossion, B., Gauthier, I., Tarr, M. J., Despland, P., Bruyer, R., Linotte, S., & Crommelinck, M. (2000). The N170 occipito-temporal component is delayed and enhanced to inverted faces but not to inverted objects: An electrophysiological account of face-specific processes in the human brain. Neuroreport 11 (1), p69-74.

Rossion, B., Joyce, C. A., Cottrell, G. W., & Tarr, M. J. (2003). Early lateralization and orientation tuning for face, word and object processing in the visual cortex. NeuroImage, 20(3), p1609-1624.

Rolls, E.T. (1992). Neurophysiology and functions of the primate amygdala. In : The Amygdala,, Aggleton, J.P. (ed), p143-165. New York, Wiley.

Rousselet, G.A., Mace, M.J-M., and Fabre-Thorpe, M. (2004). Animal and human faces in natural scenes: How specific to human faces is the N170 ERP component? Journal of Vision 2004 (4), p13-21.

Rugg, M. & Coles, M. G. H. (Eds.) (1995). Electrophysiology of mind: Event-related brain potentials and cognition. Oxford, England: Oxford University Press.

Rushton, J.P., and Ankney, C.D. (1996). Brain size and cognitive ability : correlations with age, sex, social class and race. Psychonomic Bulletin and Review 3, p21-36.

Sagiv, N., & Bentin, S. (2001). Structural encoding of human and schematic faces: Holistic and part- based processes. Journal of Cognitive Neuroscience 13(7), p937-951.

Saklofske, D.H., Austin, E.J., and Minske, P.S. (2003). Factor structure and validity of a trait emotional intelligence measure. Personality and Individual Differences 34, p707-721.

Sala, F. (2002). Emotional Competence Inventory technical manual. Philadelphia: HayGroup.

Salovey, P. and Grewal, D. (2005). The science of emotional intelligence. Current Directions in Psychological Science 14(6), p281-285.

Salovey, P., and Mayer J.D. (1990). Emotional Intelligence. Imagination, Cognition and Personality 9, p185-211.

Salovey, P., Mayer, J., Goldman, S., Turvey, C., & Palfai, T. (1995). Emotional attention, clarity, and repair: Exploring emotional intelligence using the Trait Meta-Mood Scale. In J. W. Pennebaker (Ed.), Emotion, disclosure, and health. Washington, D.C.: American Psychological Association.

Sandman, C.A., and Barron, J.L. (1986). Parameters of the event-related potential are related functioning in the mentally retarded. Int. J. Neurosci. 29, p37-44.

Schacter, D.L. (1977). EEG theta waves and psychological phenomena : a review and analysis. Biological Psychology 5, p47-82.

Scherer, K. (2007). What is an emotion ? In Bard, K. and Cornelius, R. (eds). The Emotion Researcher (International Society for Research on Emotion newsletter) 22 (1-2). Harmon & Castella Printing, Inc. Poughkeepsie, New York.

Schneider, W., Eschman, A, and Zuccolotto, A. (2002). E-Prime User's Guide. Psychology Sofftware Tools, Inc. Pittsburgh.

Schulte, M.J., Ree, M.J., and Carretta, T.R. (2004). Emotional Intelligence : not much more than g and personality. Personality and Individual Differences 37, p1059-1068.

Schutte, N. S., Malouff, J.N., Hall, L.E., Haggerty, D.J., Cooper, J.T., Golden, C.J., Dornheim, L. (1998). Development and validation of a measure of emotional intelligence. Personality and Individual Differences 25, p167-177.

Schutte, N.S., Malouff, J.M., Bobik, C., Coston, T.D., Greeson, C., Jedlicka, C. (2001). Emotional Intelligence and interpersonal relations. Journal of Social Psychology 141, p523-536.

Schutter, D.J.L.G., de Haan, E.H.F. and van Honk, J. (2004). Functionally dissociated aspects in anterior and posterior electrocortical processing of facial threat. International Journal of Psychophysiology 53, p29-36.

Sergent J, Ohta S, MacDonald B (1992) Functional neuroanatomy of face and object processing: a positron emission tomography study. Brain 115, p15–36.

Shagass, C. (1946). An attempt to correlate the occipital alpha frequency of the encephalogram with performance on a mental ability test. Journal of experimental Psychology 36, p88-92.

Shagass, C. (1972). Evoked brain potentials in psychiatry. New York, Plenum Press.

Shagass, C., Roemer, R.A., Straumanis, J.J., and Josiassen, R.C. (1981). Intelligence as a factor in evoked potential studies of psychopathology. I. Comparison of low and high IQ subjects. Biological Psychiatry 16 (11), p1007-1030.

Sheppard, L. D. (2008). Intelligence and speed of information-processing: A review of 50 years of research. Personality and Individual Differences 44, p535-551.

Shucard, D.W. and Callaway, E. (1974). Auditory evoked potential amplitude and variability-effects of tasks and intellectual ability. J. Comp. Physiol. Psychol. 87, p284-294.

Shucard, D.W., and Horn, J.L. (1972). Evoked cortical potentials and measurement of human abilities. J. Comp. Physiol. Psychol. 78, p59-68.

Sifneos, P. E. (1973). The prevalence of ‘‘alexithymic’’ characteristics in psychosomatic patients. Psychotherapy and Psychosomatics 22, p255–262.

Small, M. (1986). Hemispheric differences in the evoked potential to face stimuli. In H. Ellis, M.A. Jeeves, F. Newcombe and A. Young (eds) Aspects of Face Processing. Dordrecht, Martinus Nijhoff.

Smith,G. and Stanley, G. (1983). Clocking g: Relating intelligence and measures of timed performance. Intelligence 7, p353-368.

Smith, G.A. (1986). Inspection time and response strategies in a choice response task. Personality and individual Differences, 7(5), p701-707.

Smith, M.E., and Halgren, E. (1987). Event related potentials elicited by familiar and unfamiliar faces. Current Trends in Event-Related Potential Research 40, p422-426.

Smith, N.K., Cacioppo, J.T., Larsen, J.T. and Cha-rtrand, T.L. (2003). May I have your attention, please: Electrocortical responses to positive and negative stimuli. Neuropsychologia 41, p171–183.

Solomon, R.C. (2007). What is an emotion ? In Bard, K. and Cornelius, R. (eds). The Emotion Researcher (International Society for Research on Emotion newsletter) 22 (1-2). Harmon & Castella Printing, Inc. Poughkeepsie, New York.

Spearman, C. (1904). “General Intelligence” objectively determined and measured. American Journal of Psychology 15, p201-293.

Spearman, C. (1927). The abilities of man. London, Macmillan.
Special issue: face perception. J Cognit Neurosci 3, p1– 8.

Stankov, L. (2005). Reductionism versus charting : Ways of examining the role of lower-order cognitive processes in intelligence. In Sternberg, R.J. and Pretz, J.E. (eds) In Cognition and Intelligence : Identifying the mechanisms of the mind (Chapter 3, p51-67). Cambridge University Press, Cambridge, UK.

Steriade, M. (1993). Cellular substrates of brain rhythms. . In Niedermeyer, E. and Lopez da Silva, F. (eds.) Electroencephalography : Basic Principles, Clinical Applications, and Related Fields (3rd ed) p27-62. Baltimore, William and Wilkins.

Sternberg, R.J. Nothing fails like success : the search for an intelligent paradigm for studying intelligence. Journal of Educational Psychology 73, p142-155.

Stough, C. K. K., Nettelbeck T., and Cooper, C.J. (1990). Evoked brain potentials, string length and intelligence. Personality and Individual Differences 11, p401-406.

Stough, C., Bates, T. C., Mangan, G. L., & Colrain, I. (2001). Inspection time and intelligence: Further attempts to eliminate the apparent movement strategy. Intelligence 29, p219−230.

Stough, C.K., Nettelbeck, T., & Cooper, C. (I 992). IT, RT and AEPS as correlates of intelligence. International Journal of Psychology 27, p338.

Streit, M., Wolwer, W., Brinkmeyer, J., Ihl, R., and Gaebel, W. (2000). Electrophysiological correlates of emotional and structural face processing in humans. Neuroscience Letters 278, p13-16.

Suslow, T., Roestel, C., Orhmann, P., and Arolt, V. (2003). Detection of facial expressions of emotions in schizophrenia. Schizophrenia Research 64, p137-145.

Taylor, G. J. (1987). Psychosomatic medicine and contemporary psychoanalysis. Madison, CT: International Universities Press.

Taylor, G.J. (1984). Alexithymia : Concept, measurement and implications for treatment. American Journal of Psychiatry 141, p725-732.

Taylor, M.M. and Creelman, C.D. (1967). PEST : efficient estimate on probability functions. Journal of the Acoustical Society of America 4, p782-787.

Tett, R., Fox, K., & Wang, A. (2005). Development and validation of a self-report measure of emotional intelligence as a multidimensional trait domain. Personality and Social PsychologyBulletin 31, p859–888.

Thatcher, R.W., McAlaster, R., Lester, M.L., Horst, R.L., and Cantor, D.S. (1983). Hemispheric EEG asymmetries related to cognitive functioning in children. In Perecman, E. (editor), Cognitive processing in the right hemisphere (p125-145). New York, Academic Press.

Thayer, R.E. (2007). What is an emotion ?. In Bard, K. and Cornelius, R. (eds). The Emotion Researcher (International Society for Research on Emotion newsletter) 22 (1-2). Harmon & Castella Printing, Inc. Poughkeepsie, New York.

Thorndike, E. (1920). Intelligence and its uses. Harper’s Magazine, 140, p227–235.

Thurstone, L. L. (1938). Primary mental abilities. Chicago: University of Chicago Press.

Tootell RBH, Reppas JB, Kwong KK, Malach R, Born RT, Brady TJ, Rosen BR, Belliveau JW (1995) Functional analysis of human MT and related visual cortical areas using magnetic resonance imaging. J Neurosci 15, p3215–3230.

Trinidad, D. R., & Johnson, C. A. (2001). The association between emotional intelligence and early adolescent tobacco and alcohol use. Personality and Individual Differences 32, p95–105.

Trinidad, D. R., Unger, J. B., Chou, C. P., & Johnson, C. A. (2004). The protective association of emotional intelligence with psychosocial smoking risk factors for adolescents. Personality and Individual Differences 36, p945-954.

Tueting, P, Sutton, S. and Zubin, J. (1970). Quantitative evoked potential correlates of the probability of events. Psychophysiology 7, p385-394.

University of Stirling Psychological Image Collection (PICS). University of Stirling, http://pics.psych.stir.ac.uk/

Van der Zee, K., and Wabeke, R. (2003). Is trait-Emotional Intelligence simply or more than just a trait? European Journal of Personality 18 (4), p243-263.

Van der Zee, K., Thijs, M., & Schakel, L. (2002). The relationship of emotional intelligence with academic intelligence and the Big Five. European Journal of Personality 16, p103–125.

Van Rooy, D.L.and Viswesveran, C. (2004). Emotional intelligence: A meta-analytic investigation of predictive validity and nomological net. Journal of Vocationa Behaviour 65, p71-95.

Van Rooy, D.L., Alonso, A. and Viswesveran, C. (2005). Group differences in emotional intelligence scores: Theoretical and practical implications. Personality and Individual Differences 38(3), p689-700.

Vernon, P. A. (1950). The structure of human abilities. London: Methuen.

Vernon, P.A. and Jensen, A.R. (1984). Individual and group differences in intelligence and speed of information processing. Personality and Individual Differences 5, p411-423.

Vernon, P.A., Wickett. J.C., Bazana, P.G., and Stelmack, R.M. (2000). The neuropsychology and psychophysiology of human intelligence. In Sternberg, R.J. (editor). Handbook of Intelligence. Cambridge, Cambridge University Press.

Vetterli, C.F., and Furedy, J.J. (1985). Evoked potential correlates of intelligence : some problems with Hendrickson's string measure of evoked potential complexity and error theory of intelligence. International Journal of Psychophysiology 3(1), p1-3.

Vickers, D. (1970). Evidence for an accumulator model of psychophysical discrimination. Ergonomics 13, p37-58.

Vickers, D., & Smith, P. L. (1986). The rationale for the inspection time index. Personality and Individual Differences 7, p609–624.

Vickers, D., Nettelbeck, T., & Willson, R.J. (1972). Perceptual indices of performance: The measurement of "inspection time" and "noise" in the visual system. Perception 1, p263-295.

Vickers, D., Pietsch, A., and Hemingway, T. (1995). Intelligence and visual and auditory discrimination : Evidence that the relationship is not due to the rate at which sensory information is sampled. Intelligence21, p197-224.

Vickers, T., Nettelbeck, T., and Willson R.J. (1972). Perceptual indices of performance: the measurement of “inspection time” and “noise” in the visual system. Perception 1, p263-295.

Vigil-Colet, A., Ferrando I Piera, P.J., and Pueyo, A.A. (1993). Initial stages of information processing and inspection time : electrophysiological correlates. Personality and Individual Differences 14(5), p773-738.

Vogel, F., Kruger, J., Schalt, E., Schnoebel, R., and Hassling, L. (1987). No consistent relationships between oscillations and latencies of visually and auditory evoked EEG potentials and measures of mental performance. Human Neurobiology 6, p173-182.

Vuilleumier, P. (2002). Facial expression and selective attention. Current Opinion in Psychiatry 15, p291–300.

Wager, T.D., Hernandez, L., Jonides, J., and Lindquist, M. (2007). Elements of functional neuroimaging. In Cacioppo, J.T., Tassinary, L.G., and Berntson, G.G.

(editors) Handbook of Psychophysiology (p19-56). Cambridge University Press, New York.

Waiter, G, Fox, H., Murray, A., Starr, J., Staff, R, Bourne, V, Whalley, L. and Deary, I.J. (2008). Is retaining the youthful functional anatomy underlying speed of information processing a signature of successful cognitive ageing ? An event-related fMRI study of inspection time performance. Neuroimage, in press.

Wardlaw, J.M. (2004a). The functional anatomy of inspection time: an event related fMRI study. NeuroImage 22, p1466-1479.

Wetherill, G.B., & Levitt, H. (1965). Sequential estimation of points on a psychometric function. The British Journal of Mathematical and Statistical Psychology 18, p1-10.

White, M. (1996). Interpreting inspection time as a measure of the speed of sensory processing. Personality and Individual Differences 20, p351–363.

Widaman, K.F., Carlson, J.S., Saetermoe, C.L., and Glabraith, G.C. (1993). The relationship of auditory evoked potentials to fluid and crystallised intelligence. Personality and Individual Differences 15, p205-217.

Williams, JMG.;Watts, FN.;MacLeod, C.; Mathews, A. (1988) Cognitive psychology and emotional disorders. Chichester, UK: Wiley.

Wilson, F.A.W., O Scalaidhe, S.P., Goldman-Rakic, P.S. (1993). Dissociation of object and spatial processing domains in primate prefrontal cortex. Science 260, p1955-1958.

Wong, C., & Law, K. (2002). The effects of leader and follower emotional intelligence on performance and attitude. Leadership Quarterly, 13, 243–274.
Words, Numbers, and Colors. Cerebral Cortex 5, p544-554.

Zajonc, R.B. (1980). Feeling and thinking: preferences need no inferences. American Psychologist 35, p151–75.

Zarahn, E., Rakitin, B., Abela, D., Flynn, J., Stern, Y. (2007). Age-related changes in brain activation during a delayed item recognition task. Neurobiology of Aging 28, p784-798.

Zeidner, M., Shani-Zinovich, I., Matthews, G., and Roberts, R.D. (2005). Assessing emotional intelligence in gifted and non-gifted high school students : Outcomes depend on the measure. Intelligence 33, p369-391.

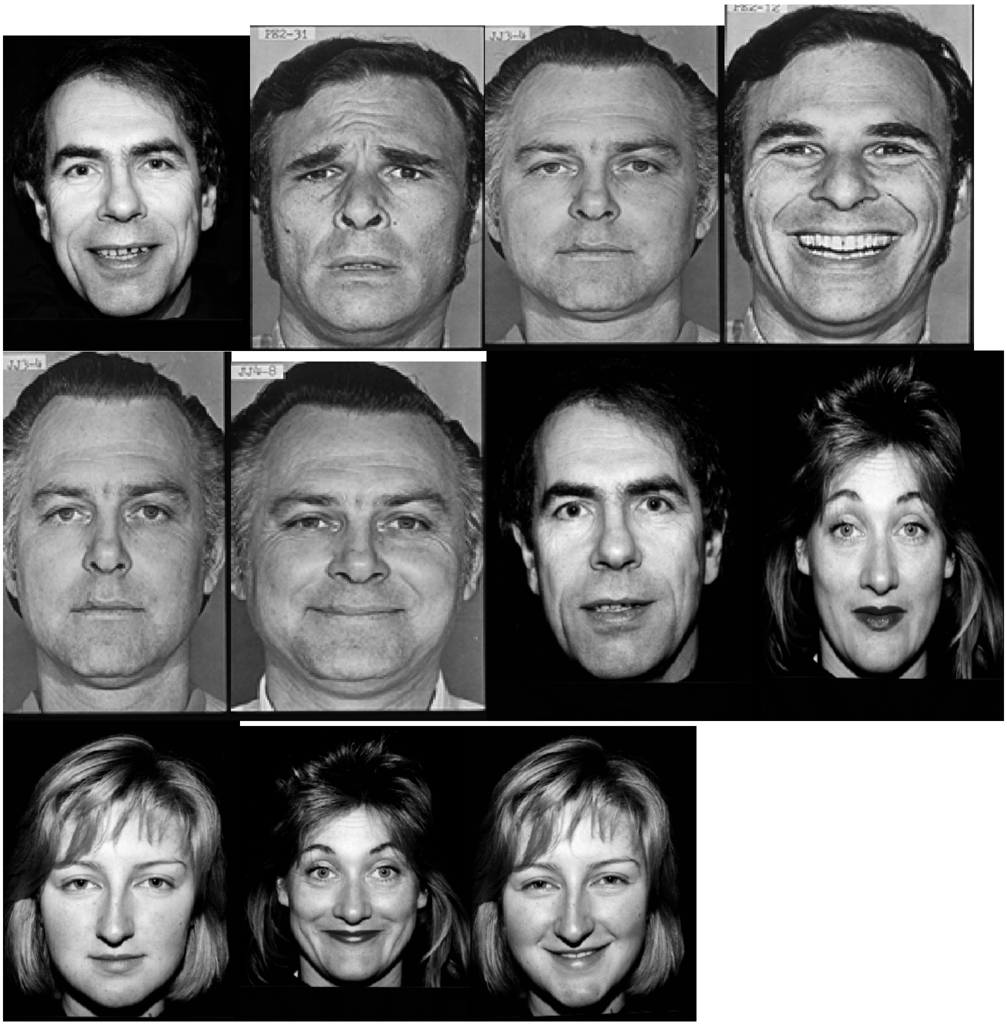
Zhang, Y, Caryl, P.G. and Deary, I.J. (1989a). Evoked potential correlates of inspection time. Personality and Individual Differences 10, p379-384.

Zhang, Y., Caryl, P.G. and Deary, I.J. (1989b). Evoked Potentials, inspection time and intelligence. Personality and Individual Differences 10(10), p1079-1094.

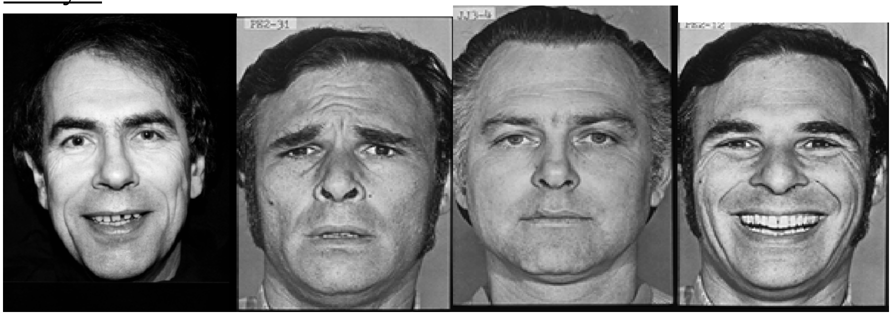
Appendices

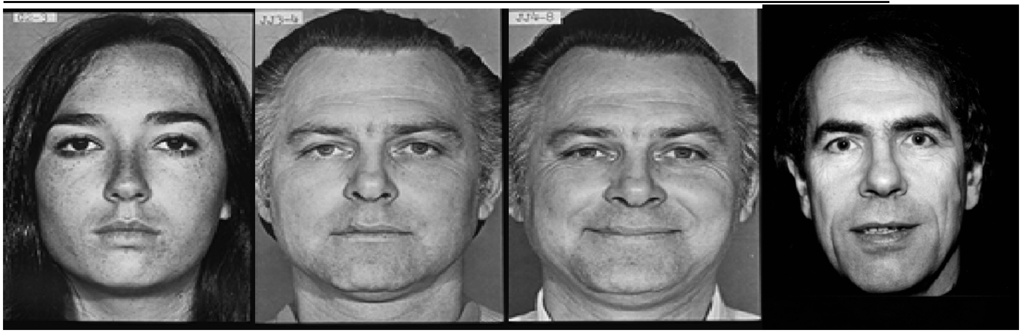
Appendix 1 : Stimulus faces used in the present series.

Study 1 and 2:

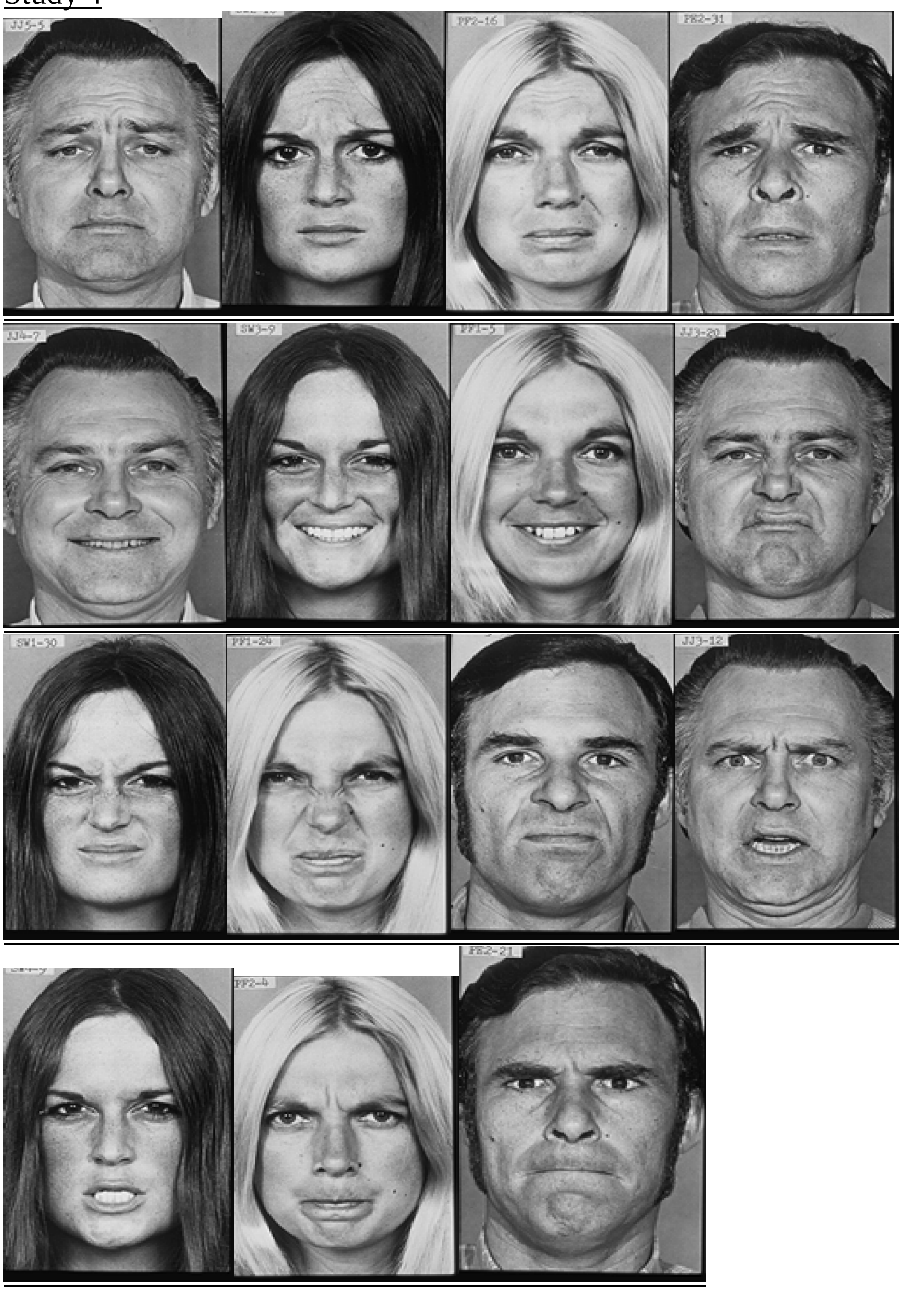


Study 3





Study 4


JJ5-5
PF2-16
PE2-31
JJ4-7
SW3-9
PF1-5
JJ3-20
SW1-30
PF1-24
JJ3-12
PF2-4
PE2-21