Detecting Social Signals from the Face

Jenny Jenkins, B.Sc.

Thesis submitted to the University of Stirling for the degree of
Doctor of Philosophy, December 1997

Table of Contents

Chapter 7: Review, Future Work and Conclusions.... 206

Acknowledgements

I would like to thank Vicki Bruce for giving me the opportunity to undertake this thesis, and for her help, advice and encouragement during its production. I am also enormously grateful to Vicki for keeping me solvent over the past year with a number of interesting jobs including the chance to work in Japan for three months.

I would also like to thank my second supervisor Ben Craven for his wonderful enthusiasm, his time and patience, and for all of the useful, and interesting discussions during the course of my thesis.

My visit to the Advanced Telecommunications Research Institute in Japan was made possible by Shigeru Akamatsu and Sakiko Yoshikawa who made my stay there a very valuable and enjoyable experience. I would also like to thank Yoshie and Kenji for translating the data described in Chapter 2 of this thesis.

I also owe considerable thanks to Andy Young and Andy Calder at the APU in Cambridge for providing access to patient SE and for collecting the data reported in Chapter 6 with DR. Many thanks also to both patients, particularly SE for taking part so enthusiastically in all of the studies reported in this thesis.

Enormous thanks to all my friends and colleagues at Stirling University and those out in the real world, for their support, encouragement, and laughter. Special thanks to Esther Walker and Glen Robertson for providing regular weekend retreats and treats in Edinburgh. To Christine Mellor, Danny Jagger and Bob Engledow for their humour and optimum use of the electronic mail system. To Trish Carlin, Will Goodall, Fiona McCall and Moira Strachan for frequenting the corridors. Extra special thanks to Donald Morrison and Steve Langton for three solid years of

entertainment and to Steve for helpful comments and discussions on some of the work described in this thesis, and for his penchant for fixing my car.

Last, but certainly not least, I would like to thank David Ness, my sister Katie, and my mother Angela, for all their love, encouragement and support, particularly over the last few years.

This thesis is dedicated to the memory of my father David Jenkins.

Abstract

This thesis investigates our sensitivity to social signals from the face, both in health and disease, and explores some of the methodologies employed to measure them.

The first set of experiments used forced choice and free naming paradigms to investigate the interpretation of a set of facial expressions by Western and Japanese participants. Performance in the forced choice task exceeded that measured in the free naming task for both cultures, but the Japanese participants were found to be particularly poor at labelling expressions of fear and disgust. The difficulties experienced with translation and interpretation in these tasks led to the development of a psychophysical paradigm which was used to measure the signalling strength of facial expressions without the need for participants to *interpret* what they saw.

Psychophysical tasks were also used to measure sensitivity to eye gaze direction. A 'live' and screen-based task produced comparable thresholds and revealed that our sensitivity to these ocular signals was at least as good as Snellen acuity. Manipulations of the facial surround in the screen-based task revealed that the detection of gaze direction was facilitated by the presence of the facial surround and as such it can be assumed that gaze discriminations are likely to be made in conjunction with other face processing analyses.

The tasks developed in these chapters were used to test two patients with bilateral amygdala damage. Patients with this brain injury have been reported to experience difficulties in the interpretation of facial and auditory signals of fear. In this thesis, their performance was found to depend on the task used to measure it. However, neither patient was found to be impaired in their ability to label fearful expressions compared to control participants. Instead, patient SE demonstrated a consistently poor performance in his ability to interpret expressions of disgust.

Experiments 2, 3, 4 and 5 of Chapter 3, have also been reported in *Perception, 1995, Vol. 24, Supplement, pp. 14*. The Face as a long distance transmitter. *Jenkins, J., Craven, B. & Bruce, V.*

Experiments 1, 2, 3 and 4 of Chapter 3 were also reported in the *Technical Report of the Institute of Electronics Information and Communication Engineers. HIP 96-39 (1997-03).* Methods for detecting social signals from the face. Jenkins, J., Craven, B., Bruce, V., & Akamatsu, S.

Experiments 2 and 5 of Chapter 3, and a selection of the patient studies from Chapter 6 were reported at the Experimental Psychology Society, Bristol meeting, 1996, and at the Applied Vision Association, Annual Meeting, April, 1996. Sensitivity to Expressive Signals from the Human Face: Psychophysical and Neuropsychological Investigations. Jenkins, J., Bruce, V., Calder, A., & Craven, B.

1

"Consider the meaning of a face. A face can be a symbol, signifying matter which would require volumes for its exposition in successive detail. A vast sum, for the person on whom it acts as a symbol, of feelings and thoughts, of remembered sensations, impressions, judgements, experiences - all rendered synthetically and simultaneously, at a single glance"

Aldous Huxley from "Eyeless in Gaza" 1936.

Facial Expressions and Eye Gaze

Overview

How sensitive are we to the socially relevant signals with which we are confronted in our non-verbal communications with other people, and how can we measure these sensitivities? In our day-to-day interactions with people we witness a huge range of dynamic facial displays varying in meaning and intensity which can change in a fraction of a second. In addition we monitor eye contact to infer the attention and also intentions of others. These demands would seem to pose huge processing loads, and yet for most of us, we perform these tasks effortlessly and accurately. Until very recently, most of the research on facial expression recognition and gaze detection has been the concern of social psychologists who have extensively studied their role in social interactions. This thesis examines our ability to detect social signals from a range of viewing conditions, using a range of methodological approaches.

Some of the problems of using the traditional forced choice paradigms of expression research are demonstrated in Chapter 2, with suggestions for improved methodology examined in Chapter 3. Similar approaches are applied in investigations into our sensitivities to eye gaze direction and the significance of the entire face in these tasks is explored in Chapter 4. Neuropsychological patients have given us great insights into the understanding of many normal brain operations. Some of the conditions that result in difficulties with facial expression processing are described in Chapter 5. Recently there has been considerable interest in the amygdala, a brain structure which has been implicated in the appraisal of danger and the emotion of fear. Chapter 6 describes how a range of tasks developed and described in the early chapters of this thesis have been used in the assessment of two such brain injured patients. This chapter reviews some of the literature which considers our faces as transmitters of socially relevant information, from recognition of familiar faces to expression and gaze sensitivity.

Face Value

A cursory glance at another individual is sufficient for us to make a wealth of decisions and judgements about that individual. Human faces provide a surface which covers a relatively small area of our bodies and yet it is involved in an amazing variety of functions. The majority of our sensory apparatus is housed in this small part of our bodies: eyes, ears, nose and mouth which allow us to see, hear, smell and taste. In addition the face provides the entry points for air and food and the lips, teeth, tongue and jaw are used for eating, but also in the generation of speech. In addition to the sensory and biological functions of our facial features, our faces are surfaces which provide an abundance of socially relevant information. From them we are able to identify familiar people, make judgements about gender, age, mood, health, tiredness and attractiveness. Intentionally or not, we also make certain judgements about the character of a person, their intelligence or personality for example, simply from our perceptions of their physical characteristics. We also use our faces to control social interactions by monitoring gaze cues and expressive signals. The amount of visible sclera in the eye gives us cues about where another individual is attending, and we use the amount of eye contact experienced to generate ideas about the levels of interest we are generating with other people. Someone else's gazing behaviour can tell us a considerable amount about a person; too much and it is considered to be inappropriate and causes unease, too little and the person is described as inattentive or rude. Our eyes are also gainfully employed to express emotion which is again achieved by moderating the amount of visible sclera by raising or lowering the eyelids and brows. The position of a person's tongue and their lip movements increase our understanding of their speech. The hearing impaired can supplement their impoverished auditory information by lip-reading and in fact all of us benefit from the ability to see the lips during speech especially in a noisy environment. MacLeod and Summerfield (1987) suggested that the ability to see a person's mouth during speech has the equivalent advantage of a 15dB increase in volume, and conveniently enough, sounds which are difficult to distinguish by ear are easily distinguished by eye and vice versa.

The small area occupied by the facial features and the constraints upon them regarding their position means that variations between individuals are very subtle and yet, with the possible exception of identical twins, no two faces are the same.

Despite the small size of the individual facial features and the limited range over which they can move, we can see how they combine to make us efficient sensory and biological organisms with a highly developed non-verbal communication system. The saliency of the human face is demonstrated explicitly by the human neonate. Within the first few minutes of birth, human infants have been shown to follow a schematic pattern of a face with their gaze and head further than a pattern which contains an equivalent amount of visual information but does not conform to a face i.e. scrambled features or an inverted image (Johnson, Dziurawiec, Ellis & Morton, 1991). Bushnell, Sai and Mullin (1989) demonstrated that infants appeared to learn the face of their mother within a matter of days whereas the ability to distinguish between other faces takes several months. Neonates have also been shown to imitate facial expressions (Meltzoff & Moore, 1977), and to recognise expressions when only a few days old (Field, Woodson, Greenberg, & Cohen, 1982). Walker-Andrews (1986) found that infants aged 7 months seemed sensitive to the pairing of facial expressions with the correct affective auditory sounds.

The power of the face is realised most dramatically when its dynamic ability to portray emotion is absent or lost. Möbius syndrome is a congenital condition which is manifested by a complete facial paralysis (Giannini, Tamulonis, Matthew, Giannini, Loiselle, & Spirtos, 1984). These patients often lead very isolated lives and have difficulty in experiencing emotion as a direct result of their lack of expression. Patients who experience facial paralysis, perhaps as the result of a stroke, are unable to make appropriate responses to the people around them. Cole (1997) reported one such patient who, lacking the appropriate facial language, doctors had deemed demented despite the fact that she was intellectually unimpaired. The lack of a face had the effect of invalidating her as a person. Cole also reported the experiences of a man who lost his sight in adulthood and whose memory for the faces he once knew, including his own, had faded. The impact that this loss had on the individual was not just confined to the loss of his vision, but also involved a sense of loss of who he was. Our faces seem to be inextricably linked with much deeper perceptions of ourselves, and serve much more complicated roles than their obvious biological and sensory functions.

At first thought, the face may seem a fairly unsophisticated subject for study and in this modern age of rational thought and cognitive deduction quite how useful are our faces and the signals they portray? One of the best examples of the importance of our ability to express and feel emotion is seen in the story of Phineas Gage. Gage was a construction foreman of the nineteenth century. An accident while using explosives resulted in an iron rod over three and a half feet in length and one and a quarter inches in diameter entering his left cheek, piercing the base of his skull, crossing the front of his brain and exiting through the top of his head. Miraculously Gage survived and after only a few months convalescence was considered to be cured. Despite a remarkable physical recovery, Gage's personality was severely altered and remained so for the rest of his life (Damasio, 1994). Brain injury like the one experienced by Gage which reduces or removes an individual’s ability to feel emotion can result in the individual making decisions which are positively disadvantageous to their well-being. This can occur despite normal intelligence, memory and rational problem solving. However, many decisions are made by considerations of possible outcomes, for which a person must be able to attribute an emotional feeling to potential consequences. Cognitive reason and information alone is not sufficient to make a decision, we all need input from our emotions and the ability to express these emotions to function as normal human beings. The face is one of the most important sources of information about emotion. Considered like this, our faces and their bewildering range of functions can be considered one of our most valuable assets.

Memory for Faces and their Owners

We are able to recognise the face of someone whom we may have only met on one occasion several years ago, and despite the changes of ageing, weight or hairstyle we are still aware that this person is known to us and we experience the sensation of 'recognition'. In addition, there appears to be no limit to the number of faces we can store and hence recognise. The loss of the ability to recognise familiar faces - prosopagnosia, which can occur as a result of a brain injury, can have a profound effect on the life of the patient. Of course the face is not the only means by which we can recognise familiar individuals and many prosopagnosic patients develop idiosyncratic strategies to overcome their disability. Recognition can be achieved from voices, hairstyles or even a person's clothing or gait. However, the face is the most distinctive and available means by which we identify people. In order for us to recognise a familiar person we must be able to access previously stored knowledge of every individual we meet and retrieve information about the semantic knowledge we may have of the person, i.e. their occupation, nationality or interests. So, the study of faces offers us the potential to investigate the way in which the brain integrates incoming sensory information about a person including making judgements such as gender, age and expression with stored memories of that person. The ability to access these stored memories is very important as it ensures that we behave in a manner appropriate for that person.

Models of Face Recognition

The study of face recognition has interested psychologists for several decades now providing insight into cognitive and perceptual mechanisms in the brain. More recently, psychologists have joined with computer scientists and engineers to further their understanding of how this process is achieved. These findings have implications in a forensic setting, e.g. eye witness testimony, and also for security purposes. For example, Hancock, Burton and Bruce (1996) have used the technique of Principle Components Analysis for machine based recognition and shown that such image-based statistics can provide an insight into actual human face processing.

(i) The Bruce & Young Model of Face Recognition

During the late eighties, considerable advances were being made in the understanding of the stages involved in the process of face recognition and several functional models describing these stages were published (e.g. Bruce & Young, 1986). All of the models were broadly similar although the Bruce and Young (1986) model has received the most attention over the years.

The model was designed by combining empirical data obtained from normal subjects in the laboratory, information from everyday errors and data obtained from neuropsychological patients. The model reflects different aspects of face processing; person recognition, expression analysis and facial speech analysis which are shown as occurring in parallel routes (Figure 1.1). Important though this model is, however, it omitted to account for gaze perception as an element of face processing.

The face recognition route has received the most attention over the years. The Bruce and Young (1986) model describes the distinct sequential stages which are involved in the process of identifying a person by their face. The first stage involves 'face recognition units' (FRUs) which are responsible for perceptual classification. The FRU becomes activated when any view of the appropriate face is seen. The product of structural encoding must match a previously stored structural code for that particular face in order for recognition to be achieved. Once the FRU is activated, the appropriate 'person identity node' (PIN) becomes activated. The PIN provides semantic information about each known face; nationality, profession, interests, context of previous encounters etc.

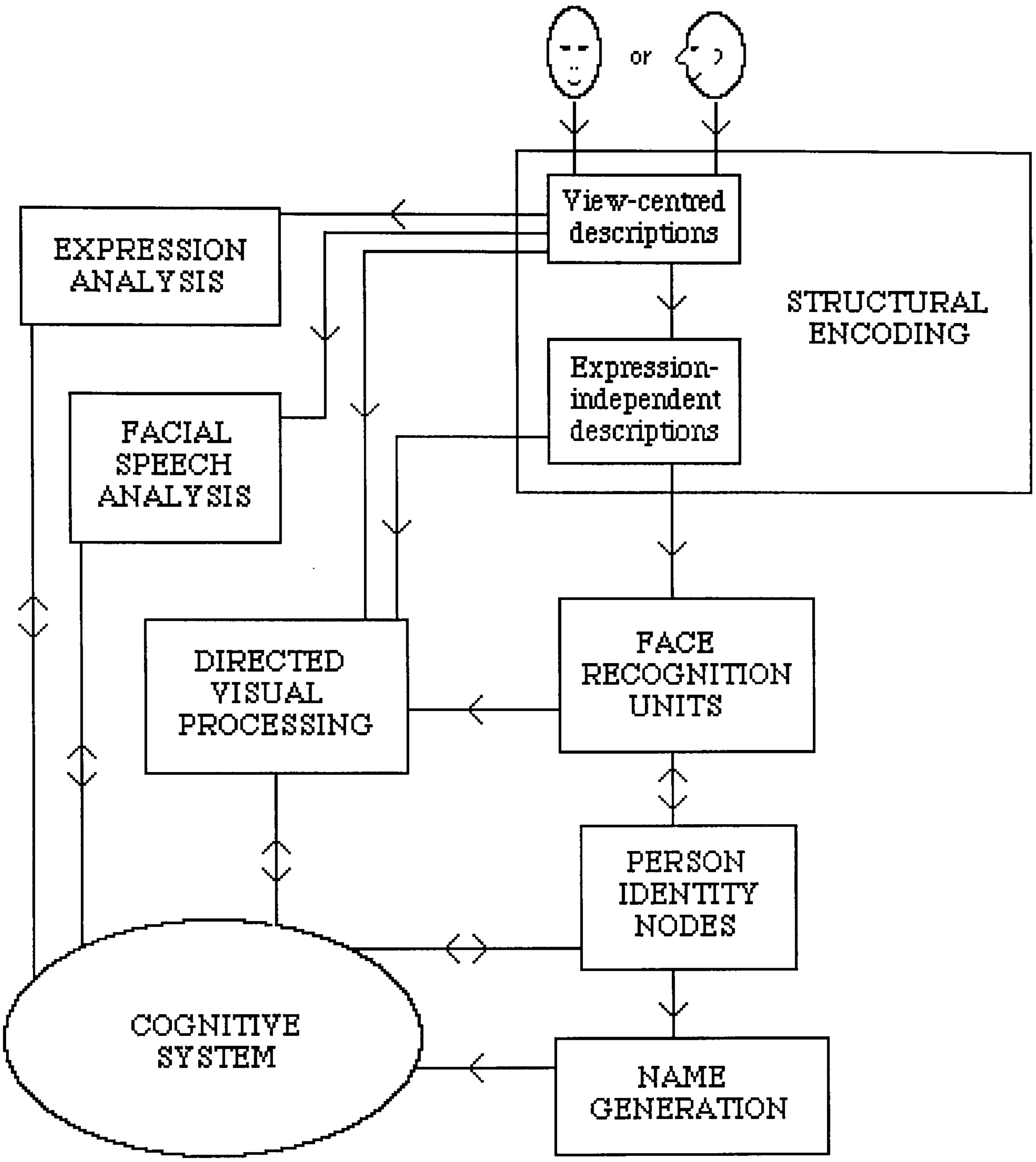


Figure 1.1. Bruce and Young's (1986) functional model of face recognition.

Unlike FRUs, PINs are activated by any input modality, the face, voice, or even a written or heard name. The final stage in this process, if the face is known, is the retrieval of the individual's name which according to Bruce and Young (1986) can occur only via the PINs. This model also supposes that the cognitive system plays a role in deciding if the match is close enough for recognition, or if the seen face simply resembles one from stored units. According to Bruce and Young (1986) there are major differences in the processing of familiar and unfamiliar faces. Recognition of familiar faces as described, primarily depends on structural encoding, face recognition units, person identity nodes, and name generation. Unfamiliar faces seen for the first time are not represented in the FRU/PIN system, but, in common with familiar face processing, the processing of unfamiliar faces involves structural encoding, expression analysis, facial speech analysis, and directed visual processing.

(ii) The Interactive Activation and Competition (IAC) model

In more recent years, the microstructure of the components of the Bruce and Young (1986) model concerned with recognition has been explored by the development of an interactive activation and competition (IAC) network (Burton, Bruce & Johnston, 1990). Models like IAC can be used as a framework for developing predictions which can subsequently be tested within the field of face recognition (e.g. Burton, Young, Bruce, Johnston, & Ellis, 1991).

The IAC model has a connectionist architecture of active units connected by modifiable links. The model consists of a number of units organised into pools. This model assumes three pools of information: The FRU's are view independent units which are activated by the presence of any familiar face; PIN's are domain and modality free gateways into semantic information, and are where familiarity decisions are made (rather than as Bruce and Young (1986) proposed, at the FRU's). A face is recognised as familiar when activation in the appropriate PIN reaches a threshold level of activation. Recognition is achieved in this way irrespective of input modality, i.e. face, voice, name or other information. The third pool contains semantic information units which, according to Burton and Bruce (1992), contain names and other information about an individual (e.g. occupation;

interests). So unlike the Bruce and Young (1986) model, this model has no separate store for names. Burton et al (1990) demonstrated that this model was capable of accounting for a range of findings from empirical studies regarding recognition which included face familiarity decision tasks, semantic and identity priming tasks.

This thesis concerns the processing of signals other than identity. The next section explores the relationship between facial identity and other face processing mechanisms which are discussed in greater detail later.

Parallel Processing of Facial Signals

Bruce and Young (1986) proposed that the three primary aspects of face processing: identification, expression analysis, and lip-reading proceed independently within the human information processing system. Convincing evidence to support the idea of separate pathways has been presented from neurophysiological research and research with neuropsychological patients. There are numerous reports of double dissociations in neuropsychological patients who lose their ability to perform one aspect of face processing while others remain intact (Young, 1992; Young, Newcombe, de Haan, Small, & Hay, 1993; Malone, Morris, Kay, & Levin, 1982; Campbell, Landis & Regard 1986). Observations of dissociable impairments which affect different aspects of face processing are consistent with the idea that the brain processes different types of social signals independently from one another.

(i) Identity and Expression

The idea of separate pathways for the processing of identity and expression is intuitively appealing. We need to recognise individuals regardless of their expression and we need to recognise expression regardless of the individual portraying it.

Neuropsychological and neurophysiological studies have provided particularly strong evidence for the separate processing of these facial signals. Tranel, Damasio and Damasio (1988), described three patients who were impaired in their ability to recognise identity from the face but whose ability to recognise facial expressions was intact. Kurucz and Feldmar (1979) described a group of elderly patients with chronic organic brain syndrome, some of whom were found to be severely impaired in their ability to recognise facial affect although their ability to recognise famous faces was preserved. Young et al (1993) conducted an extensive study with a group of ex-servicemen who had all sustained unilateral brain injuries which affected the posterior areas of the left or right cerebral hemisphere. The nature of the impairment was confirmed by measuring the performance of each participant on two different tasks for each of the postulated impairments. A selective impairment was diagnosed if performance on both tests was found to be significantly impaired. Amongst the group, they found evidence from their accuracy data for selective impairments in the ability to recognize familiar faces, to match unfamiliar faces and to process facial expressions. However, when response latencies were examined the position became less clear. Nonetheless, the selective deficit for expression was still evident. Thus there is clear evidence of a double dissociation between identity and expression.

Evidence from normal participants has been reported by Young, McWeeny, Hay and Ellis (1986) who used a speeded matching task on normals and found that matching faces on identity was faster for familiar faces than for unfamiliar faces, but that expression matching was unaffected by the familiarity of the face.

Physiological evidence is consistent with this double dissociation. Hasselmo, Rolls, and Baylis (1989) reported populations of cells within the temporal lobe cortex which responded preferentially to identity or to expression. The cells which were found to be sensitive to expression were found within the superior temporal sulcus which Perrett, Smith, Potter, Mistlin, Head, Milner, and Jeeves (1985) have also shown to house cells which are sensitive to the direction of gaze.

Perceptual experiments have shown that judgements about facial expressions are made with the same accuracy to familiar as to unfamiliar faces, further support for the independent routes account (Bruce, 1986; Young, McWeeney, Hay, & Ellis, 1986). In contrast to identity recognition which we remain remarkably good at despite changes in age or hairstyle for example, facial expressions and gaze information needs to be monitored constantly to gage the intentions, emotions and desires of others from moment to moment. Recent research into facial expression analysis would also suggest that we may have specific neural substrates for each of our expressions, (Young, Aggleton, Hellawell, Johnson, Broks, & Hanley, 1995) and that perhaps the mechanism responsible for facial expression analysis in the Bruce and Young (1986) model should be divided into separate systems devoted to the analysis of the different emotional categories.

Finally, further evidence in support of separate pathways for identity and expression is illustrated in the idea of Universal facial expressions (Ekman, 1992). Ekman, for example, supports the idea that basic emotions are recognised by all people regardless of culture and yet we know that recognising identity from different race faces is difficult (Valentine, 1991).

(ii) Identity and Gaze

Campbell, Heywood, Cowey, Regard and Landis (1990) reported gaze direction sensitivities in two patients, KD and AB, who were both impaired in their ability to recognise familiar individuals, label facial expressions and in judging age and gender from the face. In a forced choice gaze task, KD was only found to be impaired at discriminating small gaze deviations, however, AB performed at chance level for most of the discriminations and relied more heavily on the orientation of the head rather than the eye orientation to make her decisions. This research, and evidence for the independence of identity and gaze processing from neurophysiological studies are described in more detail later in this chapter and also in Chapter 4.

(iii) Identity and Unfamiliar Face Matching

Two patients were described by Malone, Morris, Kay, and Levin (1982) who showed different patterns of recovery after brain injury. One of the patients was initially diagnosed as prosopagnosic, however his ability to recognise familiar faces was regained after a period of time. However, he was still found to be impaired on tests which required matching unfamiliar individuals as 'same' or 'different'. The second patient showed the opposite pattern of recovery with his ability to match unfamiliar faces intact, he was unable to recognise once familiar faces. When matching unfamiliar faces, a detailed analysis of individual features is required in addition to more general facial attributes such as the sex and approximate age of the person. The finding that this patient was able to perform such a detailed analysis and yet was unable to recognise familiar individuals, and the presence of a patient with the opposite trend provides compelling evidence for a separate routes account of face processing.

However, Young et al (1993a) investigated this further using two tasks of familiar face recognition and unfamiliar face matching. From the results of this investigation, Young et al (1993a) could not conclude that these tasks were completely separate. Young et al (1993a) noted increased response latencies which could have been the result of the implementation of an alternative strategy which the participant had learnt in order to compensate for their disability. However, some of the patients could have been trading speed for accuracy, a long response latency could simply reflect cautiousness on behalf of the participant.

(iv) Expression and Lip-reading

Interestingly, and perhaps less obviously than the separate processing of identity and expression, is the discovery of a dissociation between expression analysis and lip reading (Campbell, Landis, & Regard 1986; Campbell, Brooks, de Haan, & Roberts 1996). The ability to interpret the configuration of the lips is needed for both expression recognition and lip-reading and yet there is evidence that the two processes are distinct. Campbell et al (1986) described two patients, one who was unable to recognise identity or expressions from the face but the ability to lip-read remained intact and the patient exhibited a normal McGurk effect (i.e. experienced blends between conflicting visual and auditory cues to a phoneme (McGurk & MacDonald, 1976)). In contrast the other patient was found to be normal on all face processing tasks with the exception of lip-reading and consequently failed to show the McGurk effect.

So, there is evidence for initial independence for these processes, but, recent research suggests that this may not be quite so simple. Schweinberger and Soukup (in prep) designed a series of experiments using the Garner paradigm to investigate selective attention to identity, expression and speech reading and have suggested that although identity is perceived independently of expressions and facial speech analysis it may exert an influence on their perception. They suggest that despite the universal nature of many of our facial expressions, at an individual level small idiosyncratic facial movements which are specific to their owner could influence recognition. Schweinberger and Soukup suggest that the analysis of facial expressions could be optimised or modified if the system was able to take identity into consideration. Similarly, they argue that speech reading may not be totally independent of identity. Schweinberger and Soukup note that speakers show systematic interindividual variation in articulating particular phonemes and these idiosyncrasies are evident both in auditory and facial speech. As a consequence, they therefore suggest that the speech reading system could improve its performance if identity was also a factor. Certainly, it would be feasible to imagine that knowing that a particular individual has a distinctive accent which would influence the shape of their lips when enunciating certain vowel sounds would help in the processing of speech-reading information. Walker, Bruce and O'Malley (1995) using a McGurk type paradigm also demonstrated that speech reading was affected by whether or not the stimulus face was known to the observer.

It would appear then that the different aspects of face processing are at least initially independent though the signals may come together at a later stage of processing. Here we are concerned with the earliest stages in the perception of social signals from unfamiliar faces so the identification route need not concern us further. In the remaining section of this chapter, a more detailed review of previous findings in the areas of Expression and Gaze processing are described, which forms the focus of this thesis.

Emotional Expressions

Physiology from Physiognomy

Our facial expressions are very powerful signals which allow us outwardly to display internal emotions. Some facial expressions have been shown to correspond to specific patterns of autonomic nervous system activity. As such the ability to detect and interpret the facial expressions of others carries importance as it provides information about a person's internal physiology and from an external display of this, we can make assumptions about a person's probable behaviour.

However, distinctive patterns of autonomic response for every one of our emotions have not been found. This could be explained if we consider what possible advantage there is behind the manifestation of such a response. It could be, as Ekman (1992) suggests, that these different patterns of autonomic nervous system (ANS) activity evolved to prepare the organism for specific motor actions which would be produced as a response to specific emotions e.g. fear, anger, or disgust which would be relevant to the animal's survival. It seems less likely that an emotion-specific ANS activity would be found for happiness since it is not obvious why an ability to smile or to detect happiness would be of any survival advantage to an organism.

Further evidence to support the idea that organisms may be biologically prepared to respond to expressive cues was suggested by Orr and Lanzetta (1980). We monitor the facial expressions of others on the assumption that particular facial expressions are linked with particular outcomes. For example, the expression of happiness typically signals a pleasant outcome, whereas a fearful expression could signal an aversive encounter. Orr and Lanzetta (1980) used facial expressions of emotion as conditioned stimuli in an investigation of autonomic response in humans. They measured galvanic skin response when subjects were presented with stimuli which paired congruous expression and outcome (fearful expression followed by a mild electric shock) and incongruous expression and outcome (a happy facial expression followed by an electric shock). They found that both the magnitude and the rate of acquisition of the conditioned response was greater when the fear stimuli was reinforced by shock than when the happy face was reinforced by shock. Orr and Lanzetta (1980) proposed that well established codes which relate signals of affect to specific outcomes exist in our long-term memory stores. Their results would support this idea as when participants were presented with congruous pairings of expression and outcome, a scenario which would match stored codes, conditioning was achieved very quickly. Conversely, when the experimentally presented contingencies were incompatible with the codes in long term memory stores this actually served to inhibit the learning of a new code.

Hemispheric Specialization in Affect Processing

Evidence from neuropsychological patients and visual field experiments has shown that the right cerebral hemisphere plays a more significant role than the left in processing expressions of emotion (Ley & Strauss, 1986; Sergent, 1986). Patients with damage to their right cerebral hemispheres tend to have more problems in processing facial affect than those patients with damage to the left hemisphere. When pictures of facial expressions are presented to participants' left and right visual field, they are faster and more accurate to identify the expression when it is presented to the left visual field i.e. the right hemisphere. If the two halves of the face portray different expressions, the expression presented to the participant's left visual field will tend to have a stronger influence on their response (Atkinson, Atkinson, Smith, & Hilgard, 1987).

It is not impossible, however, for damage to the left cerebral hemisphere to result in impaired facial affect processing and in normal participants, the degree of hemispheric specialization may not be as extensive as imagined. Heller and Levy (1981) tachistoscopically presented left and right handed participants with photographs of facial composites which were constructed so that the face was divided vertically with half of the face smiling and the other half not smiling. Both left and right handers perceived faces as happier when the left half of the image contained the smile. In addition, right handers and not left handers perceived faces as happier when the smiling half face was presented to the left visual field. Left handers displayed no overall advantage for either visual field although individual left handers each showed their own preference for one field or the other. The majority, but not all, of right handers appeared to be specialized for the perception of emotion in the right hemisphere, and Heller and Levy (1981) report that even when there was a right hemisphere advantage, the magnitude varied significantly. They suggest that the hemispheric specialization for the discrimination of facial affect signals in right and left handers is more variable than is the lateralization of the cognitive aspects of verbal and non-verbal processes. In addition they found that left and right-handed actors who posed the expressions expressed more happiness on the left side of their faces.

However, there is considerable additional evidence that the right cerebral hemisphere is better than the left at perceiving facial expressions of emotion since it is typically patients with right hemisphere damage who have been found to be impaired at discriminating signals of facial affect.

Hemispheric specialisation has also been examined in participants from different socioeconomic groups. Alvarez and Fuentes (1994) tested the ability of the right hemisphere to recognise facial affect signals of happiness, anger, sadness, disgust, fear and surprise in a tachistoscopic task. Participants from a university and others from a low-socioeconomic group were tested. All were male and right handed. The university students recognised facial affect images presented to their left field (right hemisphere) significantly better than with their right field (left hemisphere). The low-socioeconomic group showed no difference in their abilities to recognise facial expressions when the images were presented to the left or right field, however their performance was significantly worse than that of the university students in the right hemisphere condition. Alvarez and Fuentes (1994) suggest that these results provide evidence for greater hemispheric specialisation in the university sample group. Unfortunately, Alvarez and Fuentes (1994) did not report recognition scores for the individual expressions and instead provided an overall mean. It would have been particularly interesting in the context of this thesis (see chapter 5) if the overall mean for the low socioeconomic group was due to difficulties experienced for specific expressions. The overall means presented were actually very low for each of the groups. The university and low socio-economic group scored 22.26 and 20.85 respectively out of a possible 45 when the images were presented to the left hemisphere, and 26.95 and 21.7 respectively when the images were presented to the right hemisphere. It would have been useful to know the errors for the individual expressions to see if the mean was greatly decreased due to one or two expressions, or if performance was generally bad for all expressions.

How are Expressions Perceived?

Face recognition has been extensively studied by researchers from a number of diverse fields: psychologists, neurologists, clinicians, and more recently engineers and computer scientists have adopted the challenge of discovering the processes behind recognition. Far less interest has been concentrated on the understanding of the signals which transmit socially relevant information regarding a person's emotional expression. Over three decades ago, Paul Ekman began what is now considered to be a seminal research programme into the recognition of our facial expressions. Despite this, and the contributions of other research groups, our understanding of these signals is still in its infancy.

One of the controversial areas of expression recognition is how these signals are perceived. There are two basic viewpoints: the first suggests that we encode facial expressions in terms of a number of underlying dimensions (Schlosberg, 1952, 1954; Russell, 1980). Schlosberg (1952) envisaged a circular representation of emotions which involved dimensions of attention-rejection and pleasantness-unpleasantness. Later, he suggested a third dimension, sleep-tension (1954). The second view suggests that emotions are perceived in distinct categories. Ekman (1992) suggests a small number (six or seven), basic emotion categories, and more recent perceptual research has supported this view (Ekman, 1992; Etcoff & Magee, 1992; Calder, Young, Perrett, Etcoff, & Rowland, 1996b; Young, Rowland, Calder, Etcoff, Seth, & Perrett, 1997)

A Circumplex Model of Emotion

Russell (1980) supports the idea that affective states are best represented as a circle in a two dimensional bipolar space. He suggests that affective dimensions are interrelated in a highly systematic manner. His circular model of affect, shown in Figure 1.2, has the following order: pleasure (0°), excitement (45°), arousal (90°), distress (135°), displeasure (180°), depression (225°), sleepiness (270°), and relaxation (315°).

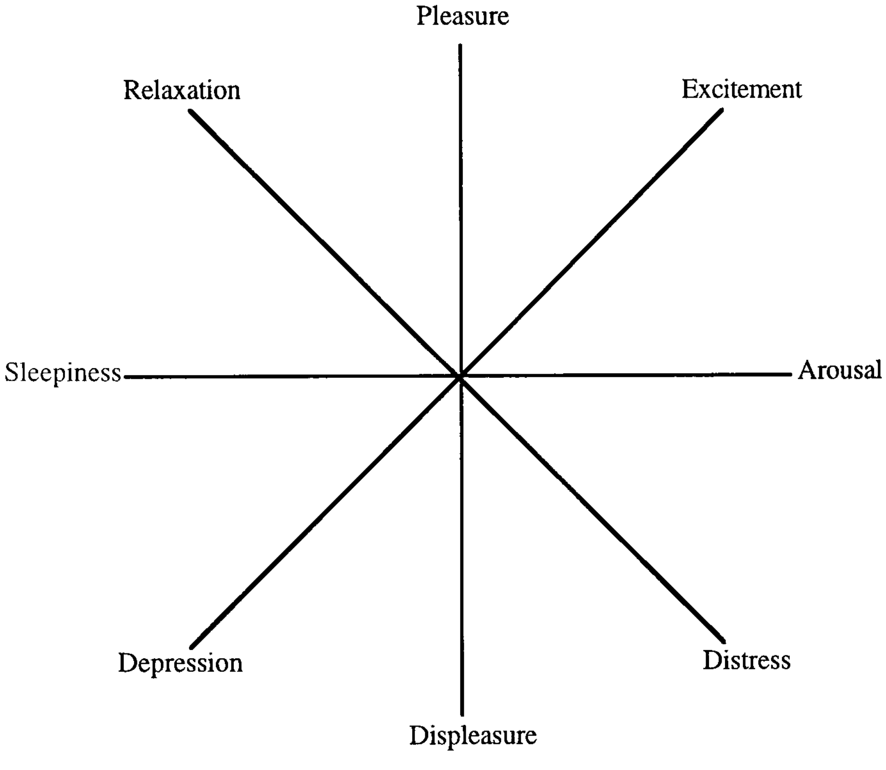


Figure 1.2: Circumplex model of affect, from Russell (1980).

In this model, opposing emotions are positioned at opposite ends of the bipolar space, e.g. pleasure at 0° and displeasure at 180°. Russell (1980) argues that it is our *interpretation* of emotional information, be it labelling facial expressions, or self report, rather than the actual information we receive which produces our affective experience. In this way, the experience of an emotion only occurs as the outcome of a cognitive process which conceptualizes emotion. Russell believes that this cognitive conceptual structure is suitably described by this circumplex model.

Categorical Perception of Facial Expressions

Russell's (1980) description of a circular model of affect with expression recognition occurring by locating its position within a dimensional space was challenged by Etcoff and Magee (1992) who used the idea of categorical perception to investigate expression recognition. They used sets of computer generated line drawings each consisting of a series of faces which varied by constant physical amounts running between expressions. Participants performed a discrimination task and an identification task which revealed that the expressions were being perceived categorically since faces within a category were discriminated more poorly than faces belonging to a different category despite the fact that the images differed by a constant physical amount.

Young et al (1997) also presented convincing evidence for the categorical perception of facial expressions using a more ecologically valid stimulus set. They used computer-manipulated images of photographs depicting facial expressions taken from the Ekman and Friesen (1976) series. A set of images was created interpolating between prototype images of two expressions to create a series of pictures with smooth transitions between different expressions. Participants were asked to label each image as to whether it was most like happiness, sadness, anger, disgust, fear or surprise. Young et al (1997) found that there were abrupt shifts between perceiving one emotion and another near the mid-point of each continuum. Such abrupt shifts would not be consistent with a dimensional account. Young et al (1997) also described a matching task in which pairs of adjacent images had to be judged as 'same' or 'different' along the continua from one expression to another.

Once again, Young et al (1997) predicted that if expressions are perceived along some kind of dimension then the predicted performance would be almost linear, however, performance was found to be highly non-linear with peaks corresponding to the boundaries between expressions. These data strongly support the idea of categorical perception. Categorical perception would also support the idea that instead of a single system devoted to the analysis of facial expressions, we may possess a number of discrete systems each tuned to a specific emotion. This suggestion is strongly supported by much of the recent research on patients with amygdala damage who experience specific difficulties with the expression of fear (Adolphs, Tranel, Damasio, & Damasio, 1994; Calder, Young, Rowland, Perrett, Hodges, & Etcoff, 1996a; see chapters 5 and 6).

Gaze

Our eyes have the ability to send a range of very powerful, socially relevant signals. The amount of eye visible to an observer varies according to our facial expression, and the direction of our gaze signals the focus of our interest, or perhaps the referent of a remark (Kleinke, 1986). We also use our gazing behaviour to signal turn taking during conversations. The role of eye gaze in communication has been usually considered to be the domain of social psychologists who have studied gazing behaviours during social interactions (Kendon, 1967; Kendon & Cook, 1969; Cook, 1977). Kendon (1967) suggested that where a person is looking during an interaction serves to regulate the maintenance and exchange of speaker role.

Kendon noted that when the roles of the speaker and auditor were exchanged, typically, the speaker would end his/her utterance while maintaining eye contact and the auditor would look away as s/he began speaking. He also found that speakers would maintain eye contact during periods of fluent speech, but would look away during periods of broken speech to avoid interruption. Exline and

Winters (1966) suggested that an alternative explanation for this pattern of gazing behaviour could be that the speaker looks away so as to avoid any distracting effects from the listener's face and likewise, they suggest that this explains why a speaker looks away at the beginning of an utterance, to enable them to formulate carefully what is to be said.

Mutual gaze can, especially if it is extended in time, indicate to a participant that the attention of the person extending the gaze has shifted away from the common focus of the encounter. Now the person's attention is focused entirely on the other individual which appears to have the effect of intensifying the interactions between the participants (Kendon, 1967). Regulating the amount of mutual gazing within an interaction controls the intimacy between participants. The amount of mutual gaze increases in a friendly encounter but is seen to decrease when the individuals concerned are eager to terminate the interaction. It is also possible for the amount of eye contact to be reduced during a friendly encounter if the interactants are smiling a lot. This could be in an attempt to reduce levels of arousal. Chance (1962) observed the behaviour of fighting rats and noticed that one of the essential elements of the rats defensive posture was for it to ensure that it couldn't see its opponent. The consequence of this behaviour is that the rat will be unable to receive any visual input by which its aggressive behaviour could be influenced, but the advantage is that the reduced input will have the effect of lowering the rat's general arousal level which means that it can be more flexible in its behaviour and resume aggressive action.

Kobayashi and Koshima (1997) propose that the reason for the lack of a white sclera in non-human primates and most other animals is to conceal cues which could be interpreted as a direct stare - a signal of threat or dominance. In humans, the presence of the white sclera which forms a marked contrast against the coloured iris, and the width to height ratio of our eye structure, all combine to give us a unique signalling device.

Sensitivity to Gazing from Others

How sensitive are we to the minute changes in gazing behaviour which signal the attentional focus of other individuals? The power and saliency of eye contact, and the arousal it appears to evoke, would suggest that we must be very sensitive to these cues. In this thesis, sensitivity to gaze direction is measured using a psychophysical technique both in a 'live' set-up and in a screen based task. In the light of plentiful evidence from neuropsychological and neurophysiological investigations, Baron-Cohen (1995a) has proposed the existence of a specialised system tuned to detecting the presence of eyes, or eye-like stimuli. He suggests that an ‘Eye Direction Detector’ (EDD) exists to locate the presence of eyes and to determine if the eyes are directed toward the individual or to an object in the scene. Baron-Cohen (1995a) suggests that the ability to detect eye gaze and to process this information subsequently to establish joint attention is an important stage in the development of a child’s understanding of mental state concepts such as desire and belief.

The importance of the eyes in signalling their focus of attention is not in question. However, we may also use cues from head orientation and/or body posture to augment these decisions. Perrett, Hietanen, Oram, and Benson (1992) located cells in the superior temporal sulcus (STS) of the macaque which were responsive to eye position but also to the position of the head and body. For example, Perrett et al (1992) found that the same cells which were preferentially excited by eyes looking downwards also demonstrated a preference for a lowered head and a quadrapedal body posture. Perrett and his colleagues have suggest that more than just eye direction detectors, these cells determine the “social attention” of an individual.

Later, Perrett and Emery (1994) proposed the existence of a more general "Direction of Attention Detector" (DAD) which combines the information from the eye, head and body positions to determine the direction of another's social attention. The information received from each of these inputs is arranged hierarchically with information on eye position capable of overriding information regarding head position if it is incompatible, and information regarding head position overriding information on body posture. In this way, the STS cells use information from the eyes if it is available to determine the direction of attention, but if the eyes are obscured by long distance or poor lighting, this system can default to using the information from the head orientation. Similarly, if the head is also obscured from view, the cells rely on postural information.

This model of social attention detection is very attractive, however, a few studies have demonstrated a more important role for the head in the determination of social attention than Perrett et al's (1992) hierarchical model would suggest. Vecera and Johnson (1995) demonstrated that participants' sensitivity to gaze direction from a schematic face was worse when the eyes were presented in the context of an inverted or scrambled face compared to an upright presentation suggesting that the information provided by the face influenced the processing of information from the eyes.

Not only has the context of the face been shown to influence gaze perception but also the orientation of the looker's head has been shown to be important in perceptions of a looker's gaze. Gibson and Pick (1963) demonstrated this in their gaze set-up where a looker and a participant were seated opposite one another at a distance of 2m. The looker was told to fixate their gaze on each of several markers positioned horizontally on a wall positioned just behind the participant's head. Each of the markers was separated by 10cm, equivalent to an angular separation of 2.9°. Three head orientations were tested: 0°, head oriented toward the participant; 30° to their left; and 30° to their right. The task for the participant was to determine if the looker was gazing directly at them or not. Gibson and Pick (1963) found that when the looker's head was averted, participants misjudged a fixation of 2.9° in the same direction as a gaze that was looking directly at them. From this finding, they concluded that in order to detect eye contact from a looker, the observer attended not only to the central position of the iris in the sclera but also to the position of the eyes in the face and their relation to the orientation of the whole head.

Cline (1967) conducted a similar study in which observers were requested to indicate the line of regard of a looker whose head was oriented 30° to the right whilst their eyes were fixed on targets at 0°, 4° or 10° to the right or left of the observer. Cline (1967) found that the observer's perception of the looker's gaze was influenced by the orientation of the looker's head and that the head orientation and eye gaze direction interacted such that the perceived direction of the looker's attention fell somewhere between these two positions.

More recently, Maruyama and Endo (1984) reported that an observer's perception of the direction of gaze from schematic faces was at an intermediate point between the correct line of gaze and the orientation of the face. They described this effect by describing the orientation of the head as "towing" the perceived line of gaze. However, they found that head orientation was not influenced by the perceived line of regard of the eyes. This result and that reported by Cline (1967) and Gibson and Pick (1963), would seem to suggest some kind of interaction between head and gaze information at a perceptual level. Participants appeared to be combining the information they received from the eyes with that apparent from the head orientation, a process which resulted in a perceived direction of attention which falls somewhere between the actual direction of gaze and the actual orientation of the head. The finding by Maruyama and Endo (1984) that the eyes were unable to influence the perception of head orientation is not consistent with Perrett et al's (1992) hierarchical attention detector.

The way in which individual facial features may, or may not, be influenced by the facial surround has also been investigated in the context of the perception of face identification. The next section is a brief digression which introduces this work as it is relevant to later studies in this thesis.

The Saliency of the Face

Our faces belong to a highly homogenous group of stimuli and in order to distinguish one from another we have developed a highly tuned process which is sensitive to minor variations between faces.

The processing of faces from individual features or wholes is explored in this thesis in an investigation of gaze direction sensitivity when the eyes are presented in various facial surrounds. Young, Hellawell and Hay (1987) demonstrated the importance of configural information in the *recognition* of familiar faces with the use of composite faces where the top and bottom halves of known people were arbitrarily combined to create a plausible new identity. The new unfamiliar facial configuration was found to disrupt the process by which the individual facial features could be recognised. In an identification task, participants were slower to name composite faces compared to non-composite faces and the effect was more obvious when participants were requested to name the top portion of the composite. Young et al (1987) found that this effect disappeared when the composites were inverted and in fact the task became easier.

Young et al's (1987) results demonstrate the importance of configural information in face perception and that this information is only available when the face is in its characteristic orientation. However, individual facial features can play an important role in recognition, particularly if the features are distinctive in some way, e.g. Cerano de Bergerac's nose. The two processes could compliment each other, each providing information for the common goal of recognition.

Tanaka and Farah (1993) also supported a more holistic view of face processing with the finding that participants were less accurate at identifying the parts of faces when presented in isolation than they were at identifying whole faces. In contrast, the disadvantage for part identification was not found for scrambled or inverted faces or other homogenous stimuli such as houses.

Additional support for the holistic processing of faces comes from neurophysiological investigations. Perrett, Mistlin and Chitty (1987) reported a subpopulation of cells in the STS which respond to the sight of facial parts and wholes. Desimone, Albright, Gross and Bruce (1984) discovered that the deletion of a facial feature did not greatly effect the excitation of these cells but if the individual features were all present but scrambled the excitation was abolished altogether, a finding consistent with a holistic view of face representation. The presence of cells which respond solely to the eyes may not be involved in a feature based recognition scheme but instead be more involved in the perception of other social cues such as gaze direction and attentional focus.

In this thesis, the importance of our individual features for signalling socially relevant information is investigated in tasks which test our perceptual abilities in determining gaze direction from a real face when the eyes are presented upright or inverted within the context of an upright, inverted or absent face.

This Research

Our ability to detect social signals from the face is explored in this thesis with investigations into sensitivities to facial affect and gaze direction. Many problems which are inherent in popular techniques such as forced choice and free naming for the interpretation of facial expressions are described in Chapter 2 with the results of a small cross cultural study highlighting some of these problems. In Chapter 3, attempts are made to measure our sensitivity to expressive signals from the face in a way which *avoids* the need for participants to interpret what they see. Two psychophysical methodologies are employed which require participants to discriminate the presence of a signal - a facial expression, from a non-signal - a neutral face. The distance over which these stimuli were viewed was varied. In this way, our sensitivity to each of the facial expressions could be determined by measuring the distance over which the signal could be detected. Manipulations were made to the image set to illustrate the power of these facial signals and to investigate the salience of the face in processing these signals.

The importance of the face as a context for the perception of gaze direction detection is considered in Chapter 4 and performance in a live gazing set-up is compared with a screen based task.

A number of congenital conditions and brain injuries result in impairments associated with certain aspects of face processing. Some of those that affect the analysis of facial expressions are described in Chapter 5. One of the pathologies which has been shown to play a central role in processing socially relevant information, is damage to the amygdala. Two patients with bilateral amygdala damage are described in Chapter 6 and their performance on a range of the tasks developed in earlier chapters of this thesis are reported. Chapter 7 summarises the findings of this thesis and discusses the possibilities for future research in this area.

2

Interpreting Facial Expressions

Overview

In this chapter, the methodologies that are commonly employed to explore our interpretation of facial expressions are reviewed. The authenticity of a new set of facial affect images is evaluated using a forced choice paradigm, and the results compared to performance in a free naming task where participants are not confined to using a given list of emotion labels, but are still restricted to using only one word. The same tasks are also performed by a group of Japanese participants, the results of which are compared with the data from the British group. The difficulties of implementing the tasks and translating the data are described. The limitations of these techniques is discussed and the potential for a new approach introduced.

Emotions on Faces

The vast majority of us are equipped with the ability to determine a person's internal state simply by looking at their external countenance (assuming no attempt at deception has been made). Why an emotional experience should manifest itself in our facial expressions has been an area of interest for well over a century. In fact, many of the ideas under investigation by researchers of the twentieth century can be found in early Greek and Roman texts. Aristotle (384-322 BC) supposed that the face was able to provide a myriad of information about a person; soft hair was the trait of a coward, poor proportions belonged to a rogue and a smile was a sign of a happy person. The latter supposition has withstood the test of time although soft hair and poor proportions are thought to tell us significantly less about a person.

Darwin (1872) considered that the ability to express emotions either by gesture or expression was an important evolutionary factor. The ability to outwardly express internal emotions can communicate to other humans the emotional state experienced at a particular time and also provide information about what behaviour to expect. Being able to detect and interpret these signals accurately is an obvious advantage as it could lead to the avoidance of a confrontation and hence increased chances of survival for both the expressor and the person (or animal) observing the expression. This chapter and the next, concentrate not on *why* we exhibit our internal emotions using external signals, but rather *how sensitive* we are in detecting and recognising these important social signals. If the configuration of our features into a smile when we are happy, and a scowl when we are angry, for example, are remnants of our ancient ancestry, then it is reasonable to suppose that these expressions could be universal signals amongst all humans and that they are perhaps genetically determined. The next section considers both suppositions.

Genetic Basis of Facial Expressions

Evidence for the genetic origins of facial expressions comes from observations of infants who have been blind from birth. These children exhibit the same facial expressions under the same emotional conditions as sighted children despite the fact that the visually impaired children have obviously not been able to learn these facial configurations from visual cues (Eibl-Eibesfeldt, 1972). Field, Woodson, Greenberg and Cohen (1982) presented evidence that infants as young as thirty-six hours were able to imitate the facial expressions of happiness, sadness and surprise as portrayed by a model. Both the neonate and the model were filmed during their interactions and independent judges were able to determine, significantly better than chance, the expression portrayed by the neonate from observing its face. Field and her colleagues suggest that from birth, we have an innate ability to compare the sensory information of perceived facial expressions with proprioceptive feedback of the movement of the facial muscles used in the generation of these facial signals. Of course, copying does not necessarily mean the recognition of the emotional content of the expressions, although accurate copying would require that there was perceptual discrimination between expressions.

However powerful these genetic vestiges may be, we are all capable of overriding them by portraying an expression which does not reflect the true emotion we are feeling. For example, we sometimes choose to hide our true feelings and instead project the expression we would like people to interpret as our true emotion. Klineberg (1940) described how cultural norms often dictate when to mask, inhibit or exaggerate natural facial expressions.

Universality of Facial Expressions

Evidence for the universality of facial expressions comes from a large number of cross cultural studies (Ekman & Friesen, 1971; Izard, 1971; Cücelogiu, 1970; Russell, 1994) which have tested literate and pre-literate cultures using photographs of facial affect. Ekman tested native American and Japanese participants and also members of an isolated New Guinea tribe with pictures of Western faces. All participants made similar judgements which Ekman and colleagues interpreted as providing evidence for universal signals of facial affect. Those involved in researching universality are in agreement that there are 6 basic emotions: happiness; sadness; anger; disgust; fear and surprise which are used pan-culturally to signal the same affect. Klineberg (1940), although not opposed to the idea of universality, suggested that different scenarios could be responsible for generating different emotions in different cultures. He also found some facial expressions which appeared to be genuinely culture specific, for example tongue protrusion amongst the Chinese to display the emotion of surprise.

Russell (1994) reviews the universality thesis by considering the views held by different researchers as lying somewhere on a continuum with the extreme dipoles describing a non-specific and a specific definition of universality. The non-specific end would be defined by the belief that some facial expressions have some sort of emotional attribute which is interpreted by others at an above chance level by some people in most cultures. The conclusions asserted by Klineberg (1940) would fall towards this end of the continuum. At the other extreme end would be the belief that there are specifically six facial expressions which explicitly signal six distinct emotions which are effortlessly recognised by all people regardless of cultural background. The conclusions asserted by Ekman and Izard fall towards this more specific end of the continuum.

Universality studies have contributed a substantial volume of data to the field of expression analysis. However, the methodologies that are employed in the task of investigating affect 'recognition', for example, free and forced choice paradigms, are not without their problems and the data obtained using these paradigms should be interpreted with care. The next section reviews these methodological techniques and also addresses some of the common procedural practices in their implementation.

Methods for Investigating Facial Expression Recognition and their Problems

Most research on facial expressions in a laboratory setting has used static, posed stimuli. In our interpersonal interactions we do not see a disembodied two dimensional face in isolation but are privy to body language, gesticulations, auditory information and contextual cues that complement the movements of the facial features into affect signals. The combination of all these actions leads us in our everyday lives to make rapid and effortless decisions about a person's emotional and communicative state with a high level of accuracy. However, static posed expressions are widely used due to the difficulties in assembling a set of informatively equivalent experimentally produced expressions.

A great deal of the literature which investigates facial expression recognition has been concerned with the universality argument or the perceptual aspects of facial identification, and there is a relative paucity which has investigated our sensitivity to these expressions and considered them as facial signals (Hager & Ekman 1979). In addition facial expression research has largely relied on forced choice labelling of the stimuli in ways which are often difficult to control; for example, Hager and Ekman (1979) used live performances for part of their study.

In a forced choice paradigm, participants are required to label expressions from a given list of emotion categories provided by the experimenter, previewing stimuli is also a frequent practice as is maintaining a constant viewing order between participants. In cross cultural studies, designing experiments can be problematic as can interpreting the data. The next section discusses the problems which are inherent in many of the procedures which are commonplace in expression research.

Free and Forced Choice Tasks

The use of forced choice tasks in expression recognition studies is fairly standard but actually only provides a very limited insight into the signals being perceived by the observer. The task forces participants to label an expression from a given list and as such experimenters are forcing participants to claim that they are perceiving a specific signal. They may, however, not wish to attribute any of the labels to the images they are presented with but instead are forced to use a 'best guess' and thereby provide the experimenter with the information they require.

Both the forced and free choice technique presuppose that participants are actually perceiving an emotion when they are asked to label an expression image. They may in fact only be interpreting the facial expression as a response to a situation, for example, the response "looks as though she has seen a ghost". From this an emotion may be inferred but only because the participant is being asked to ascribe an emotion to the image which may not be something the observer would do naturally.

In addition, the word 'recognition' is used ubiquitously and implies that what is being 'recognised' is truly there, but this may not be the case. When a forced and free choice paradigm are compared, it becomes apparent that observers do not necessarily wish to use the labels they are provided with in the forced choice task. This has the effect of inflating the 'recognition' scores in the forced choice experiments to levels which do not accurately reflect the participant's true interpretation.

Russell (1994) discusses the limitations of the use of free and forced choice paradigms in expression labelling tasks and remarks that by their very nature the experimenter is presupposing that there is only one word which can accurately describe the expressions shown to the observers. He suggests that this implies a dichotomous relationship between emotion labels and facial expressions. Neither of these techniques allows the participant the freedom to express a wider description of the stimuli which they may actually perceive as portraying a mixture of emotions.

Ekman et al (1987) presented participants with a set of expressions and asked them to give each image a rating on an eight point scale as to how accurately the face portrayed the intended expression. In addition, they were asked to give ratings for how accurately another expression label could describe the same image. For example, the expression chosen by Ekman to represent 'anger' was rated 6.0 for anger, 5.6 for disgust, 4.9 for afraid, 4.4 for calm and so the list continues. These results clearly demonstrate that participants do not interpret facial expressions dichotomously. If this were the case, participants would give very high ratings for the target expression and very low or zero ratings to the others. However, one problem with this interpretation is that the participants could have felt compelled to provide the experimenter with a rating for each expression without genuinely feeling that a particular label was appropriate. This notion is perhaps supported by the fact that the average score for each label was approximately 4 which is the mid-point of the scale which could also suggest a general uncertainty with rating scales and a tendency to use the middle scores.

Previewing Stimuli

In much of the literature on facial expression recognition, participants are presented with the stimulus set prior to testing in order to familiarise themselves with the task. Providing participants with a preview of the stimuli to be used within a task has the benefit of helping the participant to adopt a response criterion which would minimise noise within the experiment as the participant would be more likely to maintain a constant response strategy. However, previewing has its drawbacks. If the observer is aware that there are an equal number of exemplars representing each expression, performance in a forced choice task could be facilitated, particularly if the entire set has been shown to the participant. Russell (1991) reported that the expression of contempt used by Matsumoto and Ekman (1988) was judged as contempt in a within participants design and disgust in a between participants design. The physiognomic difference between the two expressions is obvious if the images can be compared simultaneously. However, Russell (1991) reported that both stimuli would be labelled as disgust when viewed separately, but the same participant would differentiate between the two if they had previewed the entire image set and if they were participating in a forced choice task which provided them with the labels.

Order of Presentation

The response made to a given stimulus is often dependent on what has come before. For example, a neutral face could be labelled as happy if it was presented in the context of a set of happy faces or sad if presented in the context of a set of sad faces. The opposite could also be true that a neutral face embedded amongst happy faces could appear sad by comparison, or happy if placed amongst sad faces, (Russell & Fehr, 1987). In general, the order of presentation is important in these tasks since if each participant is presented with the same stimulus set in the same order, then this could have the effect of increasing the amount of agreement amongst participants.

This level of agreement could serve to mask true 'recognition' scores or alternatively, serve to inflate evidence for a hypothesis. In many of the studies that Russell (1994) describes in his meta-analysis of expression recognition, the order of presentation was constant between participants. The implication of this is that participants are not simply responding to any one individual expression but rather to that expression in the context of the preceding images and each participant will be potentially influenced in the same way.

Translating data from cross cultural studies

In cross cultural studies, difficulties can arise in the translation of responses in a free naming task, or in the choice of labels used in a forced choice task especially when cultures which differ greatly from our own are involved. When Ekman and Friesen (1971) were testing a pre-literate society, members of the Fore tribe in New Guinea, they experienced difficulties in designing a task that would be appropriate. Since the members of the tribe could not read, they could not be asked to choose a word from a printed list, and if the list was repeatedly read to them on each trial they had problems in remembering the list. Ekman and Friesen also (1971) doubted whether the meaning of an emotional concept could be adequately translated from one English word into one Fore word. In addition, they discovered that there was no indigenous word for surprise amongst the Fore.

Summary

The sections above illustrated the limitations of free and forced choice tasks and the practice of maintaining a constant viewing order or previewing stimuli. However, these tasks are still useful in some contexts. In the following section, a Six Alternative Forced Choice (6AFC) task is used to authenticate a new set of expression images which were created for this thesis. A free naming task is also used to demonstrate the inflated scores obtained using forced choice and to illustrate the variety of words participants choose to use when they are not constrained by a list. The performance of a group of Japanese participants in these tasks is also measured and the results compared with the British group. However, this is only a starting point since the purpose of developing this image set was to go on to develop tasks which do *not* have the same limitations.

Western and Japanese interpretations of images of facial affect

The remainder of this chapter is concerned with creating a new set of facial expressions to be used in a variety of investigations in this and subsequent chapters. In this chapter, performance of Western and Japanese participants in forced and free naming tasks using the new image set is compared. The results from the Japanese group serve to illustrate some of the difficulties experienced in cross cultural studies. The problems of design and procedure discussed earlier are of great importance when investigating our interpretation of these facial signals. The limitations of using forced and free choice paradigms need to be recognised and the results obtained using these techniques interpreted carefully. We need to ensure that the tasks used to assess these sensitivities are not merely implementing self fulfilling hypotheses.

Creating the new image set

Ekman and Friesen's (1976) images of facial affect have enjoyed something of a monopoly over the last three decades in expression research. The majority of tasks designed to explore the processing of facial expressions have used the same techniques and the same stimuli and consequently agreement between researchers has been high. A new facial affect database of images was created for the investigations reported in this thesis. Twenty-four staff and student volunteers (referred to as expressors in the text), whose ages ranged from 20 to 35 years participated in this procedure. Spectacles, if worn, were removed during filming.

All expressors were filmed in the same location seated against a black background under the same lighting conditions. Only the head and neck were framed in the image. Expressors were instructed to look into the camera and in their own time perform the chosen selection of facial expressions. Six emotions were portrayed which signal six distinct affects: happiness, sadness, anger, disgust, fear and surprise.

Equipment

Expressors were filmed using a Sony Video Hi8 Handycam video recorder mounted on a tripod. The tape was then played through a Macintosh Centris 660 av computer and the images grabbed using Apple Software. All of the following experiments were run on a Macintosh Centris 660 av using Superlab 1.5.7 Beta 10. Examples from the expression set are shown in Figure 2.1.

Six-AFC (Image authentication)

Despite the shortcomings of the forced choice technique described earlier in this chapter, this technique was used as a means of validating the images which were to be used in subsequent experiments. For each expressor, the best representation of each expression was chosen from the video and the image printed so that the expression exemplars could be labelled by independent judges.

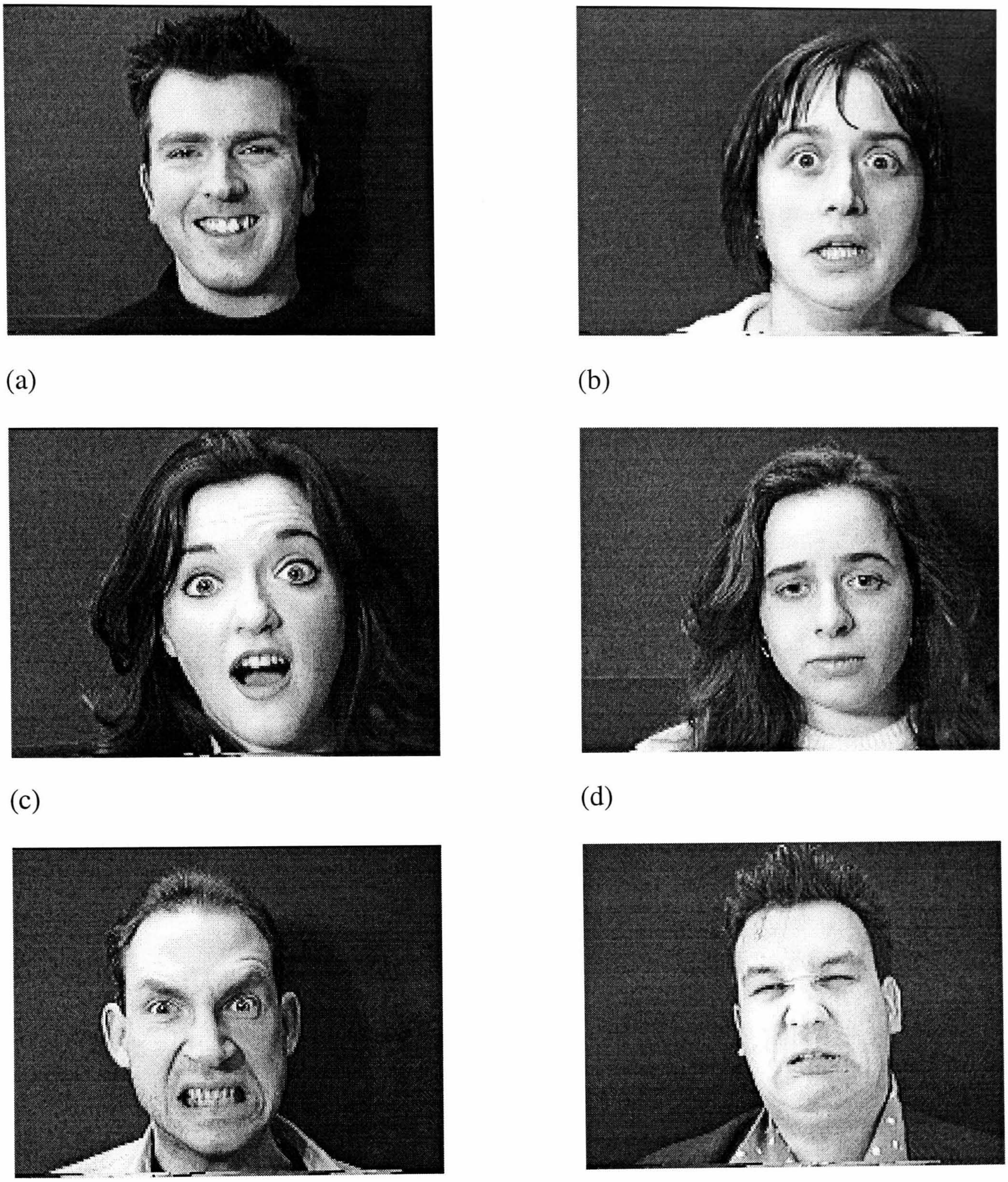
Participants

Ten volunteers took part in the forced choice task. All were undergraduate students at Stirling University with an average age of 21.7 years.

Procedure & Results

Participants were asked to attribute an expression to each image from a given list of the six expressions used. The list of expressions was available for reference throughout the task. There was no previewing of the expression set and the order in which the images were presented was randomised between participants.

Only those images which were labelled with an accuracy of 100% were retained for use in subsequent experiments resulting in 10 exemplars of each of the six expressions. It was important for the subsequent psychophysical tasks that participants were at ceiling on the interpretation of these signals. Contributions from 21 of the 24 expressors were used although it was not possible to use all 6 expressions from each expressor. This would have been the preferred design since it is desirable to have all items (facial identities) appearing equally often in all conditions (facial expression set). This would increase the certainty that the observable effect was caused by the manipulation and not by the specific item. Unfortunately however, it was not possible to use all exemplars from each expressor and maintain the quality of the image set. The final set consisted of: five male and five female exemplars for the expressions of happiness, surprise, sadness and anger; four male and six female exemplars for the expression of disgust and six male and four female exemplars for the expression of fear. (A table which illustrates the contributions made by each expressor appears in the Appendix section).



(a) (b) (c) (d) (e) (f)

Figure 2.1: Images (a) to (f) show examples of the expressions of happiness, fear, surprise, sadness, anger and disgust.

The actors who contributed to the Ekman and Friesen (1976) image set were trained to produce each of the facial expressions using a system called Facial Action Coding (FACS) (Ekman & Friesen, 1978). Using this system, actors were taught to contract specific facial muscles to create an expression. In this way, the intensity of expressions between expressors could be controlled. The actors who contributed to the image set used in this study were not trained in any way prior to filming and therefore the emotional intensity of the expressions could vary. This is of obvious concern in signal detection studies as the same expression may have a varying intensity depending on the expressor portraying it. However, the complex procedures required to control for expression intensity were out with the scope of this investigation.

Free Naming Expression Allocation Task

Participants

Ten undergraduate students from Stirling University took part in this study. Participants had a mean age of 25.2 years.

Procedure

Participants were shown the 60 expression faces and 21 neutral faces (one for each of the expressors) and asked to define the emotion they believed to be portrayed in a 'free choice' expression naming task. Participants were requested to use one word which they felt best described the emotion depicted. Words which were synonymous with the target label were scored as correct.

The figures presented in Table 2.1 compare very favourably with identification means from other studies. Russell (1994) quotes mean 'recognition' scores from eight different studies with literate participants. The majority of these studies used *forced choice* labelling of expressions.

Expression	% of responses which match label from list	Synonym (%)	Incorrect labelling (%)
Happy	95	5	0
Sad	63	23	14
Anger	75	20	5
Disgust	45	39	16
Fear	16	59	25
Surprise	73	22	5
Neutral	61	17	22

Table 2.1: Mean performance (%) of ten participants in a free choice expression allocation task.

Table 2.2 provides the means obtained from Russell's meta-analysis and compares them with the means obtained in the 6-alternative forced choice and the free naming expression allocation tasks described in this study.

	Happy	Sad	Anger	Disgust	Fear	Surprise
Russell ('94) Forced choice	96.4	80.5	81.2	82.6	77.5	87.5
Jenkins Forced choice	100	100	100	100	100	100
Jenkins Free naming	100	86	95	84	75	95

Table 2.2: Forced choice data from a meta-analysis of eight separate studies as reported by Russell (1994), and forced and free choice data from this study. (All scores represent mean % correct).

Performance in the free naming task was inferior to that recorded in the forced choice task (Mann-Whitney U-test, $U = 0$, $p < 0.01$). This finding serves to illustrate how performance scores can be inflated when a forced choice paradigm is used. However, the labelling accuracy is still high in the free naming condition and the scores from the Jenkins affect image set compare very favourably with those from the forced choice studies that Russell (1994) reports, with higher labelling accuracies/hits for all expressions with the exception of ‘fear’. This comparison also serves to illustrate that the quality of the images used in this thesis compares very well with stimuli used in published studies.

The relatively high number of 'misses' for the neutral exemplars could be explained by the fact that participants were asked to allocate an ‘expression’ to the images and may have been reluctant to say ‘no expression’. Most participants who did not report 'blank' or 'neutral' for these stimuli labelled them with words such as 'calm', 'peaceful' or 'relaxed' and did not confuse them with the exemplars of sadness.

Discussion

The images created for use in this thesis have been authenticated by ten independent judges who each accurately attributed an expression label to a set of emotional exemplars using a forced choice paradigm. When a further ten judges were requested to attribute an emotional label to each of the images in a free naming task, the potency of the stimuli was seen to decrease slightly with some errors, particularly for the negative expressions, and a large number of responses using synonyms of the target expression. This finding in itself exemplifies the need for caution in the interpretation of data obtained using a forced choice paradigm in expression research.

The remainder of this chapter describes the use of this new image set using the same free and forced choice paradigms to test the performance of a group of Japanese participants.

A Cross Cultural Comparison

In this study, the ability of a group of Japanese participants to interpret facial expressions from Western faces was investigated. The problems encountered in implementing these tasks within a different cultural group, and the difficulties experienced both for the participants performing the tasks and for the analysis of the data are described.

Six-AFC Expression Task

The ability of Japanese participants to interpret signals of facial affect from Western faces was measured using a forced choice paradigm. As mentioned earlier, the labelling accuracies are not reported as 'recognition' scores but performance between Japanese and Western participants is compared.

Participants

Ten Japanese volunteers participated in this investigation, five were staff members at the Advanced Telecommunications Research Institute in Kyoto, and five were undergraduate students visiting the Institute from Doshisha University, Kyoto. Eight females and two males took part who had an average age of 25.3 years.

Procedure

Instructions for this task were explained to the participants in Japanese. Participants were shown a list of the six expression labels in English and Japanese, each label also corresponded to a number. The list was available for consultation throughout the task. Five of the participants responded using the English labels. The other five participants recorded their results using the label number. Results are shown in Table 2.3 which compares the results with data obtained from Western participants in the same task.

Results

Participants	Happiness	Sadness	Anger	Disgust	Fear	Surprise
Japanese	98	78	57	75	36	86
Western	100	100	100	100	100	100

Table 2.3: Comparison of Western and Japanese participants in a 6AFC expression allocation task. Figures represent mean % correct for 10 participants.

Performance by the Japanese participants was lower than the Western sample in every case with performance for the expression of fear being particularly poor.

Table 2.4 presents data from six independent studies of forced choice tasks performed by Japanese and American participants. The data is taken from Ekman, Sorenson and Friesen (1969), Izard (1971), Ekman et al (1987), Matsumoto and Ekman (1988), Matsumoto and Ekman (1989), and Matsumoto (1992), as reported in Russell (1994).

	Happiness	Sadness	Anger	Disgust	Fear	Surprise
American participants	97.1	92.2	86.5	79.8	83.6	83.9
Japanese participants	94.1	88.2	75.4	52.9	68.5	64.8

Table 2.4: Mean % correct scores from 6 separate studies in a 6AFC task with Japanese and American participants

For each of the expressions, labelling accuracy is lower in the Japanese group. From the results shown in Table 2.3, fear stands out as being particularly poorly interpreted. Fear has also been found to be poorly interpreted in other studies as can be seen from the meta-analysis reported in Table 2.4, although disgust and surprise were labelled with even less accuracy. Two of the studies that contributed to the data in Table 2.4 were reported by Matsumoto and Ekman (1988; 1989). They reported mean 'recognition' scores for fear of 37.6% and 30.8%. The number of participants contributing to these studies was 154 and 110 respectively. Despite the small number of participants who contributed to the present investigation, the low score for fear would not appear to be particularly low when compared with reports from other research.

Free Naming Expression Allocation Task

Participants

Participants were five female and five male members of staff at the Advanced Telecommunications Research Institute in Kyoto with an average age of 33.4 years.

Procedure

In this task, participants were instructed to use one word which best described the emotion portrayed in each one of the 60 expression exemplars in the Jenkins affect set. Instructions were given in Japanese and six out of the ten participants recorded their responses in Japanese, the remaining four participants were confident in their English vocabulary and chose to write their responses in English.

The data was translated by two independent judges; a research assistant at the Institute whose English was very good, although not perfect, and a Japanese student at

Stirling University who spoke Japanese as a first language but was also fluent in English having lived in this country for most of his life. Responses were scored as correct if the translated word was synonymous with the target label.

Results

Participants	Happiness	Sadness	Anger	Disgust	Fear	Surprise
Japanese	97	77	62	40	28	90
Western	100	86	95	84	75	95

Table 2.5: Performance (mean % correct) of 10 Japanese and 10 Western participants in a free naming expression allocation task.

As in the forced choice task, accuracy scores in this task were lower for the Japanese group compared to the British group. If the data in Table 2.5 and Table 2.4 are compared, it is possible to see that the expressions which are labelled with poor accuracy in the forced choice task (fear, anger and disgust), are labelled with an even greater inaccuracy in the free choice task. This finding demonstrates how a forced choice task serves to inflate accuracy scores by providing an emotion label which the participant would not spontaneously choose themselves. Instead, the participant adopts a 'best guess' strategy thus artificially raising the accuracy scores.

Figure 2.2 illustrates the data obtained from the two groups. Both the Japanese and the Western participants experienced most difficulty with the negative expression exemplars, particularly fear and disgust. Performance for the positive expressions of happiness and surprise was considerably better and was equivalent to performance by the British participants which demonstrated that the goal of the task was understood.

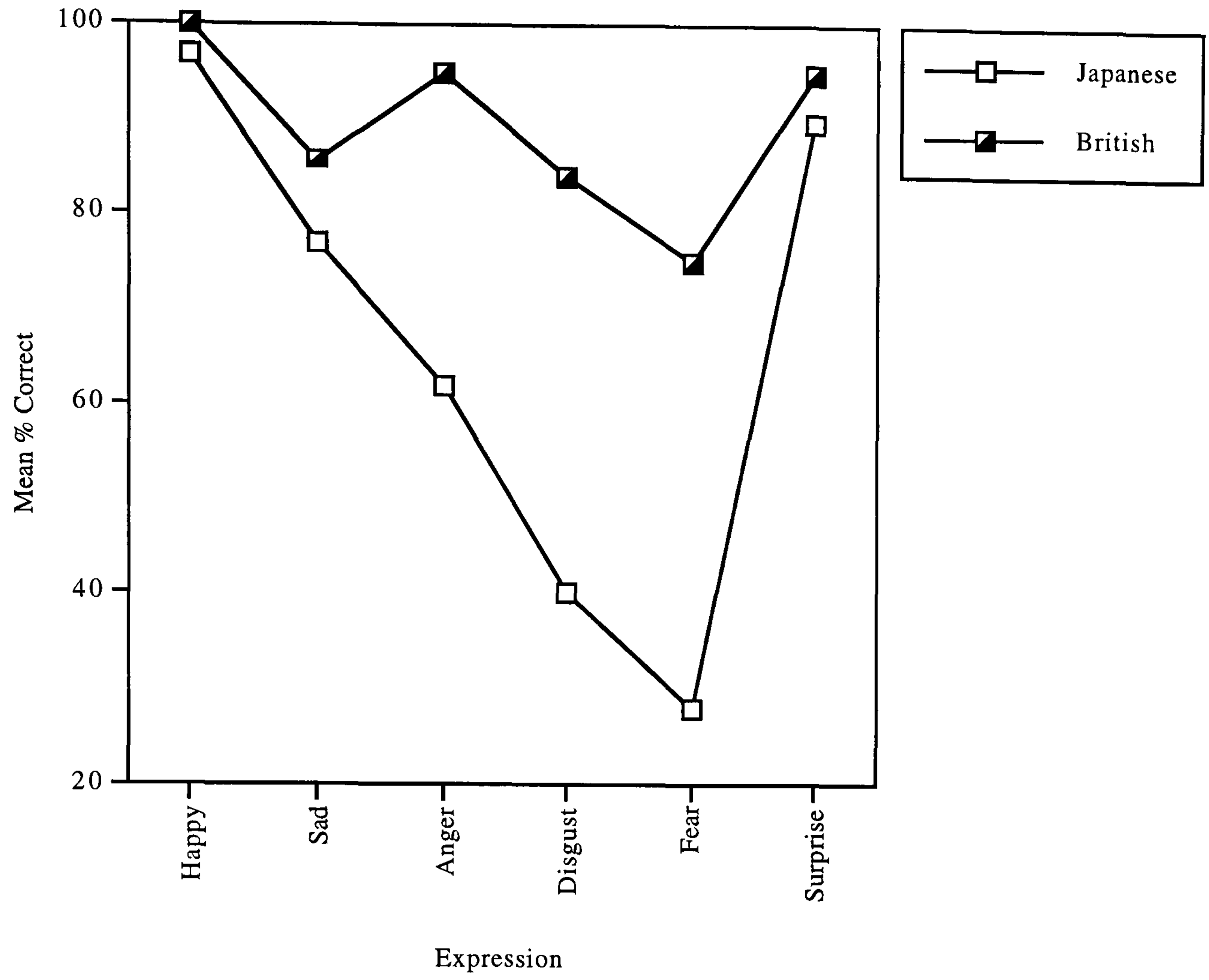


Figure 3.11: Performance (mean % correct) of 10 Japanese participants and 10 British participants in a free naming expression allocation task.

A 2(participant group) x 6 (expression) ANOVA revealed a main effect of participant group [F (1, 18) = 32.61, P < 0.001], and of expression [F (5, 90) = 31.33, P < 0.001] with a significant interaction [F (5, 90) = 9.90, P < 0.001]. Simple Main Effects analysis revealed that there was a significant effect of participant group for the expressions of fear, disgust and anger (P < 0.001) but not for the expressions of happiness, surprise and sadness. There was also a significant effect of expression for the two cultures (p < 0.01). A Tukey HSD ($\alpha = 0.05$) revealed that the accuracy for labelling expressions of anger, sadness, surprise and happiness was significantly better than for the expressions of fear and disgust. The Tukey HSD test also revealed that fear was a difficult expression to interpret for the Western participants with a significant difference between fear and each of anger, surprise and happiness.

General Discussion

The performance of the Japanese participants was inferior to that of their Western counterparts in both the forced and the free naming task. In particular, the Japanese participants experienced difficulty with expressions of negative affect. Japanese culture dictates that outward displays of emotion should be controlled, as a result, true feelings are often masked. Perhaps the results reflect a general unfamiliarity with examples of negative expressions in conjunction with an unfamiliarity with Western faces. However, this should not be a factor if such expressions are indeed universal.

The poor performance measured in the free naming task may have improved if only those exemplars which were consistently scored as correct in the forced choice task had been used. If the participants were poor at interpreting some of the facial expressions when they were given a choice of labels, their performance without any possibility of a 'best guess' strategy is almost certainly going to be worse. If the exemplars that the Japanese found most difficult had been removed from the image set after the forced choice task, performance in the free naming task may have been seen to improve.

The free and forced choice tasks performed by the Japanese participants and by the patients who will be described in Chapter 6, did not include the neutral exemplars as these were collected for use in the psychophysical tasks descibed in Chapter 3. A retest of the free and forced choice tasks without the neutral exemplars with a new group of healthy British participants may have yielded slightly less than perfect scores as the lack of neutral faces may exert some effect. This is only a remote possibility as the neutral faces are only likely to effect the interpretation of the sad exemplars and these were not found to be confusable in the tasks reported here.

There are of course certain limitations in describing the data obtained in this study as a comparison of the performance of British participants in equivalent tasks using Japanese faces was not possible.

Ekman and Friesen (1971) in their study also found that the expression of fear caused the most difficulty for members of a New Guinea tribe who were tested in their ability to allocate a facial expression to an emotional story. In this task, a story was told to each participant which was intended to arouse feelings of happiness, sadness, anger, disgust, fear or surprise. Three photographs depicting three different expressions were presented to the participants who were requested to choose one of the pictures which they felt best portrayed the emotion described in the story. When participants were told a story which was intended to describe a fearful situation, only 28% of participants chose the fearful exemplar with the remaining participants choosing the face that portrayed surprise. However, when participants were told a surprising story, 71% were able to choose the correct exemplar and did not confuse this emotion with the fearful distractor. It appears as if the expression of fear is the most difficult of the six expressions to interpret for most of the cultures that have been tested. This observation will be important when we turn to consider the neuropsychological impairments which affect the perception of fear.

However, it is not *only* fear that the Japanese participants in this study experienced problems with. As mentioned, two independent judges were used to score the data from the free naming expression allocation task. This was decided after the first judge expressed difficulties in translating some of the responses. The difficulty in the translation became evident with a greater understanding of the Japanese language. Problems arose due to the participants being asked to use only one word to label the expression exemplars. Japanese is written using a combination of three different alphabets, the primary alphabet uses kanji, symbols which represent concepts, or words which only take on their meaning when written in the context of other kanji.

This means that the same kanji could have subtle or gross differences in its meaning depending on the context within which it is written. Some of the participants took their instructions for the free naming task quite literally and tried to respond using only limited kanji which then caused difficulties at the translation stage. Others wrote whole phrases to try and capture the emotion they felt was being portrayed. Unfortunately, the meaning of many of these phrases was lost in the translation. For example, two responses translated by the research assistant in Japan were: "Once on shore we pray no more"; and "The danger past and God forgotten". Quite what emotion these phrases were intended to convey is unclear. However, despite a few problems, agreement between the two translators was very high (approximately 97%) but there were a few important contradictions. On ten occasions the translators differed in their interpretations with the same kanji generating a translation of sadness from one and disgust from the other, or anger from one and disgust from the other, or sadness from one and anger from the other. Although these interpretational difficulties only arose ten times out of a possible three hundred and sixty, they cause concern as they were translated as completely different emotion labels. In addition, when setting up the study the Japanese translator had to discuss with several colleagues the most appropriate kanji to use to translate the English label of 'disgust'. In a further study conducted at ATR, which is briefly mentioned in Chapter 7, it became apparent that actors used for an expression data base who were all drama students were unable to pose the expression of disgust as they were not familiar with the facial physiognomy for this affect. The difficulties experienced by the Japanese with the expression of disgust were not limited to their ability to portray this emotion, they were also poor at labelling it as shown in the results of the free and forced tasks where their performance was well below that of their Western counterparts. Their difficulty in the forced choice task could have arisen as a result of the kanji chosen to represent the English word of disgust. Perhaps some participants interpreted the kanji differently from others.

It is interesting to note that the expressions which caused the Japanese participants the most difficulty are the ones which seem to present difficulties with certain groups of neuropsychological patients (see Chapters 5 and 6). For example, patients with damage to the amygdala are impaired in their ability to label fear from faces and some also show difficulty with the expression of anger (Calder, Young, Rowland, Perrett, Hodges, & Etcoff, 1996). In addition, Huntington's disease sufferers have been shown to be impaired in their perception of disgust from faces (Sprengelmeyer, Young, Calder, Karnat, Lange, Homberg, Perrett, and Rowland, 1996). The results reported here are from a group of healthy individuals, but a group who are less familiar with Western faces and consequently less experienced in processing signals of affect from Western faces. It seems unlikely that exposure alone could account for the poor performance since Western culture has been highly pervasive in Japan for a number of years through the film and music industry. In addition, all of the participants who took part in the free naming task were members of staff at the ATR Institute, a place where approximately 40% of the staff at any one time are Westerners. Perhaps the poor performance observed from patient studies are a consequence of the fact that these particular expressions are simply the most difficult to interpret and a more highly tuned system sensitive to these signals is required. Such a system could develop with increased exposure and expertise with faces (hence the low scores from the Japanese participants) but could perhaps also be the most vulnerable to damage (see Chapters 5 and 6).

Summary

In this chapter the methods which are commonly employed to investigate the interpretation of facial expressions were reviewed. Forced choice and free choice paradigms were used to assess a new facial affect image set containing 10 exemplars of each of happiness, sadness, anger, disgust, fear and surprise. The same tasks were also performed by a group of Japanese participants whose accuracy in interpreting the images was inferior to that of the British group, particularly for the expressions of fear and disgust. The forced and free choice paradigms are useful for comparing behaviour between participants but their use for the purpose of explicitly measuring recognition is limited. As long as there is an awareness of the limitations of these tasks then they still have an important role in investigating comparative behaviours between groups. The limitations of the free and forced choice paradigms described in this chapter motivated the design of a task which could measure our sensitivity to signals of facial affect, without the need for interpretation. Chapter 3 describes the design of such a task and its implementation in exploring a range of aspects concerned with the signalling of our facial expressions.

3

Psychophysical Investigations Into Facial Expression Detection

Overview

The methodological difficulties involved in the use of free and forced choice tasks were reviewed in the previous chapter and the need for a more controlled approach became apparent. A number of questions have arisen as a result of the performance of the Japanese participants described in Chapter 2: Are the expressions that generate low scores in these tasks simply harder to *see*? Are they weaker signals? Or is it the *interpretation* of these signals which causes the poor performance?

The experiments descried in this chapter were motivated by the wish to attempt to answer these questions. A task was designed to investigate our sensitivity to expressive signals from the face in a way that required no direct interpretation of the expressive signals presented. All experiments described in this chapter used images from the Jenkins facial affect set, the production of which was described in Chapter

2. A two alternative forced choice (2AFC) paradigm was used for most of the tasks described in this chapter. Participants were never required to recognise, label or interpret the stimuli they were shown but were simply required to detect the difference between a signal - one of six expressions, and a non-signal - a neutral face. All trials were randomised to ensure that the context of each presentation was different for every participant. In addition, using a 2AFC paradigm meant that each trial involved making the distinction between signal and non-signal, so the expressive content of the previous trial held little significance. Manipulating the viewing distance allowed the signalling strengths of the individual expressions to be explored and provided a technique for examining our sensitivity to these signals under increasingly demanding circumstances.

The following set of experiments were designed to investigate our sensitivity to facial expressions, manipulating the viewing distance from an expressor (the expressor is the person portraying the expression). The first task was designed to establish the optimum presentation duration for the stimuli. Once an optimum duration had been found which avoided floor and ceiling effects, this duration was implemented in all further tasks. Participant's sensitivity to the stimuli was then measured in experiments two and three which described the implementation of two psychophysical techniques; 2AFC, and a signal detection paradigm (1AFC), to determine if the methodology used could influence participant's responses. The power of the signals transmitted by the face were then investigated in Experiment 4 by presenting the facial expressions as very impoverished signals of only 1-bit per pixel. The results of all of these studies revealed that some expressions were capable of transmitting a detectable signal over further distances than others. Thus human vision is more sensitive to some expressions than others. The question arose as to *how* these images were being processed. Did the task simply engage low level visual processes which detected contrast in a complex pattern, or were these images engaging higher order processing which considered the images as faces? Inverting faces is known to impair recognition and to interfere with face processing. This effect was used as a tool in Experiment 5 to explore the nature of the processing which generated the results in the upright condition. If the performance of participants in the upright condition was due to responses made to a complex pattern alone, then no effect of inversion would be expected, and the same pattern of results should be observed. If however a decrease in performance was observed then this would indicate the disruption of a process linked to the perception of faces as a specific stimulus class.

General Procedure

In the 2 Alternative Forced Choice (2AFC) task, there were two events separated by an interstimulus interval (ISI). One of the events comprised the target stimulus, and the other the distractor stimulus. Each presentation of two intervals is called a trial and in these studies 60 trials comprised one block, or run, (1 trial for each of the 60 expression exemplars). The experiment was designed with a 0.5 probability of the target stimuli appearing in the first interval and the task for the participant was to identify the location of the target. Figure 3.1 illustrates the form of the 2AFC task.

In the experiments described in the remainder of this chapter, the target is always any one of the six facial affect signals: happiness; sadness; anger; disgust; fear or surprise, and the distractor is the neutral expression of the corresponding actor. The participant responded using a keyboard pressing '1' if they detected the target in the first interval and '2' if they detected it in the second. Both target and distracter stimuli were immediately followed by the presentation of a mask for 100msec. Two masks were created, a male mask to follow a male face and a female mask to follow a female face. The masks were created using Apple software. The outline of the face and hairline were retained but the internal features were scrambled and overlaid. The faces used to generate the masks were not used in any other part of the experiment. There was an inter-stimulus interval (ISI) of 1000ms which separated each event. The end of each trial was punctuated by the presence of a blank screen which would remain until the participant had made their response. No feedback was given to the participant. The next trial began as soon as the participant's response had been recorded.

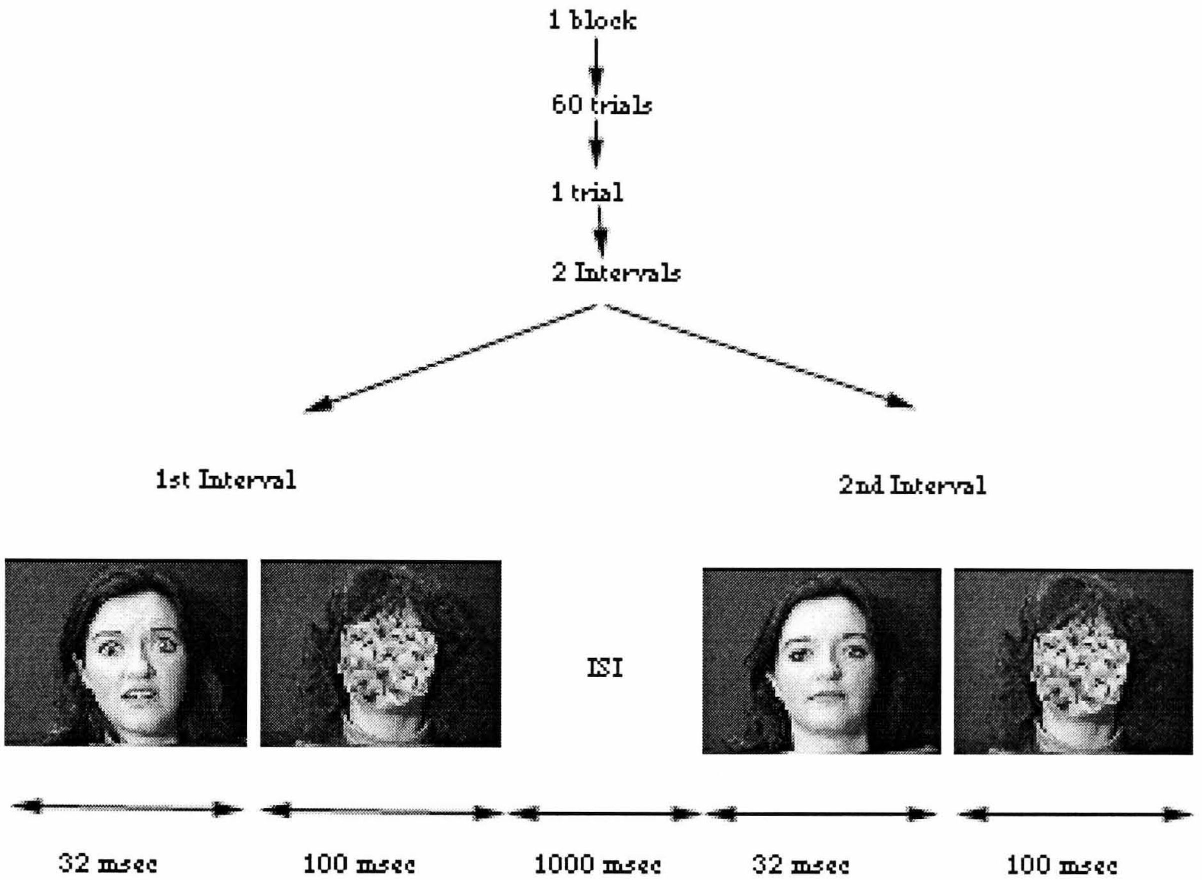


Figure 3.1: Illustration of the content of each experimental block in a 2AFC task.

Experiment 1: Preliminary Study of Facial Expression Detection

This study was performed to determine the optimum presentation duration for investigating the detection of facial expressions. Results from this study were subsequently used in further tasks where the exposure duration was constant and the viewing distance manipulated in order to measure the signalling strengths of facial expressions with increasing distance from the display.

Participants

Six participants were employed in this investigation, all were undergraduate students from Stirling University aged between 18 and 30 years. All participants reported normal, or corrected-to-normal vision and were paid for their time.

Design and Procedure

This experiment was conducted as a within-subjects design with two factors. The first factor was facial expression (happiness, sadness, anger, disgust, fear and surprise). The second factor was display duration (1, 2, 3, 4 and 5) measured in screen cycles. (The refresh rate of the screen was 60Hz, as measured using an oscilloscope, the screen cycles quoted above are approximately equivalent to 0/1, 16, 32, 48 and 64 milliseconds).

The design of this experiment is illustrated in Figure 3.2. The experiment was divided into five separate blocks with each block containing all 10 examples of each of the 6 expressions. Within a block, the 60 images were divided into five sets of 12 stimuli so that each set could be displayed at one of five test durations. Each set of 12 exemplars consisted of 2 examples of each of the 6 expressions under test. Participants completed each of the five blocks so that at the end of the task, all expression exemplars were seen at each of the 5 durations.

The order of presentation of expressions and durations was randomised by the computer. Participants were able to take a short break between blocks to prevent them tiring. The screen was viewed binocularly at a distance of 1m. Each stimulus subtended 4° of visual angle. Participants were instructed to fixate on the centre of the screen although no fixation marker was provided, nor was fixation monitored.

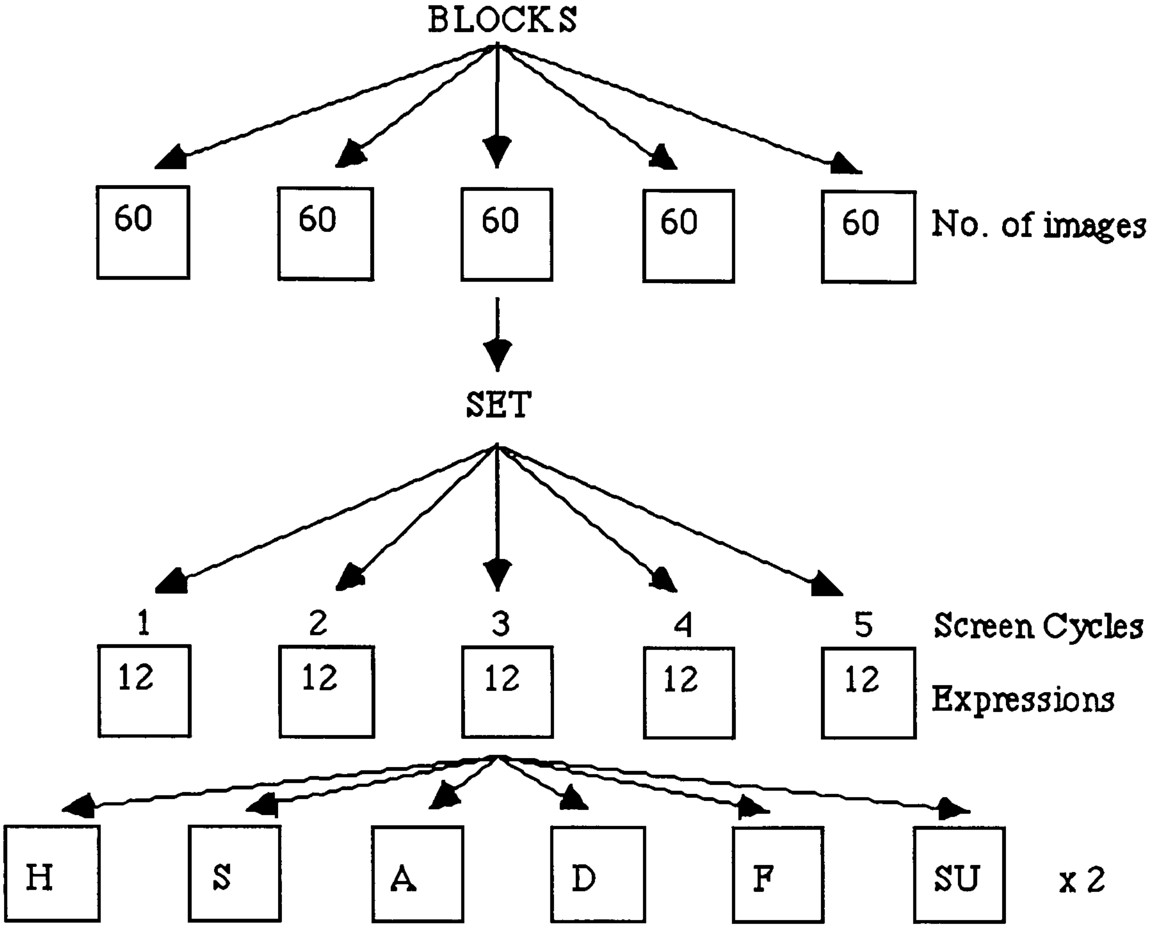


Figure 3.2: Illustration of the content of each set within one block, where H = happiness, S = sadness, A = anger, D = disgust, F = fear, Su = surprise.

Participants were shown a brief demonstration to ensure they understood the verbal instructions they had been given. All image display durations were increased for the demonstration and different faces to those in the test phase were used.

Results

Figure 3.3 shows a plot which illustrates the mean performance of six participants at the five image display durations measured in this task. (No error bars are illustrated as the graph would become too cluttered, standard errors for all experiments in this chapter are reported in the Appendix section). At one screen cycle, participants were behaving randomly with performance for all the expressions at chance. At five screen cycles, performance was at ceiling for the majority of expressions with only sadness not being recognised with an accuracy over 80%. Note that the expressions of fear and disgust which were found to be difficult to interpret, are not particularly difficult to *see*.

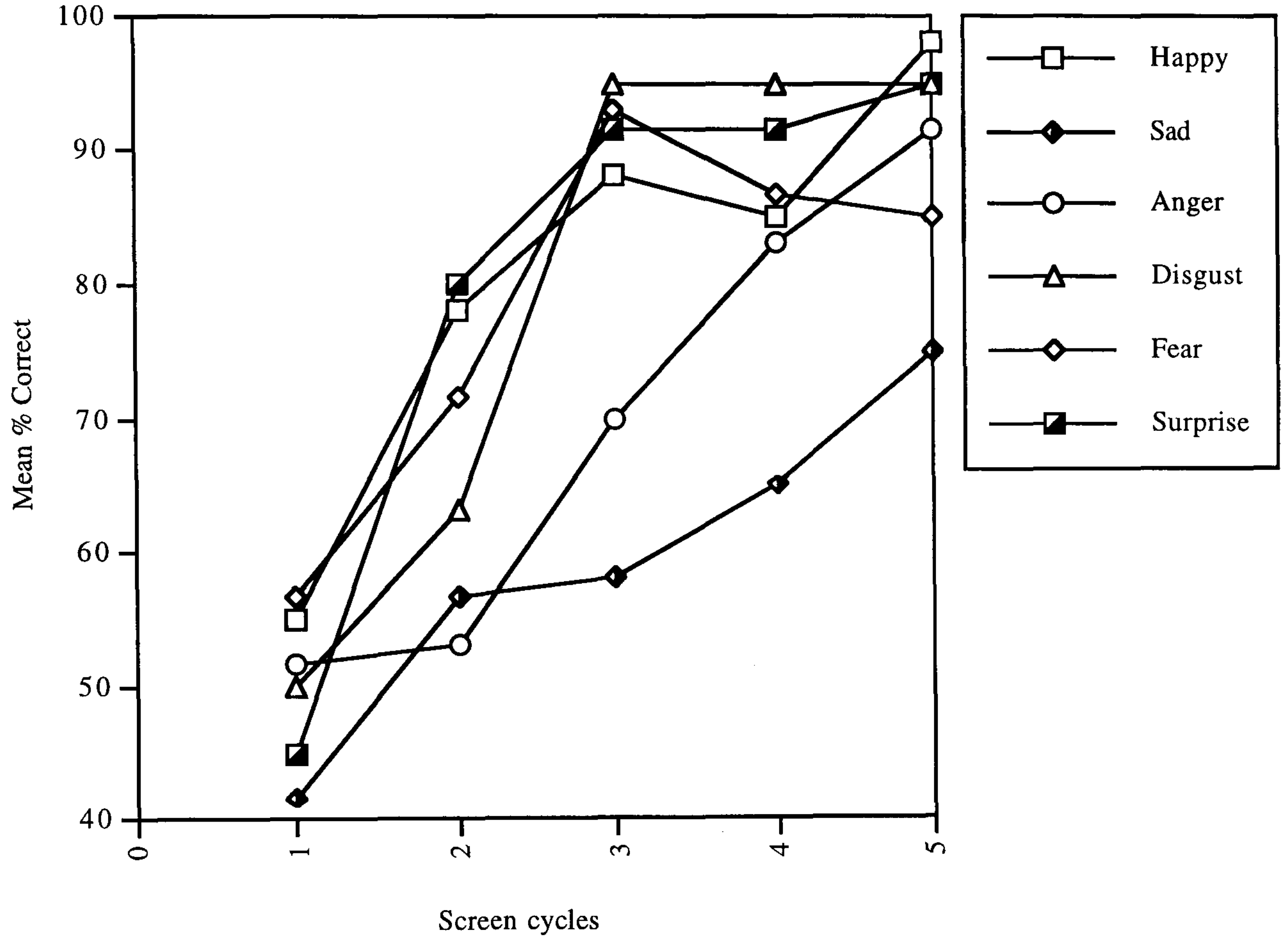


Figure 3.3: Performance of six participants in a 2AFC expression detection task at five presentation durations.

The duration of three screen cycles (approximately 32ms) was chosen as it produced a range of scores which avoided floor and ceiling performance. This duration was used in all of the following tasks.

Experiment 2: Using a 2AFC Paradigm to Measure Sensitivity to Expressive Signals from the Upright Face

The aim of this experiment was to investigate our ability to detect emotional signals from the face. The viewing distance from the stimuli was varied in order to measure the signalling strength of the individual expressions.

The ability to detect the facial expressions of another individual is important if we are to monitor and control our conduct with them appropriately. An interesting observation is that our facial expressions are capable of sending an effective signal over very large distances, distances well beyond those of intimate face-to-face interactions. However, researchers have not shown a great deal of interest in this observation and those that have report widely differing results. Hall (1969) claimed that 9.15m was the limit of discriminability for facial expressions and that beyond this distance the details of these facial signals disappear. Hager and Ekman (1979) proposed that certain facial expressions could be reliably identified at distances over ten times greater than Hall's original estimate. Hager and Ekman (1979) also reported differences in the effective signalling of male and female expressors, with male angry faces being perceived at greater distances than female angry faces. However, the methods used in these previous experiments were not well controlled. Experiment 2 explores this issue again using the psychophysical method developed in Experiment 1.

Participants

Six participants were employed in this investigation, all were undergraduate students from Stirling University aged between 18 and 30 years. All participants reported normal, or corrected-to-normal vision and were paid for their time.

Design and Procedure

This experiment was conducted as a within-subjects design with two factors. The first factor was facial expression (happiness, sadness, anger, disgust, fear and surprise). The second factor was distance (equivalent to a real face at distances of 10m, 20m, 30m, 40m, 50m).

A 2AFC paradigm as described in the general procedure section, and Figure 3.1, was used in this study. This task was presented to the participants in five blocks, one block for each of the five distances measured, with all sixty expression exemplars appearing in a random order in each block. The duration of the image display was constant throughout the trials at 3 screen cycles. The ISI was maintained at 1000ms and the mask remained on for 100ms after each presentation of a face.

The viewing distance was physically manipulated by the participant moving his/her chair to markers on the floor which were positioned so as to be equivalent to viewing a real figure at distances of 10, 20, 30, 40 and 50m. The 'equivalent' viewing distances were calculated by simply scaling the size of the images with reference to the size of a real head. Short breaks between block presentations prevented the participants from tiring.

The order in which participants completed the task (i.e. the order of viewing distances) was randomised. In this task due to the large distances involved between participant and screen, the participant was required to give his/her decisions orally to the experimenter who would record the responses on their behalf using the keyboard as described in the previous section.

Figure 3.4 shows a plot of the mean performance calculated for six participants in this facial expression detection task.

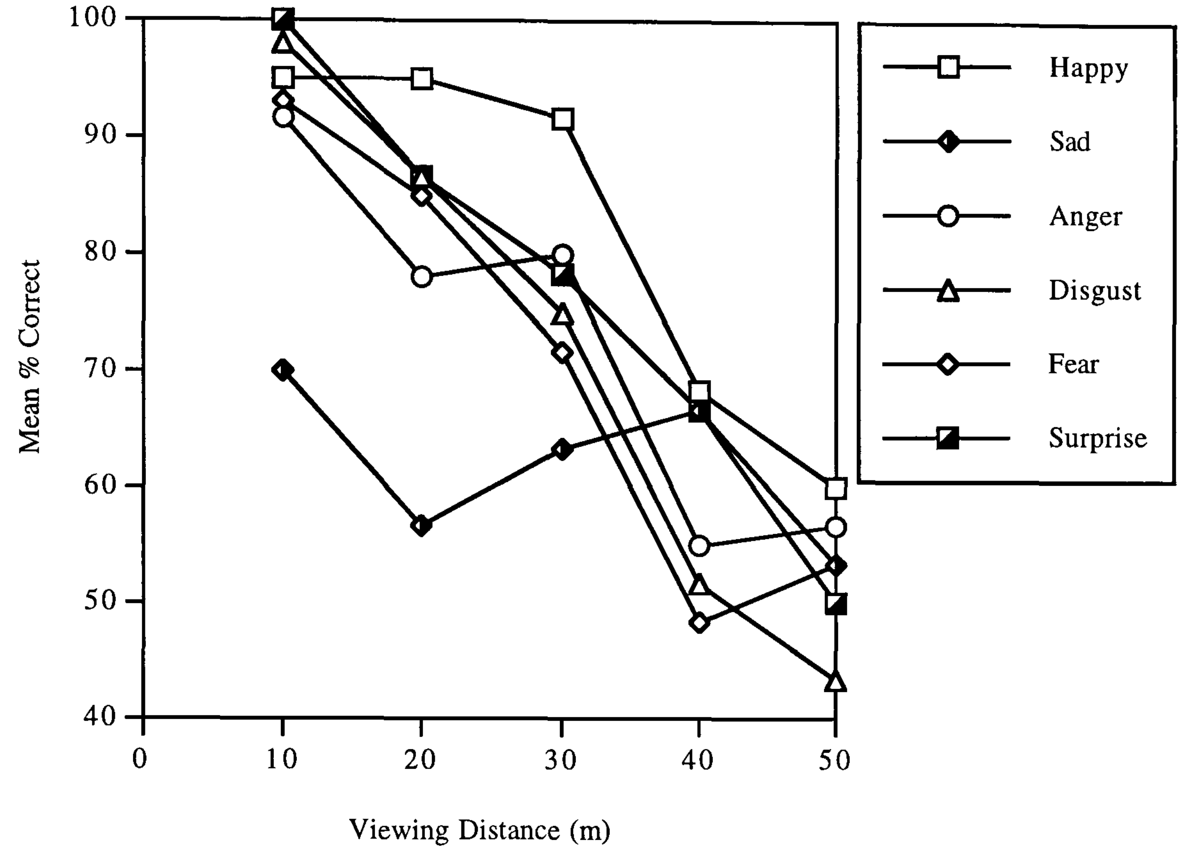


Figure 3.4: Mean accuracies expressed as percentages for six participants in a 2AFC expression detection task.

A 5 (viewing distance) x 6 (expression) analysis of variance (ANOVA) conducted on participants accuracy scores revealed a main effect of distance [F (4, 20) = 54.11, $p < 0.01$] and expression [F (5, 25) = 7.41, $p < 0.01$] with a significant interaction [F (20, 100) = 2.48, $p < 0.05$].

A Simple Main Effects analysis revealed that the effect of expression was significant at all of the distances measured ($p < 0.05$) except at the 50m viewing distance.

A Tukey HSD test revealed that at 10 and 20m, all expressions, with the exception of anger, were detected significantly better than sadness. Only the expression of happiness was detected significantly better than sadness at 30m. At 40 and 50m, no significant differences in performance were recorded for any of the expressions tested.

Participants found the expression of sadness the most difficult to detect. Simple Main Effects analysis demonstrated that detection accuracy for all of the expressions decreased with increasing viewing distance with the exception of sadness ($p < 0.01$). A Tukey HSD test showed that distance was not a significant factor for this expression with no significant difference in performance over all the distances measured.

Discussion

This psychophysical task revealed that some facial expressions were capable of transmitting their affect over greater distances than others. In particular, the expressions of happiness and surprise were the most reliably detected. At 40m participants were able to discriminate these affect signals from neutral with an accuracy above chance. The ability of participants to discriminate sadness from neutral was poor over all the distances measured. For all the expressions, excluding sadness, the greatest decrease in performance occurred between 30 and 40m suggesting that beyond this distance our facial signals become indistinct. Watt (1992) predicted that at a distance 40m, it was possible to recognise a highly familiar face, in addition, at this distance he suggested that observers may be able to discern if the person's mouth was open or closed. As such, the *gross* expression of the individual may be just detectable at this distance. At 20m, Watt (1992) reported that the brows and mouth were easily visible and the eyes just about so, making finer discriminations regarding expression possible at this distance. These predictions, which Watt (1992) proposed from theoretical knowledge of the visual system, such as two point resolution, have been supported in this study which demonstrated that expression detection for all expressions with the exception of sadness was highly accurate at 20m and significantly impaired a 40m.

To investigate Hager and Ekman's (1979) finding that male angry faces were capable of transmitting a stronger signal than female angry faces, participant's responses to these stimuli were analysed separately. An ANOVA showed there to be no significant difference between the ability of these expressors to transmit this emotion. [$F(1, 5) = 0.429$, $p = 0.542$]. The finding in Hager and Ekman's (1979) study could have been the result of stimulus artefact rather than any generalisable property of male angry faces.

In Experiment 3, a different psychophysical paradigm was used to measure expression detection. Participants' performance in a signal detection (1AFC) paradigm was measured and compared with that obtained in this experiment.

Experiment 3: Using a Signal Detection Paradigm to Measure Sensitivity to Expressive Signals from the Face

This experiment was conducted to investigate the possibility that participants' performance in the previous expression detection task could have been influenced by the nature of the psychophysical methodology used. Using a 2AFC paradigm essentially allows the participant 'two chances' to categorise the stimuli as target or distractor. In this experiment, the participant was required to generate a decision based on only one presentation; either the signal, *or* the non-signal. Using this technique, the participant was presented with either an expression or a neutral face and their task was to label each stimuli as ‘expression’ or ‘neutral’.

Participants

Six participants were employed in this investigation, all were undergraduate students from Stirling University aged between 18 and 24 years. All participants reported normal, or corrected-to-normal vision and were paid for their time.

Design

This experiment was conducted as a within-subjects design with two factors. The first factor was facial expression (happiness, sadness, anger, disgust, fear and surprise). The second factor was distance (10m, 20m, 30m, 40m, 50m). Participants viewed all expression exemplars at each of the five viewing distances. The complete facial affect set was used in this task as well as an additional 39 neutral exemplars which made the total number of distracters 60. This was to ensure an equal probability of being presented with an expression or a neutral face.

Procedure

As in the previous task, the viewing distance was manipulated to investigate the signalling strength of the affect signals. Each trial in this task consisted of one interval in which either an expression or a neutral face appeared for 3 screen cycles immediately followed by a mask presented for 100ms. A blank screen followed which was displayed until the participant voiced his/her decision to the experimenter who recorded the response using a keyboard. The task for the observer was to determine whether they had been presented with a neutral face or any one of the six expression exemplars. Each block consisted of 120 randomised trials (60 targets and 60 distractors). As in the previous task, the viewing order was randomised between participants.

The analysis was performed on the hit rate data as there is no sensible way to allocate false positives to different expressions. A 5 (viewing distance) x 6 (expression) ANOVA conducted on the hit rate data revealed a main effect of distance [F (4, 20) = 14.3, $p < 0.01$] and expression [F (5, 25) = 15.838, $p < 0.01$], with a non-significant interaction [F (20, 100) = 1.536, $p > 0.05$].

The overall false positive rate collapsed across expression at each of the distances is shown in the Table 3.1. These scores represent the proportion of trials in which a neutral exemplar was presented which participants believed to be an expression.

Viewing Distance (m)	Mean False Positive Rate (%)
10	22.8
20	32.2
30	42.2
40	54.7
50	51.4

Table 3.1: Overall false positive rate at each of five viewing distances measured in the 1AFC expression detection task.

For completeness, a Simple Main Effects analysis was carried out as the interaction approached significance. This analysis revealed that all expressions with the exception of sadness ($p > 0.1$) were significantly affected by the viewing distance ($p < 0.05$). The analysis also revealed that the effect of expression was significant at all viewing distances except at 50m ($p > 0.1$), as was the case in the 2AFC task.

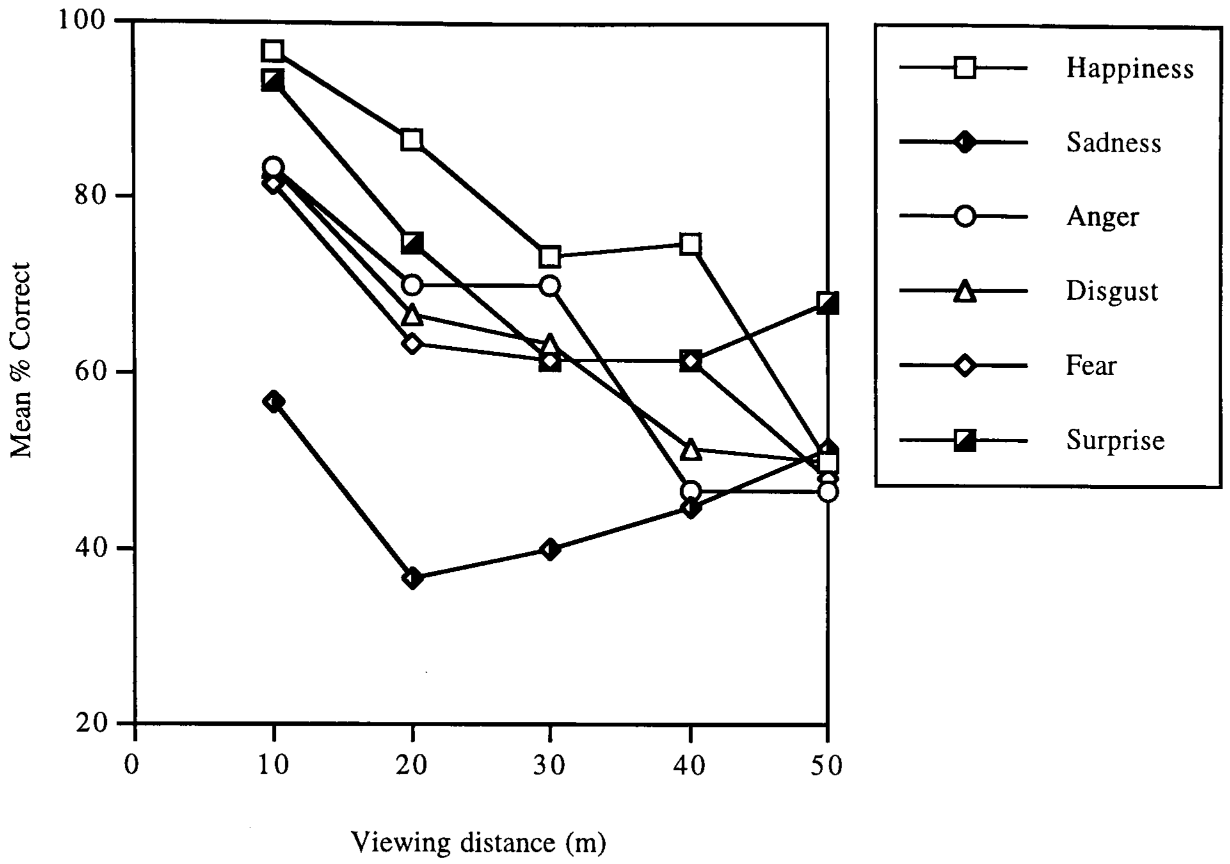


Figure 3.5: Performance of six participants in a 1AFC expression detection task. (Mean percentage calculated from the hit rate data).

A Tukey HSD analysis revealed that at 10m, the expressions of happiness, anger, disgust and surprise were all detected significantly better than sadness ($p < 0.05$). At 20m, the expressions of happiness, fear, anger and surprise were still being detected significantly better than sadness ($p < 0.05$). At 30m, only happiness remained significantly better detected than sadness ($p < 0.05$).

Discussion

The pattern of results found in this experiment were very similar to those found using the 2AFC methodology. The same overall trend in expression discriminability was shown by participants, with sadness proving to be the most difficult, and happiness and surprise remaining the best detected expressions with increasing distance.

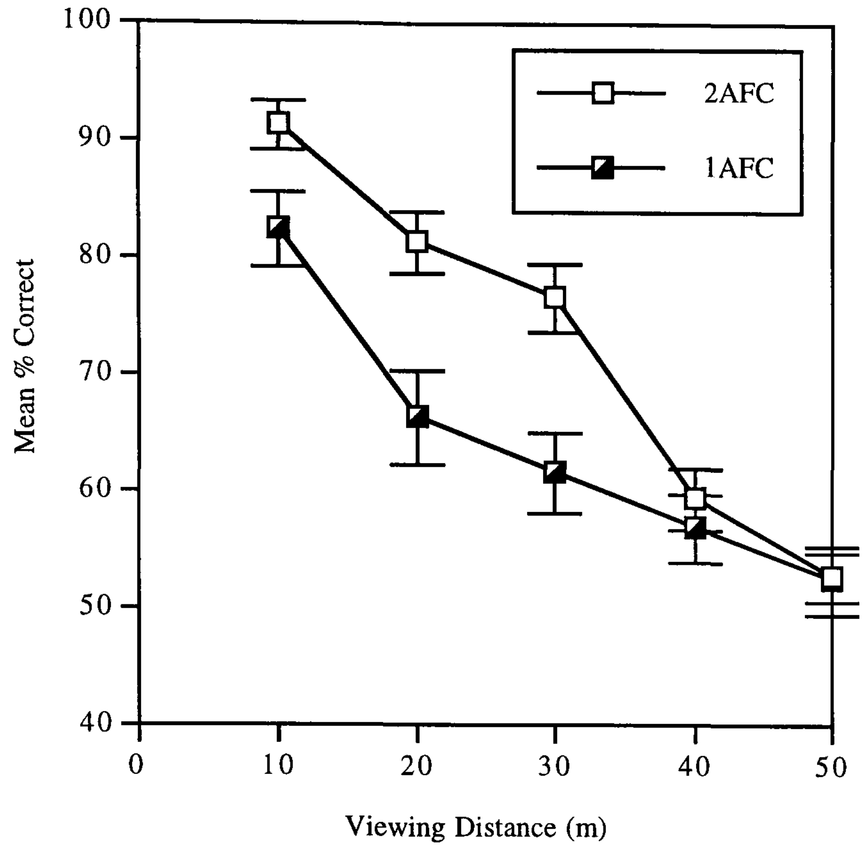


Figure 3.6: Overall performances collapsed across expression in a 2AFC task (Experiment 2) and a 1AFC task (Experiment 3).

Figure 3.6 shows a plot of the overall performance, collapsed across expression calculated for six participants from each of the two psychophysical experiments described. A 2 (experiment) x 6 (expression) x 5 (distance) ANOVA performed on the hit rate data from each experiment revealed a non-significant 3 way interaction [F (20, 200) = 1.021, $p > 0.05$], a significant main effect of distance [F (4, 40) = 51.4, $p < 0.01$] and a significant main effect of expression [F (5, 50) = 22.54, $p < 0.01$] with a significant interaction [F (20, 200) = 2.77, $p < 0.01$]. There was also a significant main effect of experiment [F (1, 10) = 6.51, $p < 0.05$] with a significant interaction with distance, [F (4, 40) = 3.44, $p < 0.05$]. As can be seen from Figure 3.6, at the 40 and 50m viewing distances, there are no significant differences in performance between the two paradigms.

However, the important finding was that despite the performance in the 2AFC experiment being significantly better than that measured using the 1AFC paradigm, ‘experiment’, as a factor, did not significantly interact with ‘expression’. This means that the overall pattern of expression detection did not differ significantly between the two psychophysical paradigms.

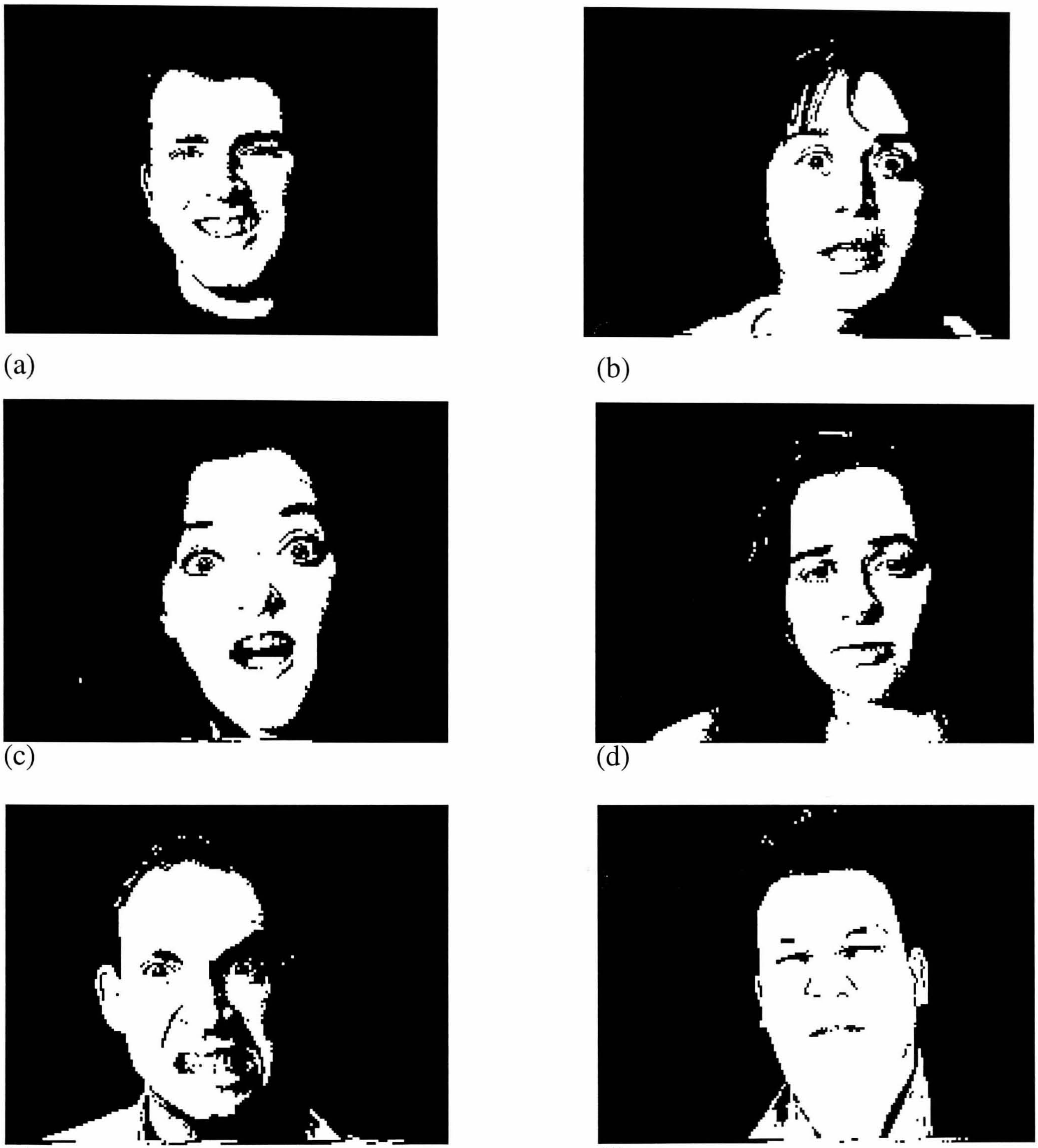
Experiment 4: Facial Expression Detection from 1-bit per pixel images

The advantage of the psychophysical method is that it may provide a more sensitive way to assess the signalling strength of different images. This point is illustrated in the next experiment using a threshold manipulation. A large amount of the visual information we process may actually be superfluous and not required for many of the tasks we perform. To examine this, a 2AFC expression detection experiment using thresholded images (1-bit per pixel) was designed to investigate our ability to recognise expressions from a considerably depleted image. In addition, the transformed images were printed and presented to a group of participants to label in a 6AFC task.

Participants

Sixteen participants were employed in this investigation, ten postgraduate students aged between 21 and 36 years volunteered to take part in the forced choice task.
The remaining six participants were undergraduate students from Stirling University aged between 18 and 22 years. All participants reported normal, or corrected-to-normal vision and the undergraduates were paid for their time.

Materials



(a) (b) (c) (d) (e) (f)

Figure 3.6: Images (a) to (f) show examples of the expressions of happiness, fear, surprise, sadness, anger and disgust when the amount of visual information has been reduced to 1-bit per pixel.

All exemplars in the Jenkins affect image set were thresholded i.e. converted to 1-bit per pixel stimuli, the grey levels were removed using Image 1.49. This software works by setting an arbitrary threshold above which all grey levels are turned to black, and below which all grey levels are transformed to white. Examples of the images used are shown in Figure 3.6.

Design and Procedure

In the first task, the transformed images were printed and shown to ten volunteers who allocated an expression to each image from a given list, as described in the 6AFC task of Chapter 2.

To investigate the detection of these transformed images in a psychophysical task, a 2AFC paradigm was used. The procedure for this task was as for that described under the general procedure section and the 2AFC task using full grey level images, (page 58 and 64), with the exception that performance in this task was only measured over the first three viewing distances as the task became too difficult thereafter.

This experiment was conducted as a within-subjects design with two factors. The first factor was facial expression (happiness, sadness, anger, disgust, fear and surprise). The second factor was distance (10m, 20m, 30m).

Results and Discussion

The 6AFC task revealed that labelling accuracies for each of the expressions remained high (see Table 3.2) despite the large loss in visual information.

6AFC	Happiness	Sadness	Anger	Disgust	Fear	Surprise
Grey-level	100	100	100	100	100	100
1-bit/pixel	99	98	82	73	80	95

Table 3.2: Comparison between scores of mean % correct from 10 participants in a 6AFC task using full grey-level images and 1 bit per pixel images.

The worst performance was recorded for the expression of disgust, although labelling accuracy was still very high at 73%. Importantly, the measured performance for several of the expressions remained near ceiling, suggesting no loss of signal from the reduced grey scale.

The results of the psychophysical experiment demonstrated that performance decreased with increased viewing distance and was also worse than performance at equivalent distances when full grey scale images were used, although a similar trend was observed. Figure 3.7 shows a plot of mean % correct as a function of increasing distance. Sadness was the most difficult expression to detect with performance fluctuating around chance over all the distances measured. As in Experiment 2, the expressions of happiness and surprise were detected with the most accuracy. In this task the largest decrease in performance occurred between 10 and 20 meters.

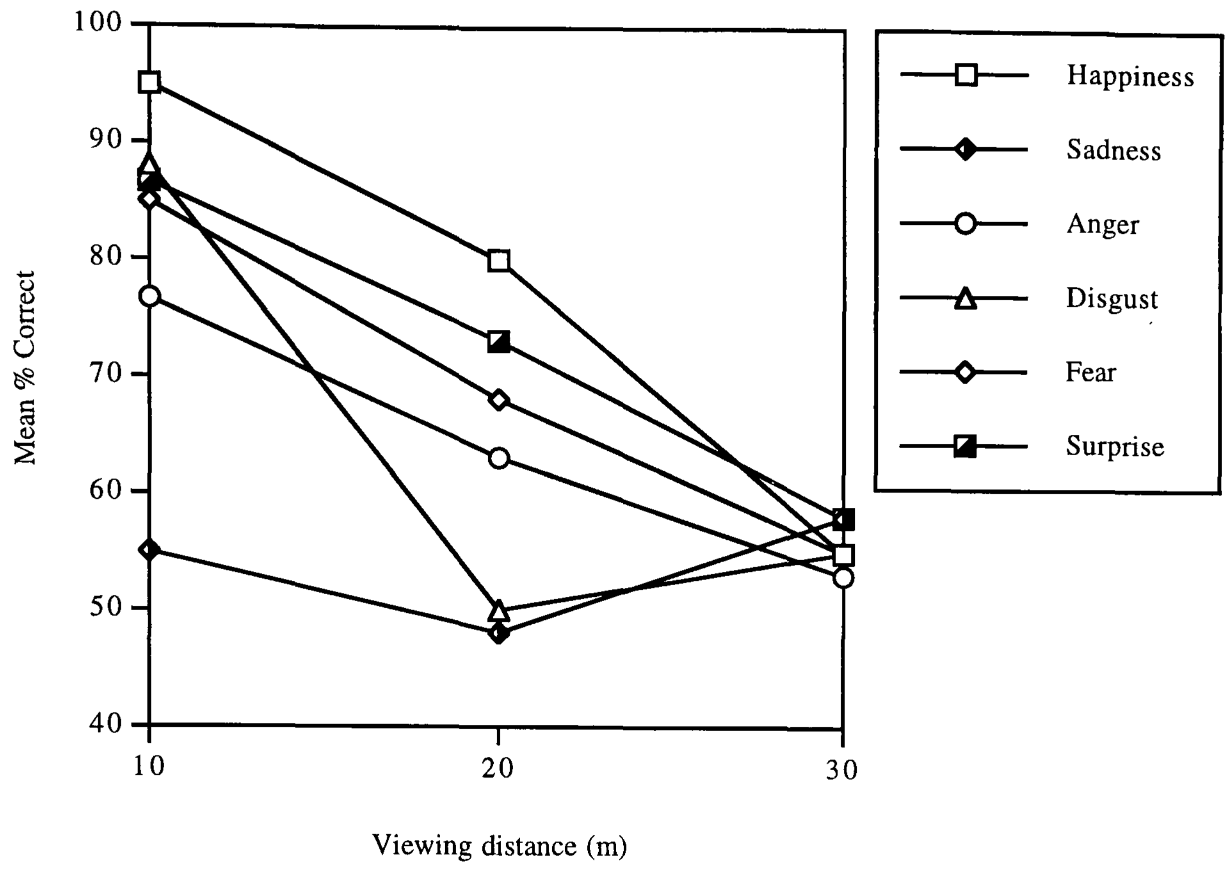


Figure 3.7: Mean performance (%) of six participants in a 2AFC expression detection task using 1-bit per pixel images.

A 3 (viewing distance) x 6 (expression) ANOVA conducted on accuracy scores revealed a main effect of distance [F (2,10) = 32.291, $p < 0.01$] and of expression [F (5, 25) = 5.647, $P < 0.01$] with a significant interaction [F (10, 50) = 3.0, $P < 0.01$]. Simple Main Effects analysis revealed that viewing distance had a significant effect for five of the expressions ($p < 0.05$), only the expression of sadness was unaffected by viewing distance ($p > 0.1$). The analysis also revealed significant effects of expression at 10 and 20m ($p < 0.05$) but not at 30m ($p > 0.1$).

As was found in the 6AFC investigation, the expression of disgust proved to be difficult to detect with performance showing a rapid decrease and falling to chance levels at only 20m. At this viewing distance, a Tukey HSD test revealed that the expression of happiness was detected significantly better than both of disgust and sadness ($p < 0.05$).

A 2 (experiment) x 6 (expression) x 3 (distance) ANOVA to compare the results obtained in the full grey level and 1-bit per pixel tasks showed main effects of distance [$F (2, 20) = 38.38$, $p < 0.01$], expression [$F (5, 50) = 17.56$, $p < 0.01$] and experiment [$F (1, 10) = 97.84$, $p < 0.01$]. Simple Main Effects analysis revealed that performance was significantly better at each of the viewing distances in Experiment 2 (full grey-level) than in Experiment 4 (1-bit per pixel). Once again however, expression was not found to interact with experiment which illustrates that the same overall pattern of detectability was measured in both of the tasks.

The results of the 6AFC investigation show that in a free viewing task participants are able to make accurate identifications of several of the expressions shown, but with increasing task demands, such as brief presentation and increased distance, detection of a target stimuli from a distracter stimuli becomes more difficult. Therefore this shows how a detection task might be a more sensitive task than a 6AFC paradigm for examining our sensitivity to expressive signals.

Experiment 5: Using a 2AFC Paradigm to Measure Sensitivity to Expressive Signals From the Inverted Face

Thus far, psychophysical methods appear to provide a promising way to explore expression perception without requiring any problematic interpretation. However, a plausible explanation for the pattern of results obtained from the psychophysical tasks described so far, is that participants were responding to a pattern of stimulation corresponding to light and dark areas, with some patterns (expressions) containing more contrast and hence being more visible than others. To be really useful as tests of expression perception, performance should be attributable to the operation of *face* processing and not merely *pattern* processing. The recognition of familiar faces is found to be impaired if the faces are inverted, (Yin 1969; Valentine, 1991; Young Hellawell & Hay, 1987), as such, the inversion of facial stimuli is often used as a tool to estimate the contributions of higher order processes. Based on raw image properties alone, no effects of inversion would be expected for the images used in the first 2AFC task since inversion only trivially effects image properties. If however the stimuli are being processed as faces and not just complex patterns, then a large effect of inversion, similar to that found for recognition would be expected. Before describing this experiment, a brief review of studies using inverted faces is provided.

The recognition of faces is more severely impaired by inversion than is the recognition of other types of objects. Yin (1969) found that recognition memory for upright faces was better than that for pictures of other stimulus classes e.g. houses and aeroplanes. However, when these images were inverted, faces were found to be disproportionately difficult to recognise compared with the other stimulus groups. Typically for faces there is a 20-30% decrement in recognition accuracy associated with the inversion condition, compared with 0-10% inversion decrement for stimuli from other classes. This finding could be a consequence of the ubiquitous nature of upright faces. The more familiar we are with a characteristic orientation for an object, the more detrimental the effect of changing that orientation will be on subsequent recognition. In addition, faces belong to a highly homogenous class of stimuli. Each face can be defined in terms of a fixed set of points, this is not the case for a randomly chosen set of landscapes, houses or bridges for example.

Diamond and Carey (1986) have attributed the inversion effect to the use of second order relational properties that are important for but not unique to face recognition. Second order relational properties are described as the distinctive relations among the elements of a stimulus class that define the shared configuration. For faces, the most relational features include face shape, ratios of distances and the internal spacing of the eyes, nose and mouth. It is this dependence on second order relational properties that distinguishes the recognition of faces from that of most other stimulus classes.

Young et al (1987) using composite faces, demonstrated that the encoding of spatial relations among facial parts was orientation sensitive. In an upright composite face, the top and bottom halves fuse to make a plausible 'new' face, making the identification of the person in the top half difficult. This phenomenon is not seen if the face is inverted.

Diamond and Carey (1986) found that the disproportionate effect of inversion was not specific to just faces, but was also likely to be found for the recognition of any highly familiar and highly homogenous stimulus class. They found that dog experts showed a similarly large inversion effect in their ability to recognise individual dogs. According to Diamond and Carey's hypothesis (1986), a large inversion effect will be found if there is common configural information shared by all exemplars of a stimulus class with only small differences in the second order relational information. Also, observers must be sufficiently expert to distinguish between exemplars on the basis of these differences in configural information. The notion of expertise is supported by the finding that compared to adults, children are far less sensitive to the inversion effect of faces. This suggests an increased reliance on configural aspects of faces with increasing age and exposure to the stimulus class and also the development of a rigid schema for faces.

Materials

The Jenkins affect image set was used in this study. All images were rotated by 180° before presentation.

Design and Procedure

This experiment was conducted as a within-subjects design with two factors. The first factor was facial expression (happiness, sadness, anger, disgust, fear and surprise). The second factor was distance (10m, 20m, 30m, 40m, 50m). The procedure for this task was as for that described under the general procedure section and the 2AFC task using upright faces.

Results and Discussion

Expression detection performance from inverted faces is shown in Figure 3.8. Comparison with Figure 3.4 shows that inversion had a detrimental effect on participants' ability to differentiate between neutral face stimuli and any of the six expressions tested. In the upright condition, the expressions of happiness and surprise were the most successfully detected out of the six different expressions. This was also found to be the case in this experiment but only for the 10m viewing distance. Performance for all expressions fell to chance levels between 20 and 30m. This represents a shorter viewing distance than was found in the upright condition. In the upright condition, performance did not reach chance levels until between 40 and 50m.

A 5 (viewing distance) x 6 (expression) ANOVA conducted on the accuracy data revealed a main effect of distance [F (4, 20) = 30.51, $p<0.01$], performance at 10m and 20m was significantly better than at any of the further distances measured. There was no significant effect of expression [F (5, 25) = 1.093, p = 0.389] and no significant interaction [F (20, 100) = 1.508, p = 0.1].

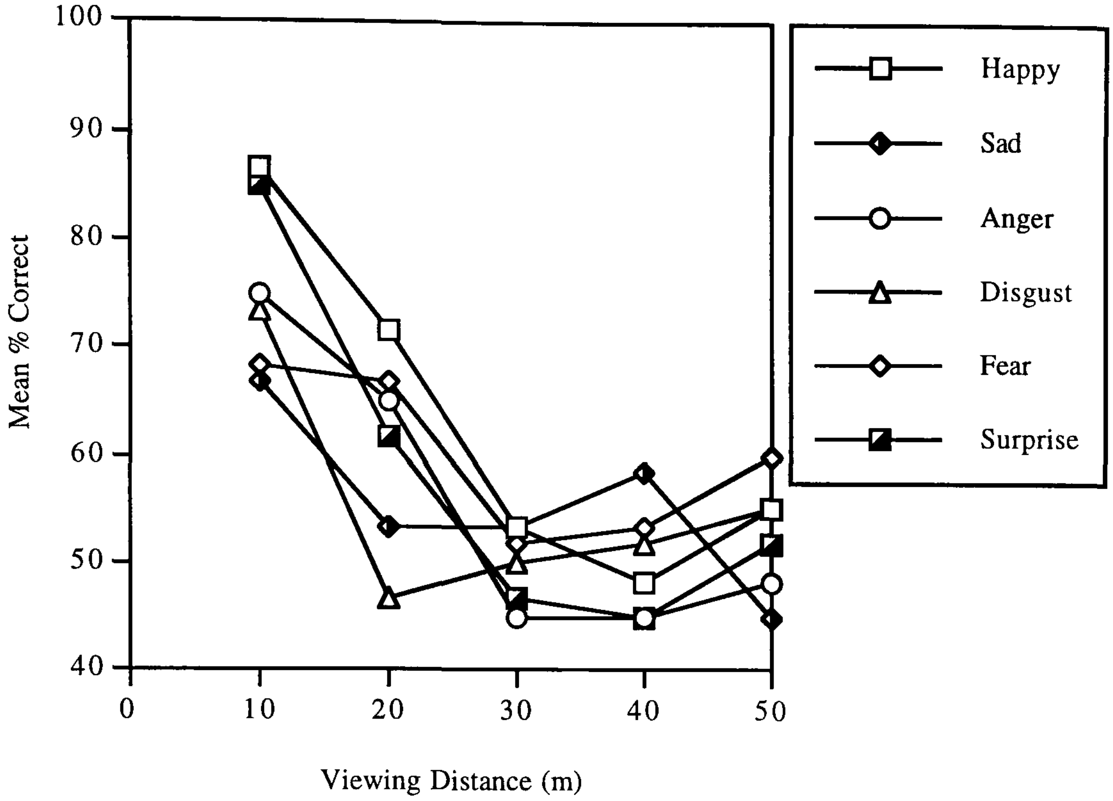


Figure 3.8: Mean accuracies (%) representing the performance of six participants in a 2AFC expression detection task using inverted faces.

A 2(experiment) x 6 (expression) x 5 (distance) ANOVA was performed to compare the performance between the upright (Experiment 2) and inverted (Experiment 5) experiments. The analysis revealed a significant 3 way interaction, [F (20, 200) = 1.798, $p < 0.05$], a significant main effect of experiment [F (1, 10) = 138.3, $p < 0.001$]. A Tukey HSD test showed significant differences in performance at 20, 30 and 40m ($p < 0.05$). The difference in performance between the two conditions is illustrated in Figure 3.9 which shows the mean performance collapsed across expressions in both the upright and inverted conditions. Performance between the two tasks is only comparable at a viewing distance of 50m which corresponds to chance behaviour in each condition.

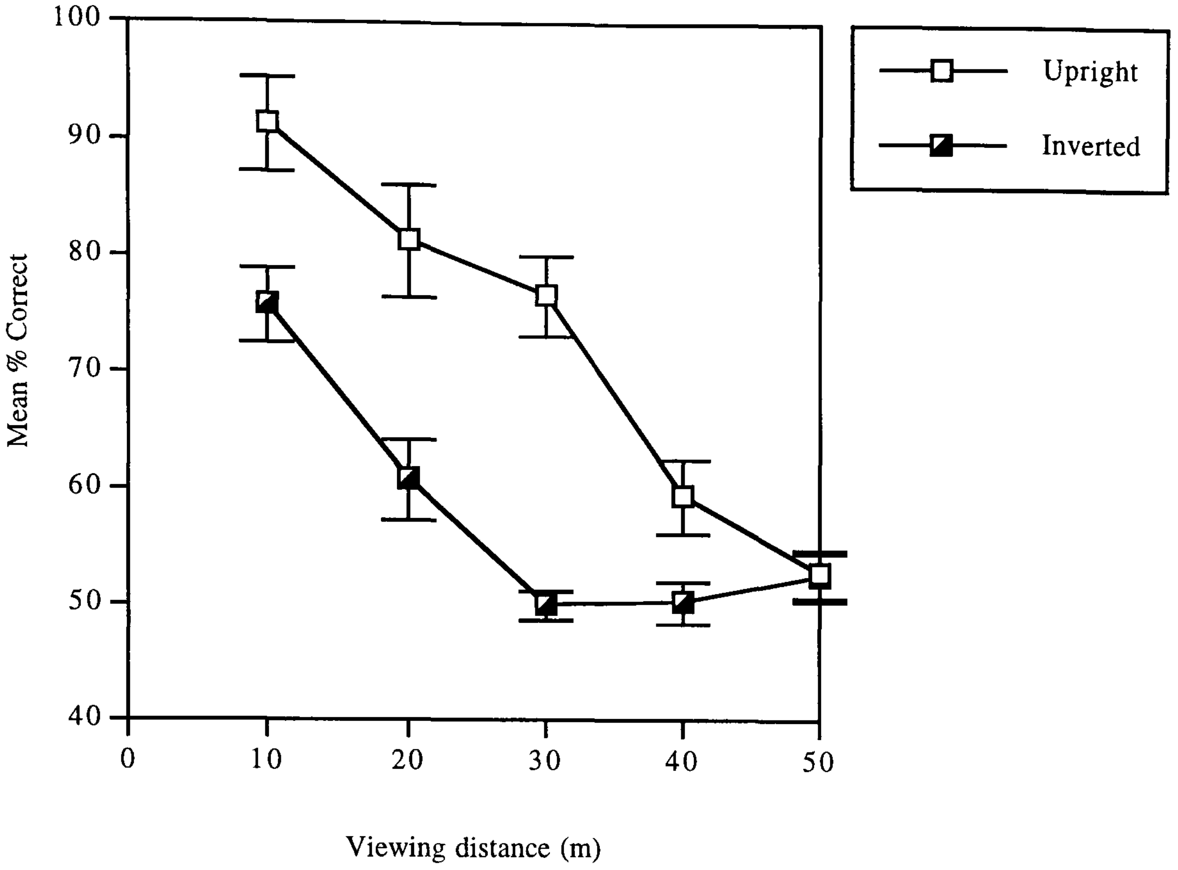


Figure 3.9: Mean performance (%) in a 2AFC expression detection task with upright and inverted faces in Experiments 2 and 5.

GENERAL DISCUSSION

Detection Versus Identification

The questions presented at the beginning of this chapter were aimed at discovering the signalling strengths of our facial expressions, and at establishing whether the expressions we find difficult to recognise are also the ones that are most difficult to detect. In this chapter, two psychophysical tasks were designed to measure sensitivity to signals of facial affect. Neither of the tasks required overt recognition of the expressions presented but instead required a discrimination of an expression from neutral. Participants' performance in these experiments demonstrated that when no interpretation of the affect stimuli was required, a pattern of performance different to that obtained in recognition tasks was observed. Sadness was poorly detected over all distances in the psychophysical tasks, but was not difficult to recognise in a free or forced choice task. In the forced choice task, sad expressions were recognised with an accuracy of 100% and the neutral faces were not mistaken for sad exemplars in the free naming task, a finding which indicates that these exemplars are not confusable in labelling tasks.

In the free naming task described in Chapter 2, both Western and Japanese participants experienced most difficulty labelling the expression of fear. Fear was not found to be difficult to detect in the psychophysical tasks with performance for this expression being detected significantly better than sadness and being detected with accuracies similar to surprise, anger and disgust, as shown in Table 3.3. Similar results were found in the detection and recognition tasks for the expressions of happiness and surprise. These expressions are accurately labelled in the free and forced choice tasks and also transmit an affective signal over the greatest distances.

Viewing distance (m)	Happy % correct	Sad % correct	Anger % correct	Disgust % correct	Fear % correct	Surprise % correct
10	95	70	91.7	98.3	93.3	100
20	95	56.7	78.3	86.7	85	86.7
30	91.7	63.3	80	75	71.7	78.3
40	68.3	66.7	55	51.7	48.3	66.7
50	60	53.3	56.7	43.3	53.3	50

Table 3.3: Mean scores for six participants in a 2AFC expression detection task at five viewing distances

Despite this similarity, detectability is not a good predictor of recognisability but it does provide a representation of the strength of the individual expressions. It also demonstrates that the expressions which are most difficult to see are not the ones which are most difficult to interpret. However, there may be some confusion between different negative expressions which would not be noticed using this psychophysical methodology.

The ability to interpret the expression of fear has obvious survival benefits for an organism and yet it is this expression that often yields the lowest scores in forced and free naming tasks. However, the psychophysical tasks reveal that it is reliably detected, and is detected with similar accuracies to other negative expressions (anger and disgust). Detection is an important first step in identification, that is, an expression must first be detected before its emotional content can be interpreted. If, in the real world, we were to encounter another individual with a fearful expression, it is unlikely that we would be in any doubt as to their internal state. We would inevitably have access to emotional cues from many other sources which would compliment the information being signalled in the face.

Many neuropsychological patients are known to have specific facial processing difficulties, a task like this could attempt to establish the nature of the difficulty. For some, the problem may be one of perception i.e. the patient may simply be unable to *see* the expression. Alternatively, it may be an inability of the patient to access semantic information regarding expressions, in which case, a task like the one described here which does not require interpretation, would not present a difficulty to such a patient since they are only required to differentiate between a signal and a non-signal. Later in this thesis, a patient with bilateral amygdala damage who has difficulties with some aspects of face processing is described. His ability to discriminate between affect signals and neutral distractors is investigated using the signal detection paradigm, which we have seen yields a similar pattern of results to the 2AFC paradigm.

Expression detection from an impoverished source

Removing all the grey-levels from the expression set to create the 1-bit per pixel images quite dramatically illustrated how little visual information we require to make quite complicated decisions. Performance in Experiment 2, with upright full grey level stimuli obviously exceeded that seen in Experiment 4 with the grey-levels removed, however, the signals were still detected over very large distances. The results of the forced choice task produced very high recognition scores although not as high as in the equivalent task with the grey-levels present. Disgust proved to be the most difficult expression to recognise generating a mean of 73%. The expression of disgust is most easily recognised by a wrinkling of the nose rather than any characteristic eye configuration, as the nose is not a feature that varies greatly in contrast, it produced only scant information in the 1-bit per pixel form. The psychophysical task demonstrated the power of the expressive signals, despite the lack of grey-levels to provide detail and shading information, the gross configurations of the expressions in the 1-bit per pixel form was sufficient for the discrimination of these signals at considerable distances.

Mode of processing

Inverting the grey level images had a very detrimental effect on the ability of participants to perform the detection task. The results of this investigation support the suggestion that the responses made to the individual expressions in the 2AFC upright expression detection task were made as a result of the images being processed as faces, and as such showed a large sensitivity to orientation due to the disruption of second order relational information. However, the results of this study only allow us to suggest that the images are being processed as faces. It cannot tell us if the images are being processed specifically as facial expressions rather than just an unusual face pattern with no reference to affect. Despite this obvious drawback, these results do suggest the role of a higher order function, although low level visual processing could also be affecting judgements. The patterns of contrast created by the configuration of the facial features in particular expressions create specific shading patterns which are more prominent in some expressions than others. Nonetheless, the results of this study do show that certain expressions are capable of sending an affect message over further distances than others. The mouth, the eyes and eyebrows comprise the three main features which signal information to an observer. If we look at these features individually we can estimate the contribution made by each in signalling a particular emotional state.

The Eyes

The eye is composed of the white sclera which surrounds the dark iris and pupil. A marked contrast is produced by the boundaries of the sclera and iris. As the eye or eyelid is moved the amount of sclera visible to an observer is modulated which provides powerful cues to expression recognition and eye gaze direction detection. Kobayashi and Koshima (1997) describe the morphology of the human eye as unique, comparing it to 88 other primate species. Humans are the only primate species to possess a white sclera. Humans also have the greatest ratio of exposed sclera in a horizontally elongated eye outline. They suggest that this is an adaptation which allows for extended eye movement, particularly in the horizontal direction, which consequently extends the range of the visual field. In addition, it aids the detection of where another individual is gazing. The colouration of the sclera in other primates is suggested to have arisen to prevent other individuals perceiving a directed stare since this can often result in a confrontation (Kobayashi & Koshima, 1997). It may also serve to deceive predators. If a predator believes its prey to be aware of its presence then it may be less likely to attack. Kobayashi and Koshima (1997) suggest that a small change in the colouration of the sclera may have had the effect of changing "gaze camouflaged" eyes to "gaze signalling" eyes. An exception to the exclusively dark sclera's noted in all non-human primates is the white sclera observed in the macaque monkey which is present until the macaque reaches juvenile age (Perrett and Mistlin, 1990). As an infant, it may be more important for the individual to be able to send effective gaze signals to its carer. In addition, adults within a monkey group would be unlikely to perceive a directed stare from an infant as threatening. As the individual matures, it becomes increasingly important to avoid eye contact and consequently the amount of pigment in the sclera increases to camouflage gaze direction. Perrett and Mistlin (1990) describe how adult macaque monkeys observe each other by averting their heads, but keeping watch out of the corner of their eyes. In this way they can covertly gather information and avoid the risk of a confrontation.

For humans, the risk of predation probably decreased with increased body size and the use of tools and fire. The evolution of the white sclera we have today could have developed to satisfy the need for enhanced communication between individuals and indeed the contrast it produces allows for its detection over great distances, especially in the expression of surprise where the area of exposed sclera is increased.

The Mouth

Open mouth expressions particularly happiness and surprise produce a facial configuration which generates quite marked contrast across the face. When the mouth is open, the mouth cavity is revealed which produces contrast against the lighter lips and teeth. In the investigations described in this chapter, participants frequently reported that the visibility of the teeth provided a powerful cue in the detection of the target. Bared teeth in other primates is usually a signal of threat or a display of dominance. Our sensitivity to what are now fairly tame orthodontics could be a consequence of our ancestors needs to detect the threat of attack.

The Eyebrows

Our eyebrows can be highly prominent features. In our evolution from hirsute creatures to largely smooth skinned organisms there must have been a selective advantage in retaining a small area of hair above the eyes. Their primary role is considered to be one of protection, shielding the eyes from sweat running from the forehead, however, they also lend themselves to communication. Perhaps we have adopted these features and learnt to mobilise them to signal affect. Large brow movements alter the amount of visible sclera dramatically as well as increasing the distance between the eyebrow and the eye. More subtle movements only change the distance between the eye and the eyebrow without altering the amount of visible sclera. The eyebrows are capable of moving not only upwards and downwards, but can also be brought together, or angled away from one another.

(i) Happiness and Surprise

Taking these properties of the signalling features into account it is possible to propose explanations for the results obtained in this study. The expressions of happiness and surprise appear to be capable of transmitting their affect over the furthest distance. In happiness, the eyes are slightly compressed as a result of the cheeks moving upwards. The images of happiness used in these experiments all have broad smiles with the lips separated and the teeth exposed. This kind of smile causes a deepening of the nasolabial folds generating prominent contours on the face. In the expression of surprise the eyebrows are curved and drawn upwards displaying a large area of eyelid and the amount of visible sclera is greatly increased enhancing the strength of the contrast against the dark iris. The jaw is lowered causing the mouth to open resulting in exposure of the teeth and the mouth cavity.

The fact that these gross movements of the facial features produce large fluctuations in light and dark regions across the face could explain why the expressions of happiness and surprise are capable of being transmitted over the furthest distances. Perhaps the ecological value of the ease of recognition for surprise stems from its similarity to the friendly greeting which shares the characteristic brow raise. The detectability of the expression of happiness could be attributed to the bared teeth and the confusability of this signal with a threat gesture. Both of these facial movements would be useful to detect at a distance since they could prime our 'fight or flight' response if we could distinguish between an approaching figure with a friendly or hostile countenance.

In addition, the smile is thought to have served a very different purpose in our evolutionary past which could explain the importance of developing the ability to transmit this signal well. Van Hooff (1972) proposed the view that human laughter and smiling had different phylogenetic roots. A relaxed open mouth display in non-human primates is widely believed to be the phylogenetic precursor of human laughter, and the silent bared teeth display as the possible ancestor of the human smile (Preuschoft, 1992). The silent bared teeth display is used by non-human primates to signal submission and appeasement while the relaxed open-mouth display, which is often called the 'play face' is an expression of fun. The play face is intended to function as a metacommunicative signal to clarify ambiguous movements in pretend biting or fighting. In the course of evolution the 'smile' has become emancipated from its original motivational background of appeasement and is now used by humans in similar contexts as laughter.

(ii) Sadness

The expression of sadness has the least powerful signal and is characterised by a lowering of the eyes with the inner region of the brows turned upwards and drawn together. The mouth is closed and the corners of the mouth may be turned downwards. None of these actions allow for large variations in contrast across the face and could explain the weakness of the signal. In addition, it is not immediately obvious why an ability to transmit or detect this expression over great distances would be of any benefit to an organism.

(iii) Anger, disgust and fear

Anger, disgust and fear all elicited a similar performance level in both psychophysical tasks. All are open mouth expressions in which the teeth are visible. The eyebrows play important expressive roles in each of these states being drawn downwards and together in anger, lowered in disgust and straightened and raised in fear. The most prominent cue for the recognition of disgust comes from the nose and upper lip. Usually the upper lip is raised which lifts the flanges of the nose. The bridge of the nose is often wrinkled and sometimes the tongue is brought forward in the mouth in an action simulating the expulsion of food. All of these facial movements lead to the generation of powerful communicative signals capable of travelling over fairly large distances, but do not produce changes in contrast as marked as those in the facial movements of happiness and surprise.

Calculations of visibility

Finally, the results found in this study confirm Hager and Ekman's (1979) finding that the face is a long distance transmitter which is capable of generating an effective signal with the strength to project over large distances. From the results of this study however, it seems unlikely that any of the expressions could be reliably detected at distances between 100 and 220m as Hager and Ekman (1979) proposed. If we consider the resolving power of the human visual system, the high frequency cut off point for a standard observer can be determined from the contrast sensitivity function plot. The finest, useable spatial frequency is approximately 60 cycles/deg. If we assume an average face width of 0.15m, at a viewing distance of 220m the face subtends 0.039 degrees of visual angle which translates to 2.34 cycles per face. With only such coarse visual information available, it seems highly improbable that any categorical decisions could be made about any expression being portrayed or in fact even if the stimuli would be recognisable as a face at all. Figure 3.10 shows a male 'happy' face at an equivalent viewing distance of 220m. (This image was created using software written by Roger Watt).

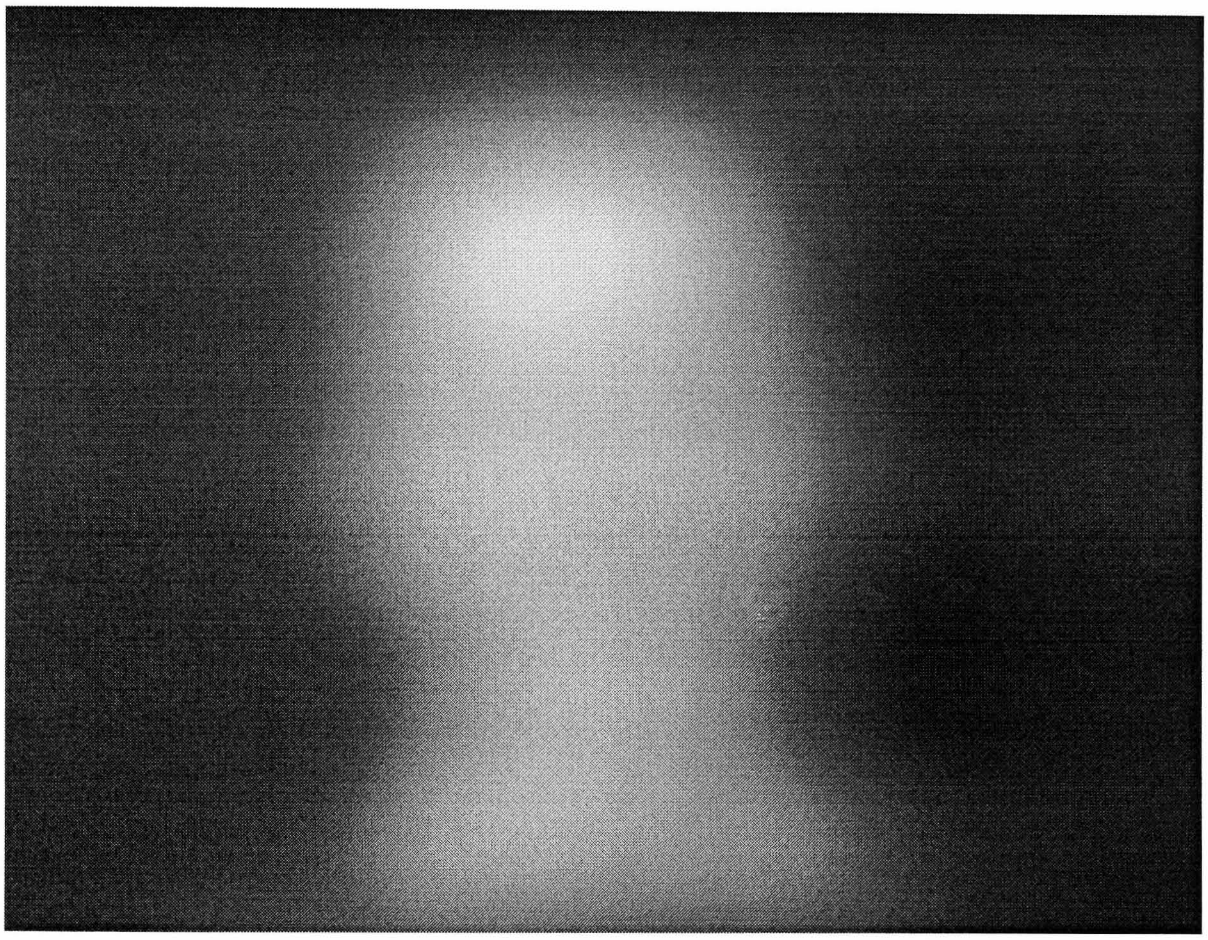


Figure 3.10: Full grey-level image of a male 'happy' face filtered to represent a real face at a 200m viewing distance.

Summary

In this chapter, our sensitivity to signals of facial affect was measured using two psychophysical paradigms. These techniques avoided the problems associated with the forced and free naming tasks described in Chapter 2 and revealed our sensitivities to each of six of our facial expressions. The results of these studies suggest that the expressions which are labelled with the least accuracy in free and forced choice tasks are not simply the hardest to see, and do not have the weakest signal. Expressions of fear and disgust which were labelled with the least accuracy in the tasks described in

Chapter 2 were not found to be difficult to detect. This suggests that these expressions are simply the most difficult to interpret, a finding which is important in later chapters of this thesis.

In the next chapter, our sensitivity to another of the social signals our faces convey, eye gaze direction, is measured and compared between a ‘live’ set-up of gazer and observer, and a screen-based task. In addition, the contribution of the facial surround in judgements of gaze direction is investigated.

4

Detecting Gaze Direction

Overview

In this chapter, sensitivity to gaze direction is measured and compared using two psychophysical techniques. The first examines the detectability of gaze direction between a gazer and an observer in a live set-up, and the second explores performance in an equivalent screen-based task using full grey-level images of the same gazer. The advantages of using a screen based task are many, but the primary advantage is that it allows for manipulations of the facial stimuli that are obviously not possible for a real face. The contribution of the facial surround in detecting gaze direction is investigated. Gaze direction sensitivity is explored in a variety of facial contexts, the eyes are presented upright or inverted, in isolation, or within the context of an upright or inverted face.

First, some of the literature on gaze perception which motivated these studies is described in more detail than was provided in Chapter 1. Gaze detection is an aspect of face processing that Bruce and Young (1986) omitted from their model of face processing. Neuropsychological evidence exists to support the idea that gaze and other types of face information are processed separately. In addition, neurophysiological evidence has shown the existence of populations of cells within the non-human primate which are specialised for the detection of faces and some which show specific sensitivity to eyes. The saliency of our eyes to the human neonate are described, but first some early psychophysical studies are reported which demonstrate how accurately we are able to detect these signals.

Psychophysical Investigations of Gaze Detection

Cline (1967) used an experimental set-up which was constructed similarly to that which will be described in this chapter. The apparatus were assembled such that the gazer was able to view a target board and the observer had a frontal view of the gazer's face and eyes. This was achieved by using a semi-silvered mirror. Fixation markers were positioned on the target board representing 2°, 8° and 12° of angular rotation of the gazer's eyes upwards, downwards, and to the left and right. (Only the horizontal gaze movements are of interest in this thesis). The observer had a circular response board in their reach which contained 65 points, including 13 which corresponded to the actual target markers radiating out from the central target. Observers were requested to point to the marker on the board which corresponded to the line of regard of the gazer. Cline reported that the lateral displacement of the gazer's eyes that the observer could just detect was 0.75°.

Gibson and Pick (1963) used the method of constant stimuli to determine gaze direction sensitivity in their study. A gazer gazed in turn at one of seven markers positioned along a horizontal line on or near to the face of the observer. Out of the seven markers, marker 'four' corresponded to a straight ahead look and markers three and five related to the observer's right and left ear respectively. Gazer and observer were separated by 200cm. Gibson and Pick calculated a threshold for detecting a deviation of the gazer's regard from the straight ahead position which corresponded to an angular deviation of the gazer's eyes of 2.8°.

Both of the psychophysical tasks described above demonstrate our acute sensitivity to where another individual is gazing. However, neither task allows for much experimenter control. The use of a response board like that described by Cline (1967) which required the observer to point to the target under fixation could result in the observer moving in such a way as to disturb the relative locations of the markers. In addition, the spacing of the 52 distractor points was not exactly specified but the first marker from the central target was at an eccentricity of 2° to the left and right. The very low threshold reported in their study could be due to the experimenter's sampling too coarsely at the upper end of the psychometric function (i.e. if 2° fell in the upper portion of the psychometric function). The use of a response board as described by Cline (1967) does not appear to be a very satisfactory way of conducting investigations into a highly sensitive process.

The psychophysical tasks in this chapter were designed so that only limited demands were made of the observers. Instead of observers having to point to markers or report that the gazer was looking at their nose or left shoulder, in these tasks, participants simply had to decide if the gazer was looking to their left, or to their right. This was the case for both the live gaze experiment and the screen based task.

Gaze Awareness

Despite our apparent sensitivity to eye contact when explicitly measured in psychophysical tasks, studies which have investigated sensitivity to gazing awareness during an interaction have shown that people are largely insensitive to the precise gazing pattern of their interactant (Argyle & Cook, 1976). The inference that most people draw from the directed gaze of another is that the person is attending to them.

Kleinke and Bustos (1973) reported that participants who were told that their fellow interlocutor looked at them less than normal (regardless of their actual gazing pattern) rated that person as less attentive. This finding demonstrates the way in which we attribute mutual gaze as a sign of interest when engaging in conversations with others, and failure to do so, as a sign of impoliteness or lack of concern. In many situations the very act of 'catching someone's eye' is sufficient to engage them in subsequent interaction. As a result of the strength of this facial signal, many waiters have developed a highly specialised mechanism for avoiding such ocular encounters.

In any given dyadic interaction, there is a certain amount of 'intimacy' which is signalled by various factors such as the nature of the conversation, the physical proximity of the interactants, smiling and eye-contact (Argyle & Dean 1965). These variables were reported to share an interactive relationship such that if one factor was disturbed, the others could compensate to return the levels of intimacy to their acceptable, or appropriate level.

Stephenson, Rutter and Dore (1972) manipulated the viewing distance between pairs of interactants and found that the duration of eye contact and the proportion of a pair's looking which resulted in eye contact increased with distance. This behaviour could be explained by considering Argyle and Dean's (1965) idea of intimacy levels. When the separation between interactants is large, there is a loss of intimacy which could be compensated for by an increase in the amount of eye contact. When the interactants are seated close together, intimacy levels may be too high and so the amount of eye contact is reduced to return the equilibrium.

When the viewing distance from a confederate is increased, or illumination decreased, participants are found to be more willing to assume eye contact (Martin & Jones 1982). The same result is apparent even when the gaze stimuli consists of a video recording which would have the effect of decreasing the intimacy of the task (Martin

& Rovira 1981). A preference to report eye contact when this signal becomes obscure could be explained if we assume on a basic survival level there would be a greater penalty for ignoring eye contact than for imagining its presence.

In the investigations reported in this chapter, gaze sensitivity is measured between a gazer and an observer and also when the observer discriminates gaze direction from a face presented on a computer screen. Performance in the two tasks is compared. It is expected that observers would experience different levels of intimacy in performing these tasks and that this may have an effect on their accuracy.

Gaze Detection in Infants

Developmental studies can provide us with indications regarding the maturation of the neural substrates which may underlie processes such as gaze detection. Baron-Cohen (1995a) has proposed that humans are born with a "mentalist bias" and as such are sensitive at an early age to signals which specify the intentions of other individuals. Baron-Cohen (1995a) suggests that the importance of the eyes in humans and primates in signalling potential threat and also in more pro-social behaviour, has led to the development of a neurocognitive system tuned to detect the eye orientation of other individuals, a system which Baron-Cohen has termed an eye direction detector (EDD). This EDD is supported by an intentionality detector (ID) which interprets directed movement as volitional and purposeful. The combination of the EDD and the ID would predict that young infants would interpret an adult who turned both their face and eyes towards them as an act which was goal directed and intentional and would interpret averted gaze as an interruption in communication. From this model, Caron, Caron, Roberts and Brooks (1997) predicted that the direction of an adult's gaze, towards or away from an infant should affect the responsiveness of the child, with infants decreasing their levels of smiling when gaze was averted. Caron and his colleagues presented three and five month old infants with video tapes of adult interactors who either appeared or did not appear to make eye contact. A lack of eye contact was produced in three different ways, by the adult averting just their eyes, averting the head and eyes and closing the eyes. A fourth condition involved averting the head alone but maintained eye contact. Their findings demonstrated that the younger infants were insensitive to adult eye gaze direction and were instead predominantly influenced by head orientation, and if the face was frontal, to eye visibility. The older infants were also found to be predominantly influenced by the orientation of the head but showed sensitivity to the visibility of the eye and also to the orientation of the eye. However, Caron et al (1997) found that the stimulus to which the infants were most attuned was frontal head with visible eyes, regardless of the direction of the gaze. Caron et al (1997) suggest that if infants do possess a neurocognitive system tuned to these social cues, it is more likely to involve a sensitivity to head direction and an eye detector rather than an eye direction detector as Baron-Cohen (1995a) has suggested. Caron et al (1997) defend their use of video episodes as stimuli by observing that a similar study conducted by Hains and Muir (1996) found comparable behaviour when the adult interactor was on video or when the set up was live.

Vecera and Johnson (1995) also conducted studies on the ability of young infants to discriminate between directed and averted gaze direction. They used a two choice preferential looking paradigm and formed a prediction based on the assumption that infants would show a difference in looking behaviour to the two stimuli if they perceived a difference between the faces. They made no predictions regarding which type of stimuli the infant would prefer to look at. They found that 4 month old infants were able to distinguish between direct and averted gaze from photographs of faces if the eyes were averted by a large amount (30°). An eccentricity of 15° was not distinguishable from a direct gaze. Samuels (1985) presented 3 month old infants with two images, each of the same face but one with a directed gaze and the other showing an averted gaze. The infants demonstrated no preference for either of the images and gazed equally at both the averted and the directed gaze. This finding would be consistent with the suggestion that young infants (below three months of age) are stimulated by an en face adult regardless of their eye direction. Vecera and Johnson (1995) suggest that the human infant may acquire the ability to discriminate gaze cues somewhere between 2.5 and 4 months postnatally. Caron et al's (1997) study would support this general suggestion although their results would suggest that the ability to discriminate gaze direction may take upwards of 5 months.

Vecera and Johnson (1995) also investigated whether or not young infants would show context effects in gaze discrimination tasks. They suggested that if infants were found to be influenced by the context of the surrounding face, this would support the hypothesis that gaze discrimination abilities emerge as a result of the maturation of central face processes, as opposed to the development of visual acuity or contrast sensitivity. These lower stages are not thought to be specifically tuned to processing gaze information, but are needed in order to perceive gaze direction, and as such, any difficulties with the detection of gaze in young infants could be attributable to the immaturity of these operations. Using a standard infant-controlled habituation task, infants were presented with schematic faces which were either intact or scrambled. Their investigations showed that 4 month old infants were able to detect the difference between directed and averted gaze and concluded that the ability to do this task was not therefore solely attributable to visual processes such as acuity. Performance in the task was attributed to the infant identifying and processing the stimuli as a face, which would indicate the role of higher order functions. When Vecera and Johnson conducted the same experiment with younger infants of 2.5 months of age, the results suggested that the majority (but not all) of these younger participants were unable to perform the gaze discrimination task. Vecera and Johnson (1995) cited this as providing evidence that the ability to discriminate gazing patterns is not innate and arises once the infant has experience of faces. However, just because an ability is not present from birth, does not necessarily preclude an innate contribution e.g. walking, ejaculation.

Neurophysiological and Neuropsychological Studies of Gaze Detection

Cells which respond selectively to faces have been found in the macaque brain in several sub-areas of cortex; the lateral and ventral surfaces of the inferior temporal cortex (IT) and the upper bank, lower bank and fundus of the superior temporal sulcus (STS). Each area is thought to be responsible for a particular role in face processing. Cells in the IT are concerned with the identification of familiar individuals whereas STS cells have been shown to be specialised to different views of the face and head (Perrett, Smith, Potter, Mistlin, Head, Milner, & Jeeves, 1985; Perrett, Oram, Harries, Bevan, Hietanen, Benson, & Thomas, 1991; Heywood & Cowey, 1992). Perrett et al (1991) reported that out of a sample of 119 cells in the STS, 110 exhibited view selectivity to the head. Furthermore, approximately 65% of these were found to be sensitive to gaze direction. Importantly, cells which were most excited by a frontal view of the face preferred eye contact, whereas those which were sensitive to a face in profile preferred gaze that was averted. From this observation, Perrett and his colleagues predicted that these cells could have a role in social attention. The ability to determine where another individual is attending would require a system which was capable of making very fine discriminations. Perrett and his colleagues concluded that these cells exhibited conjoint sensitivity to eye gaze and head orientation, but information from gaze cues could override information regarding head orientation.

The eye and head sensitivity exhibited by cells in the STS reported by Perrett et al (1985; 1991) was confirmed by Campbell, Heywood, Cowey, Regard, and Landis (1990) who explored the sensitivity of gaze direction in monkeys in which the rostral STS had been removed and also in two prosopagnosic patients. Both patients were impaired in their ability to recognise familiar individuals, label facial expressions, and in judging gender and age from the face. The gaze task in this investigation used stimuli which consisted of head and neck photographs of a single gazer who looked 5, 10 and 20° to the left or right with the head angled 20° to the left or right or straight ahead. In the study reported by Campbell and her colleagues, monkeys were taught to discriminate between the pairs of photographs. This task was readily learnt by the monkeys pre-operatively but performance was impaired after STS ablation. However, the specificity of the deficit could not be asserted as some visual functions may also have been disturbed. The same stimuli were used for the human participants who were asked to choose which of two faces was looking at them in a series of trials which incorporated all head and eye angles. Control participants were also shown the face pairings and a number of them also performed the task with the faces inverted. They found that for the seven control participants who viewed the stimuli in the inverted condition, gaze detection accuracy was only significantly impaired when the eyes were deviated by 5°. The prosopagnosic patients were impaired to different extents in the gaze discrimination tasks. KD was only impaired at discriminating eye deviations of 5° from the straight ahead faces. AB performed at chance levels for most of the discriminations and depended heavily on head posture rather than eye orientation when attempting to solve the task. AB's inability to perform gaze discrimination tasks was not simply due to poor vision, her visual acuity and contrast sensitivity were found to be good when measured using gratings. So, despite the similarity in the impairments experienced by both of the patients reported by Campbell and her colleagues, they showed a dissociation in their ability to discriminate gaze direction in addition to the dissociation between gaze direction perception and other face processing tasks.

Campbell et al (1990) found that normal participants discriminating gaze direction from inverted faces were less accurate when the faces were presented in this orientation for the 5° deviations compared to the upright condition although a high level of accuracy was apparent for the larger gaze deviations. Campbell et al (1990) compared this 'mild' effect of inversion with the more dramatic detrimental effects inversion has on identity recognition (Yin, 1969). They concluded that the detection of a straight ahead gaze need not be dependent on configural information which defines the relative positions of the facial features and that the presentation of two eyes in their correct horizontal alignment, albeit upside-down, was sufficient to support sensitivity to gaze direction perception.

In addition, patients AB and KD illustrated the fact that good acuity and contrast sensitivity are needed for, but not sufficient to perform the detailed analysis required for gaze direction detection. Campbell et al (1990) suggest that adequate gaze discrimination must require deeper levels of processing which they propose requires the establishment of a detailed representation of facial features within the context of a facial frame.

Coincident with this research, Vecera and Johnson (1995) investigated adult sensitivity to directed and averted gaze from different facial surrounds. They used simple schematic faces in their investigations representing upright, inverted and scrambled faces. The eyes either looked directly at the observer or the pupils were moved 0.1cm (0.1° of visual angle) to either the left or the right of the central position. All other facial features were constant in each of the conditions to maintain equal amounts of visual information. The task for the observers was to decide if the eyes were looking directly at them or away from them. They found that sensitivity to gaze direction was significantly higher in the upright face condition which Vecera and Johnson (1995) suggest provides evidence for the role of cortical circuits in gaze sensitivity which are also involved in other aspects of face processing.

Aim of the Present Study

The experiments described in this chapter investigate the contribution of the facial surround in processing gaze direction and also challenge the view presented by Campbell et al (1990) that eyes in an inverted configuration are able to support our sensitivity to gaze direction perception. Gaze accuracy is measured in a screen-based task when the face is upright, inverted or absent and when the eyes within these facial contexts are themselves either upright or inverted. Firstly, a straightforward measure of our accuracy in perceiving these signals is investigated in a psychophysical task with a gazer and an observer. This task was designed to capture sensitivities to a wide range of gaze eccentricities including a very narrow range around the 'straight ahead' position using a psychophysical technique designed to adapt to the performance of each participant. A comparison between the 'live' gaze task and the 'upright face-upright eyes' screen based task is made although the number of physical changes makes a direct comparison difficult.

Experiment 1: Measuring Gaze Direction Sensitivities Between a Gazer and an Observer.

This task used the psychophysical technique of Adaptive Probit Estimation (APE) which is an adaptive version of the method of constant stimuli (Watt & Andrews 1981). APE generates a range of stimulus levels between zero and infinity. At APE = 100% the target stimuli (i.e. the fixation marker) is presented at a large eccentricity and the participant is expected to perform perfectly. At APE = 0%, the target is presented in the straight ahead position, so the discrimination task is impossible and the participant is expected to respond randomly. During the course of the task, the APE program plots a psychometric function of the participant's responses which is adapted on each trial. APE presents a range of stimuli in a pseudo random sequence which is influenced by the participant's own response pattern. It samples most heavily at those points on the psychometric function where the participant's performance changes most rapidly. This paradigm is sensitive to the participant's performance during the task and can adjust its range of stimuli accordingly. Probit analysis is applied to the data to determine the best fitting cumulative Gaussian.

Participants

Four postgraduate students from the Psychology department at Stirling University participated in this study and were paid for their time. The average age of the participants (referred to as observers) was 26 years. All observers had normal or corrected-to-normal vision.

Design

The gazer was required to produce and hold a fixed gaze on a series of markers which were generated on a computer screen positioned directly in front of the gazer at a distance of 1.5m. As mutual gaze is believed to be such a powerful and salient stimulus, it was essential for this set-up that the gazer and participant be positioned such that they could experience this phenomenon. To allow the gazer an unobstructed view of the observer and the computer screen, a semi-silvered mirror was positioned at a 45° angle between the gazer and the screen. The distance between the gazer and the computer screen was equivalent to the apparent distance between the gazer and the observer (i.e. the sum of the distances of each to the mirror, $x = y + z$ in figure 4.1).

The experiment was conducted in a small room in which the walls had been covered with black card to increase the contrast of the reflected image by reducing any stray light. Two lamps were positioned overhead and on either side of the gazer to provide a uniform and powerful illumination of the gazer's face. All observers reported that the experience of looking at the image of the gazer in the mirror was as powerful as if they were looking directly at the gazer's face. To summarise, in this set-up, the gazer could see the computer screen and the face of the observer, and the observer could only see the face of the gazer.

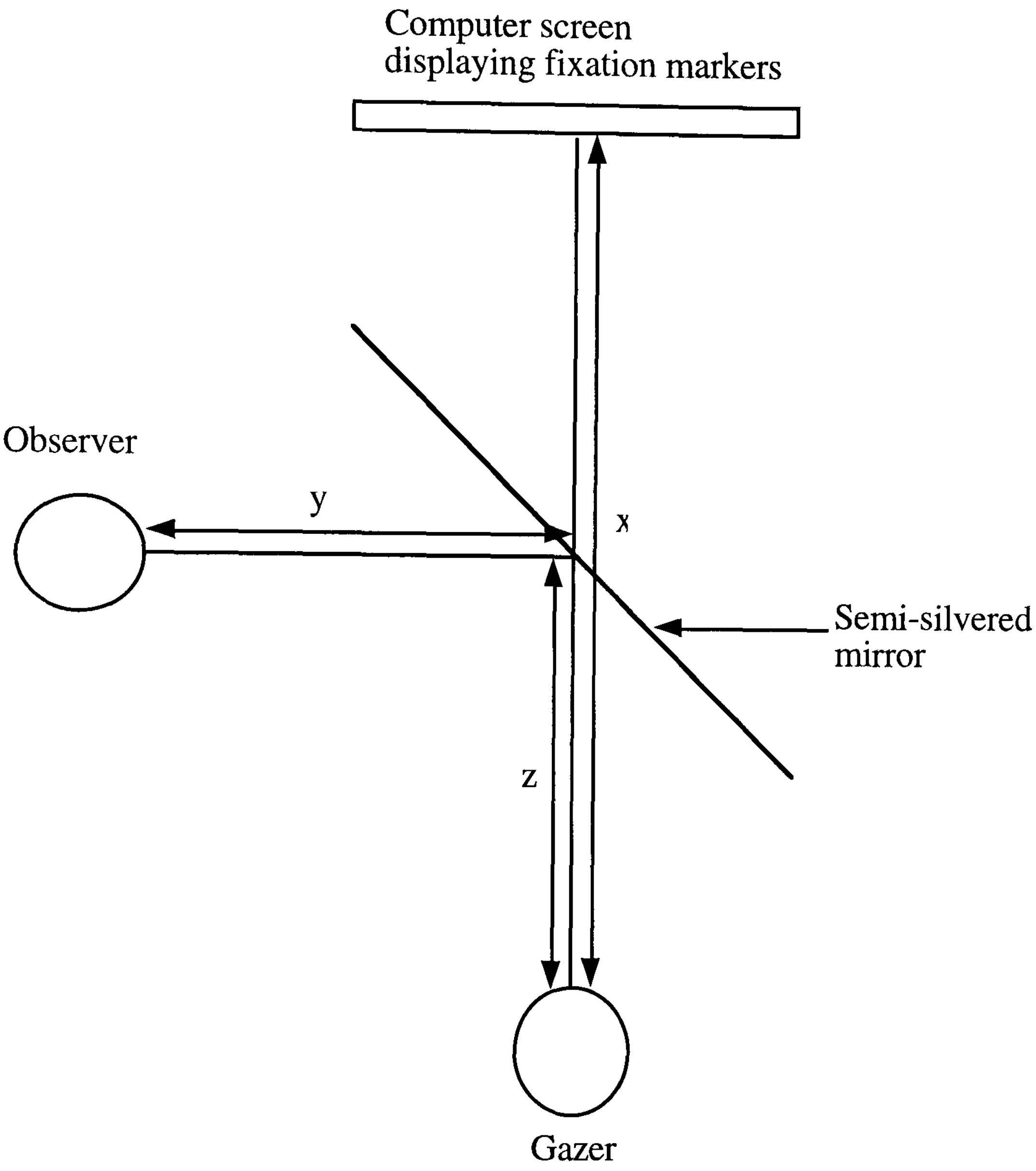


Figure 4.1: Plan of apparatus

Observers were seated during the experiment with their heads restrained by a chin rest with vertical supports to prevent lateral head shifts. The gazer's head was also prevented from making any movements by the use of a foam rubber head support which was positioned behind the gazer on the wall. The support was designed to cup the back of the head and to be invisible to the observer. This type of head restraint was chosen instead of a chin rest as it allowed a more natural view of the face.

Procedure

Observers took part in fourteen experimental blocks each containing eighty trials. Each block of trials began with the presentation of a large cross in the centre of the computer screen. The purpose of the cross was to align the gazer and observer. The gazer was able to instruct the observer to alter the position of the chin rest until the image of the horizontal part of the cross was at the same height as the observer's eyes, and the vertical component bisected the distance between the eyes. This was to ensure that a fixation target presented in the straight ahead location would appear directly between the observer's eyes. The experiment began once the observer was in the correct position.

A single trial consisted of the presentation of a small white target (1cm in diameter) which was presented straight ahead, or to various eccentricities to the left or right of centre along a horizontal axis. The observer was able to look at the gazer's face for an unlimited duration. Their task was to determine whether the gazer was looking to their left or to their right. The observer responded by pressing one of two keys to indicate a leftward or rightward gaze.

The observer was required to close their eyes immediately after making each decision. This was to prevent the observer viewing the gazer while they adjusted their fixation to the next target. This was to prevent the possibility of the observer perceiving a shift of focus to the left, for example, from a large rightward gaze to a smaller rightward gaze as a gaze in a leftward direction. While the observer's eyes were closed, the gazer would quickly relocate their gaze, the participant would open their eyes for the next trial after the presentation of an auditory signal.

Results

The sensitivity of each observer was calculated and their mean thresholds are reported in Table 4.1. APE operates using an arbitrary threshold of 84%, therefore the interpretation of a threshold of 1.89° is that an angular deviation of this amount to the left or right of 0°, will be reported as 1.89° to one side on 84% of trials, and on 16% of trials will be perceived as a gaze in the opposite direction.

Observer	Mean threshold	SD
P1	1.89°	0.65°
P2	2.56°	1.52°
P3	1.41°	0.36°
P4	2.62°	0.78°

Table 4.1: Mean threshold scores (degrees) for 4 participants in a gaze direction sensitivity task.

Gibson and Pick (1963) reported that a gazer's line of regard displaced by 9cm as seen from 200cm was just visible. This corresponds to an angular deviation of 2.6° which is comparable with the worst participant in this task, but slightly larger than the group's overall mean of 2.12°. Cline (1967) reported a threshold of 0.75° which is considerably smaller than the thresholds reported in this study. However, the response board used in his study was constructed with targets radiating out from a central position with the first marker positioned at an eccentricity of 2°. It could be the case that at a viewing distance of 122cm, participants were very accurate at discriminating between a straight ahead gaze and one averted by 2° and so made few errors when the gaze was at 0°. In addition, if we consider that in the psychophysical task described in this chapter, an angular displacement of 2.12° was detected significantly above chance at a viewing distance of 150cm, it is conceivable that the separation on the target board used by Cline (1967) was just great enough for a 2° gaze to be consistently discriminated from straight ahead.

Experiment 2: The Contribution of the Facial Surround in Gaze Discrimination Tasks (I)

Gaze direction sensitivity was measured when participants viewed grey level images of the same gazer who participated in Experiment 1. If Argyle and Dean's (1965) theory regarding eye contact and intimacy is correct, it may be the case that participants who took part in Experiment 1 felt uncomfortable maintaining a directed stare at the gazer to interpret their direction of gaze, particularly when the gaze was 0°, or close to 0°, and consequently made their decisions more rapidly and with less accuracy than they would have had the stimuli been presented to them on a screen. Conversely, the transition of the stimuli from a live set up to a grey-level image, reduced in size, could have the effect of reducing accuracy due to the artificiality of the stimuli. However, Martin and Rovira (1981) reported that a willingness to report eye contact when distance increased, or lighting decreased was evident from a live display and from a video taped display (Martin & Jones, 1982). In the next two investigations, sensitivities to gaze direction perception are measured using gaze stimuli presented on a screen and performance is compared to that found in Experiment 1.

The context of the facial surround, and its contribution to discriminating gaze direction is also investigated. Investigations by Vecera and Johnson (1995) coincident with this research demonstrated that gaze judgements were influenced by the facial context in which the eyes were presented. Their stimuli consisted of schematic faces upright, inverted and scrambled. In all conditions, the location of the eye region was maintained at fixation. They found that performance was significantly improved when the eyes were embedded in an upright face compared to either a scrambled or inverted face.

In the next experiment, the gaze stimuli are full grey-level images of a gazer's face presented upright and inverted. In addition, eyes are presented in isolation, without the presence of the facial surround in both an upright and inverted orientation. In Experiment 3, further manipulations of the stimuli are made and a more sensitive measure of observer's threshold obtained.

Participants

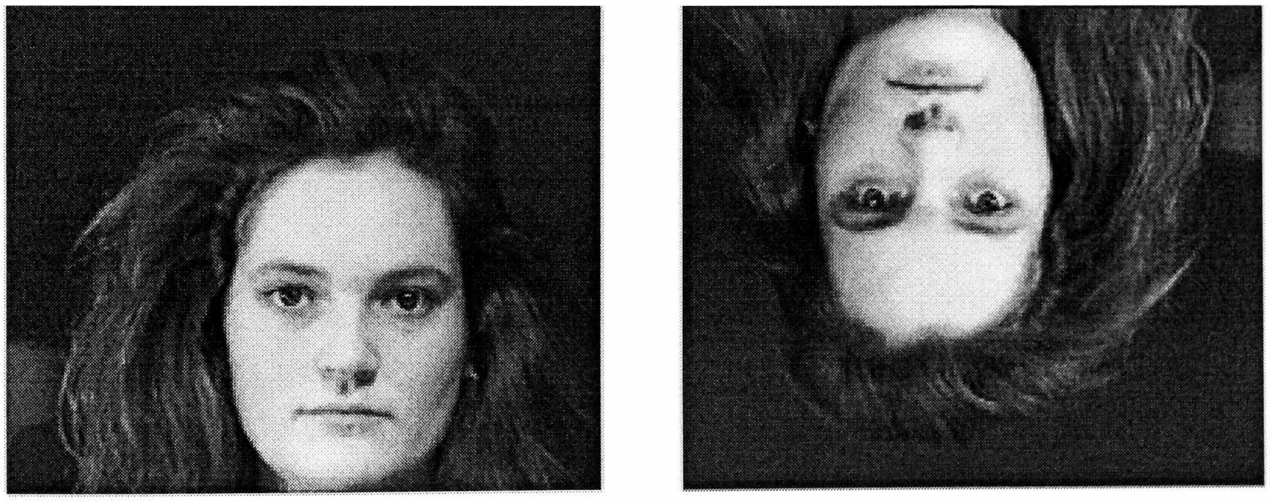
Forty undergraduate students from Stirling University participated in this study. Ages ranged from 17 to 23 years with a mean of 20.1 years. All participants reported normal or corrected-to-normal vision.

Materials: Creating the stimuli

The first set of images created for use in this task were obtained by filming the gazer while they fixated on a range of markers which were presented on a gaze chart in front of them. A video camera was positioned immediately beneath the gaze chart at the central position. When the video tape was examined it was found that the gazer did not appear to look straight ahead when the gazer fixated at 0°, but instead appeared to be gazing upwards slightly due to the relative positions of the camera and the chart. It was important for the design of the task for the line of regard of the gazer to appear to be directed towards the observer's eyes. To overcome the problem, the same experimental set-up was employed as was described in Experiment 1 (Figure 4.1). The video camera was positioned in the location of the observer and the gaze chart positioned in place of the computer screen. The semi-silvered mirror allowed a straight ahead gaze to be captured and despite the fact that the stimuli were reflections, the quality of the images was not impaired. The chart displayed a range of markers representing visual angles from 0 to 13.3° left and right in 0.23° increments. Each marker was revealed one at a time to the gazer who fixed their gaze on each of the targets in turn. Prior to each fixation, the gazer would hold up a label which corresponded to the next viewing angle. This was to ensure that the correct gaze eccentricity would be grabbed from the film when the stimuli were created.

To create the stimuli, the video tape was played through a Macintosh 660av computer and an image representing each gaze eccentricity grabbed using Apple software. The frame that was selected to represent a given angle was chosen after a succession of frames in which the eyes remained static.

The stimuli for the 'eyes only' condition were created by selecting the eye and brow region from the full face exemplars at each of the gaze angles. Care was taken to ensure that each image was the same size. Examples of the stimuli used in this experiment are shown in Figure 4.2



(a) Upright Face and Eyes (-2.75°) (b) Inverted Face and Eyes (+2.75°)

(c) Face Absent Eyes Upright (+7.3°) (d) Face Absent Eyes Inverted (-7.3°)

Figure 4.2: Examples of the stimuli used in Experiment 2 (not shown to size)

Design

This experiment was conducted as a between-subjects design with two factors. The first factor was facial context (present or absent). The second factor was orientation (upright or inverted).

The experiment was created using Superlab software. Stimuli were made for gaze eccentricities from 0° increasing in 0.23° increments to 2.76° and then in increments of 0.46° until an eccentricity of 13.3° in both a leftward and rightward direction. Each cue value was presented to the observer in a random order a total of three times. This made a total of 216 trials with an additional 12 trials of 'straight ahead' gaze (i.e. 0°).

Procedure

As in Experiment 1, the task for the observer in all of the following conditions was to decide if the gaze was directed to their left or to their right and to guess if they were undecided. Observers were not told that a proportion of trials consisted of straight ahead views only that some of the angular deviations were very small. Observers viewed each presentation of a stimulus for an unlimited duration and made their responses on a keyboard positioned in front of them. Once the observer made their decision a blank screen would be presented for 250 msec the offset of which triggered the next stimulus to appear. The screen was viewed binocularly and at a distance of 1m. The full-face images measured 11cm x 8.5cm and subtended 6.3° of visual angle, the 'eye's only' images measured 4cm by 1.4cm and subtended 2.29° of visual angle. Thus the eye features were the same size in each condition.

The task for observers taking part in either of the inverted conditions remained the same. There was no requirement for the observer to 'mentally rotate' the images, if the eyes appeared to be gazing in a leftward direction they were asked to respond by pressing the left key press regardless of the fact that the face was inverted and therefore displaying a rightward gaze.

Results and Discussion

Probit analysis was applied to the data to determine the best fitting cumulative Gaussian. From this analysis, thresholds were calculated which are reported in Table 4.2 as mean thresholds for ten participants in each condition.

		FACE CONTEXT			
		Face present		Face absent	
		Threshold	SD	Threshold	SD
Orientation	Upright	3.17°	2.04°	3.2°	1.04°
	Inverted	3.98°	1.18°	4.34°	1.54°

Table 4.2: Mean thresholds (degrees) for 10 participants in each of four gaze direction detection tasks.

The mean thresholds reported in Table 4.2 illustrate that sensitivity to gaze direction is greatest in the 'upright eyes' condition and the 'upright face-upright eyes' condition. Performance is also very similar between both the inverted conditions but with lower thresholds compared to the upright conditions. A 2 (context) x 2 (orientation) ANOVA conducted on the threshold scores revealed a non-significant two way interaction [F (1, 36) = 0.112, $p > 0.05$], a significant main effect of orientation [F (1, 36) = 4.21, $p < 0.05$], and a non-significant effect of context [F (1, 36) = 0.16, p = 0.69].

The cue values were sampled with a very high frequency, particularly around the smaller gaze eccentricities, and as a result of the small number of trials at each cue value, the data appeared to be very noisy. In Figure 4.3 the performance of one participant in the 'face upright-eyes upright' condition was taken and neighbouring cue values pooled to eliminate some of the noise. The data was plotted in bins of 2° and Figure 4.3 illustrates how well the curve fits the data.

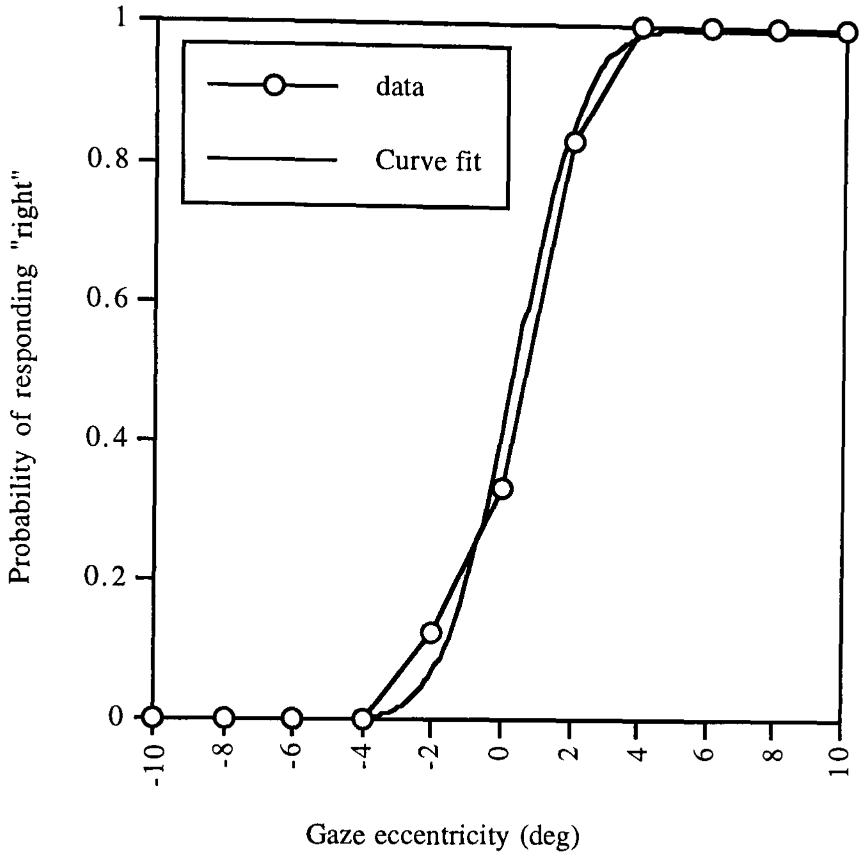


Figure 4.3: Psychometric function illustrating the performance of one participant in the 'face upright-eyes upright' condition of Experiment 2 with cue values pooled to eliminate noise.

The threshold for the upright face and eyes condition is higher in this experiment than that measured in the live gaze set up of Experiment 1 (3.17° compared to 2.12°). However, the number of trials at each of the cue values was much lower in this experiment so the power of the calculation is decreased.

In this experiment it would appear that sensitivity to gaze direction is not influenced by the facial surround. However, the power of the experiment was quite low with only three trials for each value of the cue. In the next experiment, the number of trials for each cue was doubled and the range reduced to avoid wasted trials at the larger eccentricities where performance was at ceiling for all observers. In addition, context was confounded with orientation in the design. In the next experiment, these factors are manipulated independently in further investigations into the contribution of the facial surround in gaze direction detection.

Experiment 3: The Contribution of the Facial Surround in Gaze Direction Detection Tasks (II)

A more sensitive test of gaze direction detection was employed in this experiment with more trials performed at each of the gaze eccentricities, and a narrower range of angles tested. Two additional conditions were tested in this experiment which presented the eyes in an incongruous orientation to the face. If the facial surround was found to contribute to our ability to perceive gaze direction, then performance in these conditions was expected to exceed that of the 'eyes only' conditions despite the fact that the facial surround and the orientation of the eyes was incongruous. In addition it was predicted that a contribution of the facial surround to gaze direction detection in the conditions described in Experiment 2 would be evident with an increase in the power of the design.

Participants

Thirty-six observers took part in this study (six in each of the six conditions). Observers were Open University students attending Summer School at Stirling University. The age of the observers ranged from 28 to 56 with a mean age of 37.9 years. Twenty-one females and fifteen males took part, all observers contributed on a voluntary basis.

Materials

Creating the stimuli for the first four conditions was described in the materials section of Experiment 2. To create the stimuli illustrated in Figure 4.4 the eye region was 'cut out' of each of the gaze stimuli and pasted over the face in its new orientation. A blending tool was then used to eliminate sharp lines so that the resulting 'face' appeared smooth. Each 'face' condition measured 11cm by 8.5cm and subtended 6.3° of visual angle and the 'eye's only' condition measured 4cm by 1.4cm and subtended 2.29° of visual angle. Thus the size of the eye features in each condition was the same.

(a) Inverted Face Upright Eyes (+0.46°) (b) Upright Face Inverted Eyes (+0.46°)

Figure 4.4: Examples of two of the conditions used in Experiment 3 (not to size)

Design

This experiment was conducted as a between-subjects design with two factors. The first factor was facial context (upright, inverted or absent). The second factor was eye orientation (upright or inverted).

In Experiment 2 it was found that a proportion of the cues representing the large gaze angles were superfluous as participants were found to reach ceiling performance at eccentricities of approximately 8°. For this reason, cues exceeding 8° were removed from the study and a greater proportion of trials were repeated around the smaller angles. The number of trials at all the remaining cue values was increased to six. This resulted in 264 trials with an additional twelve at 0°. The procedure was the same as that described in Experiment 2. The task in all cases required the observer to discriminate the direction of gaze to their left, or to their right. Observers were not told that a proportion of trials consisted of straight ahead views only that some of the angular deviations were very small.

Results

Mean thresholds and standard deviations are reported in Table 4.3 for six observers in each of the six conditions tested. As predicted, with an increase in the power of the design, differences in performance between the conditions became apparent. From the threshold data it is evident that participants demonstrate greatest sensitivity when the face *and* eyes are in the upright orientation. To compare performance in each of the conditions, the data was submitted to an ANOVA.

	FACE CONTEXT					
	Upright		Inverted		Absent	
	Threshold	SD	Threshold	SD	Threshold	SD
Eyes Upright	2.55°	1.18°	3.24°	1.07°	4.86°	0.55°
Eyes Inverted	6.79°	4.39°	6.62°	3.84°	5.78°	3.91°

Table 4.3: Mean threshold (degrees) for six participants in each of six gaze direction detection tasks.

The measures of standard deviation of the mean thresholds varied more than eight fold between two of the conditions. This result violated the assumptions of ANOVA, therefore the data was transformed by taking the reciprocal of the threshold values.

The results of this 3 (face context) x 2 (eye orientation) ANOVA showed there was no significant effect of the orientation of the face [F (2,30) = 2.397, p > 0.1], but a significant effect of eye orientation [F (1, 30) = 10.827, p < 0.01] and a significant interaction [F (2, 30) = 3.397, p = 0.047]. Simple Main Effects analysis revealed a highly significant effect of context (i.e. the face) in the eyes upright condition [F (2, 60) = 5.66, p <0.01] and a non-significant effect of context in the inverted eyes condition [F (2,60) = 0.135, p = 0.875], so the context of the facial surround did not influence gaze direction detection when the eyes were inverted. A post-hoc Newman Keuls (p<0.05) test revealed that performance in the 'Upright Face-Upright Eyes' condition was significantly different to that of the 'Face Absent-Eyes Upright' condition.

Simple main effects analysis also revealed that the orientation of the eyes was significant when the face was in the upright orientation [F (1, 30) = 12.37, p < 0.001], similarly, the orientation of the eyes was significant when the face was inverted [F (1, 30) = 5.15, p < 0.05]. There was no significant effect of the orientation of the eyes when the face was absent as can be seen in Figure 4.5.

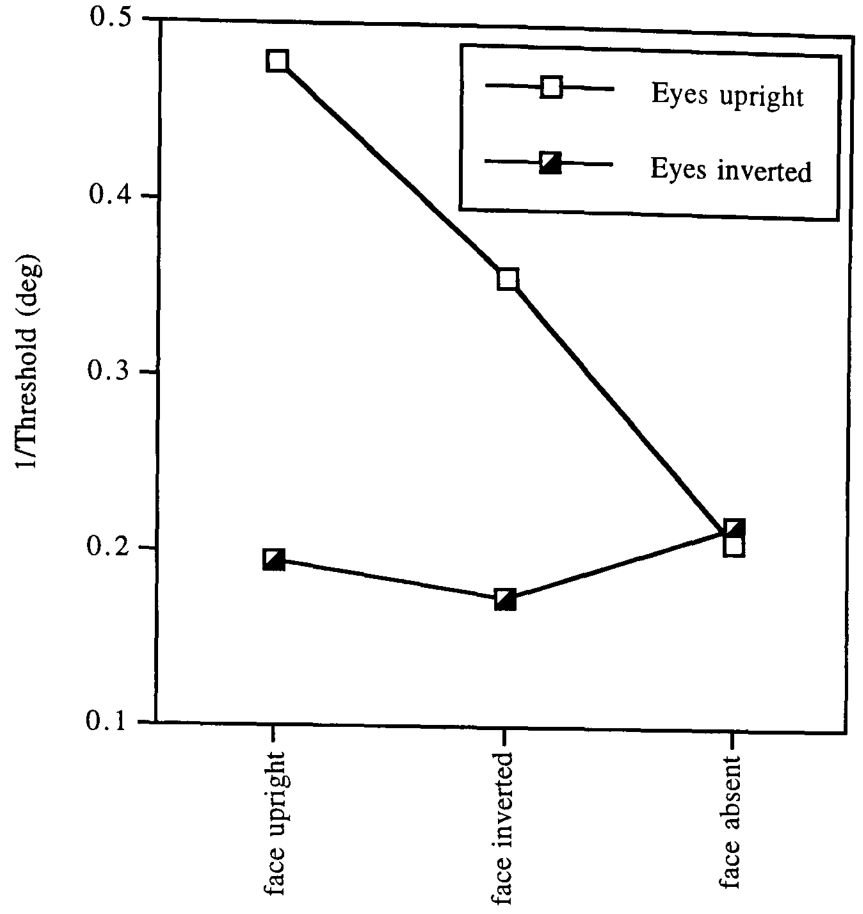


Figure 4.5: Mean performance of six observers in each of six conditions investigating the contribution of the facial surround in the detection of gaze direction

Summary

When the facial surround is absent and the eyes are presented in isolation, performance is not affected by the orientation of the eyes. Figure 4.5 illustrates that performance in the face absent condition is poor and independent of eye orientation. Performance in the 'upright face-upright eyes' condition is significantly better than that measured when the eyes are presented in isolation demonstrating the importance of the facial surround in this gaze discrimination task. The importance of the facial surround is also apparent when the eyes are presented in an upright orientation within the context of an inverted face. Despite the incongruity of the image, performance in this condition exceeds that seen when the eyes are presented in isolation although this does not reach statistical significance.

An alternative measure of sensitivity

The threshold values reported in each of the gaze direction detection experiments provide a measure of sensitivity for observers in this task. Another more visual way of interpreting the data is to calculate the angle subtended at the observer's eye by the lateral displacement of the gazer's eye, i.e. the distance through which the gazer's eye has to move before it is reliably detected by the observer is calculated. Figure 4.6 illustrates the angles and distances involved in the calculation and the results are reported in Table 4.4.

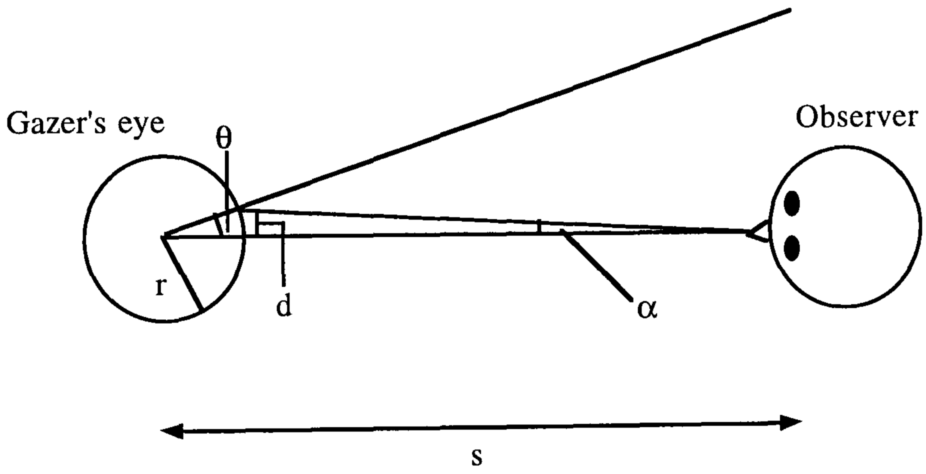


Figure 4.6: Illustration of the distances and angles involved in calculating the angle subtended at the observer's eyes (α) by the lateral displacement of the gazer's eyes (d).

θ = the angle through which the gazer's eye must turn before it is reliably detected by the observer (this is the threshold measured in radians)

s = the distance between the gazer and the observer

r = the radius of the gazer's eye

d = the distance through which the gazer's eye must turn before it is reliably detected by the observer

α = the angle subtended at the observer's eye by the lateral displacement of the gazers eye

Therefore, $\alpha = (r/s)\ \theta$ radians

The lateral displacement is calculated from:

$d = r\theta$

Experiment	α (arc mins)	SD (α) arc mins	d (mm)
Experiment 1	1.0	0.24	0.44
Experiment 2	0.7	0.43	0.22
Experiment 3	0.6	0.28	0.18

Table 4.4: Participants sensitivities to gaze direction as measured in three different tasks. Figures represent the angle subtended at the observers eye (α) by the lateral displacement of the gazer's eye (d).

It is slightly ambiguous to compare α and threshold values obtained in the different tasks as they only covary when measured in the same task. Hence Experiment 1 producing the smallest threshold but the largest α. However, these calculations provide us with a guide to sensitivity in each task. Clinically normal visual acuity is equivalent to one arc minute in the Snellen test, so it appears that performance in all of the gaze tasks is at least as good as Snellen acuity.

(The ratio of the size of the head on screen compared to the real size of the head was accounted for in these calculations).

The same analysis was applied to the data from Experiment 3 and the results are shown in Table 4.5.

	FACE CONTEXT					
	Upright		Inverted		Absent	
	α (arc mins)	d (mm)	α (arc mins)	d (mm)	α (arc mins)	d (mm)
Eyes Upright	0.6	0.18	0.78	0.23	1.2	0.34
Eyes Inverted	1.64	0.48	1.6	0.46	1.4	0.4

Table 4.5: Analyses of the angle subtended at the observer's eyes (α) by the lateral displacement of the gazer's eyes (d) in six gaze direction detection tasks.

In all of the gaze tasks which presented the eyes in an inverted orientation, regardless of the facial surround, the distance through which the gazer's eyes must be displaced before the deviation can be reliably detected is greater than in the upright eyes condition.

General Discussion

In this chapter sensitivity to gaze direction was measured from a live set-up of gazer and observer, and also from observer's perceptions of a screen image. In addition, gaze direction sensitivity was measured when the facial surround was manipulated to create different facial contexts. The aim of these investigations was to obtain a threshold measure for gaze sensitivity and to explore the contribution of the facial surround in making these fine discriminations.

A smaller threshold was reported for performance in the live gaze task compared to the screen tasks although all sensitivities were very similar. The worst performance was measured in Experiment 2, the first screen-based task, although the power of this experiment was limited due to the low number of trials at each of the stimulus values. Performance in Experiments 1 and 3 was very similar which would suggest that observers were not inhibited by the intimacy of a live gaze task and also that the task transferred well to screen. When the sensitivities of the observers in each of the experiments was compared by calculating the angle subtended at the observer's eye by the lateral displacement of the gazer's eye, it was apparent that sensitivities were very similar in all experiments.

Gibson and Pick (1963) suggested in their psychophysical experiment which measured gaze accuracy of an observer in a live set-up, that it was conceivable that the gazer unconsciously betrayed themselves when maintaining a straight ahead look by some slight change in expression. They therefore recommended the use of a model or pictures which would enable the experimenter to have complete control over the experiment and guarantee the elimination of unintentional cues. It would appear that there was no such problem in Experiment 1 as performance was found to be comparable between the live and screen based tasks. However, transferring the task to screen allowed for interesting manipulations of the stimuli.

How sensitivity was affected by manipulations of the facial surround is illustrated in Table 4.5 which reports 'α' and 'd' for each of the conditions tested in Experiment 3. In the screen based tasks, observers were most sensitive to gaze direction in the 'upright face-upright eyes' condition where the direction of gaze could be reliably detected from a displacement of the gazer's eyes of 0.18mm, in the 'upright face-inverted eyes' condition, the gazer's eyes needed a lateral displacement two and a half times greater than this to be reliably detected by the observers.

The aim of Experiment 2 and in particular Experiment 3 was to establish the influence of the facial surround in a gaze direction detection task. Figure 4.5 illustrates data from Experiment 3 and the effect of facial context in this task is evident. Observers are most sensitive to gaze direction when the face and eyes are upright. When the facial surround is removed, performance is significantly impaired. There is also a trend in the data to suggest that the presence of the facial surround facilitates gaze detection even when the orientation of the face and eyes is incongruous. Inverting the eyes had a very detrimental effect on gaze perception, most dramatically illustrated if performance in the 'face upright-eyes upright' and 'face upright-eyes inverted' conditions are compared. Observers commented on the hideousness of the images created for the 'upright face-inverted eyes' condition, a facial manipulation famously modelled by Margaret Thatcher in Thompson's illusion (1980). When the face is inverted, the individual features are processed separately at a local level rather than processing configural information as would happen in an upright face. So, when the face is presented in an upright orientation with inverted eyes, configural processing is disrupted which would appear to interfere with gaze direction perception. However, inverting the eyes had a detrimental effect on gaze perception regardless of the orientation or presence of a facial surround.

From these results it would seem that gaze discriminations from upright eyes are facilitated by the presence of the facial surround and as such it can be assumed that gaze discriminations are probably made in conjunction with other face processing analyses. These findings are consistent with Vecera and Johnson (1995) who concluded that a higher order mechanism was responsible for gaze discriminations and that low level visual characteristics like acuity and contrast sensitivity were simply needed for, but not responsible for gaze direction detection. Vecera and Johnson (1995) used schematic eyes and did not measure gaze sensitivity from eyes presented in isolation as they suggested that individual facial features could be discriminated as accurately as features presented in the context of an upright face (Homa, Haver, & Schwartz, 1976). The analyses performed on the data obtained in this study revealed that performance was significantly different in the 'face upright-eyes upright' condition and the 'face absent-eyes upright' condition. It may be the case that the *recognition* of isolated facial features is not influenced by a facial surround, however, the ability to make fine judgements like those needed in gaze direction *detection* are affected. However, more recent studies than Homa et al (1976), have demonstrated the importance of holistic processing in face recognition tasks (Young et al, 1987; Tanaka & Farah, 1993). The enhanced perceptibility of gaze judgements when the eyes are embedded within the context of the face is consistent with the operation of configural processes which operate not only for recognition, but also for the more finely tuned processes such as gaze direction detection.

Campbell et al (1990) proposed that the detection of a straight ahead gaze was not necessarily dependent on configural information and that the presentation of the two eyes in horizontal alignment was sufficient to support sensitivity to gaze direction perception. This would certainly be true if the eyes were gazing at large eccentricities as performance reached ceiling within the range of cues used in these tasks in all conditions. However, at small gaze eccentricities, the orientation of the face and eyes significantly effects the sensitivity to displacements of a gazer's eyes. Campbell and her colleagues did predict that gaze discriminations would require the establishment of a detailed representation of facial features within the context of a facial frame, a prediction which has been supported by the findings of this study.

These results are also compatible with neurophysiological studies which have reported populations of cells in the macaque STS which are sensitive to eye and head position (Perrett et al, 1991). Perrett and his colleagues found that information from the eyes and head was complimentary but that information regarding eye orientation could override information regarding head orientation. The results of this study would support a higher order process for gaze and the existence of a specialised system tuned to the perception of these ocular signals. However, the results of this investigation would seem to suggest that we are more sensitive to the combination of face and eyes and that the eyes presented in isolation have a significantly reduced signal value. Maruyama and Endo (1984) also found that the face had a powerful effect on the perception of gaze, describing the effect of the orientation of the head as "towing" the perceived line of gaze. This phenomenon would not occur if the eyes alone were capable of overriding signals from the face.

Overview

So far in this thesis, sensitivity to facial expressions and to gaze direction has been investigated using a variety of methodological approaches. The gaze tasks revealed sensitivity to gaze direction was in the region of Snellen acuity and that accuracy was comparable when the task was performed between a live gazer and observer and when the gazer's image was transferred to the screen. The facial surround was also found to contribute significantly to the detection of gaze direction.

The tasks performed in Chapter 3 demonstrated the signalling strengths of our facial expression and our ability to detect them under less than perfect conditions. Performance with signals of positive affect were consistently detected with the greatest reliability. Negative affect images were not detected as well, and in particular the expression of sadness was poorly detected in all experimental conditions.

In the next chapter, the neurological basis of social communication is introduced which describes a few of the many conditions that result in difficulties with processing social signals from the face. This chapter introduces some of the highly specialised problems experienced by patients suffering from congenital diseases or recovering from brain injuries. Chapter 6 then describes the use of some of the methodologies described in this and earlier chapters in the appraisal of two patients with bilateral amygdala damage, a brain pathology known to interfere with the processing of socially relevant information.

5

Neurological Basis of Social Communication

Overview

Investigations into the damaged human brain have revealed a number of distinct face processing impairments. Of obvious interest in this thesis are the impairments that result in specific difficulties with the processing of socially relevant information from the face such as emotion and eye gaze. In this chapter, a few of the neuropsychological conditions which are characterised by difficulties in processing these social signals are described. Damage to the amygdala is one brain pathology which has been shown to impair the processing of socially relevant signals and which appears to have a central role in many of the conditions described in this chapter. The pathology of other conditions described in this chapter, such as autism, is not entirely clear since many different areas of damage have been found in different cases (Baron-Cohen, 1995a).

Over the years there has been a very extensive body of research which has investigated face processing impairments as a result of brain injury (For example, Heywood & Cowey, 1992; Young, 1992). In particular this research has concentrated on prosopagnosia, a patient's inability to recognise familiar faces, (Young, Newcombe, de Haan, Small, & Hay, 1993; Bruyer, 1993; Benton, 1990). Rather less is known about impairments of facial expression perception. However, the existence of a double dissociation between these deficits has been extensively documented in neuropsychological investigations (Young et al, 1993), and confirmed in PET studies (Sergent, Ohta, MacDonald, & Zuck, 1994). The evidence from human studies has been supported with evidence from studies on primates which have revealed cells selective for facial identity in the inferior temporal gyrus and cells which respond to expression in the superior temporal sulcus (Hasselmo, Rolls, & Baylis, 1989). Recently however, interest is increasing in the field of expression analysis with evidence for specific impairments for the processing of individual expressions. For example, patients with Huntington's disease have been reported to exhibit difficulties with emotion perception (Jacobs, Shuren, & Heilman, 1995a) with a differentially severe impairment for the expression of disgust (Sprengelmeyer, Young, Calder, Karnat, Lange, Homberg, Perrett, & Rowland, 1996). In addition, patients with damage to the amygdala have been reported to be severely impaired in the perception of the emotion of fear (Calder, Young, Rowland, Perrett, Hodges, & Etcoff, 1996; Adolphs, Tranel, Damasio, & Damasio 1994; Scott, Young, Calder, Hellawell, Aggleton, & Johnson, 1997).

In this chapter face processing impairments as a result of congenital conditions such as autism, Huntington's disease and Urbach-Wiethe disease are described, as well as the delusional syndromes of Capgras and Cotard. In addition, face processing impairments which have arisen as a consequence of brain injury, in particular damage to the human amygdala are described. Many of the conditions described, particularly in relation to the damaged human amygdala, are very rare, consequently, evidence is often available from only a few patients.

Autism

Autism is a condition which severely affects many forms of social communication. Baron-Cohen (1995a) proposed three cardinal symptoms of autism: (i) abnormalities in social development, (ii) abnormalities in communication development, and (iii) abnormalities in pretend play. Autism effects 4-15 out of every 10,000 infants occurring more commonly in males than females. It is a disorder which occurs panculturally and crosses all social classes. At least some forms of autism are believed to be heritable and caused by biological factors since the risk of autism in identical twins or siblings is substantially higher than if autism simply struck by chance (Baron-Cohen, 1995a). The condition can also be associated with many biological abnormalities such as epilepsy, mental handicap and a number of brain pathologies.

Autism and the Salience of the Face

The face is where we, as un-brain injured people, focus our attention in order to communicate with other people since from it we are able to glean information regarding a person's affective state from the configuration of their facial features, attentional focus from their gaze and consequently perhaps their intentions. An autistic child appears not to have an understanding of the internal states of others such as their intentions, goals or desires, all of which can be inferred from facial signals. Autistic children lead very egocentric existences and do not invest the same interest in other people's faces as they fail to understand the communicative content of non-verbal gestures (Baron-Cohen, 1995a).

Autism and Gaze

Autistic children are frequently reported to have abnormal eye-contact. For a time, this behaviour was attributed to gaze avoidance (Richer, 1978), although Hermelin and O'Connor (1970) demonstrated that gaze avoidance did not occur if the children were specifically asked to look at a face. More recently, it has been shown that autistic individuals engage in the same overall quantity of eye-contact, but do not use gaze information in the same way as non-autistic individuals (Baron-Cohen, 1988). Gaze processing abnormalities are not the result of a more generalised impairment in face processing skills since children with autism are able to recognise identity and gender from photographs of faces (Langdell, 1978) and can recognize basic emotional expressions from the face (Hobson, Ouston, & Lee 1988). However, Langdell (1978) reported that autistic individuals appeared to make less use of the eye region when making judgements of facial identity.

Baron-Cohen (1994) and Baron-Cohen, Campbell, Karmiloff-Smith, Grant, & Walker (1995b), described a series of studies designed to investigate if children with autism were able to understand and use gaze information in the same way as normally developing children. On the premise that one of the many roles of our gazing behaviour is to communicate interest in an external object, Baron-Cohen et al (1995b) conducted a series of experiments which used a cartoon drawing of a face which was shown with its line of regard directed towards one of four objects (sweets). The children were asked which of the sweets the cartoon character wanted. Autistic children failed to use the eye-direction of the cartoon figure to infer mental states such as interest or desire, and instead responded in an egocentric fashion by choosing the sweet they would like regardless of the gaze of the cartoon. Baron-Cohen et al (1995b) did show that autistic children were able to judge which of a pair of cartoon faces was looking at them, illustrating that they understood the concept of directed and averted gaze. Baron-Cohen and his colleagues suggested that this provided evidence that autistic children were able to attend to the eyes and face. However, the amount of information contained within a simple cartoon compared to the complexities of a real, animated face is hardly comparable. Cole (1997) in his book "About Face" describes encounters he has had with adult autistics who attribute their lack of eye contact to a defensive mechanism designed to limit incoming sensory information. For some, the intense arousal experienced in eye contact is too great and so to prevent a sensory overload, eye-contact is avoided. This description is reminiscent of Exline and Winters (1966) who described the gazing behaviour of normals during an interaction. They explained the action of a speaker looking away from their partner during an utterance as a sign that the speaker was organising their thoughts and that this required a decrease in incoming information which was achieved by averting their gaze from their partner's face. In autistic individuals, perhaps a similar system is in operation for much of the time but enormously magnified. Returning to Baron-Cohen's study, the autistic children's ability to judge where the cartoon face was looking at least demonstrated that their poor performance in the 'four sweets task' was not due to an inability to understand where someone was looking, but was caused by an inability to infer mental states from eye-direction. Baron-Cohen suggests that this is because children with autism have difficulty in mapping internal concepts like desire onto external behaviours such as gaze direction.

Leekam, Baron-Cohen, Perrett, Milders, & Brown (1997) demonstrated that children with autism were able to determine what another person was looking at if instructed to do so. However, they were unable to follow another's gaze direction in response to head or eye movements. This finding illustrates that autistic children have the required geometric skill to compute gaze direction but lack the ability to employ this skill of their own volition. Leekam et al (1997) suggest that this could be the result of a general difficulty experienced by autistic individuals in shifting attention, or that children with autism are unable to marry the relation between the orientation of a gazer's head and the direction in which they should look. This latter suggestion is supported by Baron-Cohen's (1995b) finding that autistic children failed to use gaze direction as a signal of intention or desire.

Language development is abnormal and often severely delayed in autism. Baron-Cohen et al (1997) suggested that the poor language abilities observed in autism could be attributable to an ignorance of the language conveyed by the eyes and describes children with autism as being relatively “blind” to the mentalistic significance of this facial feature. Their study investigated whether children with autism used the same strategies as normally developing children in inferring a speaker's intended referent by attending to the speaker's direction of gaze when the speaker used a novel word in the presence of novel objects. They found that only 29.4% of autistic children compared to 70.6% with mental handicap used this strategy and instead relied on an egocentric strategy which assumed that the novel word belonged to the object that the autistic child was looking at. Baron-Cohen et al (1997) suggest that this could explain the delay in language acquisition observed in some cases of autism since this strategy would lead to false mappings of words and objects.

The origins of the egocentric behaviour observed in autistic individuals is unclear. It is possible that the egocentrism arises as a consequence of a lack of a 'Theory of Mind', equally the development of a 'Theory of Mind' could be denied as a result of the egocentrism. Assigning 'cause and effect' in this domain is not a simple task.

Identity Recognition in Autism

Langdell (1978) tested two age groups of normal and autistic children and a group with mental handicap for their ability to recognise their peers from isolated facial features and inverted photographs. Normal children and those with mental handicap were found to rely on the upper regions of the face for identification, whereas the younger autistic children found the lower features more useful. The older autistic children showed no specific reliance on any one area and appeared to have a more homogenous knowledge of the entire face and could use both the upper and lower portions of the face for recognition.

If the face is regarded as a simple visual pattern, the mouth and eye areas may rank equally as the most discriminable areas of the human face. If the face was not viewed as a social stimulus, the area of the face from the mouth down may be just as easy to recognise as the area from the eye upwards.

The younger autistic children and their normal controls were found to be poor at identifying their peers from inverted faces, whereas the older autistic children performed very well. Langdell (1978) suggested that the younger autistic and normal children may both use a certain portion of the face as a focal centre, whereas the older autistic children did not appear to have a reliance on any specific area for recognition. Thus both the younger autistic and normal children may possess fairly well defined scanning strategies that centre around this focal area. Inversion of faces then, changes the relative position of the focal centre and may therefore disrupt the scanning strategy to much the same extent for each of these groups. The older autistic children by contrast, lacking a focal centre may have a less well defined or more flexible scanning strategy such that their recognition ability would be less affected by transformation of the faces.

Cole (1997) reported a high functioning autistic adult who commented that she had only looked at her husband's face in its entirety twice, a strategy to limit incoming sensory information. She described how she would look at individual facial features, such as, *an* eyebrow. If autistic individuals do not process faces holistically and instead use a more feature based analysis which is not dependent on configural information, autistic individuals would be less likely to exhibit the same decrease in recognition shown by non-autistic individuals when a face is inverted.

Facial Expression Sensitivity in Autism

Weeks and Hobson (1987) devised a task in which autistic and non-autistic retarded children were required to sort a set of photographs either according to facial expression (happiness or sadness), type of hat, (floppy or woollen), or sex of the person depicted. They found that most non-autistic children chose to sort by facial expression before they sorted by type of hat whereas the reverse was true of autistic children.

Hobson, Ouston and Lee (1988) investigated the ability of a group of autistic adolescents to recognise identity and emotion from photographs. In each of the photographs, the outline of the individual's face was cut out so as to mask the hair. Hobson and his colleagues used full face photographs, photographs in which the mouth had been blanked out and photographs in which the mouth and brow region had been blanked out. They used a total of sixteen photographs, of two males and two females each portraying the expressions of happiness, sadness, anger, and fear. The photographs were used in sorting tasks in tests of emotion recognition and identity recognition. Participants were required to recognise emotion across changes in identity and identity across changes in expression.

Hobson et al (1988) found that the ability of the autistic group to match full faces for emotion and identity was not significantly different from that of their age and IQ matched controls. However, when the cues to emotion and identity were reduced by masking the facial features, the autistic participants demonstrated a decrease in performance which was more profound for the recognition of emotion than identity relative to the non-autistic group. Non-autistic participants were able to sustain relatively high levels of performance in emotion recognition when blank mouth and blank mouth and forehead faces were presented.

As in Langdell's study (1978), autistic individuals exhibited a superior ability compared to their controls in processing information from inverted faces. The autistic adolescents were found to outperform their control participants in judging inverted faces by identity both for photographs of their peers and for unfamiliar faces, and also by emotion. Hobson et al (1988) suggested that this superior performance was a result of the autistic children using strategies which were different either in kind or efficiency from those used by non-autistic children. Hobson et al (1988) questioned the existence of a relationship between the degree to which recognition ability was orientation specific, and the degree to which individuals perceived the objects as meaningful. If autistic individuals view the face simply as an abstract pattern then they would employ the same strategy for person identification regardless of the orientation of the face. Hobson et al (1988) suggested that the children could have been sorting the upright faces with little or no regard for the meaning of personal identity or emotion and were matching the images purely as abstract patterns. However, the autistic participants were more proficient in sorting full upright faces than in sorting these same faces presented upside-down, a finding which may simply reflect the greater familiarity of upright faces rather than their meaning.

Brain Pathologies in Autism

Little is known about the site or sites of brain damage in autism since many different pathologies have been reported from different individual cases. Allman and Brothers (1994) have suggested that autism could stem from a defect associated with the amygdala since autistic individuals fail to use gaze direction cues normally (Baron-Cohen, 1995b) and the amygdala is a brain region which has associations with gaze sensitive neurons (Brothers and Ring, 1993). In addition, patients with damage to the amygdaloid complex characteristically show abnormalities of social perception, diminished judgement of affective signals, in particular the emotion of fear, and a failure to attach emotional significance to stimuli, e.g. the threat potential of a dangerous situation, all of which are symptoms which are commonly observed in autism.

Two other brain areas that have been shown to be dysfunctional in autism are the temporal and frontal lobes. Baron-Cohen (1995a) describes how many of the symptoms typical of autism are also associated with characteristic behaviours of brain lesions from these particular areas. For example, lesions to the Superior Temporal Sulcus (STS) involve impaired gaze direction detection and face processing tasks and possibly language difficulties. Damage to the orbito-frontal cortex (OFC) often manifests itself with diminished aggression, excessive activity, abnormal pragmatics of language, impaired social judgement, diminished appreciation of danger and hyper-olfactory exploration. Once again, these symptoms are common complaints experienced by people with autism.

Delusional Syndromes

Capgras delusion and Cotard's delusion are phenomenally distinct but share several similarities in that they are both very rare neurological syndromes which give rise to delusional beliefs about existence and also impairments in facial processing.

Capgras Syndrome

In Capgras syndrome patients come to regard close family members, typically parents, children, spouse or siblings as 'imposters'. Patients often claim that the imposter looks exactly like the family member but is not them. The Capgras patient, despite this bizarre delusion is often mentally lucid in other respects. Capgras syndrome is most commonly observed in psychotic patients although one third of cases occur in conjunction with traumatic brain lesions which suggests a biological basis to the syndrome.

Pathology of Capgras Syndrome

Ellis and Young (1990) have proposed that Capgras syndrome is a 'mirror image' of prosopagnosia, a related although distinct disorder. Prosopagnosia is characterised by the patient's inability to recognise familiar faces (For example, Young et al, 1993; Bruyer, 1993). This face agnosia typically occurs with bilateral lesions in the region of the brain believed to be partially specialised for face recognition, the inferior temporal lobes (IT). In some cases of prosopagnosia, covert recognition is possible, such that despite the patient reporting that they are unable to distinguish between a set of faces containing a mixture of both familiar and unfamiliar faces, they, like un-brain injured people, register a stronger skin conductance to the known faces. This covert recognition implies that the area of the brain responsible for person identity still has functional connections to the limbic system. Ellis and Young (1990) suggest that the recognition of a familiar face involves two components. The first is for the conscious recognition of the face and the recall of the relevant semantic information, and the second which is responsible for the limbic mediated emotional arousal which includes the feelings of familiarity which accompany the recognition of a familiar face. A dissociation between these components would explain the recorded skin conductance in the absence of covert recognition. In the case of Capgras delusion, Ellis and Young (1990) suggest that the ventral route from the visual centres to the temporal lobes is preserved which thus allows overt person identification, however, the dorsal visual route which is responsible for giving the face its emotional significance is damaged. As a result of the damage to these neuroanatomical pathways which are responsible for providing the emotional reactions to familiar visual stimuli, Young, Reid, Wright and Hellawell (1993b) suggest that the condition of Capgras delusion thus arises as a consequence of the patient attempting to reconcile the fact that these familiar stimuli no longer have the appropriate emotional significance. This suggestion is consistent with the observation that Capgras patients most commonly misidentify their close relatives as presumably they would be expected to arouse the strongest emotional response. However, a patient, DS, described by Hirstein and Ramachandran (1997) who had been diagnosed with this syndrome also produced multiple identities for an unfamiliar face which was used in a task of gaze direction perception (see later).

Hirstein and Ramachandran (1997) have proposed an alternative account of the pathology behind this delusional syndrome suggesting that Capgras arises in the event of a failure of communication between areas of ventral stream processing in the temporal lobe, for example they suggest IT and other face sensitive areas around the superior temporal sulcus (STS), and the limbic complex. Hirstein and Ramachandran (1997) report how this breakdown in communication between areas of ventral stream processing in the temporal lobe and the limbic complex, particularly the amygdala, leads to disturbances in the management of memory. They explain the phenomena by supposing that each time we meet a new person, our brains open up a new file into which we put all information regarding this person. However, when DS meets a new person, his brain creates a new file, as it should, but on meeting this person for a second time, even if the separation is only a matter of minutes, instead of retrieving the original file, DS creates a totally new file. Hirstein and Ramachandran (1997) suggest that the absence of any arousal of recognition when DS meets the person again causes the brain to create a new file. Alternatively, DS could have a more basic problem in his ability to extract and integrate common factors between episodic events. DS does not forget about the previous person but assumes that the next encounter with them is in fact a new person who simply looks a lot like the original. Cells selective for faces in the amygdala have been reported to be involved in linking successive views of the same face across time (Rolls, 1995). Leonard, Rolls, Wilson and Baylis (1985) have suggested that the social and emotional behaviour produced as a result of damage to the amygdala in monkeys, is in part due to damage to a neuronal system which is specialized in using information from faces so that appropriate social and emotional responses can be made to different individuals. Damage to such a system in humans could be seen to result in the loss of affective attachment to familiar individuals seen in Capgras delusion. In addition, recent studies have revealed a role for the amygdala in the memory of emotional events (Cahill, Babinsky, Markowitsch, & McGaugh, 1995; O'Carroll, Drysdale, Young, Calder, & Cahill 1997).

Case studies with these rare patients have revealed more generalised face processing impairments which are described in the next section.

Facial Expression Recognition in Capgras Syndrome

The patient DS was found to be unimpaired in a task of expression recognition (Hirstein and Ramachandran, 1997). Pairs of photographs were shown to DS of models posing basic emotions, the task for DS was to name the expression and also to decide if the two different models were expressing the same or a different emotion. This task posed no difficulty for DS. Hirstein and Ramachandran (1997) suggested that DS's problems were not in recognising emotion from the face, but in associating the appropriate affect in his memory for a particular familiar face.

However, evidence for the impaired processing of facial expressions in Capgras syndrome was presented by Young, Reid, Wright and Hellawell (1993b). Patients ML and MC were both impaired in their ability to label facial expressions in a 6AFC task with faces from the Ekman and Friesen (1976) series. Unfortunately the scores reported by Young et al (1993b) were collapsed across expression so the possibility that they were more impaired in labelling some expressions than others, or differentially severely impaired for a particular expression was not apparent. Young, Leafhead and Szulecka (1994) also reported that another Capgras patient, GS, was severely impaired in his ability to recognise emotion in a forced choice task.

Gaze Detection in Capgras Syndrome

Hirstein and Ramachandran (1997) reported that DS was severely impaired in a simple gaze direction detection task. DS was asked to determine if the person in a series of photographs was looking at him or away from him. The stimuli consisted of a series of photographs of a single model gazing at various eccentricities away from the straight ahead position. At small angular deviations, 3.3° and 6.6°, DS was only 17% and 39% accurate respectively. Even at 9.9° when controls were performing at ceiling, DS only scored 50% correct. Although the identity of the model was the same throughout the task, DS perceived a total of three different models during the 30 trials of the task, attesting that they looked alike but that their ages were different.

Familiar Face Recognition in Capgras Delusion

Young et al (1993b) described two patients who had experienced Capgras delusion, MC and ML. Both patients were found to be impaired in their ability to name, or provide occupations for familiar faces. However, neither patient made errors in their ability to reject unfamiliar faces as faces that were not known to them. Both were also found to be impaired in their ability to match unfamiliar faces when presented with a target face and six possible identities. In the Warrington Recognition Memory Test, MC's performance was not significantly different to controls for her recognition memory of faces or words, ML demonstrated excellent recognition memory for words, but performed no better than chance in her recognition memory for faces.

Hirstein and Ramachandran (1997) reported that DS was unable to recognise himself from photographs, he would comment that the man in the picture was another DS who looked identical to him but was not him. He did not experience this delusion of himself when looking in the mirror however.

Cotard Delusion

Cotard delusion sufferers come to the conclusion that they must be dead because they 'feel nothing inside', this has parallels with the reported lack of affective responses in Capgras patients.

Facial Expression Recognition in Cotard Delusion

Young et al (1994) tested two patients, WI and JK on their ability to recognise emotional facial expressions using images from the Ekman and Friesen (1976) series. The patients were required to attribute a label to 24 exemplars of facial affect. Both patients scored 19 out of 24 which was significantly below the control mean in this task.

Person Identification in Cotard Delusion

Young et al (1994) also tested the recognition of familiar faces by presenting a set of photographs to the patients which consisted of a mixture of familiar and unfamiliar individuals. The task for the patients was to identify the familiar individual and provide their occupation and name. Both patient's responses were significantly below that of the mean control data. Impaired performance was also measured on the Benton test of face recognition which requires patients to match a target face with one of 6 simultaneously presented faces. Recognition memory as tested using Warringtons Recognition Memory Test (RMT) was impaired for both WI and JK. In marked contrast to the poor performance with faces, recognition memory for words was unaffected, a finding mirrored by the Capgras patients (Young et al, 1993b).

Discussion

The common factors between the two delusional syndromes described here is that both types of sufferer share a delusional belief about existence, either of their own, or of other people's, and that both experience difficulties with general face processing tasks. Young et al (1994) suggest that the pathophysiology and neuropsychology of the two syndromes may be related and that the delusions manifested by the patients are attempts to make sense of fundamentally similar experiences. Young also reports that cases of the syndromes co-existing or being experienced sequentially have been described which strengthens the idea of a link between the two syndromes.

The exact pathophysiology has yet to be precisely determined. Ellis and Young (1990) proposed that the syndrome was the result of damage to the dorsal stream with the ventral stream intact. However, as Hirstein and Ramachandran (1997) pointed out, the ventral stream is required to perform a variety of face processing tasks which are found to be impaired in patients with Capgras. They suggest instead, that the syndrome arises from a breakdown in communication between the ventral stream processing in the temporal lobe and the limbic system, in particular the amygdala.

Face Processing in Patients with Amygdala Damage

Selective damage to the human amygdala is rare. In the majority of cases, patients have incurred damage to this brain area as a result of surgical procedures for epilepsy, or as part of more widespread damage after brain injury. Urbach-Wiethe disease is an extremely rare hereditary disorder that causes calcium to deposit in the amygdaloid complex, and can occur without affecting neighbouring neocortical structures or the hippocampus. Recently a wealth of evidence from neurophysiological and neuropsychological research, has come to light which defines a role for this brain structure in the emotion of fear and the appraisal of danger (LeDoux, 1995). Before the neuropsychological research is presented, a historical background of the amygdala, and its emerging role as a brain structure involved in aspects of our emotions is described, with evidence from primate and human investigations.

The Amygdala

The human amygdala is roughly the size and shape of an almond nut and forms part of the limbic system. It lies deeply buried in the temporal lobe, in the oldest part of our cerebral hemispheres. Figure 6.1 illustrates its location in the human brain.
The nuclei of the amygdaloid complex include the medial, lateral, basal and central, all of which are anatomically distinct. The limbic system also contains parts of the hypothalamus, the septal area, the hippocampus, the mammillary bodies and parts of the cortex. These structures form a crude border around the brain stem. As part of the limbic system, the amygdaloid complex has been implicated in many brain functions including emotion, learning, memory and epilepsy (Aggleton, 1992).

The early anatomists assumed that the role of the limbic system was concerned exclusively with smell due to its connections with the olfactory receptors. Then, almost a half century ago, the physiologist MacLean (1949) noted that the evolution of the limbic system appeared to coincide with the development of emotional responses. Kluver and Bucy (1939) reported how damage to the limbic system had dramatic effects on emotional behaviour. However, early research which attempted to identify the role of the amygdala produced conflicting evidence since removal of the amygdala was found to have diametrically contrasting effects on emotional behaviour.

Kluver and Bucy (1939) reported that damage to the amygdala resulted in extreme docility from normally irritable monkeys. In addition the monkeys were noted for no longer expressing any of their usual fears or avoidance responses and were found to approach previously threatening stimuli. Karl Pribram in 1962 noted that in higher animals such as monkeys, the dominant-submissive hierarchy was under neural control and involved the amygdala. He discovered that removal of the dominant males amygdala resulted in submissive behaviour when reintroduced to the colony. This resulted in relegation to the bottom of the social hierarchy with the previous 'second in command' taking over as the dominant male.

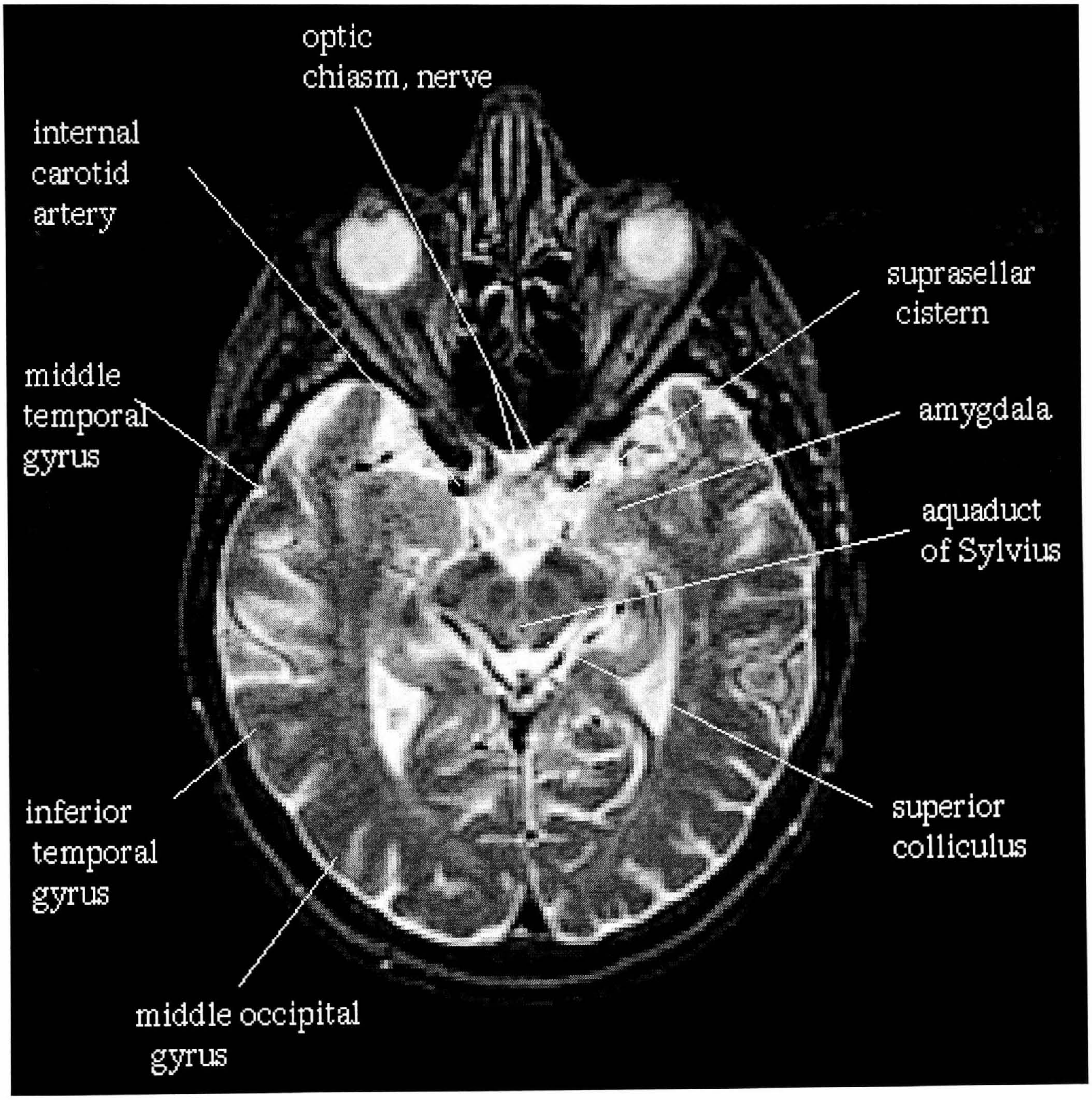


Figure 6.1: MRI scan showing the location of the amygdala

In contrast, other non-human primate studies reported that removal of the amygdala produced rage, (Bard & Mountcastle, 1948). In humans, temporal lobe epilepsy,

which is a form of epilepsy in which abnormal electrical activity remains confined to the temporal lobes (which includes the amygdala) has been reported to produce violent behaviour in a small proportion of sufferers (Mark & Ervin, 1970).
Egger and Flynn (1962; 1963) found that attack behaviour in monkeys generated by stimulating the hypothalamus could be *inhibited* if the basomedial nucleus of the amygdala was stimulated concurrently, and that it could be *facilitated* if the stimulation was from the posterior portion of the amygdala's lateral nucleus. If as suggested, the amygdala has excitatory and inhibitory systems, then the observed behaviour post lesion could depend on the exact placement of that lesion.

Historically then, the amygdala has been implicated in emotional behaviour, and damage to this brain structure has been reported to cause aggression or complacency. However, the precise function of the amygdala has been greatly underestimated. Recently, a more cogent picture is emerging through investigations into the behaviours and impairments demonstrated by individuals with damage to this important brain area (Calder et al, 1996a; Young et al, 1995; Adolphs, Tranel, Damasio, & Damasio, 1995; Adolphs et al, 1994; Andersen, 1978). Adolphs et al (1994) proposed that bilateral destruction of the human amygdala resulted in the impairment of essential elements of human behaviour including the recognition of some basic emotional facial expressions, and also the more complex recognition of a combination of several emotions shown in a single expression. In recent literature, the labelling of the negative emotions of fear and anger, but particularly fear, have frequently been reported to be impaired following damage to the amygdala, both in primates and humans. These findings suggest a more specific role for the amygdala in the appraisal of danger and the emotion of fear. Fear is a socially contagious emotion with a long evolutionary history. Displays of fear or anger by other people indicate a potentially dangerous situation. Therefore, a system specifically tuned to the perception of these important affect signals would be a significant survival advantage for an organism.

Adolphs et al (1994) described patient SM, who has a nearly complete bilateral lesion of the amygdala as a result of Urbach-Wiethe disease. SM was compared with twelve brain-damaged controls in her ability to perform a range of tasks involving facial expressions. SM was shown expressions of happiness, sadness, anger, disgust, fear, surprise and neutral from the Ekman and Friesen (1976) face set and was asked to rate each face according to several emotional adjectives. Adolphs et al (1994) found that SM rated expressions of fear, anger and surprise as less intense than the controls, and also demonstrated a severe recognition impairment which was specific to the expression of fear. SM was however able to recognise identity, and to learn the identities of new faces. (This finding provides further evidence that expression and identity are subserved by anatomically separable neural systems).

Adolphs et al (1994) also suggested that the amygdala was responsible for the recognition of multiple emotions which could be signalled in a single expression. They tested SM's ability to recognise similarities between expressions using a multidimensional scaling (MDS) technique. In an MDS plot, the perceived similarity between expressions corresponds to their proximity in the plot. For example, happiness and surprise are rated similar and so are positioned close together, but happiness and sadness are not similar and are consequently located far apart. SM was able to judge expressions from the same category as similar to one another but failed to recognise similarity amongst expressions of different emotions and did not produce the nearly circular ordering that the controls showed.

Adolphs et al (1995) reported that bilateral, but not unilateral damage to the human amygdala results in an inability to process fearful facial expressions as a result of an insensitivity to the intensity of fear expressed by faces. Adolphs et al (1995) describe how in order to recognise someone as afraid, the amygdala must make the sight of a fearful face activate a number of cortical and subcortical areas whose co-ordinated activity constitutes the concept of fear. Adolphs et al (1995) suggest that the amygdala engages limbic and somatic activity during danger or threat, and engages sensory cortices that represent items and scenarios related to fear. In this way, the amygdala may integrate patterns of neural activation from various parts of the brain that would encode features of the stimuli such as shape and position in space, and also the value that particular stimuli have to the organism (e.g. their emotional significance).

Calder et al (1996a) investigated expression recognition in two patients who have both suffered bilateral amygdala damage, DR as a result of surgery for intractable epilepsy, and SE after suffering from presumed herpes simplex viral encephalitis. Calder et al (1996a) set out to investigate if the recognition of all emotions was compromised by damage to the amygdala, or if some expressions were more severely affected than others. SE and DR's ability to label expressions from the Ekman and Friesen (1976) series in a forced choice task was measured. Both SE and DR were only found to be significantly impaired in their labelling of the expression of fear.

In a more complicated expression task, Calder et al (1996a) used photographs of affect posed by one actor from the Ekman and Friesen (1976) series and ordered the expressions in terms of their maximum confusabilities. The resulting order ran happiness-surprise-fear-sadness-disgust-anger, the ends of the sequence were then joined to make a hexagon. Morphed images were created for the six continua that lie around the perimeter of this hexagon. Each continuum consisted of five morphed images, blending between two prototype images (e.g. happiness and surprise) to create the intermediate blends. DR and SE were presented with the resulting 30 morphed faces and asked to decide whether the morphed image was most like happiness, sadness, anger, disgust, fear or surprise. Both patients participated in this task several times. DR and SE scored fewer overall correct responses across each of the regions. DR was particularly impaired in the recognition of fear, anger and disgust regions. SE was unimpaired with expressions of happiness, sadness, disgust and surprise and showed borderline impairment of fear and anger. In addition, both SE and DR made 'remote prototype errors'. This was the expression used by Calder et al

(1996a) to describe the situation where the patients labelled a photograph with an expression which was not typically confused with the exemplar (e.g. if a surprise morph was labelled with sad, disgust or anger). This task revealed overall difficulties with fear, anger and disgust for DR, and for SE difficulties with fear and possibly anger and surprise. Calder et al (1996a) also presented DR and SE with a simple two-way forced choice task where they were presented with continua from anger to fear and happiness to sadness. They were required to categorise the morphs as 'anger' or 'fear' in the former continuum and 'happy' or 'sad' in the latter. Both patients performed within the normal range for the happy-sad faces. DR was unable to categorise the faces in the anger-fear continuum and labelled all 11 images as afraid, in contrast, SE's performance fell within the normal range for this task, although as the authors point out, this task only requires the participant to identify one of the end points, anger in SE's case, which then only requires him to categorise the image at the other end of the continuum as 'not anger'.

A similar experiment conducted with morphs of famous faces presented no problem to either patient. However, a more complex version which required the identification of the person in each morph, revealed that SE was impaired, a finding consistent with his mild prosopagnosia. DR showed no impairment in her ability to recognise identities from morphed images, thus confirming that the results for the expression task were not due to the level of task demand, and again providing evidence for the dissociation between expression recognition and person recognition.

The Amygdala and Auditory Emotional Stimuli

DR also participated in a study designed to test her ability to interpret emotion from auditory information. Scott, Young, Calder, Hellawell, Aggleton and Johnson (1997) performed this investigation in order to establish if the amygdala was specifically involved in the perception of visual signals of emotion from the face, or if its role involved perception of emotion from other sensory modalities.

DR was not found to have any generalised hearing deficit, or problems with speech perception. However, she was found to be impaired in a number of tasks which required the interpretation of auditory signals. Scott et al (1997) tested DR's ability to understand vocal expressions of emotion by presenting her with a tape which contained 24 sentences of a neutral content. The sentences were read with an emotional tone of voice and DR was asked to decide if the tone was happy, sad or angry. DR's performance was found to be well below that of normals. DR was also poor at deciding if speakers were the same or different when samples of sentences were read out by the same or different speakers. She was also poor at recognising familiar voices. DR also had difficulties distinguishing between sentences of neutral content read with intonation patterns indicating a question, a statement or an exclamation, despite the fact that DR was found to have no generalised hearing deficit.

DR had impaired ability to make use of intonation patterns with communicative significance, including those used to signal emotion. Scott et al (1997) consider it likely that DR's problems in matching unfamiliar voices and recognising familiar voices is also derived from the same source, since intonation patterns form an important determinant of what voices sound like.

DR was also tested for her ability to interpret basic emotions from a single word or emotions conveyed by a non-verbal sound pattern. The first test involved reading out single neutral words in an angry, happy, sad, fearful and disgusted tone. DR's performance was at floor level for the expression of fear, she was also impaired with anger and borderline for the expressions of sadness and happiness.

The second test, which used stimuli such as laughing for happiness and growling for anger, revealed that DR was highly significantly impaired for anger and fear and normal for the other expressions. This finding demonstrated that DR had difficulties with the interpretation of paralinguistic signals which are involved in day to day communication of emotion.

Scott et al (1997) consider that as DR was impaired in her ability to recognise fear and anger from auditory cues, and that these were also the emotions which were affected in the visual domain, that this finding is consistent with the impairment of a mechanism which is able to interpret emotional signals regardless of their source, rather than a mechanism which is purely responsive to faces. Although it contains many cells responsive to faces seen, the amygdala is known to receive inputs from other sensory modalities and is therefore in a position to be involved in multimodal recognition.

Scott et al's (1997) findings in conjunction with those already discussed in this chapter confirm the suggestion that the amygdala forms part of the neural substrate for social cognition. The negative emotions of fear and anger seem to be primarily affected by amygdala damage and this appears to be independent of input modality.

The Amygdala and Emotional Memory

Cahill, Babinsky, Markowitsch and McGaugh (1995) have recently reported that the amygdala is involved in the long term memory of emotional events. Cahill et al (1995) tested BP, a patient suffering from Urbach-Wiethe disease in his recall of a story he had heard a week earlier. The story consisted of a brief narration accompanied by a slide show. The story was divided into three phases, the first and last contained relatively neutral material, but the middle phase contained highly arousing material involving severe injuries to a child involved in a traffic accident. Control participants consistently demonstrate superior recollection for the emotional phase of the story compared to the relatively unemotional initial and final phases. In contrast, BP showed no enhanced memory for the emotional events of the middle phase despite normal memory recall for phase 1. BP's self assessed emotional reaction to the story as determined immediately after the story was comparable to that of the controls suggesting that the results were not due to a more generalised reduction in emotional responsiveness. Cahill, Prins, Weber and McGaugh (1994) have also shown that β-adrenergic blockade in normal human participants selectively impaired long term (1 week) memory for the emotional events of the same story. Cahill et al (1995) concluded that the influence of emotional arousal on conscious long term memory involves β-adrenergic receptor activation and contributions mediated by the amygdala.

The Role of the Amygdala in Conditioning

Human and non-human primate studies have established that the hippocampus and surrounding regions are necessary for establishing declarative knowledge. Bechara, Tranel, Damasio, Adolphs, Rockland, & Damasio (1995) reported a study with three patients: one with selective bilateral amygdala damage (who for ease of explanation will be referred to as S1), a second (S2) with selective bilateral damage to the hippocampus, and a third (S3) with bilateral damage to the amygdala and hippocampus. Bechara et al (1995) conditioned participants with either auditory or visual stimuli and used a 100dB boat horn as the unconditioned stimulus. Skin conductance was used as the dependent measure of autonomic response since all three participants had a normal skin responses when the unconditioned stimulus was presented with the conditioned stimulus. This finding is consistent with Tranel and Damasio (1989) who found that the amygdala was not essential for the generation of electrodermal activity but was needed for associations of sensory stimuli with affect. They found that S1 was unable to acquire a conditioned autonomic response to either visual or auditory stimuli but was able to acquire the declarative facts about which of the auditory or visual stimuli were paired with the unconditioned stimulus. The opposite finding was true for S2 who did acquire a conditioned response to both types of stimuli but was unable to provide factual information about the nature of stimulus pairings. In keeping with these findings, S3 with damage to both amygdala and hippocampal areas was unable to acquire conditioned skin conductance responses and unable to acquire new facts.

Bechara et al (1995) suggest that the amygdala is necessary for emotional conditioning and for the combination of external sensory information with internal information regarding somatic states and that the hippocampus is essential for learning the relationship amongst various exteroceptive sensory stimuli. Bechara et al's (1995) study demonstrate a double dissociation between emotional and declarative learning in humans which offers some insight into how different forms of knowledge are integrated in the human brain.

Activation in the Normal Amygdala

Positron-emission tomography (PET) was used by Morris, Frith, Perrett, Rowland, Young, Calder and Dolan (1996) to measure neural activity whilst participants viewed photographs of fearful or happy faces which were systematically varied for emotional intensity. They measured regional cerebral blood flow (rCBF) whilst participants viewed photographs of facial affect chosen from the Ekman and Friesen (1976) series. The task for the participants was to classify the images as male or female so that no explicit categorisation of emotional expression was required during the task. Morris et al (1996) compared regions of activity in response to the emotional expression contrasts which were fearful relative to happy expressions and happy relative to fearful expressions.

Morris et al (1996) found that the presentation of fearful faces caused increased rCBF in the region of the left amygdala and left periamygdaloid cortex, there was no activation of the right amygdala. Other areas of activation included the left cerebellum, left cingulate gyrus and right superior frontal gyrus. In contrast, when the participants were shown examples of happy faces, increased activation was measured in the right medial temporal gyrus, right putamen, left superior parietal lobe, and left calcarine sulcus. Morris et al (1996) report that as the intensity of the expressions was changed from the most happy condition to the most fearful condition, the measured rCBF response in the left amygdala increased monotonically. Morris et al's (1996) results lend further support for a role of the amygdala in neural responses to fearful facial expressions. They also show that explicit processing of these fear faces is not essential for activation of the amygdala as demonstrated by the covert nature of their task. The amygdala is therefore able to process fearful stimuli without the need for higher level processing. The localization of neural activation measured when participants were presented with images of happy faces, suggest that it could be conceivable to find a patient with damage to these areas who would be impaired in their ability to recognise expressions of happiness. To my knowledge no such patient has yet been described.

Does Amygdala Damage Necessarily Cause Impairment in the Processing of Fear?

Contrary to the many reports expounding the role of the amygdala and the expression of fear, Hamann, Stefanacci, Squire, Adolphs, Tranel, Damasio and Damasio (1996) report findings from two men aged 73 and 57 years who both have complete bilateral lesions of the amygdala and additional temporal lobe structures as a result of herpes simplex encephalitis and yet both patients, EP and GT are unimpaired in their recognition of facial expressions including fear. Hamann et al (1996) make two suggestions for these opposing results. Firstly that damage to the amygdala in conjunction with damage to other areas outside of the amygdala are required to impair the recognition of facial affect. In Urbach-Wiethe disease, lesions *can* extend beyond the amygdala to include other brain areas. Secondly, Hamann et al (1996) favour the explanation that lesions to the amygdala impair the recognition of emotion only if these lesions are incurred in early development rather than in adulthood. Urbach-Wiethe disease is a congenital condition whereas EP and GT sustained their injuries after the age of 50 years. This second hypothesis is not supported by evidence from SE (Calder et al, 1996a) who like EP and GT suffered herpes simplex encephalitis after the age of 50 years but unlike EP and GT, SE has been reported to be impaired in his ability to label facial expressions and in particular the expression of fear (Calder et al, 1996a). A further patient, DR reported by Young et al (1995) also has difficulty processing signals of facial affect due to partial bilateral lesions to her amygdala and to the right basal ganglia. DR has epilepsy, the onset of which however was not triggered until her second pregnancy at the age of 28 years. The history of both these patients fails to support the second and preferred suggestion posed by Hamann et al (1996) and instead lends more support to the first. However, Hamann et al (1996) also suggest that perhaps it is a combination of factors which may include a congenital lesion, low full scale IQ and/or additional damage to other brain areas. All of these factors could determine how readily other strategies are available for the identification of facial affect signals.

Huntington's Disease

Huntington's disease (HD) is a hereditary neurodegenerative disorder which arises as the result of a single gene mutation. The characteristic symptoms include involuntary choreiform movements, intellectual deterioration and attentional deficits. Affective disturbances, emotional problems and difficulties with visual and auditory perception of social stimuli are also commonly observed (Sprengelmeyer, Young, Calder, Karnat, Lange, Homberg, Perrett & Rowland, 1996). Jacobs, Shuren, and Heilman (1995a) reported that patients with HD also show an impaired ability to recognise emotional facial expressions. They tested the ability of five patients to match facial expressions, and also to discriminate between pairs of emotions (same or different).

In their study they used expressions of happiness, anger, sadness, fear and neutral. Unfortunately, they did not provide individual scores for each of the expressions but reported that the patient's overall scores were significantly impaired relative to the control data. However, Sprengelmeyer et al (1996) has recently shown that patients with HD exhibit a differentially severe impairment in their recognition of the expression of disgust, both from visual and auditory inputs. Jacobs et al (1995a) also reported that performance on the Benton Test of Face Recognition was impaired, a finding confirmed by Sprengelmeyer et al (1996).

Pathology of Huntington's Disease

Post-mortem examination on HD brains has revealed a 25% tissue loss in the amygdala and related structures (Sprengelmeyer et al, 1996). In the final stages of the disease, cortical atrophy of up to 30% has been reported in areas associated with vision. As such, Sprengelmeyer and his colleagues suggest that any impairments in tasks of affect recognition may simply be the result of more basic visual problems. However, if this were the case, it would be expected that all expressions would be affected in the same way and that differentially severe impairments for one expression would not be predicted. Jacobs et al (1995a) reported degeneration of the tail of the caudate in the early stages of the disease and a general transneuronal degeneration from the caudate to its cortical connections. Sprengelmeyer et al (1996) also report atrophy in the striatum, occipital and parietal cortex, and paleocortical structures. Sprengelmeyer et al (1996) also noted that the basal ganglia could play a central role in the mediation of a disgust response since the basal ganglia show the earliest pathological changes in this disease.

Gaze Detection and Gender Discrimination in Huntington's Disease

Sprengelmeyer et al (1996) reported that of the thirteen HD patients tested, none were found to be impaired in their ability to recognise sex and age from a person's face. However, their ability to discriminate between directed and averted gaze in a forced choice task was impaired relative to controls but still above chance performance.

Expression Recognition in Huntington's Disease

The amygdala has been shown to be a brain structure which is intimately involved in social communication (Aggleton, 1993), and a wealth of recent evidence has demonstrated that damage to the amygdala results in an impaired ability to interpret expressions of fear (Calder et al, 1996; Adolphs et al, 1994). Sprengelmeyer and his colleagues suggested that as the amygdala was damaged in HD patients, perhaps they would also exhibit more specific deficits focused on different emotions. Sprengelmeyer and his colleagues set out to establish whether HD compromised the recognition of all facial expressions of emotion, or if a more specific deficit was evident.

Sprengelmeyer et al (1996) reported that HD patients were severely impaired in a task of expression labelling in a 6AFC task using images from the Ekman and Friesen (1976) series. The mean scores (out of 10) for the HD group for the expressions of disgust and fear were 1.9 and 2.9 respectively. The patients were also found to be impaired in their ability to identify emotion from vocal cues scoring 0.5 and 3.4 (out of 10) for the emotions of disgust and fear respectively. Sprengelmeyer et al (1996) point out that the differentially severe problem demonstrated by the Huntington's group with the expression of disgust was not simply a consequence of that emotion being the most difficult. In this study, controls found the expression of fear the most difficult to identify. However, both the control group and the patients found disgust the most difficult to recognise from auditory stimuli. The finding that the control group experienced the most difficulty with the expression of fear in the visual modality is interesting as one possibility for the poor performance recorded from amygdala damaged patients (Young et al 1995; Adolphs et al 1994), is that the expression of fear is simply the most difficult expression to label.

Sprengelmeyer et al (1996) used the same paradigm employed by Calder et al (1996), described earlier, which used the morphed images to investigate sensitivities to facial expressions. HD sufferers were found to have a severe deficit in their ability to discriminate fear from anger and were in fact impaired at recognising all emotions with the exception of happiness, both in terms of correct identifications and the number of 'remote prototype errors'. The HD group were found to have differentially severe impairments for the expression of disgust with performance no better than chance, this score was significantly below the next most badly affected emotion which was fear.

HD patients were also shown to be emotionally less responsive as measured using self assessment questionnaires involving anger, fear and disgust. However the results only approached significance on the anger and fear questionnaire and on two out of the eight subsets of the disgust questionnaire.

Sprengelmeyer et al (1996) commented that the HD sufferers appeared to be totally unable to perceive the expression of disgust. This perceptual difficulty could not be attributed to poor vision since all of the HD participants in this group were tested to ensure that none had any measurable impairment of basic visual function. Sprengelmeyer et al (1996) concluded that HD compromises the recognition of all emotions but has the most dramatic effect on expressions of disgust. They dismissed the possibility that the impaired performance seen for disgust was a result of this expression being the most difficult to decode despite the fact the controls found this the most difficult expression to recognise from auditory signals. However, this was not the case for the visual modality where fear was the most difficult expression for the controls to identify.

Young et al (1995) described the impaired ability of patients with amygdala damage to recognise expressions of fear from photographs in the Ekman and Friesen (1976) series. They dismissed the idea that the poor performance of the patients was simply a reflection of the fearful exemplars being the most difficult to recognise since the expression of anger gave their controls the most difficulty. However, the performance of normal participants in the free naming task described in Chapter 2 demonstrated that the most difficulty was experienced with expressions of fear and disgust. In addition, Japanese participants were significantly impaired relative to their Western counterparts in interpreting these facial signals. This finding suggests that there may be something about these particular affect signals which is difficult to decode even in normals.

Sprengelmeyer at al (1996) suggest that along with evidence from studies of patients with amygdala damage who experience difficulties in the identification of fear, there is evidence to suggest that different emotions may be compromised by different types of brain damage. The impairment for the HD group with the expression of fear, although not as severe as that measured for disgust could be a result of the tissue damage sustained to the amygdala in these patients. Sprengelmeyer et al (1996) and Young et al (1995) consider the possibility that certain basic emotions may have dedicated neural circuitry. This is an attractive proposition and one for which fear and disgust would be obvious candidates. The facial expression of disgust with the tongue brought forward within the mouth represents the action of expelling food and wrinkling the nose reduces airflow through the nasal passages as a response to a bad smell. In addition, an individual who can detect and display fear would have an obvious advantage over an individual who could not. Sprengelmeyer et al (1996) note that HD sufferers seem to have poor personal hygiene which would suggest that an inability to experience disgust could be a strong possibility.

In locating the exact neural substrate for the expression of disgust, Sprengelmeyer et al (1996) suggested that this role may be attributed to the basal ganglia. Jacobs, Shuren, Bowers, and Heilman (1995b) found that patients with Parkinson's disease who suffer damage to the basal ganglia, were found to show difficulties in matching emotional facial expressions and also in the imagery of facial emotions. Jacobs et al (1995b) suggest that in order to generate an image or to activate a percept of an emotional expression, we need to make the emotional face in order to receive proprioceptive feedback. They suggest that these facial movements need only be minute. This suggestion would help to explain the lack of emotional imagery in Parkinson's sufferers since they are unable to make effective emotional faces. However, making a definitive statement regarding the basal ganglia as the neural substrate for disgust is not possible yet since Dewick, Hanley, Davies, Playfer and Turnbull (1991) found no impairment with the recognition of facial expressions amongst sufferers with Parkinson's disease.

Recently, Gray, Young, Barker, Curtis and Gibson (1997), have reported a highly selective deficit in the recognition of disgust in people who carry the gene for HD. This is a very revealing finding since this deficit was shown in people who were clinically pre-symptomatic, with no general cognitive deterioration. In addition, this deficit was evident in the absence of other face processing difficulties that occur in the later stages of the disease. Gray et al (1997) suggest that this finding provides powerful evidence for a role of the basal ganglia in the emotion of disgust. In addition, Gray et al (1997) suggests that this finding, in conjunction with the findings of impaired recognition of fear in amygdala damaged patients (Adolphs et al, 1994; Calder et al 1996a) represents a double dissociation between the recognition of two of our facial expressions. As such, Gray et al (1997) propose that the expression analysis module in models such as the Bruce and Young (1986) model of face processing, should be adapted to describe a more specific set of modules, each one dedicated to one basic emotion, or a cluster of emotions. In the light of these specific deficits affecting visual and auditory inputs (Sprengelmeyer et al, 1996; Scott et al, 1997), an emotion recognition system would need to be multi-modal. Alternatively, Gray et al (1997) suggest that these deficits are caused by damage to more central aspects involved in the ability to experience particular emotions under appropriate circumstances.

Recently, Phillips, Young, Senior, Brammer, Andrews, Calder, Bullmore, Perrett, Rowland, Williams, Gray, & David (1997) used functional magnetic resonance imaging (fMRI) to examine cerebral activation in response to the perception of expressions of disgust. Normal participants were shown computer transformed faces representing different intensities of a disgust expression. Participants were asked to make a judgement as to the sex of each face so as not to make the nature of the investigation explicit. Phillips et al, (1997) reported that both strong and mild expressions of disgust activated the anterior insula cortex, and that strong disgust also activated structures linked to the limbic cortico-striatal-thalamic circuit. Phillips et al (1997) comment that the anterior insula is involved in responses to bad tastes, thus suggesting that our response to the perception of this expression from others and that of taste may have a similiar neural substrate. As such the perception of this expression is likely to be closely associated with the actual experience of this emotion.

General Discussion

In this chapter, the neurological basis of social communication was discussed with reference to disorders such as autism, delusional syndromes, Huntington's disease and Urbach-Wiethe disease. Many of these disorders have varied aetiologies, but the amygdala emerged as a brain structure which when damaged, was at least partly responsible for some of the face processing impairments described. The Bruce and Young (1986) model of face processing represents expression analysis as a single operation suggesting that all emotions are analysed by a common perceptual mechanism. However, the evidence described in this chapter would suggest that each of our emotions may possess their own discrete processing mechanisms since the recognition of one emotion can be lost without cost to any other. This pattern was observed for SE and DR who were found to show specific impairments in the ability to recognise expressions of fear in a simple forced choice task (Calder et al, 1996a). In Huntington's disease, patients were found to be impaired in their recognition of all expressions although performance for the expression of disgust was severely impaired (Sprengelmeyer et al, 1996). Importantly though, Gray et al (1997) reported that carriers of the HD gene were also impaired in the recognition of disgust, and this impairment occurred in the absence of any difficulty with other facial expressions or other face processing tasks. This finding by Gray et al (1997) in conjunction with findings from amygdala damaged patients who can show a differentially severe impairment in the recognition of fear (Calder et al, 1996a) provides evidence for a double dissociation between two of our basic emotions, and supports the suggestion that we may possess dedicated neural circuitry for some of our basic emotions. Calder et al (1996a) have described this as the "separate substrates" hypothesis. This hypothesis would support a fractionated mechanism for expression analysis with at least some of the basic emotions represented by discrete circuitry. In terms of evolution it is possible to imagine how such circuitry could have developed with advantages for individuals who could display and perceive in particular, the expressions of fear, anger and disgust.

Evidence for the separate substrates hypothesis would be supported if it could be established that we perceive emotions categorically, a theory for which there is substantial evidence (Etcoff & Magee, 1992; Calder, Young, Perrett, Etcoff, &

Rowland, 1996b). If we do indeed have dedicated neural circuitry for individual expressions we might expect to see a range of patients with discrete difficulties for any of our repertoire of facial expressions, particularly those which are linked to more basic emotions, but this does not seem to be the case (so far). The second interpretation suggested by Calder et al (1996a) was the "perceptual difficulty hypothesis". This supports the idea of a common perceptual mechanism for all expressions with some expressions being more vulnerable to impairment than others. In particular, expressions of fear and disgust may simply be less perceptually distinct than the expression of happiness for example. This hypothesis is supported with evidence from the studies reported in this thesis from Chapter 2, and also from many other cross cultural studies which have consistently demonstrated that negative expressions, particularly fear and disgust, are the most difficult to interpret. In addition, the control participants in Sprengelmeyer et al's (1996) found fear the most difficult expression to label in a forced choice task.

Considering Gray et al's (1997) finding that people who carry the gene for HD are also impaired in their ability to recognise the emotion of disgust, it would perhaps be interesting to test the relatives of sufferers of Urbach-Wiethe disease who carry the gene responsible for this condition and determine if they too experience difficulties in recognising the expression of fear.

Research into the amygdala using PET technology has revealed areas of the amygdaloid complex which are specific for particular functions. For example, Cahill, Haier, Fallon, Alkire, Tang, Keator, Wu and McGaugh (1996), used PET to monitor glucose metabolism in the amygdaloid complex while normal participants viewed video clips, the contents of which were either emotionally arousing or neutral. After a period of three weeks, participants were recalled and their memory for the clips assessed in a free recall test. Participants were found to recall more information from the emotional clips compared to the clips containing neutral material. In addition, glucose metabolism in the right amygdaloid complex while viewing the emotional clips was highly correlated with the overall number of emotional clips recalled. Glucose metabolism in the amygdaloid complex was not correlated with the recall of the number of neutral clips recalled. From this research, it would seem that long-term memory for emotionally arousing events involves the right amygdala. Morris et al (1996) found that the presentation of fearful faces to normal participants caused increased rCBF in the region of the left amygdala and left periamygdaloid cortex, with no activation of the right amygdala. This finding was also confirmed by Phillips et al (1997) using fMRI. These findings illustrate the varied role of the amygdaloid complex in processing emotional material.

The importance of the amygdala in negative emotion and particularly fear has been described with findings from a variety of approaches including PET, memory and conditioning experiments. In the next chapter, the performance of two patients with bilateral amygdala damage who were described in this chapter, SE and DR, were tested in their ability to interpret emotion from images in the Jenkins affect set. SE also took part in a 1AFC expression detection task which was described in Chapter 3, and his ability to detect eye gaze direction was also measured using tasks designed in Chapter 4. It was predicted that both SE and DR would exhibit an impaired ability in their interpretation of expressions of fear and that SE may also have difficulty in discriminating gaze direction.

Importantly however, we will distinguish the *perception* of expressions from their *interpretation*, and examine whether expressions which are typically impaired in amygdala damage are just simply more difficult to see.

6

Neuropsychological Investigations

Overview

In Chapter 5, elements of the neurological basis of social communication were described with examples from patients with brain injury and those with congenital conditions. Damage to the amygdala was one of the brain pathologies which was seen to result in problems with processing emotional expression from the face and from auditory signals. Two patients, SE and DR, who were introduced in Chapter 5 are described in more detail in this chapter. Both patients have been found to be impaired in tasks of expression perception following bilateral amygdala damage (Calder et al, 1996a). This chapter predominantly describes the performance of SE who took part in a series of tasks, designed and described in earlier chapters, which serve to investigate his sensitivity, and understanding of signals of facial affect and his sensitivity to gaze direction detection. DR performed only two of the expression tasks using the Jenkins expression set. The data reported here for DR was collected by Andy Calder from the MRC Applied Psychology Unit in Cambridge.

The aim of the investigations reported in this chapter was not primarily to demonstrate that patients with amygdala damage have difficulties with certain aspects of expression processing as this has been impressively demonstrated in much of the recent literature describing patients with damage to this important brain area. Instead, the investigations in this chapter highlight the difficulties facing researchers in choosing an appropriate task for investigating sensitivity to facial expressions since the choice of paradigm appears to significantly influence the measured performance.

The next section describes the pathology and clinical history of patients SE and DR, both with bilateral amygdala damage. In subsequent sections, SE's performance in a range of tasks designed to assess his sensitivity to signals of facial affect and gaze direction, and DR's performance in two facial expression tasks using the Jenkins image set are described.

Case Summary SE

Clinical History and Neurological Investigations

The pathology of SE's condition has been described extensively in published journal articles. This description has been adapted from McCarthy, Evans and Hodges (1996).

In 1986 SE, a 66 year old ex-railwayman was diagnosed with viral encephalitis due to herpes simplex. His initial symptoms included disorientation, nausea, headache, pyrexia and confusion. He spent a three week period in hospital after which time his orientation had improved but he showed signs of a memory impairment. Five years after his initial illness SE was being investigated by a research group who discovered that he was suffering from topographic amnesia (an inability to find his way around previously familiar surroundings, and in learning to navigate in new surroundings) and was also showing a mild prosopagnosia. His ability to recognise his family and friends remained intact but his ability to recognise less familiar people like TV personalities and politicians was impaired. SE was found to have a severe bilateral anosmia, and displayed a very distorted sense of taste.

A CT scan taken when SE was first admitted to hospital showed damage to the right temporal lobe. More recently an MRI scan was performed which revealed extensive damage to the right temporal pole, amygdala (all nuclei), uncus, hippocampus, parahippocampul gyrus, and inferior and middle temporal gyri to the level of the insula with compensatory dilation of the temporal horn of the right lateral ventricle. The left cerebral hemisphere was normal with the exception of small regions of damage to the uncus and the amygdala. Diencephalic and frontal lobe structures were normal.

Neuropsychological Investigations

SE's measured visual acuity was normal, 6/6 bilaterally. He made no errors on the Ishihara colour chart and was found to have full fields and fully reactive pupils. McCarthy et al (1996) reported that in a bedside cognitive evaluation SE was completely alert and oriented and obtained a perfect score on the mini mental state examination. The naming of objects and repetition tasks was faultless and he was able to retain information and recall it accurately after a filled delay. SE showed no evidence of visuospatial or other basic perceptual deficits.

McCarthy et al (1996) tested SE on the standard battery of neuropsychological tests. He showed well preserved intellectual abilities with his measured IQ (WAIS-R full scale IQ = 100) being no different from his predicted premorbid IQ as obtained on the National Adult Reading Test. His perceptual, language and executive functioning was reported to be satisfactory. His performance was also reported as satisfactory on a verbal memory test, but impaired on visual memory showing difficulties in the delayed recall of visual information. McCarthy et al (1996) also reported that at the time of testing, SE showed impaired performance on picture naming and word-picture matching tasks with his scores falling just outside the normal range which they reported as suggesting a mild semantic disorder.

Case Summary DR

A full case description for DR can be found in Young et al. (1995). The relevant elements of her neurological history are reported below.

Clinical History and Neurological Investigations

DR, now aged 53 years, first suffered from epilepsy during her second pregnancy at the age of 28 years. Two weeks after the onset of epilepsy, DR began suffering from complex partial seizures which occurred two or three times each day. Since then DR has continued to experience three types of seizure: tonic clonic seizures which occur approximately monthly; absences which occur several times every day; and complex partial attacks which last for a couple of minutes which occur almost daily, these attacks are followed by a period of confusion and automatic behaviour. Over the years, has been treated with a number of anti-convulsants which have failed to control her seizures.

A series of electroencephalogram investigations in the 1970's established the locus of the seizures as the left anterior temporal lobe plus some autonomous discharge in the right temporal lobe. Between 1978 and 1981 DR underwent a number of stereotaxic procedures which targeted the left amygdala initially and then the left and right amygdala. In total, DR had four cryoprobe lesions and one electrocoagulation lesion on the left side, and two cryoprobe lesions on the right side. After this procedure, a CT scan revealed a haematoma in the region of the right caudate nucleus.

Despite this extensive surgery, DR still experiences six or seven attacks per day in which she becomes absent and makes fidgeting movements. These seizures can leave her feeling confused and disinhibited although she usually regains normal orientation quite quickly.

MRI scans performed in 1991 and 1992 showed extensive lesions of the left medial amygdala with destruction of much of the basal nuclei although the lateral nucleus was largely spared. The rostro-caudal region of the amygdala up to the anterior horn of the left hippocampus was also damaged. Associated damage extended dorsally beyond the amygdala to effect part of the anterior commisure, lateral putamen and external capsule. In the right hemisphere, the MRI scan revealed a small posteriorly placed lesion at the caudal limit of the amygdala and a further lesion in the right anterior amygdaloid region.

DR experiences some word finding difficulties but is reported to engage readily in conversations. She is not impeded by this mild aphasia as she uses effective circumlocutions. She experiences occasional lapses of everyday memory which often involve the faces of people she knows, particularly if they appear in an unusual context.

Neuropsychological Investigations

DR's predicted premorbid IQ is 111 as measured using the revised version of the National Adult Reading Test. Her latest assessment with the WAIS-R gave a full scale IQ of 87. DR's basic visual functions are unimpaired with full visual fields to confrontation testing and normal spatial contrast sensitivity. DR was unimpaired in recognising that famous faces were familiar, but was impaired at naming them, however she could provide their occupations. DR was also able to reject unfamiliar faces. As for emotions, DR is able to provide examples of occasions that she has felt happiness or sadness and is able to describe circumstances in which other people would feel happy, sad, angry, afraid etc.

Summary

Both SE and DR have extensive amygdala damage which is more severe in the right amygdala for SE, and in the left for DR. In face related tasks, SE was poor at providing the names or occupations of familiar faces, consistent with his mild prosopagnosia, whereas, DR was unimpaired in the recognition of familiar faces but had difficulties with name retrieval. For both SE and DR basic visual functions were found to be unimpaired. Therefore any problems in face processing could not be simply attributed to poor vision.

Interpretation of Facial Expression

In this next section, SE and DR's performance in the forced choice and free naming expression tasks described in Chapter 2 are compared with data from a group of control participants. SE's sensitivity is investigated further using additional paradigms to measure his performance in facial affect tasks.

Control Participants

Six participants contributed to the control data in the following investigations of affect sensitivity. All were male, aged between fifty and sixty-four years of age, with a mean age of 58.3 years, SD = 4.89. All control participants were security or portering staff at Stirling University who were paid for their time.

Free Naming Expression Allocation Task

This task was performed using the Jenkins image set. SE and DR were shown each of the sixty expression exemplars consecutively (10 of each of the six expressions, happiness, sadness, anger, disgust, fear and surprise) in a random order. SE and DR were asked to label each of the cards with a single emotional label which they considered best described the expression depicted. They were not restricted to any set of words, nor given examples of possible answers. The viewing time was not restricted and the participants voiced their answers to the experimenter who recorded their responses.

Results

A correct score was given if either the exact word or a synonym of the word was used to label the expression. The overall scores for SE and DR are shown in Table 6.1 along with scores from control participants.

SE appeared to be more severely impaired in this task than DR, however, despite the very low scores for the expression of fear, the patients' performance in this task was not significantly different to that of the control group. However, SE's score of zero out of ten is likely to represent a floor effect and suggests that this particular task was not sufficiently sensitive to reveal any possible abnormality.

DR actually out-performed controls in her ability to label the expression of fear. In fact, DR's performance was not found to be significantly different to the control group for any of the expressions. In this task, SE was only found to be significantly impaired in his ability to label expressions of disgust.

Asterisked scores are significantly impaired in comparison to the performance of controls: **z> 3.10, p < 0.001.

Expression	SE	DR	Controls	
			Mean	SD
Happiness	10/10	10/10	9.83	0.37
Sadness	6/10	9/10	6.5	1.61
Anger	9/10	8/10	4.17	1.57
Disgust	3/10**	7/10	7.67	1.25
Fear	0/10	5/10	2.83	1.46
Surprise	10/10	9/10	7.3	1.25

Table 6.1: Interpretation of emotion in faces from the Jenkins facial affect set in a free naming task by SE and DR, with mean scores and standard deviations for six control participants.

Synonyms

The labels provided for each card by SE and DR were scored as correct if the word they allocated was synonymous with the target label. The synonyms used by SE are shown in Table 6.2. In most cases he would use one of these labels several times for the same expression. For example, he used the label 'smile' to describe two of the 'happy' stimuli. If SE used a label with an ambiguous interpretation, he was asked to clarify his answer. For example, he consistently defined "shock" as "a look of surprise". Consequently all responses of "shock" for fear stimuli were scored as incorrect and not synonymous with the target.

SE	Happy	Sad	Disgust	Surprise
Synonym	Smile Laugh	Sullen Misery	Horror	Shock

Table 6.2: Synonyms used by SE in his judgement of stimuli in the Jenkins expression set.

DR was tested by Andy Calder, the synonyms used by DR to label the expression stimuli are shown in Table 6.3. Some of the responses, for example "fed-up" and "shocked" were thought to be slightly ambiguous since she used these same labels in more than one emotion category. When asked to clarify her responses, DR defined "fed-up" as "disgust and possibly anger", consequently the response of 'fed-up' was scored correct for disgust and incorrect for anger and sadness. DR also defined her label of "shocked" defining it as "surprise, could really only be that".

DR	Happy	Sad	Anger	Disgust	Fear	Surprise
Synonym	Pleased	Miserable	Annoyed	Fed-up	Frightened	Shocked
	Jolly		Nasty		Scared	

Table 6.3: Synonyms used by DR in her judgement of the Jenkins expression set in a free choice expression allocation task.

The range of synonyms used by control participants is illustrated in Table 6.4. The contents of this table demonstrate the variety of ways in which people perceive the same facial expression exemplars. As Russell (1994) observed, there does not appear to be a dichotomous relationship between emotion labels and facial expressions. Despite the fact that all participants were requested to use one word, an emotional label, many of the controls used words of exclamation which could not be described as emotions, but rather responses to situations, e.g. ugh! and phew! for the expressions of disgust.

SYNONYMS					
Happiness	Sadness	Anger	Disgust	Fear	Surprise
pleased	depressed	annoyance	revulsion	shocked	shock
joyful	unhappy	aggressive	phew!	frightened	astonished
enjoyment	glum	threatening	stinky	scared	amazed
contented	sorrow		gruesome	startled	aghast
merry	downcast		ugh!		
delighted			horrified		
cheerful			nauseous		
pleasure			repugnant		
gleeful			distaste		

Table 6.4: Synonyms used by six control participants in the free naming expression allocation task using images from the Jenkins expression set.

Errors

SE made no errors in his labelling of the expressions of happiness and surprise. The most common error for SE was in his interpretation of fearful expressions which he frequently labelled as 'surprise' (see Table 6.5). (Numbers in parenthesis represent the frequency with which each particular response was made).

Sad	Anger	Disgust	Fear
Disbelief (1)	Suspicious/ Doubting (1)	Surprise (2)	Anger (1)
Thoughtful (1)		Doubt (1)	Shock/Surprise (9)
Smug (1)			
Doubt (1)			

Table 6.5: Errors made by SE in the free naming expression allocation task using images from the Jenkins expression set. Numbers in parenthesis represent frequency of response.

As in SE's case, the errors made by DR were primarily for negative affect signals which were labelled with other negative emotion categories. This suggests that despite the low scores recorded for some of the emotion categories, both SE and DR are able to distinguish between positive and negative affect. Table 6.6 presents the errors made by DR in this free naming task.

DR	Sad	Anger	Disgust	Fear	Surprise
Errors	Fed-up (1)	Frightened (1)	Annoyed (3)	Shocked (2)	Frightened (1)
		Fed-up (1)		Surprise (2)	
				Annoyed (1)	

Table 6.6: Errors made by DR in the free naming expression allocation task using images from the Jenkins expression set. Numbers in parenthesis represent frequency of response.

Errors made by the control participants are listed in the Appendix. If any of the control participants responded with an ambiguous label, for example, 'shock' was often used to describe fear and surprise, participants were asked to clarify their response.

Discussion

Neither patient nor controls experienced difficulties in labelling images of facial affect portraying 'happy' expressions. SE experienced greatest difficulty with negative affect stimuli, and in particular expressions of fear and disgust. However, only his labelling of the disgust stimuli was significantly different to that of the control group. DR's performance was comparable to the controls for each of the expressions in the Jenkins image set.

In the patient data, fear was frequently labelled as surprise or shock, but surprise was not confused with fear, with the exception of one occasion where DR used 'frightened' to label one of the surprise exemplars. The same pattern of responses was made by the control participants. Fear was labelled as surprise on a total of ten occasions, but fear was only used once to describe a surprise exemplar. It would seem that for patients and controls alike, labelling the expression of surprise poses little or no problem. However, in this task, where the stimuli are viewed one at a time without previewing, fear is frequently confused with surprise. These results suggest the possibility of a labelling bias, such that for some reason there is a reluctance to use the label of fear. The possibility of a labelling bias is investigated in later tasks. Firstly, SE and DR's performance in a forced choice task using the Jenkins image set is reported.

6-Alternative Forced Choice Expression Labelling Task I

In this task, SE and DR were presented with the 60 expression exemplars comprising the Jenkins image set and were requested to allocate each exemplar with an expression from a given list. This list contained the six target expressions of happiness, sadness, anger, disgust, fear and surprise and was available for reference throughout the task.

For each presentation of a stimulus card, SE and DR were requested to choose one emotion label from the list that best described the facial expression being portrayed. SE performed this task on two separate occasions separated by a period of 5 months.

Results

Control participants performed very well in this task but were poor at labelling expressions of fear. Mean scores and standard deviations for the control group are reported in Table 6.7 along with the scores from SE and DR. SE's first attempt at this task demonstrated that he was significantly impaired in labelling the negative expressions of disgust, anger, sadness and fear compared to the control group. In his second attempt, nearly half a year later, he was found to only be impaired in labelling expressions of disgust. DR was impaired at labelling expressions of anger and disgust but her ability to label fearful expressions was not significantly different to the control group.

These results do not reflect SE's and DR's performance in an equivalent task using images from the Ekman and Friesen (1976) set which revealed that both patients were only significantly impaired in their ability to label expressions of fear (Calder et al, 1996a).

Asterisked scores are significantly impaired in comparison to the performance of controls: *z> 2.33, $p < 0.01$; **z> 3.10, $p < 0.001$.

Expression	SE (trial 1)	SE (trial 2)	DR	Controls	
				Mean	SD
Happiness	10/10	10/10	10/10	10	0
Sadness	8/10**	9/10	10/10	9.67	0.47
Anger	8/10**	10/10	7/10**	9.8	0.37
Disgust	8/10**	6/10**	7/10**	9.8	0.37
Fear	1/10*	3/10	4/10	5	1.41
Surprise	10/10	9/10	10/10	9.5	0.5

Table 6.7: Interpretation of emotion in faces from the Jenkins facial affect set in a 6AFC task by SE and DR, with mean interpretation rates and standard deviations for six control participants.

Errors

SE's performance in this task was significantly different to that of the controls for all of the negative expressions. The errors made by SE in his first attempt are shown in Tables 6.8. (Numbers in parenthesis represent the frequency of the response).

SE	Sad	Anger	Disgust	Fear
Errors	Disgust (2)	Disgust (2)	Sad (1)	Surprise (7)
			Anger (1)	Disgust (1)
				Anger (1)

Table 6.8: Errors made by SE in Trial 1 of the 6-alternative constrained choice task using the Jenkins facial affect image set.

SE made no errors in the interpretation of the expressions of happiness and surprise. However, his low score for the fearful stimuli was largely due to his mistaking the physiognomy of this expression with that of surprise. It is also interesting to note that SE labelled two exemplars of sadness and two exemplars of anger as expressions of disgust, and chose labels of sadness and anger to describe two of the disgust exemplars. This perhaps supports the idea of a more generalised problem reflecting a level of confusability between these negative emotions.

When SE performed this 6AFC task for a second time, his performance was only found to be significantly different to that of the control group for the expression of disgust, which on this occasion he confused with sad and fearful exemplars (Table 6.9). Once again, his performance was perfect for expressions of happiness and he only made one error in labelling expressions representing surprise. Despite the large number of errors in labelling expressions of fear, SE was not significantly different from the control group.

SE	Sadness	Disgust	Fear	Surprise
Errors	disgust (1)	sadness (2)	surprise (4)	fear (1)
		fear (2)	sadness (2)	
			anger (1)	

Table 6.9: Errors made by SE in Trial 2 of the 6-alternative constrained choice task using the Jenkins facial affect image set.

DR's performance was significantly different to that of controls for the expressions of anger and disgust which she confused with each other and with surprise. Once again, despite the large number of errors made in labelling expressions of fear, her performance was not significantly different to that of controls. Errors made by DR are shown in Table 6.10. Numbers in parenthesis represent the frequency of the response.

DR	Anger	Disgust	Fear
Errors	Surprise (2)	Anger (2)	Disgust (1)
	Disgust (1)	Surprise (1)	Surprise (5)

Table 6.10: Errors made by DR in a 6-alternative forced choice task using the Jenkins affect image set.

The errors made by the control group are shown in Table 6.11. The type of confusions made by the patients are very similar to those made by the control participants. In particular, both groups consistently attribute fearful stimuli with a surprise label, but make relatively few mistakes when labelling expressions of surprise.

Controls	Sadness	Anger	Disgust	Fear	Surprise
Errors	anger (1)	disgust (1)	fear (1)	surprise (23)	fear (3)
	disgust (1)			disgust (6)	
				happy (1)	

Table 6.11: Errors made by six control participants in a 6AFC task using the Jenkins affect image set.

Discussion

When SE and DR were able to choose their own labels to describe the expressions they were presented with, DR's performance was not found to be significantly different to that of the control group, and SE was only impaired in his interpretation of exemplars of disgust. In contrast, when a forced choice paradigm was used, DR was found to be impaired in her interpretation of expressions of anger and disgust, expressions which she interpreted with an accuracy no different to the control group in the free naming task. In addition, SE's first attempt at this task revealed that he was significantly different to the control group in his ability to interpret expressions of sadness, anger, disgust and fear, whereas his performance in the free naming task revealed only a problem with disgust. When SE performed this task for a second time, his performance for the expressions of sadness, fear and anger were no longer significantly different to that of the controls but his difficulty with disgust remained, a pattern which would seem to reflect his abilities in the free naming task more accurately than his first attempt at the forced choice task. SE's apparent improvement in the forced choice task from the first to the second attempt could reflect a general problem with the repeated testing of patients in certain tasks. SE is a very keen participant and rehearses his responses, it is possible that he has learnt some alternative strategies for performing these tasks of expression perception. In future work with SE it will be important to time his responses to each stimuli since learnt strategies often take longer to execute than spontaneous decisions.

The patient and control data in both the free and forced choice tasks revealed difficulties in the interpretation of fearful expressions. The next two experiments were designed to determine if the nature of free and forced choice paradigms was actually precluding participants' true ability to interpret expressions of fearful stimuli.

6-Alternative Forced Choice Expression Labelling Task II

This task was designed to investigate the possibility of a labelling bias which may have been responsible for the poor performance for both patient and controls in the first constrained choice task. The apparent inability to label expressions of 'fear' may have arisen as a result of some sort of reluctance to use this label and not as a result of a genuine inability to identify it.

In this task, SE was shown six cards on each trial representing one of each of the six expressions. On each trial he was given an expression label and was requested to choose one card from the six which best illustrated that particular emotion.

The sixty expressions were divided into ten sets with one of each of the six expressions in each set. Each set was shown to SE on six occasions such that during the course of the task SE was requested to identify all of the expressions within each set. The sets were shown to SE sequentially with a different target expression in each trial. For example, from set 1 he was asked to identify the 'happy' face, from set 2 to identify the 'sad' face, set 3 identify the 'angry' face and so on until set 10 cycling through the 6 expressions. When set 1 was shown for a second time, SE was asked to identify the 'sad' face and so on.

Results

When able to view examples of each of the six expressions at once, SE's scores, and those of controls, increased dramatically, and SE's performance did not differ significantly from the controls for any of the expressions (see Table 6.12). His performance for the expression of fear increased from scores of 1 and 3 in the first constrained choice task to 8 in this task.

Expression	SE	Controls	
		Mean	SD
Happiness	10/10	9.5	0.5
Sadness	9/10	10	0
Anger	10/10	9.5	0.5
Disgust	10/10	9.83	0.37
Fear	8/10	7	1.0
Surprise	10/10	9.5	0.76

Table 6.12: Interpretation of emotion in faces from the Jenkins facial affect set in a 6AFC task by SE, with mean interpretation rates and standard deviations for six age-matched control participants.

Errors

SE made a total of three errors in this task which are reported in Table 6.13.

SE	Sadness	Fear
Errors	disgust (1)	surprise (1)
		disgust (1)

Table 6.13: Errors made by SE in Constrained Choice Task (II). Numbers in parenthesis represent the frequency of responses.

The errors made by the control participants were similar to those made by SE for the expression of fear. Even when a comparison was available between expressions of fear and surprise, some fear exemplars were still labelled as surprise.

Controls	Happiness	Anger	Disgust	Fear	Surprise
Errors	surprise (2)	disgust (2)	fear (1)	surprise (13)	fear (2)
				disgust (3)	
				sadness (3)	

Table 6.14: Total errors made by six control participants in Constrained Choice Task (II). Numbers in parenthesis represent the frequency of responses.

Discussion

The marked improvement in SE's performance could simply be that in this task, SE was able to view examples of each of the expression exemplars, and by a process of elimination determine which face was portraying fear. As the performance of the control participants was also found to increase in this task, it is possible that the task was too easy and that all participants were performing at ceiling which could mask any true disadvantage for this expression. However, this is unlikely since the control participants scored seven out of ten which was below SE's score. An alternative explanation could be that SE is perfectly able to interpret the physiognomy of a fearful face when able to compare it directly with the slightly different physiognomy that constitutes a surprised expression. This idea is consistent with Russell's (1991) finding that expressions of contempt used by Matsumoto and Ekman (1988) were judged as disgust if presented in isolation, but if a disgust and contempt exemplar were presented simultaneously, participants would successfully distinguish between the two expressions.

Expression Matching Task

The same 10 sets of expressions were used in this task as in the previous forced choice task (II), with an additional 60 faces from the Ekman and Friesen (1976) series. (The actors used from the Ekman and Friesen (1976) set were MF, NR, WF, SW, EM, PE, JJ, MO, C and PF). Each set contained six images, one of each of the six expressions from the Jenkins expression set, which were arranged in a circle in front of SE, a seventh card, taken from the Ekman and Friesen (1976) series was placed in the centre of the circle. The task for SE was to match the central expression with one from the surround. Each consecutive trial used expression exemplars from a different set. SE performed a total of 60 trials matching each of the 6 expressions on 10 separate occasions.

Results

Asterisked scores are significantly impaired in comparison to the performance of controls: **z> 3.10, $p < 0.001$.

Expression	SE	Controls	
		Mean	SD
Happiness	10/10	10	0
Sadness	6/10**	9.7	0.75
Anger	8/10	8	1.91
Disgust	5/10**	9	1.15
Fear	8/10	5.2	2.6
Surprise	6/10	7.8	1.34

Table 6.13: Matching images of facial affect from the Jenkins set by SE, with mean scores and standard deviations for six control participants.

SE was found to be significantly impaired in his ability to match expressions of sadness and disgust, but out-performed controls in his ability to match fearful expressions. His ability to match happy facial expressions was perfect, but his performance in matching expressions of surprise, although not significantly different to that achieved by controls, was greatly reduced compared to his own performance for this expression in previous tasks.

Errors

The errors made by SE in this task are illustrated in Table 6.14. As in other expression tasks, SE often confuses expressions of sadness, anger and disgust with one another, and also confuses fear with surprise.

SE	Sadness	Anger	Disgust	Fear	Surprise
Errors	disgust (4)	disgust (2)	sadness (3)	surprise (2)	fear (4)
			anger (1)		
			fear (1)		

Table 6.14: Errors made by SE in matching images of facial affect from the Jenkins image set with single exemplars from the Ekman and Friesen (1976) series. Numbers in parenthesis represent frequency of responses.

Control participants also exhibit the same confusions with fear and surprise and frequently confuse expressions of anger, sadness and disgust, as shown in Table 6.15.

Controls	Sadness	Anger	Disgust	Fear	Surprise
Errors	anger (1)	disgust (5)	anger (3)	surprise (24)	Fear (8)
	disgust (1)	sadness (4)	sadness (2)	disgust (3)	
		happiness (1)	fear (1)		
		fear (1)			

Table 6.15: Errors made by controls in matching images of facial affect from the Jenkins image set with single exemplars from the Ekman and Friesen (1976) series. Numbers in parenthesis represent frequency of responses.

Discussion

SE was impaired in his ability to match expressions of sadness and disgust with exemplars of the same expressions posed by other actors. The errors made by SE and the control participants reflected very similar confusions, which have been evident in all of the tasks described so far.

In these tasks, SE has been required to *interpret* the images of facial affect that he has been presented with. Some of these tasks have apparently revealed impairments and others may have concealed them - or suggested the absence of an impaired ability. The results of these experiments demonstrate the difficulties facing researchers in choosing appropriate tasks for assessing a patient's ability, and also in interpreting the responses. In the next experiment, SE's ability to discriminate expression exemplars from neutral exemplars is investigated using the 1AFC task which was described in Chapter 3. This psychophysical task has the advantage that it does not require the participants to *interpret* the affect signals that are presented, instead they must *detect* the presentation of the affect signals embedded amongst neutral distractors.

Detection of Facial Expressions: 1-AFC Expression Detection Task

SE was asked to participate in this experiment as a poor performance in this task would suggest an inability to *perceive* the signal value of expressive faces compared to neutral faces. If SE's apparent difficulties in labelling expression are caused by an inability to *interpret* facial expressions, then he should be able to perform this task with ease since it only requires the discrimination of an expression (any expression) from neutral and does not require any semantic knowledge regarding individual affect signals.

Design

The design of this task was described in Chapter 3. SE performed this task at an equivalent viewing distance of 10m. As described in Chapter 3, there were 120 randomised trials consisting of the 60 expression faces (signals), and 60 neutral faces (non-signals) from the Jenkins affect image set. Each stimulus was presented for 3 screen cycles after which a blank screen appeared. The task for SE was to determine on each trial if the stimulus was a signal or a non-signal. SE voiced his response to the experimenter who responded using a key press which triggered the onset of the next trial. SE performed this task on two separate occasions separated by a period of five months.

Results

Figure 6.2 Illustrates SE's performance calculated from the hit rates on each occasion compared to a group of undergraduate students who performed the task. (Age matched controls were not asked to participate in this task as SE's overall performance matched that of the young adult group so closely).

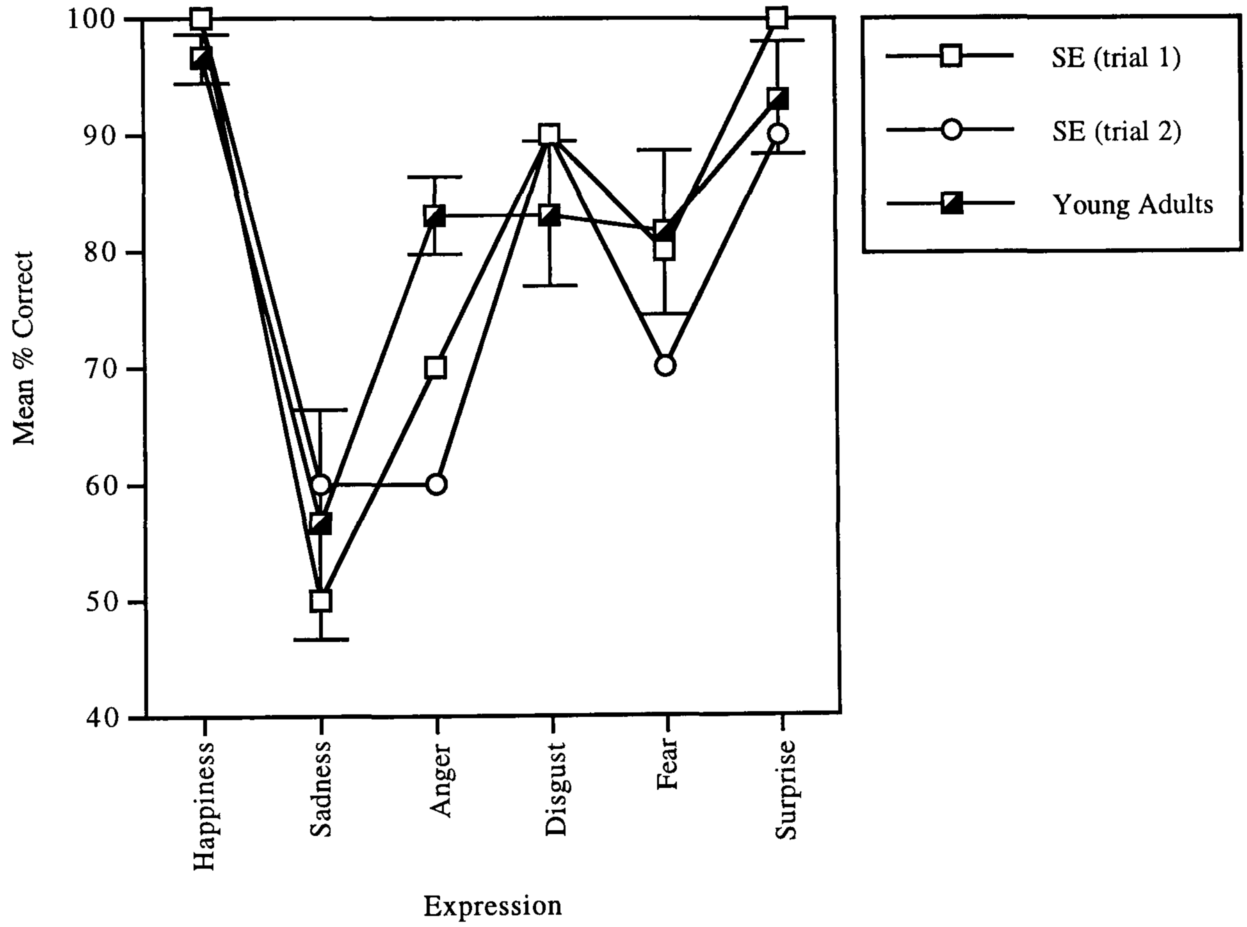


Figure 6.2: SE's performance in a 1AFC expression detection task compared on two separate occasions and with the mean performance of six undergraduate students. Error bars represent standard errors.

SE's performance in this task is comparable to the performance of a group of young adults for expressions of happiness, sadness, disgust and surprise. On SE's first attempt at this task, his performance for the expression of fear fell within the range of scores obtained by the undergraduates, but outside of it on his second attempt. His ability to discriminate expressions of anger from neutral on both occasions also fell outside the range of performance measured for the undergraduate group. However, only his performance in discriminating anger from neutral on the second attempt was found to be significantly different to the undergraduate group ($z > 2.33$, $p < 0.01$).

Discussion

In general, SE's performance was comparable to a group of young adults, only differing in his ability to discriminate angry faces from neutral ones in one of the trials. For this reason, age match controls were not used in this study. It would have been interesting, but not very surprising if SE had been compared with an age-matched control group and found to out-perform them considering his experience at psychological testing compared to theirs. The important finding of this study is that comparing him with a group of young adults demonstrates that he is clearly not impaired in this task.

This study demonstrated that SE's difficulty with facial expressions is unlikely to be due to an inability to perceive the difference between the signalling values of an expression compared to a neutral face. His impaired performance in some of the tasks reported earlier, are more likely to be caused by an inability to transform facial physiognomy into a meaningful, affective signal. A more demanding, and perhaps revealing task would have compared SE's ability to discriminate between expressions, rather than between an expression and neutral. For example, in the tasks described earlier in this chapter, SE often confused expressions of sadness, anger and disgust as well as expressions of fear and surprise. A task which required a discrimination between these expressions may have also revealed some perceptual problems.

Generating Exemplars of Facial Affect

SE consented to be filmed producing exemplars of the six facial affects of interest in this series of investigations. Examples of his expressions can be seen in Figure 6.3. Although SE was slightly nervous about being filmed, he generated these facial expressions very rapidly, producing all six affects within one minute, as can be seen from the time code at the base of each image. He found most difficulty with the expression of 'disgust' which he took a few moments to think about before generating a convincing expression. All other expressions were performed instantaneously on hearing the instructions from the experimenter.

The effectiveness of each of these signals was significantly more apparent from the moving sequence than from these static images.

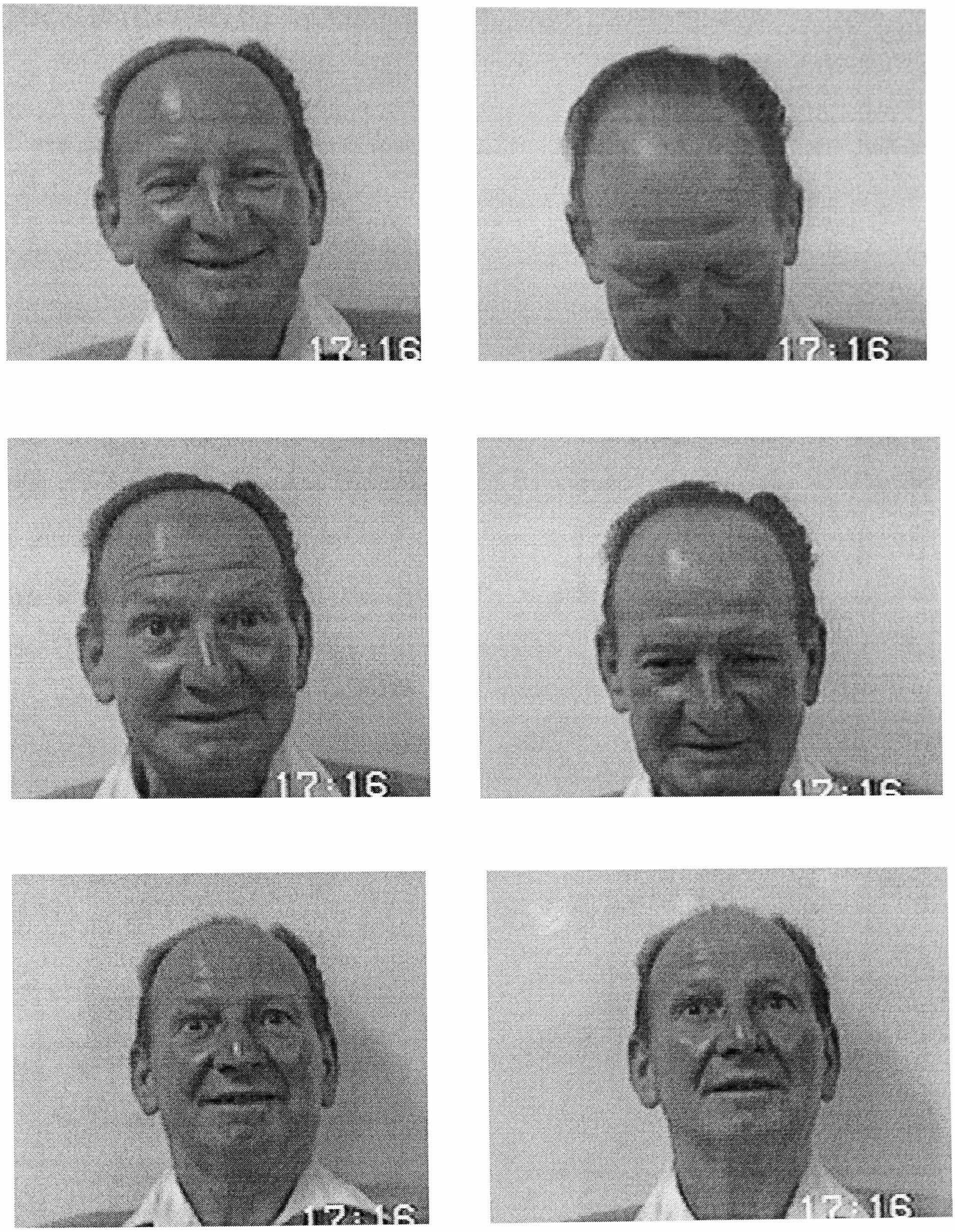


Figure 6.3: SE posing examples of facial expressions. From left to right: happiness, sadness, anger, disgust, fear and surprise.

Questionnaire to Evoke Emotional Responses

SE was given a questionnaire which was designed to assess his ability to attribute an appropriate emotional response to an emotional situation. SE was asked a total of twenty-five questions, each of the form, "how would you feel if.....?". The questions were intended to arouse feelings of happiness, sadness, anger, disgust, fear and surprise. There were 4 questions intended to evoke feelings of sadness, anger and disgust, 5 for evoking fear, 6 for surprise and 2 for happiness. Table 6.15 shows a copy of the questionnaire and SE's responses. SE was also asked to rate the intensity of his responses using a seven-point scale, one representing low intensity and seven high intensity. Some of the questions were slightly ambiguous in their intended effect. The main aim of this task was to determine if SE was capable of generating *appropriate* responses to the questions.

Results

	How would you feel if.........	SE's response	Rating
1	....someone stole your bicycle?	Angry	7
2	....you bumped into friends from home when you were holidaying in a far away place?	Very pleased	1
3	....you opened your fridge and all the contents had gone mouldy?	Very Angry	7
4	....your open top car broke down in a safari park full of roaming lions and tigers?	Scared	7
5	....someone was deliberately rude to you?	Angry	7
6	....your pet died?	Sad	5
7	....you won a large sum of money on the lottery?	Very pleased	5
8	....you got your foot caught in a railway line and could	Scared	7

	see a train approaching?		
9	....you heard that a child of one of your friends was very ill?	Sad	7
10	....you made plans to meet up with friends you haven't seen for a while?	Pleased	4/5
11	....a chemical factory was deliberately polluting a river?	Very angry	7
12	....you were sitting in a room with a very unpleasant smell in it?	Very uncomfortable	7
13	....you won a competition you thought you had done badly in?	Very surprised	7
14	....you were on a sinking ship that was far out to sea?	Frightened	5
15	....a friend that had been very ill made a complete recovery?	Very pleased	7
16	....your favourite football team lost an important match?	Very sad	5
17	....you saw a shark swimming towards you while you were swimming in the sea?	Frightened	7
18	....you saw someone being sick in a public place?	Emotionally upset or nauseated	5
19	....someone deliberately gave you false directions to a place you were looking for?	Lost Angry	7 7
20	....you opened the breadbin and found a spanner in it?	Surprised	7
21	....a member of your family died?	Devastated	7
22	....your family organised a party for you without your knowledge?	Surprised and pleased	7
23	....you saw someone eating a sheep's eye?	Nauseated	7
24	....I told you, you were going on holiday to Blackpool tomorrow?	Very pleased	7

25	....you were unexpectedly asked to give a presentation on a subject you knew nothing about?	Surprised/ Puzzled	5

Table 6.15: Questionnaire answered by SE to investigate his ability to generate an appropriate response to an emotionally arousing situation.

The majority of questions in this questionnaire were fairly extreme scenarios and not surprisingly, SE used the upper end of the rating scale in all but eight of the questions. Importantly though, he attributed an appropriate emotional response to each of the questions. His rating of question 14 with a 5 was perhaps somewhat low but this could simply reflect inexperience with rating scales. SE did not choose to label any of the events with a 'disgust' label but did use 'nauseous' on two occasions. Question three was designed to evoke a feeling of disgust but SE responded with 'very angry'.

Discussion

The use of a questionnaire as a tool for examining emotional responses is actually quite a blunt instrument since it is unlikely that responses made in questionnaires are directly related to actual emotional *experience*. It is possible that in any of the given situations posed in Table 6.15, SE would not actually experience the emotions he attributed to the scene. His responses could have been made as a result of knowing which emotion would be the appropriate response to the situation, either from recollections of past experiences or from simply being cognisant of the appropriate emotion.

In the next experiment, SE was asked to recall occasions in which he had experienced specific emotions. His confusions between certain expressions evidenced in earlier tasks could be a reflection of a poor understanding of the emotional labels used.

Memory for Emotional Incidences

SE was asked to recall occasions when he had felt the emotions of happiness, sadness, anger, disgust, fear and surprise. Once again, the task was designed to determine if SE had an accurate/appropriate representation of the six emotions in his memory for personal events. SE was asked to provide examples and also to rate them using the seven-point scale used in the questionnaire.

Results

SE provided the responses presented in Table 6.16 fluently and with ease.

Emotion	Incident	Rating
Happiness	Meeting Barbara Dixon	7
Sadness	Seeing an elderly person in despair and then dying	7
Anger	(i) John Major (ii) Tony Blair for "turning his back on socialism"	7 7
Disgust	Barbara Dixon playing the part of a prostitute in a TV drama	7
Fear	Waking up in hospital after taking an overdose	7
Surprise	Winning a singing competition in Butlins	7

Table 6.16: Examples of occasions which have caused SE to feel happiness, sadness, anger, disgust, fearful and surprised.

All of SE's responses were considered to be appropriate (perhaps with the exception of the harsh rating for disgust at Barbara Dixon for playing the part of a prostitute in a TV drama).

Some areas of the amygdala receive fear related information and others issue fear related motor responses. The amygdala receives fear information from three sources: the sensory areas of the thalamus; the sensory areas of the cortex; and the hippocampus. Information from the latter source is involved in the memory of fear information such that a previously encountered stimulus which evoked a fear response can elicit the same emotions again simply by recollection of that stimulus. ("Sends shivers down my spine just thinking about it"). SE has extensive damage to his hippocampus, so although he may be conscious of the appropriate responses to the situations given in the questionnaire, he may not actually elicit a fear response which could be measured using GSR, or by monitoring the heart rate.

Gaze Direction Sensitivity

Neurophysiological studies have revealed that cells which are sensitive for facial expressions are found in the superior temporal sulcus (STS) (Hasselmo et al, 1989), a brain region which has also been shown to have cells sensitive to gaze direction, (Perrett et al, 1985). In addition, Campbell et al (1990) found that STS ablation in non-human primates and temporal lobe lesions in humans resulted in impaired gaze direction detection.

Young et al (1995) tested DR's ability to discriminate between a directed (target) and an averted gaze (distractor). They found that DR was unimpaired if the gaze direction of the distractor face deviated by 20°, but was impaired when the angle was decreased to 10° and 5°. The performance of patients with Huntington's disease, who also have damage to the amygdaloid complex, was found to be borderline although performance was well above chance (Sprengelmeyer et al, 1996).

SE was tested in a range of gaze direction detection tasks to investigate his sensitivity to this social signal. With the extensive temporal lobe damage SE has incurred, it was expected that he would experience difficulties with this task

Control Participants

Data from control participants was collected in this investigation as SE's performance *was* found to be impaired (at least in one condition) compared to the group of healthy participants whose data was reported in Chapter 4. Age matched controls were not recruited for the 1AFC psychophysical experiment described in Chapter 3 as SE's performance *was not* found to differ from a group of young adults. Therefore, SE's performance in the following gaze tasks is compared with data collected from three control participants, two female and one male aged between 60 and 66 years with a mean age of 63.3 years, SD = 2.49.

Procedure

SE performed the six gaze tasks which were described in detail in Chapter 3:

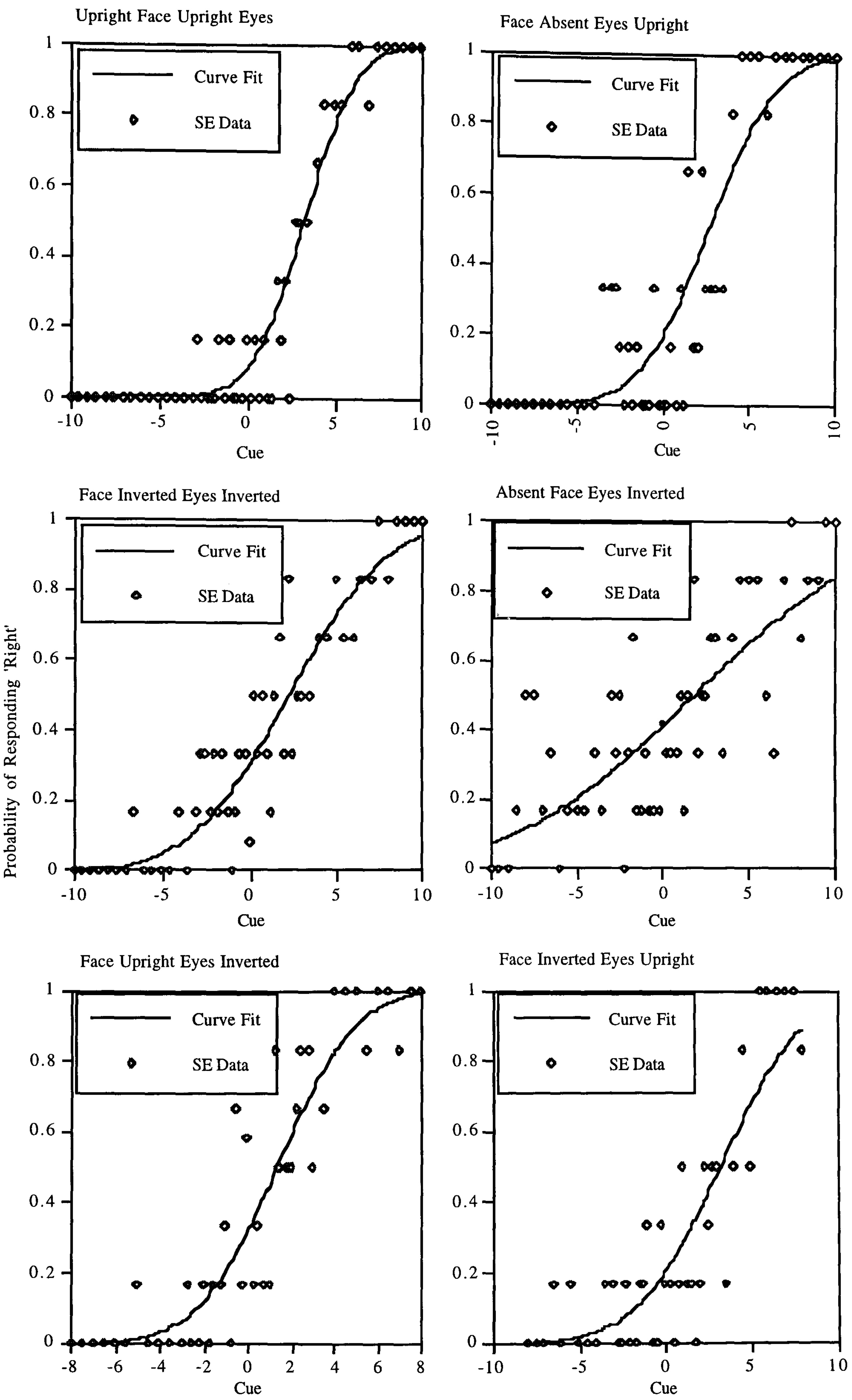
(1) Upright Face Upright Eyes
(2) Inverted Face Inverted Eyes
(3) Upright face Inverted Eyes
(4) Inverted Face Upright Eyes
(5) Absent Face Upright Eyes
(6) Absent Face Inverted Eyes

This procedure differs from that used by other research groups (e.g. Perrett et al (1988); Campbell et al (1990)) in that it requires a discrimination of gaze which is averted to the left or to the right rather than a distinction of whether the person is looking towards or away from you. In addition, this task explores the contribution of the facial surround in the patients ability to discriminate gaze direction.

SE performed conditions one to four on one occasion and conditions five and six on another visit approximately 4 months later. All conditions were as those described in Chapter 4 with the exception that the range of gaze eccentricities was increased to 10° in conditions one to four. SE viewed the screen at a distance of 1m and responded using a keypress to signify the direction of the gaze. SE took short breaks between each condition to prevent himself from tiring.

Results and Discussion

Although reaction times are not reported here, SE found no difficulty in making rapid decisions to the stimuli in each of the six conditions. Table 6.17 presents threshold performance for SE in each of the six conditions and compares it to mean thresholds and standard deviations from the control group. (See Chapter 4 for a complete account of the design and analysis of this experiment). Data from each of the conditions was submitted to a probit analysis which determined the best fitting cumulative Gaussian. Psychometric functions were plotted for SE's performance in each task and are illustrated in Figure 6.4. The data appears very noisy due to the large number of cue values. From the psychometric functions, thresholds values, which are presented in Table 6.17, were calculated in each of the six conditions. The mean threshold and standard deviations in each condition were calculated from the control data and are also reported in Table 6.17.


Upright Face Upright Eyes

Face Absent Eyes Upright

Face Inverted Eyes Inverted

Absent Face Eyes Inverted

Face Upright Eyes Inverted

Face Inverted Eyes Upright

Figure 6.4: SE's performance in six gaze direction detection tasks.

Asterisked scores are significantly impaired in comparison to the performance of controls. **z > 3.10, p < 0.001.

Condition	SE (threshold °)	Controls (threshold °)	
		Mean	SD
face upright-eyes upright	2.34	1.98	0.34
face absent-eyes upright	3.06	3.03	0.79
face inverted-eyes upright	3.85	2.39	1.07
face inverted-eyes inverted	4.39	3.86	0.68
face absent-eyes inverted	8.25**	4.10	1.03
face upright-eyes inverted	2.82	3.02	0.85

Table 6.17: Threshold performance in 6 gaze direction detection tasks by SE with mean thresholds and standard deviations for three control participants.

SE experienced most difficulty with the 'face absent-eyes inverted' condition which the control participants also experienced the most difficulty with. However, SE's performance in this condition was substantially and significantly worse than the controls. SE's performance in all the other conditions was not significantly impaired compared to the control group. SE's highest thresholds (i.e. lowest sensitivity) were recorded for the inverted conditions of 'face inverted-eyes inverted' and 'face absent-eyes inverted', surprisingly though, his performance in the 'face upright-eyes inverted' condition exceeded that in two of the other conditions in which the eyes were presented in an upright orientation. Figure 6.7 illustrates performances of SE and the control group.

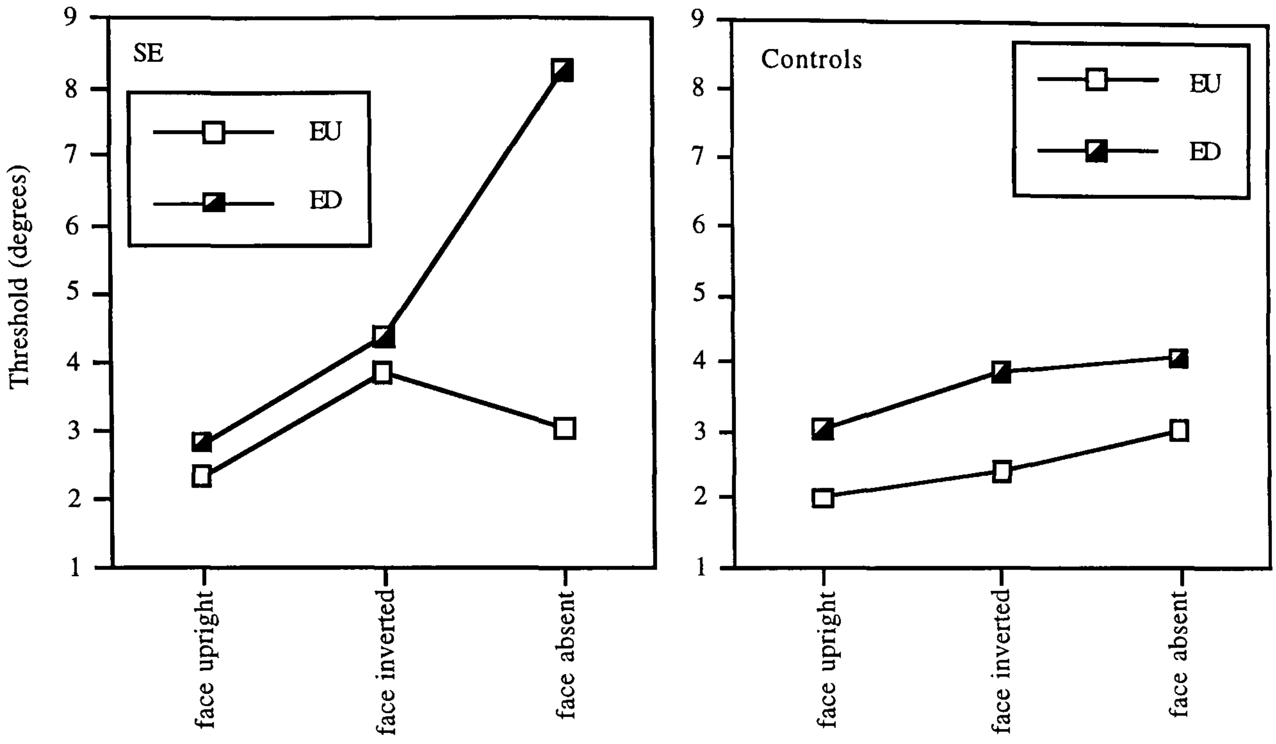


Figure 6.7: Threshold measures of performance in a gaze direction detection task by SE and three control participants.

Both SE and controls demonstrated greatest sensitivity to gaze direction when the face was in the correct configuration, i.e. the 'upright face-upright eyes' condition, a finding which suggests that SE's ability to discriminate gaze direction has remained intact.

General Discussion

In this chapter a range of tasks were employed which attempted to examine the performance of two amygdala damaged patients in their ability to process affect stimuli. As mentioned at the beginning of this chapter, the primary aim of this research was not to produce more evidence for a role of the amygdala in the appraisal of fearful stimuli, but rather to implement some of the tasks designed in this thesis and to investigate their application in a clinical setting. Of secondary interest was the ability of these patients to perform these tasks compared to a group of control participants.

Using the Jenkins affect image set, the paradigm which revealed the most significant differences between the performance of the patients and the performance of the control group was the six alternative constrained choice task (I). This paradigm is the one most commonly used in clinical investigations of affect processing. In this task SE was found to be impaired in his ability to label expressions of fear, disgust, anger and sadness, and DR was significantly impaired with expressions of anger and disgust, but not fear. Interestingly, on SE's second attempt at this task, five months later, he was now only found to be impaired in his ability to label expressions of disgust. SE has been a very conscientious contributor to several research programmes across the country. It is possible that due to extensive testing, SE has been able to develop numerous strategies which may now mask the presence of any real impairment. When Calder and his colleagues (1996) tested SE and DR in a 6AFC task using stimuli from the Ekman and Friesen (1976) series, both patients were found to only be impaired in their ability to label expressions of fear.

However, SE's potential ability to develop coping strategies does not account for the discrepancies in his performance in each of the different tasks. In the free naming task, which both SE and DR performed before the forced choice tasks, SE was found to only differ significantly from the control group in his ability to label the expression of disgust, and DR's performance was no different to controls for any of the expressions. When the nature of the forced choice task was changed so that on each trial SE was able to view examples of all six of the expressions, his performance accuracy increased dramatically and was no different to controls. There are a number of possible explanations for this finding: the poor results obtained in constrained choice task (I) could have been the result of a labelling bias, such that, for some reason SE did not make full use of the target labels presented to him. In constrained choice task (II), SE was forced to choose stimuli for every emotional label. Secondly, SE may have only been successful in the constrained choice task (II) as he was able to use a process of elimination to identify the fearful exemplars. If as Calder et al (1996a) suggested SE is only impaired in his ability to interpret expressions of fear, SE has only to correctly identify five of the images and attribute the expression he does not recognise with the label of fear. Such a strategy would obviously take longer than if an expression was spontaneously recognised, consequently, in future SE should be timed when participating in these tasks. In other tasks, the majority of the fearful exemplars were labelled as surprise, but surprise was only rarely labelled as fear. SE's success in this task could simply be due to his ability to accurately label surprise exemplars and then by default accurately label the fearful faces.

In the matching task, SE was impaired in his ability to match expression of disgust making confusions with expressions of sadness, anger and fear.

Calder et al (1996a) reported that both SE and DR were impaired in their ability to label expressions of fear in a forced choice task, a finding which has been replicated in this study for SE, but not for DR. However, when other paradigms were used to investigate expression processing, SE was not found to be impaired in his ability to label expressions of fear, but instead demonstrated a consistently poor performance in his ability to label expressions of disgust. From this data alone, one would be reluctant to report that damage to the amygdala resulted in an impaired ability to interpret fearful facial expressions, but instead may suggest that these results more closely resemble performance by patients with Huntington's disease. In addition, disgust was the only expression which caused difficulties for SE when he was asked to pose examples of each of the six basic emotions.

SE's ability to recall occasions which have been emotionally arousing, and to provide appropriate responses in the emotion questionnaire was apparently normal. Although his responses to the questions which were designed to evoke feelings of disgust may warrant further investigation. However, the problem with questionnaires like the one given to SE is that they do not actually tap into emotional *experience*. Since SE does not have a general amnesia, he is able to recall personal events which have caused particular emotions, and appears to be able to respond appropriately to emotionally arousing questions. Whether or not SE would actually experience these same emotions now is an empirical question.

O'Carroll et al (1997) tested SE's performance in an emotional memory task adopting the paradigm used by Cahill et al (1994) which was described in Chapter 5. This task involves a narrative accompanied by a slide show which describes three phases of a story. The story has a neutral beginning and end, but a highly emotional middle phase. Normal control participants exhibit enhanced recognition memory for this portion of the story in a forced choice test. SE failed to show this peak for the emotionally arousing part of the story and instead exhibited superior recall for the final neutral phase. O'Carroll et al (1997) suggest that this replication of Cahill's (1994) findings provide further support for the role of the amygdala in long term emotionally influenced memory. However, DR *did* exhibit the normative peak for the emotional middle phase of the story. O'Carroll et al (1997) suggest that DR's performance could be attributed to a hyperemotional effect which she may have experienced as a result of her epilepsy and subsequent surgical procedures. Alternatively, O'Carroll and his colleagues proposed that laterality effects could account for this finding. SE has more extensive damage to his right amygdala, DR to her left. Recent research by Cahill et al (1996) found that the glucose metabolic rate of the *right* amygdala measured while normal participants viewed the emotional film clips was highly correlated with the number of emotive clips recalled, and was not significantly correlated with the number of neutral films recalled. As such Cahill et al (1996) suggested that the amygdala is selectively involved in the long-term memory of emotionally arousing events.

SE's performance in the gaze tasks was comparable to the control group for all of the conditions with the exception of the 'face absent-eyes inverted' condition in which he was found to be significantly impaired. However, when the face and eyes were presented together in an upright orientation, SE was found to be highly accurate in determining the direction of the gaze demonstrating that his ability to perform this aspect of face processing has remained intact.

Only three participants contributed to the control data for the gaze tasks described in this chapter compared to six contributors when these tasks were originally described in Chapter 4. However, if the data from both groups are compared, it is apparent that the same *general* trend in performance is measured across all conditions. In the three conditions which presented the eyes in an upright orientation, performance was comparable between the two groups. However, the older control participants were found to be considerably more sensitive to gaze direction than the younger group reported in Chapter 4 when the eyes were presented in an inverted configuration. However, SE's performance in the 'face absent-eyes inverted' condition was still worse than these participants. It is possible to speculate that the significance of the facial surround may decrease with age. Children have been shown to be relatively insensitive to the inversion effect seen with adults for the recognition of familiar faces (Diamond & Carey, 1986), which suggests an increased reliance on configural information and the development of a rigid schema for faces. Perhaps this rigid schema becomes more plastic into old age, which could explain the superior performance of SE's control group with manipulations of the facial surround. A further difference between the control group and the participants of Chapter 4 is that the controls, and SE, took part in each of the six conditions. The participants of Chapter 4 only contributed data to one condition. The use of a between groups versus a within groups design could also have effected the data, since participants may have adopted a certain strategy in one condition which could then be used in another, alternatively participants could have employed a different strategy in each condition.

Of course, from only three participants it is impossible to draw any definite conclusions, however, the possibility of a decreased reliance on configural information with age does provide an interesting hypothesis for future consideration.

Summary

This chapter revealed the difficulties of choosing an appropriate task for the assessment of a patients ability to interpret facial expressions. The first four tasks reported in this chapter, free naming, constrained choice (I), constrained choice (II), and the matching task, all generated different results. With the exception of SE's first attempt in the constrained choice task (I), neither patient were found to differ significantly from controls in their interpretation of the expression of fear. DR was unimpaired in labelling facial expressions of emotion in a free naming task, but was impaired in her ability to label anger and disgust in the constrained choice task (I). SE was also found to be consistently poor at labelling expressions of disgust. SE also struggled to pose this expression himself but managed after a short delay. The varied results of the expression labelling tasks emphasise the need to interpret data collected in this way with care.

7

Review, Future Work and Conclusions

Overview

The research reported in this thesis employed a variety of paradigms to investigate our ability to detect and interpret social signals from the face, both in health and disease. In this chapter, the findings of this research are reviewed and suggestions for further related areas of study are suggested. Some preliminary results are also reported from an investigation designed to explore the role of dynamic information in the recognition of our facial expressions.

Review

In Chapter 2, the conventional methods of expression recognition, forced choice and free naming, were described and the problems in the interpretation of data obtained using these paradigms discussed and illustrated by comparing performance between the tasks, and between participants from Western and Japanese cultures.

The expression exemplars which comprised the image set used in this thesis were chosen from a collection of images which were labelled with an accuracy of 100% by ten participants in a forced choice task. Forced choice paradigms generally serve to inflate the apparent measure of accuracy by limiting participants to a list of labels, none of which they may feel are appropriate descriptions of the emotion they perceive. This was clearly shown to be the case when the same image set was used in the free naming task. Labelling accuracy fell for each of the expressions but was particularly reduced for the expressions of fear, disgust and sadness with scores falling to 75%, 84% and 86% respectively. These results illustrate the way in which participants use a 'best guess' strategy to label some of the expressions in a forced choice task.

In the free naming task, many participants chose not to use a word which described an emotion (despite their instructions) but instead used phrases or exclamations which were effectively describing a response to an emotional situation, rather than the emotion itself. For example, some participants used words such as "phew!" to describe a disgusted expression. Such a response was scored as correct despite it not appearing in the Oxford dictionary of Antonyms and Synonyms under disgust. This evidently makes the experimenters personal judgement of accuracy open to interpretation. Further difficulties of interpretation and translation were described in the analysis and use of these tasks when performed by Japanese participants. Two independent judges translated the data and although agreement was high between the two (97%), there were some important differences including confusions between the translations of disgust, anger and sadness.

In the forced choice and free naming tasks, the Japanese participants found difficulties in labelling expressions of fear, disgust and anger. Mean scores in the forced choice task for these expressions were 36%, 75% and 57% respectively, and 28%, 40% and 62% in the free naming task. Performance for the expressions of fear and anger were similar in both tasks, however, participants interpretation of the expression of disgust decreased dramatically from the forced choice task to the free naming task. As described in Chapter 2, the relatively low score measured in the forced choice task could have arisen due to an ambiguous choice of kanji to define this word. Alternatively, participants may have simply been unable to interpret the physiognomy of this expression and therefore allocated the label of disgust to a selection of faces which they felt unable to define using any of the other labels. This suggestion would be supported by the large decrease in accuracy when no labels were provided in the free naming task. The Japanese participants did not differ significantly from their Western counterparts in interpreting the expressions of happiness, sadness and surprise which demonstrates that the tasks were understood. In general, the *pattern* of performance measured for the Japanese participants was very similar to that of the Western group. Westerners reliably interpreted expressions of happiness and surprise and found the greatest difficulty with fearful and disgusted expressions. This pattern of performance was observed in the Japanese group only with a much reduced accuracy for the negative expressions. From the results reported in Chapter 2, it appears that in a free naming expression allocation task, *all* participants find the greatest difficulty with the expressions of fear and disgust. For the Japanese, this difficulty is more profound and suggests that cultural differences may have an influence on the amount of exposure to negative expressions, and also that these negative expressions are simply the most difficult to interpret, especially from different race faces.

After the difficulties experienced with interpretation and translation in the forced choice and free naming tasks, the use of a psychophysical technique to measure socially relevant signals was an appealing solution since problems with translation or interpretation could be overcome by the precise design of the task.

In Chapter 3 two psychophysical tasks were designed to measure the *detectability* of affect signals from the face. Measuring our sensitivity to facial expressions in this way only required the participants to discriminate between an expression (any expression) and a neutral face. As such, the participants were not required to interpret the expressions, making the task of interpreting the data considerably more straight forward. Participants were presented with the stimuli at a range of viewing distances which were equivalent to viewing a real face at distances of 10, 20, 30, 40 and 50m. Hager and Ekman (1979) had suggested that some expressions may be detectable at distance in excess of 200m and reported that male 'angry' faces were capable of transmitting an effective signal over further distances than female angry faces. Neither of these observations were confirmed in this thesis. Experiment 2, described in Chapter 3 used a two alternative forced choice paradigm in which participants were required to locate the presentation of an expression exemplar in one of two intervals on each trial. Experiment 3 used a signal detection paradigm which required the participant to determine the category (expression or neutral) of the stimulus on each presentation. The same pattern of performance was measured in each task although accuracy was generally higher using the 2AFC paradigm. However, both tasks revealed that participants were most sensitive to the expressions of happiness and surprise which were found to be reliably detected at an equivalent viewing distance of 40m. In contrast, the expression of sadness was poorly detected over all viewing distances with performance fluctuating around chance in both tasks. This would be predicted for an expression which is an external representation of an internal state which we do not need to transmit over great distances. Sadness is an emotion for which there would be no obvious survival benefit for an organism to detect or transmit over large distances. Therefore, our facial features have adopted a subtle configuration for this emotion. All of the other expressions tested are intended to be overt signals to other people, either in greeting, as in surprise and happiness, warning as in disgust, fear or anger, or threat as in anger. As such it would be expected that these expressions should be able to transmit their intended signal more effectively.

Expressions of fear, anger and disgust, which participants found difficult to interpret in the forced and free naming tasks of Chapter 2, were not found to be difficult to detect. Thus, the expressions which cause confusion in labelling paradigms, do not do so as a consequence of the strength of the signal they are able to transmit. However, the psychophysical tasks described in this thesis were not able to address the confusabilities of these negative expressions. Had these tasks required a discrimination between *expressions*, for example, instead of responding 'neutral' or 'expression' if the task had required the discrimination 'fear' or 'not fear', or 'disgust' or 'not disgust' this may have proved a more revealing task. If these expressions are perceptually distinct, then one would not expect confusions between them and other expressions. However, it might be predicted that fear would be reliably distinguished from expressions of happiness and sadness but may potentially be confused with surprise, anger or disgust as was seen in the tasks which required interpretation.

The tasks described in Chapter 3 make only a small step into the understanding of the perception of our facial expressions. Our ability to *detect* facial expressions is not simply the result of basic visual functions which can be neatly defined as the result of operations such as acuity and contrast sensitivity. Instead, our detection of facial expressions involves higher order mechanisms which treat these signals not simply as complex patterns, but as faces, as socially relevant stimuli which require a higher level of processing. The use of a specialised system tuned to the perception of faces as a specific stimulus class was illustrated when performance in the 2AFC task was found to decrease when the faces were presented in an inverted configuration. If the expression stimuli had been processed purely as complex patterns of light and dark regions, inversion would have had no effect since image properties are only trivially effected by this transformation. However, inversion is known to have detrimental effects on aspects of face processing, therefore the poor performance measured in this condition was indicative of the interruption of a process linked with the processing of faces as a specific stimulus class. However, this experiment was unable to establish if the faces were being processed as emotional signals or simply unusual facial configurations with no reference to affect whatsoever.

The power of these social signals in their upright configuration was demonstrated when the images were reduced to 1-bit per pixel format. In the 6AFC task labelling accuracy remained remarkable high suggesting no loss of signal from the reduced grey-scale. In the 2AFC psychophysical task, performance decreased with increasing distance and was worse than the performance at equivalent viewing distances in full grey-level task although a similar trend was observed. Happiness and surprise remained the best detected with increases in viewing distance, and sadness was detected with an accuracy no better than chance. In this task, participants ability to detect the expression of disgust showed a rapid decrease between 10 and 20m. This expression was also found to be the most difficult to label in the 6AFC task with a mean performance accuracy of 73%. Fear was found to be the next most difficult to label producing a score of 80%, anger followed at 82% with all other expressions being labelled with an accuracy in excess of 95%.

In these psychophysical investigations, viewing distance was used as a means of increasing the difficulty of the detection task and investigating our sensitivity to signals of facial affect. Hager and Ekman's (1979) conclusion that the face is a long distance transmitter of affective information was confirmed, although not to the extent that some of our facial expressions would be detectable at 220m.

In Chapter 4, sensitivity to gaze direction was measured using two psychophysical techniques. The first used a live set-up of gazer and observer, and the second transferred the image of the same gazer to the screen. Comparison between the two conditions was slightly ambiguous due to the changes in face size and viewing distance, however, performance in each task revealed that sensitivity was at least as good as Snellen acuity and demonstrated that the task transferred well to the screen.

Manipulations of the facial surround revealed that the ability to detect gaze direction did not rely solely on processes such as acuity to make a geometric analysis of the relative amounts of visible iris and sclera. Performance in the 'face absent-eyes upright' condition was found to be significantly inferior to that measured in the 'face upright-eyes upright' condition. The presence of the facial surround provided a necessary framework for the analysis of gaze direction. In addition performance in the 'face inverted-eyes upright' condition revealed a trend towards a beneficial effect of the facial surround even when presented in an incongruous orientation to the eyes, however, this did not reach statistical significance. Inverting the eyes had a very detrimental effect on participants ability to discriminate gaze direction regardless of the context in which the eyes were presented. In an upright orientation, the face is analysed configurally, as a whole, when the face is inverted, individual facial features are analysed at a local level. The disruption of configural processing interferes with the task of gaze direction detection which illustrates the role of higher order functions in what may have been considered to be a simple perceptual task.

Methodologies for Assessing Expression Perception in Patients

A summary of the performances of SE and DR which significantly differed from controls is reported in Table 7.1. This data demonstrates how the measured performance varied depending on the nature of the task employed, which illustrates the limitations of the traditional techniques for assessing expression recognition. In DR's case, performance in the free naming task was no different to the control group for any of the expressions, and SE was only found to be impaired in his interpretation of the expression of disgust in this task. When a forced choice paradigm was used, SE performed particularly badly and was found to be significantly impaired labelling expressions of sadness, anger, disgust and fear. However, when this trial was repeated five months later, SE's performance only differed significantly from controls for the expression of disgust. Despite DR's good performance in the free naming task, when tested using a forced choice paradigm she was found to be impaired in her labelling of expressions of disgust and anger. The decrease in accuracy measured in the forced choice task compared to the free naming task suggested that the patients may have been exhibiting a labelling bias. To investigate this possibility, SE performed two further tasks, the 6AFC task (II), in which he made no significant errors, and a matching task which caused difficulties with the expressions of sadness and disgust. In summary, unlike published studies with these patients, no differentially severe impairment in labelling accuracy for fear was found. DR did not differ significantly from controls in her perception of fear in either of the tasks she performed, and SE was only significantly impaired in this task on his first attempt at the 6AFC task (I).

	Sadness	Anger	Disgust	Fear
Free Naming			SE	
6AFC (I)	SE	SE, DR	SE, DR	SE
6AFC (II)				
Matching	SE		SE	

Table 7.1: Performance which differed significantly from controls in each of four tasks of expression perception. (DR only participated in the free naming task and the 6AFC task (I)).

However, both SE and DR did produce very low accuracy scores in their ability to label expressions of fear, but in the majority of cases, these scores did not differ significantly from the control group as this was the expression that caused the most difficulty for the controls. In fact, DR outperformed the controls in the free naming task, and SE outperformed them in the matching task. Why should the control participants have performed so badly with this expression? In a forced choice task with these images, young adults labelled each of the emotions with an accuracy of 100%, and 75% in a free naming task, so the low scores from the control participants are not a reflection of the quality of the image set. The control participants were only 50% correct in the forced choice task (I), and 28.3% correct in the free naming task. Wolfgang and Cohen (1988) reported that overall recognition scores for expressions from a standardised set, varied with the level of education achieved by the participant. Those participants with a university education had an overall score of 81%, those with a high school education, 66%, and those with only a primary school education scored only 43%. In addition, Alvarez and Fuentes (1994) found that participants from a low socioeconomic group were significantly impaired in their ability to label facial expressions compared to a group of university students. In the study reported in Chapter 6, SE and DR were compared with control participants who had received no formal education after school leaving age, and were thought to match both patients well on IQ although no formal measures were taken. The low score measured for the controls for this expression is similar to that measured for the Japanese participants who scored 36% in the forced choice task and 28% when the free naming paradigm was used. However, low IQ certainly cannot account for the poor performance measured for the Japanese participants. It could explain the poor performance of the control participants in this study, however, the control participants described by Calder et al (1996a) in their investigations with SE and DR, who were matched for IQ, did not experience the same difficulties described for the controls used in this study. The controls in Calder et al's (1996a) study found the expression of anger the most difficult to label which they propose provides evidence to suggest that perceptual difficulty alone could not account for the poor performance of the patients. However, the controls used in Sprengelmeyer et al's (1996) study did find fear the most difficult to label, and this was certainly the case in this study. If the expressions of fear and disgust are simply the most difficult to interpret, it could be imagined that a system specifically tuned to their perception would require expertise with these signals which the Japanese participants may simply not have. It appears as though the expressions, fear and disgust, which cause normal participants the most difficulty in tasks of interpretation, are also the ones which cause brain injured patients the most difficulty. These patients often have very generalised face processing impairments which are not confined to an inability to label one facial expression. It would seem reasonable that expressions which cause normal participants the most difficulty, as shown by the performance of the Western and Japanese participants in Chapter 2, are the ones which are most severely affected when general face processing abilities have been impaired.

To what extent is the perception and interpretation of affect signals correlated with the *experience* of emotion? In terms of our evolution, the development of specific neural substrates for basic emotions is most obviously applied to experiencing them. However, the research which has indicated specific neural substrates for some of our basic emotions has been concerned with the recognition of these affect signals. A link between the mechanisms involved in the *recognition* of emotions, and those required for *experiencing* them would be highly advantageous since it would enable us to learn about potentially dangerous situations without actually having to experience them ourselves (Brothers, 1989).

The observation that patients with Huntington's disease appear to be impaired in their recognition of disgust both from visual and auditory cues, and that they appear not to be concerned with their own personal hygiene (Sprengelmeyer et al, 1996), would suggest that perhaps all aspects of expression processing from perception and interpretation to experience are linked by a more central mechanism. In addition, the recent report by Phillips et al (1997), described cerebral activation in the anterior insula when normal participants were shown faces portraying disgust. This area is also associated with responses to bad tastes indicating that the neural response to the perception of this expression is also associated with the appraisal of distasteful stimuli.

The recent evidence for specific neural substrates for two of our basic emotions, fear and disgust (Phillips et al, 1997; Morris et al, 1996) has provided the most compelling evidence that the perception of these expressions from the faces of others, even in tasks which did not require the images to be overtly recognised, is linked with the experience of the emotion itself. As such, performance in tasks of detection, like those described in Chapter 3, are likely to be associated with a more central mechanism for analysing our facial affect signals. In addition, the finding that people with Möbius syndrome who are unable to express emotions facially, also report difficulties in experiencing them (Cole, 1997). In order to understand the emotional content of an experience they must intellectualise their mood, "this is a happy event, therefore I must be happy".

The research reported in this thesis has practical, methodological and theoretical implications which are described in the next section which briefly describes some preliminary research projects and possible research for the future.

Detection of Facial Expressions

The psychophysical tasks described in Chapter 3 provided a useful tool for establishing our sensitivity to signals of facial affect, and as a means of assessing the performance of a patient with face processing impairments. However, for some patients, the rapid stimulus presentation, or use of a computer may not be appropriate. A more portable and accessible version of this experiment was devised by transferring the task to paper. A Gaussian filter was applied to each of the images in the Jenkins affect set creating new images which were blurred to various degrees. In the psychophysical experiments described in Chapter 3, the difficulty of the tasks was controlled by varying the viewing distance. A Gaussian filter has the effect of blurring the images and is equivalent to increasing the viewing distance. The task remained a 2AFC with two images printed side by side on paper. One of the images consisted of the expression, and the other a neutral face of the same expressor. The location of the expression was randomised between trials and the task for the participant was to locate the presence of the target, either on the left or the right of the page. SE has performed this task and his performance was found to be equivalent to a group of young adults as was seen in the 1AFC psychophysical task reported in Chapter 6. In addition, the same pattern of results emerged from this task as from the computer based tasks with expressions of happiness and surprise remaining well detected with increased amounts of blurring, and sadness being poorly detected even with low levels of blur.

In the next section another methodological approach to explore participants interpretation of facial expressions is described. Most research in this area uses static images of facial expressions for the reasons described in Chapter 2. But what effect would a dynamic input have on tasks of expression recognition? One way to investigate this is to make the expressions harder to see and then look for an improvement in recognition from a moving sequence. This approach has been adopted in a current project which is being carried out in collaboration with Professor Vicki Bruce at Stirling University, and Dr. Sakiko Yoshikawa at the Advanced Telecommunications Research Institute in Japan. Some background to this project and some preliminary results are reported in the next section.

The Role of Motion in Facial Expression Recognition

In this preliminary investigation, the disruptive effects of negation on face processing were used as a tool to explore the contribution of dynamic information to facial expression recognition. It is a well reported phenomenon that negating grey level images makes the task of person identification difficult (Galper, 1970; Bruce & Langton, 1994; Kemp, Pike, White & Musselman, 1996; Johnston, Hill and Carman, 1992). Images in photographic negative retain the same spatial arrangement of the features but all the grey levels are reversed. It is therefore quite surprising to discover quite how disruptive this image transformation is to face recognition. Two possibilities for this effect have been proposed, the first considers the idea of shape from shading, whereby negation produces an impossible pattern of shading which interrupts the retrieval of 3D information from the face and hence the ability to access information regarding identity (Kemp et al, 1996). The second possibility concerns the disruption of the apparent pigmentation of these facial images which alone could account for the poor recognition (Bruce & Langton 1994).

Galper (1970) was the first to study the effects of negation on face recognition. He used a recognition memory task and suggested that the difficulty experienced by participants with the negated stimuli was the result of the participants being unable to 'read' the expression of the individual. This explanation is highly unlikely in the light of the wealth of evidence that has been reported in this thesis and elsewhere for the separate processing of expression and identity. The effects of negation have been likened to those of inversion, both perhaps arise due to the difficulty in encoding configural information from the transformed images. Hayes, Morrone and Burr (1986) demonstrated that it was the low spatial frequency components in an image that were sensitive to negation. Line drawings, which contain only high frequency information are difficult to recognise in positive and unaffected by negation.

Interest in the effects of negation have increased over the last ten years and its disruptive effect on person identification have been used as a tool to investigate other aspects of face processing. In this investigation, negation was used to investigate the role of motion in facial expression recognition. It has been found that *recognition* of familiar or famous faces from negative is increased if the sequences are moving. This study attempted to establish whether this benefit was also seen for facial expressions, and if so, if it arose as a result of the effects of motion itself, or simply the presentation of more static information.

Participants were shown video-clips of actors posing expressions of happiness, sadness, anger and surprise in positive and negative formats which could be either moving or static. The dynamic displays showed the actor's features moving from a neutral pose to the apex of the expression. The static displays showed a single frame representing the apex of the expression for an equivalent duration as the dynamic sequence. Participants were given a list of expressions which contained the four target expressions and two distractors and were asked to choose the most appropriate expression label on each trial.

Motion was found to have a beneficial effect for expression identification in both the positive and negative conditions. Performance was greatest in the positive moving condition and least in the negative static condition. However, the question still remains as to whether the advantage was actually due to dynamic information itself, or simply the presentation of more information. Ongoing research compares participants performance in the negative moving condition, presenting the stimuli at the normal frame rate of 30 frames per second (FPS) and at the much reduced speed of 4FPS. Slowing the presentation rate maintains the informative properties but interferes with the natural dynamics. Therefore, if the measured advantage is a result of the relative amounts of information contained within a moving sequence compared to a static one, performance at the two speeds should be the same. If however, the benefit of seeing a moving sequence comes from a special property of the actual dynamics, performance would be hindered when the presentation rate is slowed.

Recently, evidence has emerged which would support the idea of a mechanism tuned to the perception of biologically relevant motion which would contribute to the recognition of our facial affect signals. Humphreys, Donnelly and Riddoch (1993) described a patient, HJA, who was severely impaired in his ability to recognise identity and was poor at discriminating facial expressions and gender from static images of faces. However, if the images were animated using a point light display, he was able to make accurate judgements. A second patient, GK, who was not significantly impaired in his ability to recognise identity, was found to be poor at recognising facial expressions from both static and moving faces. Humphreys et al (1993) suggest that the impairments demonstrated by these patients indicates that expressions are encoded separately from static and dynamic images. Humphreys et al (1993) cite the work of Perrett and his colleagues (1990a; 1990b) who have reported the presence of cells in the STS of the macaque which exhibit sensitivity to biologically significant movement patterns. In addition, prosopagnosic patients have been shown to compensate for their inability to recognise familiar people from their faces, and instead can achieve recognition from the person's gait. Humphreys et al (1993) proposed that the neurophysiological findings provide evidence for two types of model. The first would predict the existence of separate channels for processing dynamic and static facial expressions, with a pooling of information at a later stage of processing, perhaps providing social significance to the signals. The second model would predict a central mechanism which would receive inputs from static and dynamic form channels and simply categorise the type of affect signal.

In the context of this research, we might expect that if we do possess a motion system which is specifically tuned to biologically relevant stimuli, such as facial expressions, that this system would be disrupted by interfering with the natural time course in which we typically see these displays take. We might expect that when the facial expressions are slowed to a presentation rate of 4FPS, recognition would be no greater than that which would be measured in the static condition.

Future research in this project will also investigate the ability of Western participants to recognise the facial expressions posed by the Japanese actors under the same conditions of form and presentation. Western participants may be as poor at recognising facial affect from Japanese faces as the Japanese participants were found to be in interpreting these signals from Western faces in the tasks described in Chapter 2. As such, it may be the case that Western participants will be less affected by the negation of these images, but may gain more from the animation of the sequences.

In Chapter 6, Figure 6.3, patient SE was illustrated posing expressions of happiness, sadness, anger, disgust, fear and surprise. The static images printed in this thesis were taken from the apex of the display but they are not able to capture the exposition of these affect signals as they are seen in motion, consequently, they may not appear to be convincing portrayals of the expressions being examined.

A theoretical application of the research reported in this thesis comes from the finding that our sensitivity to eye gaze direction is influenced by configural processing. Performance was found to be significantly impaired when the eyes were presented in isolation compared to within the context of an upright face. As the presence of the facial surround was found to have a significant advantage in discriminating gaze direction, it may be supposed that the expression portrayed on the surrounding face would also have an effect on the measured sensitivity. In the next section, some of the literature which would support this suggestion for a future project is briefly described.

Gaze Direction Sensitivity from Emotionally Expressive Faces

The gaze direction sensitivities reported in Chapter 4 were all measured from an actor posing a neutral facial expression (if a facial surround was present). Despite the evidence from neuropsychological and neurophysiological research for a double dissociation between facial expressions and eye gaze, perhaps at some level of processing, the two channels of information are pooled to generate socially relevant information.

Dimberg and Öhman (1983) demonstrated that responses conditioned to angry faces directed towards a participant were resistant to extinction, conversely, responses conditioned to angry faces directed away from a participant extinguished immediately.

Furthermore, the orientation of the faces during acquisition was not important, only during the extinction phase were the faces required to be directed toward the participant to maintain persistent responses. Hansen and Hansen (1988) presented participants with arrays of expressive faces and found that participants were more efficient and faster at locating angry faces in happy crowds than happy faces in angry crowds. Similarly, the same pattern was found if the happy faces were replaced with neutral faces. They also found that participants were quicker to determine the presence or absence of an angry face in a happy crowd than they were to decide the presence or absence of a happy face in an angry crowd. This asymmetry was also found to increase as the size of the crowd increased. Hansen and Hansen (1988) concluded that faces could be pre-attentively processed for signals of potential threat. Von Grünau and Anston (1995) reported the existence of a search asymmetry for the detection of a straight ahead gaze. Eye-like stimuli with a directed gaze were detected more quickly and with fewer errors when embedded in an array of averted gaze distractors, than averted gaze stimuli were detected in an array of directed gaze distractors. They did not find the same effect for geometric eye-like stimuli which would suggest that the detectability of the realistic eye-like stimuli was not simply an artifact of the directed gaze stimuli also conforming to a symmetrical pattern. This research, in conjunction with Hansen and Hansen's (1988) finding of pre-attentive processing of signals of potential threat, would suggest that it may be the case that performance in a gaze direction discrimination task would be most sensitive if the eyes were embedded within faces that signalled potential threat. So, for example, participants may be better able to discriminate gaze direction from a face which was portraying a directed expression such as anger or fear, in which case, the ability to decide if this emotion was directed at self would have obvious survival benefits for an organism. Conversely, sensitivity to gaze direction from a sad face may not be very impressive since sadness is not a signal which we usually direct at other people and would not cause the same arousal as a potentially threatening signal. The same penalty for mistaking the direction of gaze of a sad person would not befall the individual who mistook the gaze of an angry person.

Consequently, it could be imagined that participants would make more errors if the gaze was embedded in a threatening face as they may be more willing to assume that the gaze was directed towards them, since the penalty for mistaking a directed gaze could prove costly.

Conclusions

The question posed at the beginning of this thesis asked, ‘how sensitive are we to the socially relevant signals that we are confronted with in our non-verbal communications with other people, and how can we measure these sensitivities?’ I hope that by now the reader is convinced that we are highly sensitive to these signals, with evidence that our facial expressions can transmit an affective signal over great distances and that our ability to detect gaze direction is at least as good as Snellen acuity. In addition, the detection of both of these social signals was found to depend on face specific mechanisms and not simply low level visual processes such as contrast sensitivity and acuity. The second part of the question is slightly more difficult to answer. The amount of variation in SE’s performance in the first four tasks described in Chapter 6, and in DR’s performance in the free naming and 6AFC task (I) illustrates the difficulty in interpreting data collected using these paradigms. Are genuine impairments being revealed? Are some paradigms concealing genuine difficulties? Are others indicating the presence of an impairment simply as an artifact of experimental design? Are alternative strategies for coping with impairments easier to implement in some tasks compared to others? None of these questions can be easily addressed, although all are possible scenarios. The appeal of the psychophysical tasks described in Chapter 3 is that they do not require participants to interpret what they see, but simply make a discrimination between a signal and a non-signal. The suggestion of an equivalent task requiring a discrimination between ‘fear’ and ‘not fear’ for example, could provide a useful paradigm in further tests of expression processing with brain injured patients and normals alike.

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Appendices

Chapter 2

Table 1: The contents of this table represent the expressions posed by each of the twenty-one actors whose images comprise the Jenkins affect set.

Actor	Happy	Sad	Anger	Disgust	Fear	Surprise
AB	√				√	√
BC	√	√		√	√	
CG	√			√		√
FC		√		√		
FM	√	√	√	√		√
FY		√	√		√	√
HB				√	√	
HL		√	√	√	√	√
KB			√	√	√	√
KM	√		√	√	√	
LG	√				√	√
MM	√			√		
MR			√			
MY	√	√			√	√
PR			√			
RF			√			
SC	√	√	√		√	
SD			√			√
SJ		√				√
SM	√	√		√		
SY		√				

Chapter 2

Western and Japanese participants in a Free Naming Expression Allocation Task

```
SOURCE: grand mean
population    expression      N         MEAN         SD           SE
                120         7.7500     2.6703      0.2438

 SOURCE: population
 pop     exp         N       MEAN         SD         SE
 j                  60     6.5833      3.1852      0.4112
 w                  60     8.9167      1.2114      0.1564

 SOURCE: exp
 pop     exp         N       MEAN         SD         SE
      happy         20      9.8500      0.4894      0.1094
      sad           20      8.1500      1.5313      0.3424
      anger         20      7.8500      1.9541      0.4369
      disgust       20      6.2000      3.4580      0.7732
      fear          20      5.2000      3.0018      0.6712
      surprise      20      9.2500      0.8507      0.1902

 SOURCE: pop exp
 pop            exp        N       MEAN          SD           SE
Japanese         h        10      9.7000       0.6749       0.2134
 j               s        10      7.7000       1.8886       0.5972
 j               a        10      6.2000       1.2293       0.3887
 j               d        10      4.0000       3.5901       1.1353
 j               f        10      2.9000       2.3781       0.7520
 j               su       10      9.0000       1.0541       0.3333
Westerners       h        10     10.0000       0.0000       0.0000
 w               s        10      8.6000       0.9661       0.3055
 w               a        10      9.5000       0.7071       0.2236
 w               d        10      8.4000       1.2649       0.4000
 w               f        10      7.5000       1.2693       0.4014
 w               su       10      9.5000       0.5270       0.1667

 FACTOR:        subject     population  expression     score
 LEVELS:          20            2           6           120
 TYPE   :      RANDOM        BETWEEN      WITHIN       DATA

 SOURCE     SS       df              MS          F        p
 ===============================================================
 pop     163.3333    1            163.3333    32.606   0.000 ***
 s/p      90.1667   18              5.0093

 exp     314.7000    5             62.9400    31.325   0.000 ***
 es/p              180.8333        90           2.0093

 pe       99.4667    5             19.8933     9.901   0.000 ***
 es/p              180.8333        90           2.0093
```

Chapter 3: Experiment 2:Sensitivity to expressive signals from the upright face

```
SOURCE: grand mean
distance    exp    N       MEAN          SD          SE
                 180      7.2278      2.0628      0.1538

SOURCE: distance
 dist   exp         N       MEAN          SD          SE
 d1                36     9.1389      1.2225      0.2037
 d2                36     8.1389      1.6415      0.2736
 d3                36     7.6667      1.7071      0.2845
 d4                36     5.9167      1.6626      0.2771
 d5                36     5.2778      1.1859      0.1976

SOURCE: expression
 dist   exp         N       MEAN          SD          SE
        happy      30      8.1667      1.9667      0.3591
        sad        30      6.2000      1.2429      0.2269
        anger      30      7.2333      1.8696      0.3413
        disgust    30      7.0000      2.4495      0.4472
        fear       30      7.1333      2.2397      0.4089
        surprise   30      7.6333      2.0254      0.3698

SOURCE: distance expression
 dist   exp         N       MEAN          SD          SE
 d1     h           6     9.5000      0.8367      0.3416
 d1     s           6     7.0000      1.0954      0.4472
 d1     a           6     9.1667      0.7528      0.3073
 d1     d           6     9.6667      0.5164      0.2108
 d1     f           6     9.5000      0.8367      0.3416
 d1     su          6    10.0000      0.0000      0.0000
 d2     h           6     9.5000      0.8367      0.3416
 d2     s           6     5.6667      1.3663      0.5578
 d2     a           6     7.8333      1.4720      0.6009
 d2     d           6     8.6667      1.3663      0.5578
 d2     f           6     8.5000      1.2247      0.5000
 d2     su          6     8.6667      0.5164      0.2108
 d3     h           6     9.1667      0.9832      0.4014
 d3     s           6     6.3333      1.2111      0.4944
 d3     a           6     8.0000      1.2649      0.5164
 d3     d           6     7.5000      1.7607      0.7188
 d3     f           6     7.1667      2.1370      0.8724
 d3     su          6     7.8333      1.8348      0.7491
 d4     h           6     6.6667      2.0656      0.8433
 d4     s           6     6.6667      0.8165      0.3333
 d4     a           6     5.5000      1.3784      0.5627
 d4     d           6     4.8333      1.4720      0.6009
 d4     f           6     5.1667      2.1370      0.8724
 d4     su          6     6.6667      1.2111      0.4944
 d5     h           6     6.0000      1.4142      0.5774
 d5     s           6     5.3333      1.2111      0.4944
 d5     a           6     5.6667      1.3663      0.5578
 d5     d           6     4.3333      1.0328      0.4216
 d5     f           6     5.3333      0.5164      0.2108
 d5     su          6     5.0000      1.0954      0.4472
```

```
FACTOR:     subject     distance  expression    score
LEVELS:        6           5          6          180
TYPE   :     RANDOM      WITHIN     WITHIN       DATA

SOURCE      SS      df          MS          F       p
===============================================================
dist     367.0778    4        91.7694    54.106   0.000 ***
ds/       33.9222   20         1.6961

exp       64.8944    5        12.9789     7.407   0.000 ***
es/       43.8056   25         1.7522

de        80.8556    20        4.0428     2.481   0.002 **
des/     162.9444   100        1.6294
```

```
SOURCE: grand mean
 dist    sex        N       MEAN        SD         SE
                   60     1.4667     1.1856     0.1531

 SOURCE: distance
 dist    sex        N       MEAN        SD         SE
 d1                12     0.4167     0.6686     0.1930
 d2                12     1.0833     0.7930     0.2289
 d3                12     1.2500     0.8660     0.2500
 d4                12     2.3333     1.1547     0.3333
 d5                12     2.2500     1.2154     0.3509

 SOURCE: sex
 dist    sex          N       MEAN        SD         SE
         female      30     1.5667     1.2229     0.2233
         male        30     1.3667     1.1592     0.2116

 SOURCE: distance sex
 dist    sex        N       MEAN        SD         SE
 d1      f          6     0.6667     0.8165     0.3333
 d1      m          6     0.1667     0.4082     0.1667
 d2      f          6     1.1667     0.7528     0.3073
 d2      m          6     1.0000     0.8944     0.3651
 d3      f          6     1.3333     0.8165     0.3333
 d3      m          6     1.1667     0.9832     0.4014
 d4      f          6     2.1667     1.3292     0.5426
 d4      m          6     2.5000     1.0488     0.4282
 d5      f          6     2.5000     1.5166     0.6191
 d5      m          6     2.0000     0.8944     0.3651

 FACTOR:     subject     distance     sex      score
 LEVELS:        6           5          2        60
 TYPE   :     RANDOM     WITHIN      WITHIN     DATA

 SOURCE      SS        df       MS          F       p
 ===============================================================
 dist     31.9333     4      7.9833      9.466     0.000 ***
 ds/      16.8667    20      0.8433

 sex       0.6000     1      0.6000      0.429   0.542
 ss/       7.0000     5      1.4000

 ds        1.4000     4      0.3500      0.333   0.852
 dss/    21.0000     20      1.0500
```

Chapter 3: Experiment 3:1AFC task to study sensitivity to expressive signals from the face.

```
SOURCE:     grand mean
distance    expression      N        MEAN         SD          SE
                            180      6.4000       2.2363      0.1667

 SOURCE: distance
 dist    expr        N       MEAN         SD          SE
 d1                 36       8.2500       1.9030      0.3172
 d2                 36       6.6389       2.4278      0.4046
 d3                 36       6.1667       2.0633      0.3439
 d4                 36       5.6944       1.7699      0.2950
 d5                 36       5.2500       1.7788      0.2965

 SOURCE: expression
 dist    expr        N       MEAN         SD          SE
         Happy       30       7.6333       2.1573      0.3939
         Sad         30       4.6000       1.9582      0.3575
         Anger       30       6.3333       2.0398      0.3724
         Disgust     30       6.3000       2.1995      0.4016
         Fear        30       6.3333       1.9535      0.3567
         Surprise    30       7.2000       1.9896      0.3633

 SOURCE: distance expression
 dist    expr        N       MEAN         SD          SE
 d1      H           6       9.6667       0.5164      0.2108
 d1      S           6       5.6667       2.4221      0.9888
 d1      A           6       8.3333       0.8165      0.3333
 d1      D           6       8.3333       1.5055      0.6146
 d1      F           6       8.1667       1.7224      0.7032
 d1      Su          6       9.3333       1.2111      0.4944
 d2      H           6       8.6667       1.2111      0.4944
 d2      S           6       3.6667       2.3381      0.9545
 d2      A           6       7.0000       1.7889      0.7303
 d2      D           6       6.6667       2.0656      0.8433
 d2      F           6       6.3333       2.4221      0.9888
 d2      Su          6       7.5000       2.0736      0.8466
 d3      H           6       7.3333       2.3381      0.9545
 d3      S           6       4.0000       2.0000      0.8165
 d3      A           6       7.0000       1.2649      0.5164
 d3      D           6       6.3333       2.4221      0.9888
 d3      F           6       6.1667       1.1690      0.4773
 d3      Su          6       6.1667       1.8348      0.7491
 d4      H           6       7.5000       0.8367      0.3416
 d4      S           6       4.5000       0.8367      0.3416
 d4      A           6       4.6667       1.7512      0.7149
 d4      D           6       5.1667       1.4720      0.6009
 d4      F           6       6.1667       2.1370      0.8724
 d4      Su          6       6.1667       1.7224      0.7032
 d5      H           6       5.0000       2.0976      0.8563
 d5      S           6       5.1667       1.7224      0.7032
 d5      A           6       4.6667       1.7512      0.7149
 d5      D           6       5.0000       2.1909      0.8944
 d5      F           6       4.8333       0.7528      0.3073
 d5      Su          6       6.8333       1.6021      0.6540
```

```
FACTOR:      subject   distance    expression    correct
LEVELS:         6          5           6           180
TYPE  :      RANDOM     WITHIN      WITHIN        DATA

SOURCE        SS      df         MS          F       p
===============================================================
dist     192.7556    4       48.1889     14.262  0.000 ***
ds/       67.5778   20        3.3789

expr     162.6000    5       32.5200     15.838  0.000 ***
es/       51.3333   25        2.0533

de        78.5111    20       3.9256      1.536  0.086
des/     255.5556   100       2.5556
```

Chapter 3: Experiment 2 and 3 compared (2AFC & Signal Detection)

```
SOURCE: grand mean
 dist   exp   task          N       MEAN         SD          SE
                          360     6.8167     2.1850      0.1152

 SOURCE: distance
 dist   exp   task          N       MEAN         SD          SE
 d1                        72     8.6944     1.6499      0.1944
 d2                        72     7.3889     2.1919      0.2583
 d3                        72     6.9167     2.0262      0.2388
 d4                        72     5.8194     1.6978      0.2001
 d5                        72     5.2639     1.5011      0.1769

 SOURCE: expression
 dist   exp   task          N       MEAN         SD          SE
      happy                60     7.9000     2.0642      0.2665
      sad                  60     5.4000     1.8152      0.2343
      anger                60     6.7833     1.9923      0.2572
      disgust              60     6.6667     2.3192      0.2994
      fear                 60     6.7333     2.1223      0.2740
      surprise             60     7.4167     2.0025      0.2585

 SOURCE: distance expression
 dist   exp   task          N       MEAN         SD          SE
 d1     h                  12     9.5833     0.6686      0.1930
 d1     s                  12     6.3333     1.9228      0.5551
 d1     a                  12     8.7500     0.8660      0.2500
 d1     d                  12     9.0000     1.2792      0.3693
 d1     f                  12     8.8333     1.4668      0.4234
 d1     su                 12     9.6667     0.8876      0.2562
 d2     h                  12     9.0833     1.0836      0.3128
 d2     s                  12     4.6667     2.1034      0.6072
 d2     a                  12     7.4167     1.6214      0.4680
 d2     d                  12     7.6667     1.9695      0.5685
 d2     f                  12     7.4167     2.1515      0.6211
 d2     su                 12     8.0833     1.5643      0.4516
 d3     h                  12     8.2500     1.9598      0.5658
 d3     s                  12     5.1667     1.9924      0.5752
 d3     a                  12     7.5000     1.3143      0.3794
 d3     d                  12     6.9167     2.1088      0.6088
 d3     f                  12     6.6667     1.7233      0.4975
 d3     su                 12     7.0000     1.9540      0.5641
 d4     h                  12     7.0833     1.5643      0.4516
 d4     s                  12     5.5833     1.3790      0.3981
 d4     a                  12     5.0833     1.5643      0.4516
 d4     d                  12     5.0833     1.3790      0.3981
 d4     f                  12     5.6667     2.1034      0.6072
 d4     su                 12     6.4167     1.4434      0.4167
 d5     h                  12     5.5000     1.7838      0.5149
 d5     s                  12     5.2500     1.4222      0.4106
 d5     a                  12     5.1667     1.5859      0.4578
 d5     d                  12     4.6667     1.6697      0.4820
 d5     f                  12     5.0833     0.6686      0.1930
 d5     su                 12     5.9167     1.6214      0.4680
```

```
SOURCE: task
dist  exp    task              N      MEAN        SD         SE
               e2 (Expt.2)     180    7.2278      2.0628     0.1538
               e3 (Expt.3)     180    6.4056      2.2316     0.1663

SOURCE: distance task
dist  exp     task      N       MEAN        SD          SE
d1             e2       36      9.1389      1.2225      0.2037
d1             e3       36      8.2500      1.9030      0.3172
d2             e2       36      8.1389      1.6415      0.2736
d2             e3       36      6.6389      2.4278      0.4046
d3             e2       36      7.6667      1.7071      0.2845
d3             e3       36      6.1667      2.0633      0.3439
d4             e2       36      5.9167      1.6626      0.2771
d4             e3       36      5.7222      1.7503      0.2917
d5             e2       36      5.2778      1.1859      0.1976
d5             e3       36      5.2500      1.7788      0.2965

SOURCE: expression task
dist  exp      task      N        MEAN          SD          SE
       h        e2       30      8.1667      1.9667      0.3591
       h        e3       30      7.6333      2.1573      0.3939
       s        e2       30      6.2000      1.2429      0.2269
       s        e3       30      4.6000      1.9582      0.3575
       a        e2       30      7.2333      1.8696      0.3413
       a        e3       30      6.3333      2.0398      0.3724
       d        e2       30      7.0000      2.4495      0.4472
       d        e3       30      6.3333      2.1709      0.3963
       f        e2       30      7.1333      2.2397      0.4089
       f        e3       30      6.3333      1.9535      0.3567
       su       e2       30      7.6333      2.0254      0.3698
       su       e3       30      7.2000      1.9896      0.3633

SOURCE: distance expression task
dist  exp      task      N        MEAN          SD          SE
d1     h        e2        6      9.5000      0.8367      0.3416
d1     h        e3        6      9.6667      0.5164      0.2108
d1     s        e2        6      7.0000      1.0954      0.4472
d1     s        e3        6      5.6667      2.4221      0.9888
d1     a        e2        6      9.1667      0.7528      0.3073
d1     a        e3        6      8.3333      0.8165      0.3333
d1     d        e2        6      9.6667      0.5164      0.2108
d1     d        e3        6      8.3333      1.5055      0.6146
d1     f        e2        6      9.5000      0.8367      0.3416
d1     f        e3        6      8.1667      1.7224      0.7032
d1     su       e2        6     10.0000      0.0000      0.0000
d1     su       e3        6      9.3333      1.2111      0.4944
d2     h        e2        6      9.5000      0.8367      0.3416
d2     h        e3        6      8.6667      1.2111      0.4944
d2     s        e2        6      5.6667      1.3663      0.5578
d2     s        e3        6      3.6667      2.3381      0.9545
d2     a        e2        6      7.8333      1.4720      0.6009
d2     a        e3        6      7.0000      1.7889      0.7303
d2     d        e2        6      8.6667      1.3663      0.5578
d2     d        e3        6      6.6667      2.0656      0.8433
d2     f        e2        6      8.5000      1.2247      0.5000
d2     f        e3        6      6.3333      2.4221      0.9888
d2     su       e2        6      8.6667      0.5164      0.2108
```

d2	su	e3	6	7.5000	2.0736	0.8466
d3	h	e2	6	9.1667	0.9832	0.4014
d3	h	e3	6	7.3333	2.3381	0.9545
d3	s	e2	6	6.3333	1.2111	0.4944
d3	s	e3	6	4.0000	2.0000	0.8165
d3	a	e2	6	8.0000	1.2649	0.5164
d3	a	e3	6	7.0000	1.2649	0.5164
d3	d	e2	6	7.5000	1.7607	0.7188
d3	d	e3	6	6.3333	2.4221	0.9888
d3	f	e2	6	7.1667	2.1370	0.8724
d3	f	e3	6	6.1667	1.1690	0.4773
d3	su	e2	6	7.8333	1.8348	0.7491
d3	su	e3	6	6.1667	1.8348	0.7491
d4	h	e2	6	6.6667	2.0656	0.8433
d4	h	e3	6	7.5000	0.8367	0.3416
d4	s	e2	6	6.6667	0.8165	0.3333
d4	s	e3	6	4.5000	0.8367	0.3416
d4	a	e2	6	5.5000	1.3784	0.5627
d4	a	e3	6	4.6667	1.7512	0.7149
d4	d	e2	6	4.8333	1.4720	0.6009
d4	d	e3	6	5.3333	1.3663	0.5578
d4	f	e2	6	5.1667	2.1370	0.8724
d4	f	e3	6	6.1667	2.1370	0.8724
d4	su	e2	6	6.6667	1.2111	0.4944
d4	su	e3	6	6.1667	1.7224	0.7032
d5	h	e2	6	6.0000	1.4142	0.5774
d5	h	e3	6	5.0000	2.0976	0.8563
d5	s	e2	6	5.3333	1.2111	0.4944
d5	s	e3	6	5.1667	1.7224	0.7032
d5	a	e2	6	5.6667	1.3663	0.5578
d5	a	e3	6	4.6667	1.7512	0.7149
d5	d	e2	6	4.3333	1.0328	0.4216
d5	d	e3	6	5.0000	2.1909	0.8944
d5	f	e2	6	5.3333	0.5164	0.2108
d5	f	e3	6	4.8333	0.7528	0.3073
d5	su	e2	6	5.0000	1.0954	0.4472
d5	su	e3	6	6.8333	1.6021	0.6540

```
FACTOR:        subs   distance expression       task      score
LEVELS:          12          5          6          2        360
TYPE  :      RANDOM     WITHIN     WITHIN    BETWEEN       DATA

SOURCE        SS        df          MS          F      p
===========================================================
dist      523.3722    4       130.8431    51.401  0.000 ***
ds/t      101.8222   40         2.5456

exp       214.2667    5        42.8533    22.536  0.000 ***
es/t       95.0778   50         1.9016

de        115.9278   20         5.7964     2.771  0.000 ***
des/t     418.3111  200         2.0916

task       60.8444    1        60.8444     6.511  0.029 *
s/t        93.4556   10         9.3456

dt         35.0722    4         8.7681     3.444  0.016 *
ds/t      101.8222   40         2.5456

et         13.0556    5         2.6111     1.373  0.250
es/t       95.0778   50         1.9016

det        42.6944   20         2.1347     1.021  0.440
des/t     418.3111  200         2.0916
```

Chapter 3: Experiment 4: Facial expression detection from 1-bit per pixel images

```
SOURCE: grand mean
distance   expression      N       MEAN        SD          SE
                          108     6.6944      1.9114      0.1839

 SOURCE: distance
 dist    expr        N      MEAN        SD          SE
 d1                 36    8.1111      1.6523      0.2754
 d2                 36    6.3889      1.7448      0.2908
 d3                 36    5.5833      1.4015      0.2336

 SOURCE: expression
 dist    expr        N      MEAN        SD          SE
         H          18    7.6667      1.9097      0.4501
         S          18    5.3889      1.4608      0.3443
         A          18    6.4444      1.7896      0.4218
         D          18    6.4444      2.2550      0.5315
         F          18    6.9444      1.6260      0.3832
         Su         18    7.2778      1.7083      0.4027

 SOURCE: distance expression
 dist    expr        N      MEAN        SD          SE
 d1      H           6    9.5000      0.5477      0.2236
 d1      S           6    5.5000      1.3784      0.5627
 d1      A           6    7.6667      1.0328      0.4216
 d1      D           6    8.8333      1.1690      0.4773
 d1      F           6    8.5000      0.5477      0.2236
 d1      Su          6    8.6667      1.5055      0.6146
 d2      H           6    8.0000      0.6325      0.2582
 d2      S           6    4.8333      1.1690      0.4773
 d2      A           6    6.3333      1.9664      0.8028
 d2      D           6    5.0000      1.7889      0.7303
 d2      F           6    6.8333      1.1690      0.4773
 d2      Su          6    7.3333      1.2111      0.4944
 d3      H           6    5.5000      1.3784      0.5627
 d3      S           6    5.8333      1.8348      0.7491
 d3      A           6    5.3333      1.6330      0.6667
 d3      D           6    5.5000      1.5166      0.6191
 d3      F           6    5.5000      1.3784      0.5627
 d3      Su          6    5.8333      1.1690      0.4773

 FACTOR:        subj        dist        expr     correct
 LEVELS:           6           3           6         108
 TYPE  :      RANDOM      WITHIN      WITHIN        DATA

 SOURCE       SS        df        MS          F       p
===============================================================
 dist    120.0556        2     60.0278     39.291   0.000 ***
 ds/      15.2778       10      1.5278

 expr     57.1944        5     11.4389      5.647   0.001 **
 es/      50.6389       25      2.0256

 de       51.8333       10      5.1833      3.008   0.005 **
 des/     86.1667       50      1.7233
```

Chapter 3: Experiment 2 and 4 compared (Full grey-level and 1-bit per pixel)

```
SOURCE: grand mean
distance  expression  task        N        MEAN         SD          SE
                                 216      7.5046      1.9553      0.1330

 SOURCE: distance
 dista   expre   task      N       MEAN          SD          SE
 d1                       72      8.6250      1.5331      0.1807
 d2                       72      7.2639      1.8988      0.2238
 d3                       72      6.6250      1.8722      0.2206

 SOURCE: expression
 dista   expre   task      N       MEAN          SD          SE
         h                36      8.5278      1.6985      0.2831
         s                36      5.8611      1.4373      0.2396
         a                36      7.3889      1.8091      0.3015
         d                36      7.5278      2.1972      0.3662
         f                36      7.6667      1.8048      0.3008
         su               36      8.0556      1.7229      0.2871

 SOURCE: distance expression
 dista   expre   task      N       MEAN          SD          SE
 d1      h                12      9.5000      0.6742      0.1946
 d1      s                12      6.2500      1.4222      0.4106
 d1      a                12      8.4167      1.1645      0.3362
 d1      d                12      9.2500      0.9653      0.2787
 d1      f                12      9.0000      0.8528      0.2462
 d1      su               12      9.3333      1.2309      0.3553
 d2      h                12      8.7500      1.0553      0.3046
 d2      s                12      5.2500      1.2881      0.3718
 d2      a                12      7.0833      1.8320      0.5288
 d2      d                12      6.8333      2.4433      0.7053
 d2      f                12      7.6667      1.4355      0.4144
 d2      su               12      8.0000      1.1282      0.3257
 d3      h                12      7.3333      2.2293      0.6435
 d3      s                12      6.0833      1.5050      0.4345
 d3      a                12      6.6667      1.9695      0.5685
 d3      d                12      6.5000      1.8829      0.5436
 d3      f                12      6.3333      1.9228      0.5551
 d3      su               12      6.8333      1.8007      0.5198

 SOURCE: task e2 (Expt.2), e4 (Expt.4)
 dista   expre   task      N       MEAN          SD          SE
                 e2      108      8.3148      1.6443      0.1582
                 e4      108      6.6944      1.9114      0.1839
SOURCE: distance task
 dista   expre   task      N       MEAN          SD          SE
 d1              e2       36      9.1389      1.2225      0.2037
 d1              e4       36      8.1111      1.6523      0.2754
 d2              e2       36      8.1389      1.6415      0.2736
 d2              e4       36      6.3889      1.7448      0.2908
 d3              e2       36      7.6667      1.7071      0.2845
 d3              e4       36      5.5833      1.4015      0.2336
```

```
SOURCE: expression task
dista  expre  task      N        MEAN         SD         SE
       h      e2       18      9.3889     0.8498     0.2003
       h      e4       18      7.6667     1.9097     0.4501
       s      e2       18      6.3333     1.2834     0.3025
       s      e4       18      5.3889     1.4608     0.3443
       a      e2       18      8.3333     1.2834     0.3025
       a      e4       18      6.4444     1.7896     0.4218
       d      e2       18      8.6111     1.5392     0.3628
       d      e4       18      6.4444     2.2550     0.5315
       f      e2       18      8.3889     1.7197     0.4053
       f      e4       18      6.9444     1.6260     0.3832
       su     e2       18      8.8333     1.3827     0.3259
       su     e4       18      7.2778     1.7083     0.4027

SOURCE: distance expression task
dista  expre  task      N        MEAN         SD         SE
d1     h      e2        6      9.5000     0.8367     0.3416
d1     h      e4        6      9.5000     0.5477     0.2236
d1     s      e2        6      7.0000     1.0954     0.4472
d1     s      e4        6      5.5000     1.3784     0.5627
d1     a      e2        6      9.1667     0.7528     0.3073
d1     a      e4        6      7.6667     1.0328     0.4216
d1     d      e2        6      9.6667     0.5164     0.2108
d1     d      e4        6      8.8333     1.1690     0.4773
d1     f      e2        6      9.5000     0.8367     0.3416
d1     f      e4        6      8.5000     0.5477     0.2236
d1     su     e2        6     10.0000     0.0000     0.0000
d1     su     e4        6      8.6667     1.5055     0.6146
d2     h      e2        6      9.5000     0.8367     0.3416
d2     h      e4        6      8.0000     0.6325     0.2582
d2     s      e2        6      5.6667     1.3663     0.5578
d2     s      e4        6      4.8333     1.1690     0.4773
d2     a      e2        6      7.8333     1.4720     0.6009
d2     a      e4        6      6.3333     1.9664     0.8028
d2     d      e2        6      8.6667     1.3663     0.5578
d2     d      e4        6      5.0000     1.7889     0.7303
d2     f      e2        6      8.5000     1.2247     0.5000
d2     f      e4        6      6.8333     1.1690     0.4773
d2     su     e2        6      8.6667     0.5164     0.2108
d2     su     e4        6      7.3333     1.2111     0.4944
d3     h      e2        6      9.1667     0.9832     0.4014
d3     h      e4        6      5.5000     1.3784     0.5627
d3     s      e2        6      6.3333     1.2111     0.4944
d3     s      e4        6      5.8333     1.8348     0.7491
d3     a      e2        6      8.0000     1.2649     0.5164
d3     a      e4        6      5.3333     1.6330     0.6667
d3     d      e2        6      7.5000     1.7607     0.7188
d3     d      e4        6      5.5000     1.5166     0.6191
d3     f      e2        6      7.1667     2.1370     0.8724
d3     f      e4        6      5.5000     1.3784     0.5627
d3     su     e2        6      7.8333     1.8348     0.7491
d3     su     e4        6      5.8333     1.1690     0.4773
```

```
FACTOR:         subs   distance expression       task      score
LEVELS:           12          3          6          2        216
TYPE  :       RANDOM     WITHIN     WITHIN    BETWEEN       DATA
SOURCE      SS        df          MS          F       p
=============================================================
dist     150.2593     2         75.1296    38.382  0.000 ***
ds/t      39.1481    20          1.9574

exp      147.3009     5         29.4602    17.557  0.000 ***
es/t      83.8981    50          1.6780

de        40.0185    10          4.0019     2.523  0.009 **
des/t    158.6296   100            1.5863

task     141.7824     1         141.7824    97.843  0.000 ***
s/t       14.4907    10            1.4491

dt        10.4815     2            5.2407     2.677  0.093
ds/t      39.1481    20            1.9574

et         7.8565     5            1.5713     0.936  0.466
es/t      83.8981    50            1.6780

det       28.1296    10            2.8130     1.773  0.075
des/t    158.6296   100            1.5863
```

Chapter 3: Experiment 5: Sensitivity to expressive signals from the inverted face.

```
SOURCE: grand mean
distance    expression        N        MEAN          SD          SE
                            180      5.7889      1.6945      0.1263

 SOURCE: distance
 dist    expr        N      MEAN        SD         SE
 d1                 36     7.5833     1.3390     0.2232
 d2                 36     6.0833     1.6626     0.2771
 d3                 36     5.0000     1.4343     0.2390
 d4                 36     5.0278     1.2980     0.2163
 d5                 36     5.2500     1.2042     0.2007

 SOURCE: expression
 dist    expr        N      MEAN        SD         SE
         h          30     6.3000     2.1520     0.3929
         s          30     5.5333     1.3060     0.2384
         a          30     5.5667     1.5906     0.2904
         d          30     5.5333     1.5698     0.2866
         f          30     6.0000     1.4856     0.2712
         su         30     5.8000     1.9191     0.3504

 SOURCE: distance expression
 dist    expr        N      MEAN        SD         SE
 d1      h           6     8.6667     1.0328     0.4216
 d1      s           6     6.6667     1.0328     0.4216
 d1      a           6     7.5000     1.3784     0.5627
 d1      d           6     7.3333     1.5055     0.6146
 d1      f           6     6.8333     0.4082     0.1667
 d1      su          6     8.5000     1.3784     0.5627
 d2      h           6     7.1667     2.2286     0.9098
 d2      s           6     5.3333     1.2111     0.4944
 d2      a           6     6.5000     1.2247     0.5000
 d2      d           6     4.6667     1.6330     0.6667
 d2      f           6     6.6667     1.5055     0.6146
 d2      su          6     6.1667     1.1690     0.4773
 d3      h           6     5.3333     1.9664     0.8028
 d3      s           6     5.3333     1.5055     0.6146
 d3      a           6     4.5000     1.0488     0.4282
 d3      d           6     5.0000     1.0954     0.4472
 d3      f           6     5.1667     1.7224     0.7032
 d3      su          6     4.6667     1.5055     0.6146
 d4      h           6     4.8333     1.4720     0.6009
 d4      s           6     5.8333     0.9832     0.4014
 d4      a           6     4.5000     1.0488     0.4282
 d4      d           6     5.1667     1.4720     0.6009
 d4      f           6     5.3333     1.5055     0.6146
 d4      su          6     4.5000     1.2247     0.5000
 d5      h           6     5.5000     1.6432     0.6708
 d5      s           6     4.5000     1.0488     0.4282
 d5      a           6     4.8333     0.4082     0.1667
 d5      d           6     5.5000     0.8367     0.3416
 d5      f           6     6.0000     1.5492     0.6325
 d5      su          6     5.1667     1.1690     0.4773
```

```
FACTOR:     subject     distance  expression     correct
LEVELS:        6            5          6            180
TYPE  :      RANDOM      WITHIN     WITHIN        DATA

SOURCE        SS        df        MS          F       p
==============================================================
dist       172.7556     4      43.1889     30.510  0.000 ***
ds/         28.3111    20       1.4156

expr        14.5778     5       2.9156      1.093  0.389
es/         66.6889    25       2.6676

de          52.3111    20       2.6156      1.508  0.095
des/       173.4222   100       1.7342
```

Chapter 3: Experiment 2 and 5 compared (Upright & Inverted)

```
SOURCE: grand mean
 dist    exp    task       N       MEAN        SD        SE
                         360     6.5111    2.0166    0.1063

 SOURCE: distance
 dist    exp    task       N       MEAN        SD        SE
 d1                       72     8.3611    1.4946    0.1761
 d2                       72     7.1111    1.9396    0.2286
 d3                       72     6.3333    2.0624    0.2431
 d4                       72     5.4861    1.5473    0.1824
 d5                       72     5.2639    1.1867    0.1399

 SOURCE: expression
 dist    exp    task       N       MEAN        SD        SE
         H                60     7.2500    2.2370    0.2888
         S                60     5.8667    1.3080    0.1689
         A                60     6.4000    1.9151    0.2472
         D                60     6.3167    2.1589    0.2787
         F                60     6.5167    1.9872    0.2565
         Su               60     6.7167    2.1636    0.2793

 SOURCE: distance expression
 dist    exp    task       N       MEAN        SD        SE
 d1      H                12     9.0833    0.9962    0.2876
 d1      S                12     6.8333    1.0299    0.2973
 d1      A                12     8.3333    1.3707    0.3957
 d1      D                12     8.5833    1.6765    0.4840
 d1      F                12     8.0833    1.4434    0.4167
 d1      Su               12     9.2500    1.2154    0.3509
 d2      H                12     8.3333    2.0151    0.5817
 d2      S                12     5.5000    1.2432    0.3589
 d2      A                12     7.1667    1.4668    0.4234
 d2      D                12     6.6667    2.5346    0.7317
 d2      F                12     7.5833    1.6214    0.4680
 d2      Su               12     7.4167    1.5643    0.4516
 d3      H                12     7.2500    2.4909    0.7191
 d3      S                12     5.8333    1.4035    0.4051
 d3      A                12     6.2500    2.1373    0.6170
 d3      D                12     6.2500    1.9129    0.5522
 d3      F                12     6.1667    2.1249    0.6134
 d3      Su               12     6.2500    2.3012    0.6643
 d4      H                12     5.8333    1.9462    0.5618
 d4      S                12     6.2500    0.9653    0.2787
 d4      A                12     5.0000    1.2792    0.3693
 d4      D                12     5.1667    1.2673    0.3658
 d4      F                12     5.0833    1.8809    0.5430
 d4      Su               12     5.5833    1.6214    0.4680
 d5      H                12     5.7500    1.4848    0.4286
 d5      S                12     4.9167    1.1645    0.3362
 d5      A                12     5.2500    1.0553    0.3046
 d5      D                12     4.9167    1.0836    0.3128
 d5      F                12     5.6667    1.1547    0.3333
 d5      Su               12     5.0833    1.0836    0.3128
```

```
SOURCE: task
dist    exp     task      N      MEAN        SD         SE
                e2      180    7.2333    2.0581     0.1534
                e5      180    5.7889    1.6945     0.1263

SOURCE: dist task
dist    exp     task      N      MEAN        SD         SE
d1              e2       36    9.1389    1.2225     0.2037
d1              e5       36    7.5833    1.3390     0.2232
d2              e2       36    8.1389    1.6415     0.2736
d2              e5       36    6.0833    1.6626     0.2771
d3              e2       36    7.6667    1.7071     0.2845
d3              e5       36    5.0000    1.4343     0.2390
d4              e2       36    5.9444    1.6552     0.2759
d4              e5       36    5.0278    1.2980     0.2163
d5              e2       36    5.2778    1.1859     0.1976
d5              e5       36    5.2500    1.2042     0.2007

SOURCE: expression task
dist    exp     task      N      MEAN        SD         SE
        H       e2       30    8.2000    1.9191     0.3504
        H       e5       30    6.3000    2.1520     0.3929
        S       e2       30    6.2000    1.2429     0.2269
        S       e5       30    5.5333    1.3060     0.2384
        A       e2       30    7.2333    1.8696     0.3413
        A       e5       30    5.5667    1.5906     0.2904
        D       e2       30    7.1000    2.3976     0.4377
        D       e5       30    5.5333    1.5698     0.2866
        F       e2       30    7.0333    2.2967     0.4193
        F       e5       30    6.0000    1.4856     0.2712
        Su      e2       30    7.6333    2.0254     0.3698
        Su      e5       30    5.8000    1.9191     0.3504

SOURCE: distance expression task
dist    exp     task      N      MEAN        SD         SE
d1      H       e2        6    9.5000    0.8367     0.3416
d1      H       e5        6    8.6667    1.0328     0.4216
d1      S       e2        6    7.0000    1.0954     0.4472
d1      S       e5        6    6.6667    1.0328     0.4216
d1      A       e2        6    9.1667    0.7528     0.3073
d1      A       e5        6    7.5000    1.3784     0.5627
d1      D       e2        6    9.8333    0.4082     0.1667
d1      D       e5        6    7.3333    1.5055     0.6146
d1      F       e2        6    9.3333    0.8165     0.3333
d1      F       e5        6    6.8333    0.4082     0.1667
d1      Su      e2        6   10.0000    0.0000     0.0000
d1      Su      e5        6    8.5000    1.3784     0.5627
d2      H       e2        6    9.5000    0.8367     0.3416
d2      H       e5        6    7.1667    2.2286     0.9098
d2      S       e2        6    5.6667    1.3663     0.5578
d2      S       e5        6    5.3333    1.2111     0.4944
d2      A       e2        6    7.8333    1.4720     0.6009
d2      A       e5        6    6.5000    1.2247     0.5000
d2      D       e2        6    8.6667    1.3663     0.5578
d2      D       e5        6    4.6667    1.6330     0.6667
d2      F       e2        6    8.5000    1.2247     0.5000
d2      F       e5        6    6.6667    1.5055     0.6146
d2      Su      e2        6    8.6667    0.5164     0.2108
```

d2	Su	e5	6	6.1667	1.1690	0.4773
d3	H	e2	6	9.1667	0.9832	0.4014
d3	H	e5	6	5.3333	1.9664	0.8028
d3	S	e2	6	6.3333	1.2111	0.4944
d3	S	e5	6	5.3333	1.5055	0.6146
d3	A	e2	6	8.0000	1.2649	0.5164
d3	A	e5	6	4.5000	1.0488	0.4282
d3	D	e2	6	7.5000	1.7607	0.7188
d3	D	e5	6	5.0000	1.0954	0.4472
d3	F	e2	6	7.1667	2.1370	0.8724
d3	F	e5	6	5.1667	1.7224	0.7032
d3	Su	e2	6	7.8333	1.8348	0.7491
d3	Su	e5	6	4.6667	1.5055	0.6146
d4	H	e2	6	6.8333	1.9408	0.7923
d4	H	e5	6	4.8333	1.4720	0.6009
d4	S	e2	6	6.6667	0.8165	0.3333
d4	S	e5	6	5.8333	0.9832	0.4014
d4	A	e2	6	5.5000	1.3784	0.5627
d4	A	e5	6	4.5000	1.0488	0.4282
d4	D	e2	6	5.1667	1.1690	0.4773
d4	D	e5	6	5.1667	1.4720	0.6009
d4	F	e2	6	4.8333	2.3166	0.9458
d4	F	e5	6	5.3333	1.5055	0.6146
d4	Su	e2	6	6.6667	1.2111	0.4944
d4	Su	e5	6	4.5000	1.2247	0.5000
d5	H	e2	6	6.0000	1.4142	0.5774
d5	H	e5	6	5.5000	1.6432	0.6708
d5	S	e2	6	5.3333	1.2111	0.4944
d5	S	e5	6	4.5000	1.0488	0.4282
d5	A	e2	6	5.6667	1.3663	0.5578
d5	A	e5	6	4.8333	0.4082	0.1667
d5	D	e2	6	4.3333	1.0328	0.4216
d5	D	e5	6	5.5000	0.8367	0.3416
d5	F	e2	6	5.3333	0.5164	0.2108
d5	F	e5	6	6.0000	1.5492	0.6325
d5	Su	e2	6	5.0000	1.0954	0.4472
d5	Su	e5	6	5.1667	1.1690	0.4773

```
FACTOR:     subjects   distance   expression   task      score
 LEVELS:         12          5          6          2        360
 TYPE  :     RANDOM     WITHIN     WITHIN    BETWEEN       DATA

 SOURCE    SS        df          MS          F       p
==============================================================
 dist    462.2611    4       115.5653    75.328   0.000 ***
 ds/t     61.3667   40         1.5342

 exp      63.2222    5        12.6444     5.715   0.000 ***
 es/t    110.6222   50         2.2124

 de       73.6389   20         3.6819     2.202   0.003 **
 des/t   334.4333  200         1.6722

 task    187.7778    1       187.7778   138.298   0.000 ***
 s/t      13.5778   10         1.3578

 dt       74.9722    4        18.7431    12.217   0.000 ***
 ds/t     61.3667   40         1.5342
 et       17.9556    5         3.5911     1.623   0.171
 es/t    110.6222   50         2.2124

 det      60.1278   20         3.0064     1.798   0.023 *
 des/t   334.4333  200         1.6722
```

Chapter 4: Experiment 2: Contribution of the facial surround in gaze discrimination tasks (I)

```
SOURCE: grand mean
orien  conte      N      MEAN        SD        SE
                 40    3.6732    1.5299    0.2419

SOURCE: orient
orien  conte      N      MEAN        SD        SE
upr              20    3.1859    1.5771    0.3526
inv              20    4.1605    1.3481    0.3014

SOURCE: context
orien  conte      N      MEAN        SD        SE
       abs       20    3.7693    1.4077    0.3148
       pres      20    3.5771    1.6743    0.3744

SOURCE: orient context
orien  conte      N      MEAN        SD        SE
upr    abs       10    3.2024    1.0458    0.3307
upr    pres      10    3.1693    2.0387    0.6447
inv    abs       10    4.3361    1.5414    0.4874
inv    pres      10    3.9848    1.1799    0.3731

FACTOR:        subs    orient   context      data
LEVELS:          40         2         2        40
TYPE  :      RANDOM   BETWEEN   BETWEEN      DATA

SOURCE        SS       df       MS          F       p
===============================================================
orient     9.4985      1     9.4985     4.213   0.047 *
s/oc      81.1626     36     2.2545

context    0.3695      1     0.3695     0.164   0.688
s/oc      81.1626     36     2.2545

oc         0.2531      1     0.2531     0.112   0.740
s/oc      81.1626     36     2.2545
```

Chapter 4: Experiment 3: Contribution of the facial surround in gaze discrimination tasks (II)

```
SOURCE: grand mean
 face    eyes        N       MEAN        SD        SE
                    36     0.2719    0.1705    0.0284

 SOURCE: face
 face              eyes       N       MEAN        SD        SE
 Face Up (FU)                12     0.3367    0.2280    0.0658
 Face Down (FD)              12     0.2667    0.1696    0.0490
 Face Absent (FA)            12     0.2125    0.0571    0.0165

 SOURCE: eyes
 face    eyes                 N       MEAN        SD        SE
         Eyes Up (EU)        18     0.3483    0.2014    0.0475
         Eyes Down (ED)      18     0.1956    0.0830    0.0196

 SOURCE: face eyes
 face    eyes        N       MEAN        SD        SE
 FU      EU          6     0.4783    0.2384    0.0973
 FU      ED          6     0.1950    0.0965    0.0394
 FD      EU          6     0.3583    0.1915    0.0782
 FD      ED          6     0.1750    0.0804    0.0328
 FA      EU          6     0.2083    0.0223    0.0091
 FA      ED          6     0.2167    0.0814    0.0332

 FACTOR:        subs       face       eyes     score
 LEVELS:          36          3          2        36
 TYPE  :      RANDOM    BETWEEN    BETWEEN      DATA

 SOURCE       SS      df        MS         F         p
 ===============================================================
 face      0.0930     2     0.0465    2.397      0.108
 s/fe      0.5821    30     0.0194

 eyes      0.2101     1     0.2101   10.827      0.003 **
 s/fe      0.5821    30     0.0194

 fe        0.1318     2     0.0659    3.397      0.047 *
 s/fe      0.5821    30     0.0194
```

Chapter 6

Errors made by six control participants in a free naming expression allocation task. Numbers in parenthesis represent the frequency of the response, where no parenthesis are present the word was used only once.

Controls	Happiness	Sadness	Anger	Disgust	Fear	Surprise
	Satisfied	bored (5)	determination (8)	aghast (3)	surprise (10)	joy (3)
		smug (4)	spiteful (3)	puzzled (3)	disbelief (4)	disbelief (3)
		perplexed (2)	frustration (2)	pain (3)	bewilderment (3)	unaware (2)
		contemplative	hate (2)	sad (2)	determined (3)	guilty
		sulking	perplexed (2)	scared	guilty (3)	contented
		acceptance	concentration	unsure	puzzled (3)	delight
		reflective	bamboozled	grimace	amazed (2)	grimace
		disappointed	disgust	uncertain	repugnant (2)	fear
		anger	aghast		revulsion (2)	pleasure
Errors		pensive	idiot		blameless	bewilderment
		failed!	pain		anxiety	startled
		thoughtful	adamant		cagey	
		placid	serious		astonished	
			fear		shock	
			so what?!		disdain	
			grimace		worried	
			distrust		agog	
			nasty!		astounded	
					wide-eyed	
					stupid	