Individual differences in recognition memory for faces.

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INDIVIDUAL DIFFERENCES IN RECOGNITION MEMORY FOR FACES

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Thesis submitted to the University of Durham

in candidature for the degree of

Doctor of Philosophy

(1994)

This thesis is dedicated to

my family,

past and present

Abstract

Contemporary research on human memory has tended to disregard individual differences (Eysenck, 1977, 1983; Sternberg & French, 1990). However, there seems to be no empirical justification for this practice, especially in experimental situations where the stimuli that are used are 'socially relevant'. Human faces constitute one such category. Although there is strong evidence which suggests that people differ substantially in their ability to recognise faces in laboratory experiments (Baddeley & Woodhead, 1983) and in everyday situations (Schweich, van der Linden, Bredart, Bruyer, Nells & Schills, 1991), the sources of these differences are not clearly understood at present. In this thesis, individual differences in recognition memory for faces were examined using standard laboratory experimental techniques. **Part I** of this thesis consists of four chapters. Chapter One provides a general introduction to face recognition research. In Chapter Two, past research on individual differences in face recognition is described and evaluated. In Chapter Three, the theoretical implications of research on the effects of orientation, race of face and face distinctiveness are discussed. Experimental and statistical techniques that are used in the present thesis are summarised in Chapter Four. In **Part II**, three experiments which investigated the effect of individual differences in spatial ability on recognition of pictures, faces and words are reported. Among other things, these experiments showed that while individual differences in spatial ability did not significantly affect subjects' recognition of high-imagery words, high spatial ability subjects recognised faces and pictures more accurately and more quickly than did low spatial ability subjects. The theoretical implications of these results are discussed. **Part III** consists of an experiment in which differences in recognition of male and female faces by adolescent male and female subjects aged 11 years, 12 years and 13 years were investigated across two delay conditions. This experiment provided partial support for a developmental dip in recognition of faces among 12-year olds and also showed an own-sex bias in face recognition among female subjects. Theoretical accounts for these effects are proposed. In **Part IV**, a cross-cultural study in which black-African and white-British subjects who had different degrees of previous contact with faces of the opposite race were tested for their recognition of distinctive and typical own-race and other-race faces is reported. This experiment provided evidence which supported the differential-experience hypothesis of the own-race bias in face recognition among the African subjects and also suggested that the effect of face distinctiveness in recognition of faces might be a product of learning the defining characteristics of a given population of faces. In **Part V**, three experiments which explored differences between good and poor face recognisers are reported and discussed. These experiments raised some important methodological issues regarding the generalisability of the notion of 'face recognition ability' in situations where the faces to be recognised are shown in different views, in different facial expressions and in different orientations between study and test. These experiments also showed that subjects who were good in their recognition of faces following a change in view were significantly more accurate in their recognition of upside-down faces than were subjects who had initially shown poor recognition of faces in different views. However, there were no significant differences between these two groups of subjects in their ability to recognise faces that were shown in different facial expressions between study and test. It is argued that these results suggest that recognition of faces following a change in facial expression may involve the creation and use of expression-independent representations of the face while recognition of faces following a change in view or orientation may both involve the creation and use of view-independent representations of faces. General conclusions and suggestions for future experimental work are outlined in Part **VI**.

Statement of Copyright

Declaration

I hereby declare that the work in this thesis is entirely my own and that no part of it has previously been submitted for a degree in this or any other University.

Patrick Chiroro

(1994)

In Press

Chiroro, P. & Valentine, T. A Cross-cultural Investigation of the Contact Hypothesis of the Own-race Bias in Face Recognition. *Quaterly Journal of Experimental Psychology*.

Acknowledgements

I am extremely grateful to my supervisor Dr. T. Valentine for his consistent help and guidance throughout the period of my research. I also derived great benefit from the thoughtful and constructive criticisms supplied by the following persons: Dr P. Meudell (Univerity of Manchester), Dr. D. O'Boyle (University of Manchester), Dr. H. Wagner (University of Manchester), Professor A. Mayes (University of Liverpool), Professor R. S. Malpass (University of Texas), Dr. Bob Kentridge (University of Durham), Professor A.W. Young (University of Cambridge), and Dr A. Calder (University of Cambridge). It is also a pleasure for me to acknowledge Dr. R. Walker's useful criticisms and comments on an early draft of this thesis.

I would also like to thank Mr. S. Rigby, Mr. C. Chiwara, Mr. T. Garande and Mr. M. Rolling for their photographic and other technical services. My special thanks go to all the children and students who acted as subjects in the experiments that are described in this thesis, non of whom received any financial or material benefit for their participation.

I am deeply indebted to my son Tatenda who had to endure my absence from home during his early days of life which coincided with the final preparation of this thesis.

To my wife Bertha, for her encouragement and emotional support, may the completion of this thesis mark a new beginning in our life.

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Part I

LITERATURE REVIEW

CHAPTER ONE

An Overview

1.1. INTRODUCTION

Almost two-hundred-and-fifty years ago, William Horgarth noted that "... the human face is an index of the mind"[1]. Horgarth observed that of the several hundreds of faces that we know, no two faces look exactly alike. Yet, in spite of the striking similarities between faces, people are often capable of distinguishing one face from another on the basis of subtle differences. The ability to recognise many individual faces demonstrates a remarkable discriminative capacity of the human visual memory system (Bruce, 1990a). However, establishing the identity of a person is by no means the only function of the human face. Faces also provide a rich source of socially meaningful information. We use them to infer other people's moods and feelings, to regulate social interaction through eye contact and facial gestures, to assist in speech comprehension through lip-reading, to determine age, sex and race and to make attributional judgements on the basis of social stereotypes.

In order to track down criminals, the police and other law-enforcement agencies rely on the ability of eye-witnesses to positively identify the criminal's face from a parade of suspects. Accurate identification of the criminal by several witnesses often holds the key to a successful conviction.

[1] Cited in Shepherd & Ellis, 1981, p.1.

However, errors of mistaken identity are also common in the judicial system. For example, Gross (1987) estimates that in the United States alone, some 10,000 people are erroneously convicted each year largely because of problems that arise from mistaken identity. One result of such misidentifications is that innocent suspects are condemned to prison life (or even death) while the real culprits remain free to commit more crime. Face recognition research may provide some useful guidelines for eliciting more accurate face identification evidence from eye-witnesses (see Fruzzetti, Toland, Teller & Loftus, 1992 for a review).

For these and other reasons (e.g. the neuropsychological implications of deficiencies in face processing[2]), the past two decades have witnessed a marked increase in theoretical and applied research on memory for faces (see Shepherd & Ellis, 1992 for a review). Much of the recent research on face processing has been guided by information processing models of face recognition (e.g. Hay & Young, 1982; Bruce & Young, 1986; Ellis, 1986a). These models draw heavily from David Marr's computational theory of vision (Marr, 1976; 1977; 1982). The five main stages of this theory are shown in Figure 1.1. According to Marr and his associates (e.g. Marr & Hildreth, 1980; Marr & Ullman, 1981), visual perception involves the creation of a number of representations of the stimulus, beginning with the retinal image of the object and ending with the creation of a 3D representation.

The retinal image is created as a result of the way in which light reflected from an object is encoded by photoreceptors in the retina of the eye. The product of this early visual processing is a 'messy' representation of the

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[2] See De Renzi, 1989 for a review of the literature on prosopagnosia.

object's edges, what Marr and associates call the *raw primal sketch.* In order to give the raw primal sketch both form and meaning, a number of grouping procedures that are similar to the gestalt principles of perceptual organisation are applied to it. This involves extracting from the object information regarding its contour and texture. This process is thought to lead to the creation of a *full primal sketch.*

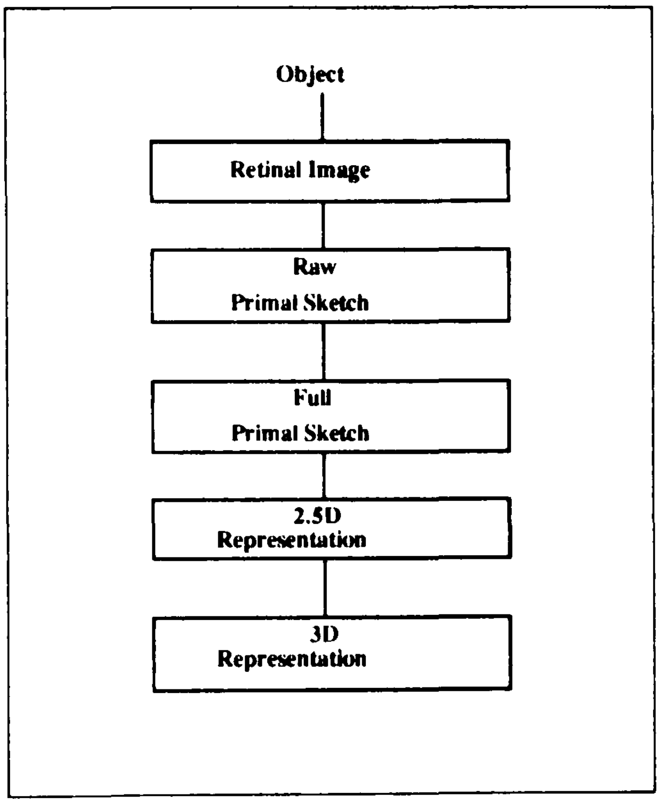

Figure 1.1. *A flow diagram showing the five main stages of David Marr's Computational Theory of Vision.*

The full primal sketch is further processed through the analysis of depth, motion and shading to develop what Marr and associates call the *2.5D sketch.* The 2.5D representation is said to be "view-centred" because it does not contain those surfaces of the object that are hidden from view. Marr (1982) argues that in order for this information to become available, different views of the object must be encoded. This process leads to the creation of a more generalised, view-independent *3D representation* of the object that enables a viewer to recognise it from different views and in various orientations. The most influential model of face processing that was influenced by David Marr's computational theory of vision was proposed by Bruce and Young (1986). This model is discussed in the next section of this chapter.

1.2. THE BRUCE AND YOUNG MODEL OF FACE PROCESSING

The functional model of face processing proposed by Bruce and Young (1986) is shown in Figure 1.2. According to Bruce and Young, seven stages are involved in face processing. These are: (i) early visual processing, (ii) expression and facial speech analysis, (iii) directed visual processing, (iv) face recognition units (FRUs), (v) person identity nodes (PINs), (vi) name generation, and (vii) the less well-defined 'general cognitive system'. This model provides a parsimonious framework within which to review most of what is currently known about face processing and face recognition.

1.2.1. Early Visual Processing

According to Bruce and Young (1986), the first stage in face processing is 'structural encoding'. This involves the production of various pictorial representations of the face through a series of processes that are analogous to 'early visual processing' in Marr's computational theory of vision. First, view-centred descriptions of the face are developed. Output from view-centred descriptions of the face serves as the raw material for expression analysis, facial speech analysis, directed visual processing and the creation of expression-independent descriptions of the face.

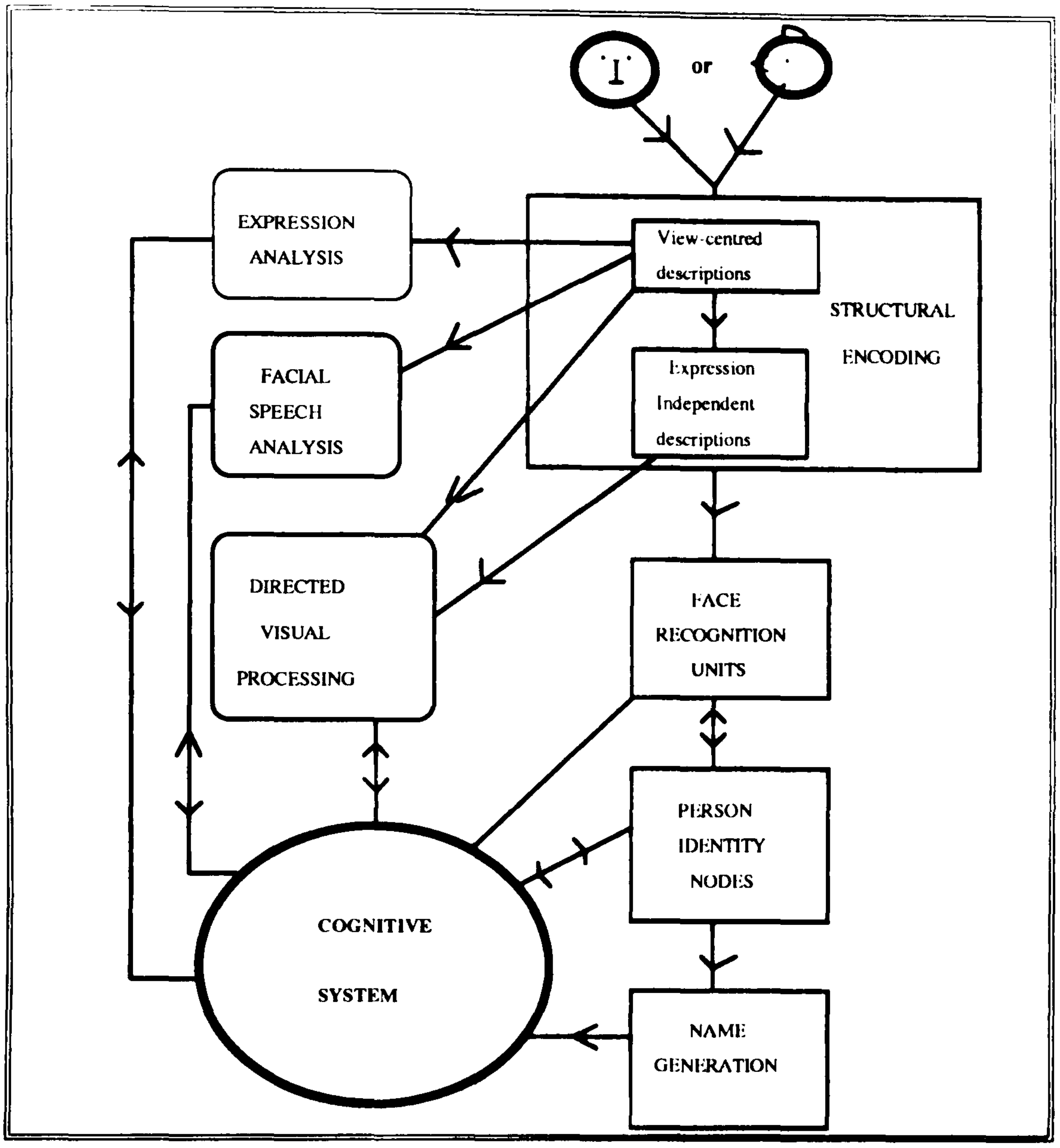

Figure 1.2. *A Functional Model of Face Processing Proposed by Bruce and Young (1986)*

1.2.2. Expression and Facial Speech Analysis

Expression analysis involves extracting from a face information that is important for determining an individual's emotional state. Using such information, we often can tell whether a person is happy, sad, angry, worried and so on. According to Bruce and Young (1986), expression analysis proceeds independently of and in parallel to facial speech analysis. The latter refers to the viewer's inference of meaning from lip-movements. Lip-reading serves to disambiguate speech, hence the point made earlier that faces help to facilitate communication. The ability to lip-read is particularly useful in situations where a conversation is held under noisy conditions.

1.2.3. Directed Visual Processing

Directed visual processing refers to "the strategic selection or use of facial information for certain kinds of tasks" (Bruce, 1990b, p.245). Bruce (1988) gives the following example. Suppose you are to meet someone at a railway station. You also know that the person normally dyes her hair "red". As the many commuters bustle you about in their rush, your attention is likely to be directed towards the sight of red hair. This focused visual attention to specific qualities of a known face illustrates what Bruce and Young (1986) call directed visual processing. As can be seen in Figure 1.2., expression analysis, facial speech analysis and directed visual processing all interact directly with the general "cognitive system". These three 'satellite systems' (Ellis & Young, 1989's term) work separately from what may be called the "core face identification system". The latter is made up of face recognition units, person identity nodes and name generation codes. It will be noticed from Figure 1.2 that in addition to providing the raw material necessary for expression analysis, facial speech analysis and directed visual processing, early visual processing also supplies the input to face recognition units which "fire" when activated.

1.2.4. Face Recognition Units (FRUs)

Face recognition units are thought to contain stored structural descriptions of each known face. If the incoming structural descriptions match those stored in (say) face recognition unit X, unit X will register the concordance by firing actively and inhibiting adjacent units. Face recognition units are thought to produce two kinds of output: (1) a signal of familiarity, and (2) a signal that is transmitted to a corresponding person identity node within the associative semantic memory network.

1.2.5. Person Identity Nodes (PINs)

Person identity nodes contain various kinds of semantic information about the person (e.g. where the person works, where the person is often encountered, what car (s)he drives, etc.). However, according to Bruce and Young (1986), accessing this kind of information about the person does not guarantee that the person's name will be retrieved. Name retrieval is thought to be a function of another separate module, the name generation system.

1.2.6. Summary and Evaluation

An underlying feature of Bruce and Young's (1986) architecture of person identification is that the modules are hierarchically organised. Structural encoding occurs first, a face recognition unit fires, after which semantic information about the face is accessed before the name of the person is retrieved. There is strong experimental and neuropsychological evidence which supports this assumption (see Bruce and Young, 1986 and Bruce, 1990a for detailed reviews). However, in spite of the rapid expansion in literature on memory for faces generated by the Bruce and Young model of face processing, little is known about individual differences in face recognition. Indeed, the model itself makes no provision for individual differences in the way people accomplish the task of recognising faces. There is strong evidence which suggests that some people consistently recognise faces more accurately than others. This has been demonstrated in laboratory experiments (Woodhead, Baddeley & Simmonds, 1979; Woodhead & Baddeley, 1981; Baddeley & Woodhead, 1983; Church & Winograd, 1985) as well as in studies of everyday errors in face recognition (Young, Hay & Ellis, 1985; Schweich, Van der Linden, Bredart, Bruyer, Nells & Schills, 1991). This evidence is discussed in the next section of this chapter.

1.3. THE EXTENT OF INDIVIDUAL DIFFERENCES IN FACE RECOGNITION

It is not uncommon to encounter individuals whose face recognition skills are either very good or very poor. My first encounter with a person whose face recognition skills were, by any normal standards, exceptionally good occurred in 1983 when I enrolled for a Diploma in Education at Belvedere College in Zimbabwe. Before being admitted as students, all applicants were interviewed individually by the college principal for approximately 30 minutes. Since the college had a rejection rate of 50-60% and a total of 206 applicants were admitted for 1983, the principal must have seen at least 400 applicants, half of whom he did not accept. Yet, from the very first day of term (three to six months later), the principal seemed astonishingly capable of remembering most of the students, *even by name*.

The principal's exceptionally good memory for faces was particularly striking because he was Caucasian and the students were black-Africans. Current research on the 'cross-race effect' in face recognition suggests that there is a strong and robust 'own-race' bias in face recognition[3]. In view of this, the principal's ability to recognise many individual African faces was undoubtedly remarkable. However, if one considers the fact that the principal in question

[3] See Chapter Three of this thesis.

had, for a very long time, been a lecturer in two other colleges designated for African students in the then colonial Rhodesia, the possibility of accounting for the own-race bias in face recognition in terms of individual differences in degree of 'contact' or experience with a sufficiently large population of other-race faces becomes apparent. This possibility is investigated in a cross-cultural study reported in chapter seven of this thesis.

Diary studies of everyday errors in person recognition have also demonstrated the existence of individual differences in face recognition. For example, in a recent study conducted by Schweich, Van Der Linden, Bredart, Bruyer, Nells and Schills (1991), subjects who described themselves as 'bad' at remembering faces in their everyday contacts with other people also reported a significantly greater number of person recognition errors than a comparable group of subjects who claimed to have no particular problems with recognising people by their faces. In another diary study conducted by Young, Hay and Ellis (1985), there were substantial individual differences in the types of face recognition errors that were frequently reported by the subjects.

Individual differences in recognition memory for faces have also been reported in laboratory experiments. For example, Baddeley and Woodhead (1983) tested 90 subjects for their recognition of a set of six faces which appeared in three different poses in a set of 108 faces. Their results showed a substantial range of individual performance which extended from 17% to 100% correct identifications. Woodhead and Baddeley (1981) also demonstrated that it is possible to select subjects who are either consistently 'bad' or consistently 'good' in their recognition faces, even when the face recognition tests were spread out over relatively long periods of time.

While these studies clearly show that individuals differ considerably in their recognition of faces both in the laboratory and in real life situations, little has been done to find out why these differences exist or whether such differences can be eliminated through training. The present thesis is concerned mainly with the *why* part of this question. More specifically, this thesis examines the extent to which individual differences in specific cognitive attributes and/or experiences interact with face characteristics and face transformations to determine subjects' performance in laboratory-based face recognition experiments. One possible reason for the apparent lack of interest among cognitive psychologists in examining individual differences in face recognition might be the historical split between the experimental approach to human cognition on the one hand and the psychometric approach on the other (see Cronbach, 1957). Historically, the study of individual differences in cognitive functioning has tended not to fall within the scope of cognitive-experimental psychology but in the sanctuaries of psychometricians. As Eysenck (1983) puts it, there appears to be an unwritten consensus among most experimental (cognitive) psychologists that individual differences in cognition should be left to psychometricians.

However, since the mid-1950s, this schism has been criticised as detrimental to both disciplines of scientific psychology (Cronbach, 1957; Eysenck, 1977, 1983; Carroll, 1983). In spite of these criticisms, many contemporary researchers on human memory in general and on face memory in particular continue to disregard individual differences in people's performance preferring instead to focus on information processing models that are designed to account for the performance of 'the average person'. Similarly, psychometricians too have tended to ignore findings from the experimental literature. In recent years however, there has been a growing realisation that our understanding of human cognition can be enhanced by employing these two approaches in a complementary way (see Sternberg & French, 1990 for example). The present thesis applies this new trend to the domain of face memory and face recognition. The desire to integrate these two approaches in one study is not the only reason for adopting an individual differences approach in this thesis. The study of individual differences in face recognition can be of both practical and theoretical significance as discussed in the next section of this chapter.

1.4. THE RELEVANCE OF INDIVIDUAL DIFFERENCES IN FACE RECOGNITION

The aim in this section is to outline some of the practical benefits and theoretical applications of research on individual differences in face recognition. More elaborate accounts of this can be found in Malpass (1981), Baddeley and Woodhead (1983), Ellis, Shepherd, Gibling and Shepherd (1988) and in Gruneberg and Morris (1992).

1.4.1. Practical Relevance

First, research on differences between 'good' and 'poor' face recognisers can assist judges to screen out potentially unreliable witnesses from investigations that depend mainly on face identification evidence (Baddeley & Woodhead, 1983). Also, as Ellis, Shepherd, Gibling and Shepherd (1988) point out, for occupations in which the ability to remember individual clients is crucial, a knowledge of the factors which differentiate 'good' from 'poor' face recognisers may be useful for appropriate selection of candidates (see also Kaess & Witryol, 1955 and Malpass, 1981). Thirdly, designing and evaluating training programmes for improving face recognition performance might be more successful if such programmes are based on a clear understanding of the differences that exist between good and poor face recognisers.

Previous attempts to train 'normal' subjects to improve their face recognition performance by either paying attention to each face's constituent features (e.g. Woodhead, Baddeley & Simmonds, 1979) or by focusing on each face's personality dimensions (e.g. Baddeley & Woodhead, 1983) have produced discouraging results. In both cases, the training programmes did not significantly affect post-training face recognition performance. Baddeley and Woodhead (1983) argued that the way in which we encode faces might be so over-learned that there is little we can do to affect it, a view that is echoed by Ellis (1985). Woodhead and Baddeley's (1983) explanation is probably correct but perhaps only for people who already possess a high degree of efficiency in their recognition of faces. For individuals who find it relatively difficult to recognise faces (e.g. prosopagnosics and other visual agnosics), training programmes that are based on a knowledge of the perceptual and cognitive attributes possessed by good face recognisers might yield more positive results.

1.4.2. Theoretical Relevance

Malpass (1981) points out that research on individual differences in face recognition can "... contribute to our understanding of the psychological processes underlying face recognition and hence our understanding of cognition" (p. 272). For example, using an individual differences approach, Woodhead and Baddeley (1981) and Church and Winograd (1985) demonstrated that while recognition of pictures of objects correlates significantly with recognition of faces, recognition of verbal material such as words, phrases and nominalisations does not correlate significantly with visual memory abilities.

On the basis of these results, Woodhead and Baddeley (1981, 1983) and Church and Winograd (1985) were able to conclude that (i) the processes that are involved in visual memory are functionally independent of verbal memory ability and (ii) that the face recognition process is not a specialised function of visual memory as proposed by Yin (1969; 1970). In chapter eight of this thesis, the distinction that has been drawn between 'stimulus recognition of faces' and 'true face recognition' (Hay & Young, 1982; Bruce, 1982) is examined by testing whether individual differences in recognition of untransformed target faces significantly affect recognition of faces that are shown in different views or different facial expressions between study and test.

An individual differences approach is also used in the present thesis to test the contact hypothesis of the own-race bias in face recognition. It has been shown that people are more accurate, more confident and faster in their recognition of faces of their own race than they are in their recognition of 'other race' faces (see Bothwell, Brigham & Malpass, 1989 for a review). However, the conceptual basis of this effect is at present not clearly understood. A theoretical understanding of this bias in face recognition and how it can be eliminated has obvious forensic applications.

1.5. CONCLUSION

In this chapter, it has been argued that the recent upsurge in experimental research on recognition memory for faces has not significantly increased our understanding of the sources of individual differences in people's ability to remember faces. The historical split between the psychometric approach on one hand and the experimental approach on the other has been identified as one of the possible reasons for the apparent lack of interest among many cognitive psychologists in examining individual differences in recognition memory for faces. The practical and theoretical relevance of research on individual differences in face recognition has also been discussed. In the next chapter, past research on the effect of individual differences in sex, age, visual imagery, field dependence and general visual memory ability on memory for faces is reviewed and evaluated.

CHAPTER TWO

Individual Differences in Face Recognition

2.1. INTRODUCTION

Psychologists have long realised that people differ "... in the personal histories and social experiences they bring to any task, and (that) these differences may be especially important when the task involves socially relevant stimuli"[4]. Human faces constitute one such category of stimuli. As the evidence discussed in the previous chapter shows, people differ considerably in their ability to recognise previously seen faces. Three approaches have been used to examine individual differences in people's recognition memory for faces: (1) the demographic variables (DV) approach, (2) the correlational/factor-analytic (CFA) approach, and (3) the extreme-groups design (EGD) approach.

The DV approach involves examining the effect that demographic variables such as sex, age and race have on people's recognition memory for faces[5]. A major problem in using this approach is that individual differences in recognition of faces are also present within each of these demographic groups. In order to account for these intra-group differences, some psychologists have used the CFA approach to investigate the intercorrelations between recognition of faces and individual differences in general intelligence, visual imagery and field-dependence[6]. As will be shown in the ensuing sections of

[4] Tajfel, *cited* in Shepherd, (1981; p.1.).
[5] see section 2.2. of this chapter.
[6] see section 2.3. of this chapter.

this chapter, correlational studies of this kind have generally tended to produce contradictory results. This equivocacy might be another reason why contemporary investigators have tended to disregard individual differences in face recognition. Also, since the correlation method does not allow for causal inferences to be drawn from the results, it is often difficult to explore additive and interactive effects using this approach. This problem can be partly overcome by using the EGD approach.

In the EGD approach, subjects are first classified into groups on the basis of their performance on one or more tests of cognitive ability before being tested for their recognition of faces[7]. For example, an investigator who is interested in the relationship between visual imagery ability and recognition memory for faces might begin by administering a test of visual imagery to a large number of potential subjects (often called 'the pool'). On the basis of each subject's score on this test, two experimental groups are then selected: (1) a 'high visual imagery' group and (2) a 'low visual imagery' group. By testing these two groups of subjects on a series of face recognition tasks, the experimenter can establish the extent to which differences in visual imagery *interact* with other factors that are known to affect face recognition performance. Each of these three approaches has its own advantages and disadvantages (see Neale & Liebert, 1986 and Rosenthal & Rosnow, 1991).

The purpose of this chapter is to examine what each of these approaches has contributed to our understanding of individual differences in face recognition. Sex differences, age differences and race differences in recognition memory for faces are discussed in section 2.2. of this chapter. The relationship

[7] see section 2.4. of this chapter.

between face recognition performance and individual differences in visual imagery and field-dependence is examined in section 2.3. In section 2.4., experimental evidence which suggests that individual differences in recognition of faces might be related to general visual memory ability is presented and evaluated.

2.2. SEX, AGE AND RACE DIFFERENCES IN FACE RECOGNITION

Psychological research on individual differences in cognitive functioning has traditionally included an examination of three demographic variables, namely, sex, age and race. This section reviews literature on the effect of these factors on recognition memory for faces.

2.2.1. Sex Differences in Face Recognition

Since the beginning of this century, several researchers have compared males and females on their recognition of male and female faces (see Shepherd, 1981 for a review). However, this plethora of research has not produced a consistent pattern of results. Cross, Cross and Daley (1971) and Feinman and Entwistle (1976) reported results which suggested that female subjects are more accurate in their recognition of female faces than in their recognition of male faces while male subjects are more accurate in their recognition of male faces than in their recognition of female faces. However, to date, no other study has replicated such an 'own-sex' bias in recognition memory for faces.

Some researchers have suggested that recognition memory for faces is generally better among females than it is among males (Bahrick, Bahrick & Wittlinger, 1975; Brigham & Barkowitz, 1978; Ellis, Shepherd & Bruce, 1973; Goldstein & Chance, 1971; McKelvie, 1978; Yarmey & Paskaruk, 1974; Marx & Nelson, 1974). However, several other studies have shown that male and female subjects perform equally well on recognition of both male and female faces (Borges & Vaughn, 1977; Carey, Diamond & Woods, 1980; Flin, 1980; Shepherd, Deregowski & Ellis, 1974; Yarmey, 1978; Shepherd & Ellis, 1973; Goldstein & Chance, 1964). To add to this confusion, there is also some evidence which suggests that when subjects are required to make judgements regarding the attractiveness of each study face during initial presentation of target faces, subsequent recognition performance by male subjects is better than that of female subjects (Yarmey, 1975).

In spite of the contradictory nature of these results, some psychologists have tended to favour the view that females remember faces more accurately than males. One long-standing account of this hypothesis is that superior recognition of faces by females might be due to their greater interest and better skills in interpersonal relations than those possessed by males (see Hoyenga & Hoyenga, 1979 for a review). However, where significant differences in recognition memory for faces have been reported between male and female subjects, the absolute values of the differences have tended to be quite small. Shepherd (1981) argues that this may have led some psychologists to dismiss sex differences in memory for faces as both trivial and inconsistent.

In order to account for the superior recognition of female faces by female subjects (as opposed to a general superiority of female subjects on recognition of faces of both sexes), some psychologists have argued that women pay more attention to other women's faces than they do to male faces because of the need to make implicit comparisons between themselves and other women.

However, there is no empirical evidence to support this hypothesis (see McKelvie's 1978 review). Indeed, some psychologists would dispute the assumption that male and female subjects orient differently to male and female faces. For a detailed discussion of this and other theoretical accounts of sex differences in face recognition, see Shepherd (1981, p.68-70). In short, studies on sex differences in face recognition performance have failed to produce a consistent pattern of results. According to Shepherd (1981), this inconsistency might be due to the fact that:

> "Only a minority of these studies have set out explicitly to examine sex differences; in most cases sex of subject has been incorporated as an incidental part of the design" (p.68).

In chapter six of this thesis, an experiment is described which directly investigated sex differences in recognition memory for faces among 11, 12, and 13 year olds across two delay conditions.

2.2.2. Age Differences in Face Recognition

Age differences in memory for faces are of special interest to forensic experts. Eyewitness testimony research has shown that memory for faces is poorer among children and elderly subjects than it is among middle aged subjects (see Deffenbacher & Horney, 1981; and Cohen, 1989 for reviews). Also, laboratory experiments have shown that face recognition performance improves substantially with age, reaching adult levels at (or around) the age of 16 years (see Flin & Dziurawiec, 1989 for a review). The developmental trend in face recognition performance is shown in Figure 2.1. This figure shows that face recognition performance increases steadily throughout early and middle childhood. However, Carey and Diamond (1977) observed a sudden decrease in recognition memory for faces among children aged 12 years (see Figure 2.1). Since 1977 when Carey and Diamond first reported this 'developmental dip' in face recognition, several other studies have replicated this result (see Flin & Dziurawiec, 1989 for a review).

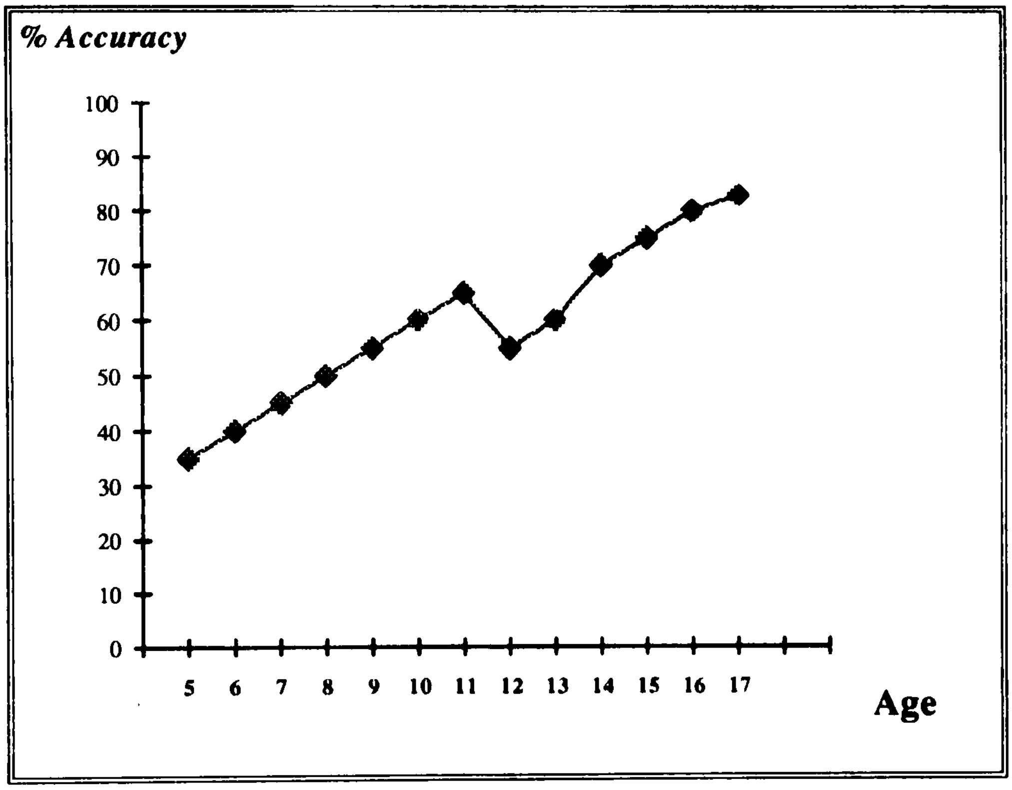

Figure 2.1. *A graph showing the developmental trend and a developmental dip in face recognition (Adapted from Ellis, 1990)*

Although the developmental dip in face recognition appears to be quite a robust effect, it is unclear at present why children in their early years of puberty should find recognising faces rather difficult. It has been suggested by Diamond and Carey (1981) that hormonal changes that occur during this period may be the cause of this disruption in face recognition performance. Diamond and Carey (1983) tested this hypothesis by comparing face recognition scores from pubertal girls with those of age-matched pre- and post-pubertal girls. The results of this experiment showed poorer face recognition scores for the pubertal girls compared to the other two groups. However, attempts to replicate this result have been unsuccessful (Ellis, 1990).

Another hypothesis that has been put forward to account for the developmental dip in face recognition performance around the age of 12 years is that it is not until this age that cerebral hemispheric asymmetry for face recognition develops and the right hemisphere of the brain becomes more specialised for face processing. This 'reorganisation' of the brain's functioning is thought to change the way in which faces are processed by adolescents during puberty. However, Young and Ellis (1975) found a right hemisphere advantage in face recognition among children aged between 5 and 10 years. It has also been shown that infants and children under the age of 1 year display cerebral hemisphere asymmetries for face perception (de Schonen & Mathivet, 1989)[8]. Therefore, it seems to be the case that the 'cerebral reorganisation' hypothesis is not entirely supported by current empirical evidence.

Ellis (1990) and Ellis and Flin (1990) have investigated this question using a somewhat different approach. They hypothesised that by examining the effect of temporal factors such as encoding time and storage interval on children's recognition of faces, it might be possible to specify more clearly the kinds of face processing skills that develop in early and middle childhood. Ellis and Flin (1990) found that when the recognition test followed immediately after the study list, 10-year olds were significantly more accurate in their recognition of faces than 7-year olds. However, when the same children were

[8] Cited in Ellis (1990).

tested for their recognition of faces after a delay of one week, 10-year olds did not outperform 7-year olds. Thus, the performance of 7-year olds was not affected by the delay between study and test while 10-year olds showed a significant fall in their recognition of faces after a delay of one week.

Ellis and Flin (1990) also found that 10 year olds recognised faces more accurately when given longer inspection times during initial presentation than when they were given shorter inspection times. Seven-year olds did not show a significant benefit in their recognition of faces from longer inspection times at encoding. According to Ellis and Flin (1990) these results suggest that there might be important differences in the strategies that are used by children of different ages to encode faces. Given longer inspection times, older children may engage in 'deeper' encoding operations (e.g. making attributional judgements) that may subsequently assist their memory for individual faces. However, Ellis (1990) was careful to point out that:

> "Until research into encoding/storage of faces at different ages has been completed, it is difficult to know exactly what to make of this data" (p.117).

To the extent that the developmental dip in face recognition is a product of some significant change that occurs to children during this period of their lives, 12-year olds should show poorer face recognition scores not only when tested immediately after seeing the target faces but also when the recognition test is administered after a longer delay interval (e.g. after one week). In chapter six of this thesis, an experiment is reported which examined two questions: (1) whether the developmental dip in face recognition that has been observed among 12-year olds occurs with the same magnitude for male and female subjects in their recognition of both male and female faces and (2) whether this phenomenon interacts significantly with delay (i.e. disappears after a delay of one week).

2.2.3. Race Differences in Face Recognition

There is no convincing evidence to suggest that people of any one particular race are more accurate in their recognition of faces than people of other races. However, it has been demonstrated several times that subjects drawn from one racial group recognise faces of their own race more accurately, more confidently and more quickly than they recognise faces of other races. Evidence for such an 'own-race' bias in face recognition is discussed in detail in the next chapter. In chapter seven of this thesis, the contact hypothesis of the own-race bias in face recognition is tested.

2.3. VISUAL IMAGERY, FIELD-DEPENDENCE AND FACE MEMORY

2.3.1. Visual Imagery and Face Recognition

There is some evidence which suggests that subjects who report experiencing clear visual images of previously encountered objects and scenes tend to be significantly more accurate in their recognition of faces than subjects who do not report the experience of such clear visual images (McKelvie, 1984; Phillips, 1978). However, contradictory findings have been reported in the literature. For example, Reisberg, Culver, Heur and Fischman (1986) found an inverse relationship between ratings of self-reported vividness of mental images and face recognition performance. Two other studies have replicated

Reisberg et al.'s (1986) results (Heuer, Fischman & Reisberg, 1986; Reisberg & Leak, 1987).

Differences in the procedures that were used to test subjects' memory for previously presented faces might account for some of these inconsistencies. McKelvie (1984) and Phillips (1978) used conventional recognition and recall procedures for testing face memory while Reisberg and his colleagues employed a *feature-by-feature* probing strategy in which subjects were asked to say whether the photograph shown at test "...matched the subjects' image of that face in age, hairstyle, size of nose, and so on". The appropriateness of either method in studies of this kind is debatable. However, it is clear from these results that research on the relationship between individual differences in self-reported vividness of mental imagery and face recognition performance has not produced a consistent pattern of findings. As a result, contemporary research in face recognition has tended to ignore this question. For a more detailed review of this issue, see Marks (1983).

2.3.2. Psychological Differentiation

Psychological differentiation refers to what some psychologists prefer to call 'field-dependence' or 'cognitive style' (Witkin, Dyk, Faterson, Goodnough & Karp, 1974). Generally, field-dependent people are thought to be more attentive to the content of their surroundings than field-independent people. An early study by Crutchfield, Woodworth and Albrecht (1958) found that field-dependent subjects were significantly more accurate in their recognition of faces of fellow servicemen than were field-independent subjects. As Hoffman and Kagan (1977) point out, a major problem in this study was that there was no control over the nature and extent of subjects' interaction with their fellow servicemen whose faces were used as stimuli. However, Messick and Damarin (1964) also found that accuracy in identification of incidentally learned photographs of persons correlated positively with field-dependence as assessed by the Embedded Figures Test. This finding replicated the results that were obtained by Crutchfield *et al.* (1958) in that field-dependent subjects tended to recognise faces more accurately that field-independent subjects.

However, Beijk-Doctor and Elshout (1969), Baker (1967) and Adcock & Webberly (1971) reported results which showed an inverse relationship between field dependence and face recognition performance. These contradictions prompted Goodnough (1976) to conduct a substantial review of the literature on this issue. On the basis of his review, Goodnough concluded that:

> "If there is any relationship, it is the field-independent subjects who do better than the field-dependent ones [on face memory tasks]" (p.62).

This conclusion was put to the test by Hoffman and Kagan (1977) in a study that included a wide range of measures of field dependence, general visual memory tasks and face recognition experiments. The results that were obtained by Hoffman and Kagan (1977) showed a small but significant *negative* correlation between field dependence scores and face recognition performance. The inconclusive nature of these findings has discouraged research on the possibility of establishing a link between field dependence and face recognition ability.

2.4. DIFFERENCES BETWEEN GOOD AND POOR FACE RECOGNISERS

Woodhead, Baddeley and Simmonds (1979), Woodhead and Baddeley (1981), and Baddeley and Woodhead (1983) demonstrated that subjects perform either consistently well or consistently poorly on a variety of face recognition tests. On the basis of this finding, Baddeley and Woodhead (1983) argued that it is possible to use laboratory experiments on memory for faces to select subjects who may be described as either 'good face recognisers' or 'poor face recognisers'. In an earlier study, Woodhead and Baddeley (1981) tested 19 good face recognisers and 19 poor face recognisers for their recognition of pictures and words. The results of this study showed significantly better recognition accuracy for pictures of paintings by good face recognisers compared to poor face recognisers but no significant difference between the two groups in their recognition of words. Woodhead and Baddeley (1981) concluded that good face recognisers appear to have a generally better visual memory than poor face recognisers. Also, Woodhead and Baddeley (1981) argued that their results did not support an earlier assertion by Yin (1970) that faces may be handled by a 'face-specific' mechanism that is entirely dedicated to face processing. Using a correlational approach, Church and Winograd (1985) also demonstrated that recognition memory for faces correlates significantly with (and loads onto the same factor as) recognition of other complex visual stimuli.

However, in both these studies, subjects were presented with the *same* pictures of target faces during study and at test. According to Hay and Young (1982), this procedure tests subjects' recognition of a particular picture of the face and not face recognition 'proper'. Hay and Young (1982) argued that while recognition of a particular picture of a face may proceed on the basis of specific visual cues that are present in that photograph (e.g. patterns of light and shade), for the subject to be able to recognise a face in different views, poses or orientations, he or she must successfully encode the face's structure as a whole, what Bruce and Young (1986) call "view-independent" descriptions of the face. Therefore, although Church and Winograd (1985) were able to show that face recognition performance in laboratory experiments correlates significantly with general visual memory ability, it is not clear whether this relationship exists only when identical photographs of target faces are used during study and at test or whether the relationship can be generalised to tasks in which different photographs of target faces must be recognised. More importantly, there is a possibility that the significant correlation between face recognition scores and general visual memory performance reported by Church and Winograd (1985) may have been confounded by individual differences in spatial ability.

It has been shown that subjects who score highly on tests of spatial ability also tend to be better 'visual memorisers' than subjects who score rather poorly in spatial ability tests (Eysenck, 1977, 1983; Salthouse, Babcock, Mitchell, Palmon & Skovroneck, 1990). Lohman (1988) demonstrated that individual differences in spatial ability reflect differences in efficiency of encoding, storing and representing visual information. This proposition, which is often referred to as the *representational-quality hypothesis* of individual differences in spatial ability, suggests that high spatial ability subjects encode visual information more precisely and generate more elaborate representations of the visual stimulus than low spatial ability subjects. The effect of individual differences in spatial ability on recognition of complex visual stimuli and transformed and untransformed photographs of faces is investigated in experiments 1, 2, and 3 reported in Chapter Five of this thesis. In subsequent experiments, the distinction that has been drawn between 'stimulus' recognition and 'true' recognition of faces is more closely examined.

In spite of the limitations discussed above, three important conclusions can be drawn from the studies conducted by Woodhead, Baddeley and Simmonds (1979), Woodhead and Baddeley (1981), Baddeley and Woodhead (1983) and Church and Winograd (1985). First, both Woodhead and Baddeley (1981) and Church and Winograd (1985) showed that recognition of visual stimuli does not correlate significantly with recognition of verbal stimuli. This is consistent with Paivio's (1971; 1986) dual coding theory of mental processes and representations. Secondly, these studies show that when the same photographs of target faces are used during presentation and at test, recognition of visual material appears to be consistent across tasks, regardless of whether the stimuli are pictures or photographs of faces. Thirdly, the studies by Woodhead, Baddeley and Simmonds (1979), Woodhead and Baddeley (1981) and Baddeley and Woodhead (1983) demonstrate that subjects show a consistent level of performance across a variety of face recognition tasks. As such, it is possible to select subjects who may be described as either "good" or "poor" face recognisers.

2.5. CONCLUSION

On the whole, correlational studies that have examined the relationship between individual differences in face recognition ability and self-reported vividness of visual images and field-dependence have produced an inconsistent pattern of results. The overall effect of these inconsistencies has been to discourage further experimental work on these issues. However, the studies conducted by Phillips and Rawles (1979), Woodhead, Baddeley and

Simmonds (1979) Woodhead and Baddeley (1981) Baddeley and Woodhead (1983) and by Church and Winograd (1985) have raised important empirical questions that are in need of further investigation. A major setback confronted by researchers in the late 1970s and in the early 1980s was the absence of clear theoretical frameworks within which face encoding, face processing and face recognition could be understood. Since that time however, the situation has changed for the better. The availability of new information regarding how faces are encoded and processed, as well as the theoretical and methodological progress that has been achieved over the past decade or so, have made the prospect of examining individual differences in face recognition seem more likely to be productive.

CHAPTER THREE

Stimulus Factors in Face Recognition

3.1. INTRODUCTION

The rated distinctiveness of a face, the orientation in which it is seen and its race are all factors that are known to affect the ability of an observer to subsequently recognise the face (Valentine, 1991b). However, the extent to which these factors interact or correlate with individual differences in spatial ability, face-matching ability, face recognition ability and individual differences in degree of contact with faces of other races has not been closely examined. These three factors are central to the hypotheses that are investigated in this thesis. As such, in this chapter, empirical findings and theoretical implications of research on recognition of upright and inverted faces, distinctive and typical faces, and own-race and other-race faces are discussed.

3.2. THE EFFECT OF FACE ORIENTATION

Turning a face upside-down makes it considerably more difficult to recognise than showing the face in its upright orientation (see Valentine, 1988 for a review). This is also true for other stimuli often seen upright (Goldstein, 1965; Hochberg & Galper, 1967). However, several studies have shown that inversion affects face recognition disproportionately compared to recognition of other mono-oriented visual stimuli such as pictures of houses, aeroplanes, stick-figures of men in motion etc. (see Valentine's 1988 review).

The disproportionate effect of inversion on face recognition was used by Yin (1969) as evidence which shows that recognition of faces is a "special process" that is accomplished by a face-specific mechanism entirely dedicated to face processing. However, in his review of the literature on this effect, Valentine (1988) observed that Yin's conclusion has failed to stand up to empirical evidence. In spite of this, research on the effect of inversion on face recognition has made a substantial contribution to the development of theories of face encoding [e.g. Rhodes *et al* (1987) norm-based coding model and Valentine's (1991b) multidimensional space framework for face encoding]. An important point that is raised by Valentine (1988) is that the disproportionate effect of inversion on face recognition might be due to "... factors affecting the observer, such as the differential experience of the observer of upright and inverted faces" (p.472). Valentine (1988) based this proposition on the assumption that, because faces are normally only seen upright, inversion disrupts the familiar pattern of facial features (i.e. configural properties of the face or what Ellis (1986b) refers to as facial syntax).

One way of testing the above proposition is to examine whether subjects who differ in their ability to handle rotated visual stimuli also show different degrees of susceptibility to the effect of inversion in their recognition of faces. There is evidence which suggests that recognition of rotated objects is significantly more accurate among subjects who score highly in tests of spatial ability than among subjects who score poorly on spatial ability tests (Poltrock & Brown, 1984; Just & Carpenter, 1985; Lansman, 1981; Lansman, Donaldson & Hunt, 1982). The extent to which individual differences in spatial ability affect recognition of upside-down faces is examined in experiment 3 reported in chapter five of this thesis.

3.3. THE EFFECT OF RACE OF FACE

Laboratory experiments and field studies have consistently demonstrated an "own-race" bias in face recognition (e.g. Valentine & Bruce, 1986a; Caroo, 1987, Brigham, 1986, Lindsay & Wells, 1983; Valentine & Endo, 1991; Lindsay, Jack & Christian, 1991). Generally, subjects recognise faces of their own race more accurately than they recognise faces of another race (see Bothwell, Brigham & Malpass, 1989 for a review). However, the theoretical basis of this effect is at present not clearly understood. One account of the effect of race on recognition of faces is the "face schema hypothesis" proposed by Goldstein and Chance (1980). According to Goldstein and Chance (1980), the "face schema" refers to an "organising mechanism for both information input and output". The face schema is thought to develop "in accordance with experience gained through an individual's interaction with a particular population of faces from infancy through childhood to adulthood" (Goldstein & Chance, 1980).

The face schema is therefore thought to provide details about expectations, determine what aspects of the face stimuli will be attended to, reduce the necessity for voluntary processing to a minimum and make retrieval processes more or less automatic but exceptionally quick (Goldstein & Chance, 1980). Apparent in these assertions is the assumption that face processing and face recognition involve a large component of learning. Many psychologists would agree with this assumption (see for example, Ellis (1990)). However, Goldstein and Chance (1980) also argued that over-learning the task of recognising own-race faces creates a "rigid" face schema that becomes inflexible and, therefore, less capable of dealing with faces of another race. In other words, the face schema is thought to be "race-specific".

Goldstein and Chance (1980) also compared 'good' and 'poor' face recognisers on their recognition of upright and upside-down faces. The results that were obtained from this study confirmed their hypothesis that good face recognisers are significantly impaired in their recognition of upside-down faces compared to poor face recognisers. On the basis of these results, Goldstein and Chance (1980) claimed that the face schema is both "race- and orientation-specific". Although the latter conclusion is debatable, a major contribution made by Goldstein and Chance (1980) is their emphasis on the role of experience and learning in accounting for the own-race bias in face recognition.

Another theoretical account of the own-race bias in face recognition is the "inappropriate-cue utilisation hypothesis" (Shepherd & Deregowski, 1981). There is evidence which suggests that both African and Caucasian subjects make use of different facial cues to recognise own-race and other-race faces (see Shepherd, 1989; Ellis & Shepherd, 1992 for reviews). Thus, encoding other-race faces along dimensions that are useful for differentiating own-race faces might account for the poorer recognition performance often observed on recognition of other-race faces compared to recognition of own-race faces.

In chapter seven of this thesis, a cross-cultural experiment is described which investigated the contact-hypothesis of the own-race bias in face recognition.

The contact hypothesis[9] of the own-race bias in face recognition is closely associated with the inappropriate-cue utilisation hypothesis (Ellis & Shepherd, 1982) and with the multidimensional space framework of face encoding proposed by Valentine (1991b). Valentine's MDS framework of face encoding is discussed in detail in section 3.5 of this chapter.

3.4. THE EFFECT OF DISTINCTIVENESS

Several studies have shown that, within a given population of faces, recognition of faces that are rated as "distinctive" (or unusual) is significantly more accurate and faster than recognition of faces rated to be "typical" (Bartlett, Hurry & Thornley, 1984; Winograd, 1981; Light, Kayra-Stuart & Hollander, 1979; Valentine & Bruce, 1986b; Valentine, 1991a; 1991b). Bartlett et al (1984) explain this effect in terms of familiarity. They argue that " ...the increment in familiarity that results from a single prior presentation is greater for distinctive faces than it is for typical faces" (p.219). Since typical faces share a number of common elements with several other known faces, they do not present anything "new" or exciting to the eye and the encoding neurones behind it. Unlike typical faces, distinctive faces present the viewer with 'unusual' and less familiar facial configurations. It is this uniqueness of distinctive faces that Bartlett et al (1984) argue is responsible for the higher hit rates and fewer false positives to distinctive faces compared to typical faces.

The "familiarity hypothesis" of the effect of distinctiveness on recognition of faces has been criticised by Valentine and Bruce (1986b) for failing to

[9] see Introduction to Chapter Seven of this thesis.

separate familiarity effects from what Valentine and Bruce (1986b) call "pure" distinctiveness effects. Valentine and Bruce (1986b) argued that these two effects are independent of each other. They explain the effect of distinctiveness in face recognition in terms of a "facial prototype" hypothesis. According to Valentine and Bruce (1986b), a distinctive face is better recognised in a subsequent encounter because it is encoded further away from the "prototype" or average face within a given population of faces. Therefore, its presence in a viewer's visual field is easier to recognise because it does not suffer from interference effects from 'neighbouring faces' in memory. Valentine and Bruce acknowledge, however, that there are important differences between their study and the studies conducted by Bartlett and his associates. For example, while the study by Valentine and Bruce (1986b) involved recognition of highly familiar faces, the study by Bartlett et al (1984) involved recognition memory for previously unfamiliar faces. Also, while Bartlett et al (1984) based their conclusions on an analysis of error rates, the study by Valentine and Bruce (1986) relied on analysis of reaction times. Valentine and Bruce concede, therefore, that "...these [methodological] differences may account for the apparently conflicting results" (p.304).

The idea of a facial prototype being abstracted from a stimulus category is closely related to that of a "generalised norm" which has been proposed by Rhodes (1985). But, how is the norm or prototype generated? Valentine (1991b) argues that our continuous exposure to own-race faces enables individuals to develop an idea of the properties that serve to distinguish individual faces within that population of faces. Deviations from the prototype are easily noticed since such deviations make the face unusual or "unique".

Thus, in his review of the literature on the effect of distinctiveness on recognition of faces, Valentine (1991b) observes that:

> "The effect of distinctiveness on recognition of faces provides some indication that category-specific knowledge, presumably acquired through experience of the population of faces previously seen, is used to facilitate recognition of faces encountered subsequently" (p. 4).

The effect of distinctiveness on recognition of faces is quite robust. It emerges from an analysis of hits, false positives and on combined measures of discriminability based on signal detection theory such as d' or A'. Although this effect has been found in a number of studies, there has until recently been no clear theoretical account for the effect of distinctiveness on recognition of faces. More recently, Valentine (1991b) has argued that the norm-based coding model (Rhodes, 1985), the facial prototype hypothesis (Valentine & Bruce, 1986b) and the face schema hypothesis (Goldstein & Chance, 1980) all make similar predictions regarding the effects of inversion, race and distinctiveness and that these effects can be understood within a multidimensional space framework of face encoding.

3.5. THE MDS FRAMEWORK OF FACE ENCODING

In proposing a multidimensional space (MDS) framework of face encoding, Valentine (1991b) aimed to provide a parsimonious and unified account of the effects of race, orientation and distinctiveness on recognition of faces. The MDS framework integrates the norm-based, the exemplar-based, and the prototype-based hypotheses into a single heuristic for understanding how faces may be encoded and represented in memory. Thus, the framework uses a Euclidean multidimensional space as "... an appropriate metaphor for the mental representation of a face" (Valentine (1991b). The dimensions of the space represent the physiognomic features which serve as the basis of face encoding.

The origin of the multidimensional space is defined as " ... the central tendency of the dimensions..", that is, typical faces are thought to be encoded close to the central tendency of the space. As such, the density of points representing individual faces will increase as the distance from the central tendency increases. Implicit in this assumption is that an individual's lifetime experience with faces will contribute to the distribution of faces within the multidimensional space. According to Valentine (1991b), the effect of distinctiveness in face recognition can be accounted for by appealing to the idea of "exemplar density". The notion of exemplar-density forms a part of both the norm-based coding model and the purely exemplar-based coding model. Since, by definition, fewer faces resemble a distinctive face, distinctive faces are thought to be encoded and located in regions where the density of points representing individual faces is low. As such, distinctive faces can be identified rapidly and more accurately than typical faces.

Unlike distinctive faces, typical faces are thought to be located close to the central tendency where, as pointed out earlier, the density of points is likely to be higher. By definition, typical faces share a number of common elements with several other faces that are known to the observer. The high density of individual points representing each typical face close to one another is thought to be responsible for the difficulty often associated with recognition of typical faces compared to distinctive faces. For a detailed discussion, see Valentine (1991b). For present purposes, the crucial point to note is that in Valentine's MDS framework of face encoding, the idea of "exemplar-density" forms the basis for the effect of distinctiveness on recognition of faces.

So far, recognition of own-race faces has been assumed to be the main task confronting the viewer. However, we are often confronted with the need to discriminate between individual faces of a race that is different from that of our own. The MDS framework has also been extended to account for the effect of race of face in recognition of faces. According to Valentine (1991b), our lack of knowledge and experience with the physiognomic properties of other-race faces raises some important questions regarding the extent to which the MDS framework might account for recognition of 'other-race' faces. Valentine (1991b) argues that, assuming the dimensions of the space are based on experience with faces of predominantly one race, the feature dimensions underlying the multidimensional space will be those that are appropriate for discriminating individual faces of that race.

In Valentine's MDS framework, the poorer recognition scores often observed on recognition of other-race faces is attributed to the fact that other-race faces might be encoded on dimensions which do not serve to discriminate well amongst faces of that race. According to Valentine (1991b), the dimensions which are salient will be those that are characteristic of faces of the 'other-race' as a whole rather than those that are characteristic of individual faces of that race. There is evidence that different facial features are used to describe black African and Caucasian faces (Ellis, Deregowski & Shepherd, 1975; Shepherd & Deregowski, 1981). Therefore, although other-race faces will not cluster around the central tendency for own-race faces, one would expect them to form a separate cluster of their own, at some point within the multidimensional space.

3.6. CONCLUSION

Although different in some respects, the norm-based coding model (Rhodes, 1985), the prototype hypothesis (Valentine & Bruce, 1986b) and the multidimensional space framework of face encoding (Valentine, 1991b) are all models that are based on the notion that the way in which we encode faces is a function of our previous experience. The effect of "contact" with other-race faces on recognition of distinctive and typical, own-race and other-race faces is examined in a cross-cultural study reported in chapter seven of this thesis.

CHAPTER FOUR

Methodology

4.1. INTRODUCTION

The experiments described in this thesis are similar in design and in the techniques that are used to analyse data. Therefore, to avoid unnecessary repetition, this chapter provides a description of the basic methods used. This thesis is concerned with recognition memory for previously unfamiliar faces that were made 'familiar' to the subjects through a single prior presentation during the experiment. The term 'recognition' is therefore used in this thesis to refer to a judgement of previous occurrence in a standard recognition memory experiment.

4.2. EXPERIMENTAL PROCEDURES FOR TESTING RECOGNITION MEMORY

According to Murdock (1982), there are two main types of procedures that can be used to study recognition memory: (1) the continuous-task procedure (Shepard & Teghtsoonian, 1961) and (2) the study-test procedure (Strong, 1912, 1913).

4.2.1. The Continuous-task procedure

In the continuous task procedure, there is no clear separation between study items and test items. A single list of items is presented to the subjects who must decide for each item whether it is being shown for the first or second time in the same list. Thus, on the first presentation of an item, subjects are expected to respond 'no' (meaning that they have not seen the item "in this list"). When the same item is encountered later in the same list, subjects are expected to respond 'yes' (meaning that they have seen the item "in this list"). The methodological and statistical limitations of this procedure are discussed in Murdock (1965; 1982).

4.2.2. The Study-test procedure

In a study-test procedure, subjects are initially presented with a series of items to inspect and memorise. These items are called 'targets'. After an appropriate delay, a test list consisting of targets and distractors is presented. The subject's task is to decide which of the items in the test list are targets and which ones are distractors. In order to test recognition memory using this procedure, one could use either the yes-no technique, or the forced-choice technique. In the yes-no technique, subjects are expected to choose 'yes' when a target is shown and to choose 'no' when a Distractor is shown. In a forced-choice procedure, each test trial consists of two simultaneously presented items, one of which is a target and the other is a Distractor. Subjects are asked to decide which of the two items is the target.

The forced-choice technique is useful when the experimenter wishes to know whether subjects have extracted from each target item specific characteristics of the visual stimuli (see Loftus, 1982). In cases where this question is not the subject of investigation, the yes-no technique is often preferred. In all of the recognition experiments described in this thesis, the yes-no technique was used. In addition to its design simplicity, the yes-no technique is a more convenient procedure if the investigator intends to calculate signal detection parameters to estimate recognition accuracy (Murdock, 1982; Loftus, 1982).

4.2.3. Recognition Accuracy and Signal Detection Theory

Murdock (1982) points out that one cannot discuss the accuracy of recognition memory in any depth without recourse to signal-detection theory. This section outlines the major components of signal detection theory and discusses how this theory is used in the analysis of experimental data in this thesis. The theory of signal detection derives from statistical decision theory (Green & Swets, 1966).

The basic idea in signal detection theory is that subjects' responses in a simple yes-no task can be thought of as comprising two underlying distributions, a *noise distribution* and a *signal distribution*. The 'familiarity' of distractors constitute the signal+noise distribution. Familiarity of targets constitute the signal distribution. It is common practice (and convenient too) to present these two distributions on the same axes. Thus, in an experiment in which 100 targets and 100 distractors are presented at test and the subject responds correctly to all the items, two response accuracy distributions that are independent of one another can be drawn (See Figure 4.1.a. *overleaf*).

However, a more typical situation is shown in figure 4.1.b.(*overleaf*). As this figure shows, the two distributions overlap inside the region marked X, suggesting that some targets were not recognised while some distractors were responded to as though they were targets.

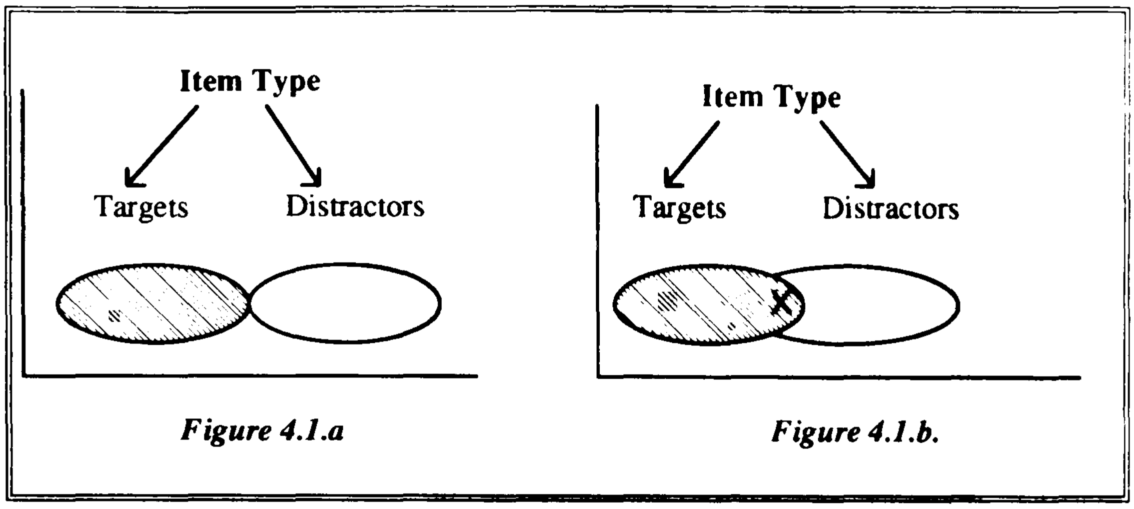

Figure 4.1. *The underlying distributions of 'old' and 'new' items as suggested by an application of signal detection theory to recognition memory experiments.*

In order to determine a subject's overall recognition performance, it is necessary to calculate a single score that captures the information contained in these two distributions. Figure 4.2. shows the four possible kinds of responses which a subject who is tested for recognition memory using a yes-no procedure could make.

	TYPE OF TEST ITEM	
	Target	**Distractor**
S says **YES**	**HIT**	**FALSE POSITIVE**
S says **NO**	**MISS**	**CORRECT REJECTION**

Figure 4.2. *Stimulus response matrix for a 'yes-no' recognition memory experiment.*

In the jargon of signal detection theory, a 'yes' response to a target is a *hit* but a 'yes' response to a Distractor is a *false positive*. Conversely, a 'no' response to a Distractor is a *correct rejection* but a 'no' response to a target is a *miss*.

Signal detection theory makes use of hits and false positives as the two most important measures of recognition performance.

Although these two measures do provide some indication of the subjects' recognition performance, neither on its own would be an adequate measure of overall recognition accuracy. Consider this example: Out of 50 targets, one subject responds correctly to 40 "old" faces (a hit rate of 80%) but misidentifies 5 "new" faces as "old" (a false positive rate of 10%, assuming the number of distractors was 50). Another subject also responds correctly to 40 targets (again, a hit rate of 80%) but misidentifies 25 "new" faces as "old" (a false positive rate of 50%). An analysis of the hit rates alone would suggest that the two subjects performed equally well. However, this would be an incorrect analysis since the 80% hit rate obtained by the second subject includes a stronger "bias" tending towards responding "yes" to most of the test items. Clearly, the first subject discriminated between targets and distractors more accurately than did the second subject.

The procedure that is followed throughout this thesis is to combine hits and false positives to obtain a single measure of sensitivity or discriminability (A'). A' is a non-parametric[10] signal detection measure of recognition accuracy (Rae, 1976). A number of published tables and computer programs for calculating A' scores are currently in circulation (e.g. Rae, 1976, Macmillan & Creelman, 1991). Throughout this thesis, A' calculations were based on Gordon Rae's formula (Rae, 1976) which is shown in Figure 4.3.

[10] i.e. does not rely on the assumption of normal distributions.

If h> or = f, then:	if h<f, then:
$A' = (h^2 + f^2 + 3h - f - 4fh) / 4h(1-f))$	$A' = (h - h^2 + f - f^2) / [4f(1-h)]$

Figure 4.3. *Gordon Rae's (1976) formula for calculating A' scores from hit and false positive rates.**

4.3. EXPERIMENTAL DESIGN AND DATA ANALYSIS

All the experiments described in this thesis were set up as split-plot factorial designs. One or more between-subjects factors were combined with one (or more) within-subjects factors in a single experiment. As such, the data were analysed using ANOVA for mixed designs. A common problem in analysis of variance is the need to ensure that the data satisfy the assumption of homogeneity of variance. Where the raw data did not satisfy this requirement, the data were transformed using the techniques described below before performing analysis of variance and any other subsequent multiple comparisons of means.

4.3.1. Data Transformation Procedures

In order to test for the homogeneity of variance, the $F_{max.}$ test (Hartley, 1940; 1950) was applied to the raw data. The formula for calculating $F_{max.}$ is shown in Figure 4.4. $F_{max.}$ has degrees of freedom equal to k and $n-1$, where k is the number of variances and n is the number of observations within each treatment condition.

* h=No of Hits Obtained/Max. No of Hits, f=No of False Positives Obtained/Max. No of False positives.

$$\text{Fmax} = \left(\frac{s^2 \max}{s^2 \min} \right)$$

Figure 4.4. *Hartley's formula for calculating* F_{max}. *(Hartley, 1940).*[*1]

The principle of homogeneity of variance is violated if the obtained F_{max}. value is greater than the tabled value of F_{max}. at *k* and *n-1* degrees of freedom. If the obtained F_{max}. value is smaller than the tabled value, the principle of homogeneity of variance is not violated (Kirk, 1968). In cases where the raw data violated the principle of homogeneity of variance (i.e. where: F_{max}. obtained > F_{max}. tabled), the raw data were subjected to an *angular sine transformation* before performing any of the statistical analyses reported. The formula that was used to transform the raw data is shown in Figure 4.5.

$$\text{Transformed } (X') \text{ score} = 2 \arcsin \sqrt{X} \, ,$$

Figure 4.5. *Angular sine transformation procedure (Kirk, 1968, p66).*[*2]

Although other alternative procedures for data transformation have been suggested [e.g. the simple *square-root transformation* (Freeman & Tukey, 1950); the *logarithmic transformation* (Kirk, 1968) and the *reciprocal transformation* (Kirk, 1968)], the angular sine transformation procedure was selected because it is more conservative and more effective in separating the relationship between sample means and variances. Also, the angular sine

*1 **Where**: s^2max=Largest cell variance, and s^2min=Smallest cell variance.

*2 Where X is a proportion.

transformation produces the smallest ratio of the relationship between the smallest and the largest ranges (Kirk, 1968, p.68).

4.3.2. ANOVA in Split-Plot Factorial Designs

Although in the present thesis all experimental data were analysed using SPSS for Windows V.6.0, it is necessary to present here a brief summary of the computational procedures that are used to analyse data from split-plot factorial experiments. There are two reasons why this is necessary. First, SPSS does not automatically use the appropriate computational procedures unless it is "told" by the user. By default, SPSS would analyse the data as though the design consists of completely randomised groups.

It was therefore considered necessary to ensure (1) that the analysis performed by the computer was the correct one for a split-plot factorial design and (2) that the resulting output provided the correct summary statistics for subsequent use in testing for simple main effects and in performing multiple comparison tests. Secondly, including the statistical computations necessary for this type of analysis here helps to clarify the differences between multiple comparison tests and tests of simple main effects that are used in this thesis.

The layout of a split-plot factorial design is shown in Table 4.1. In this hypothetical experiment, there is one *within-subjects* factor with four levels of treatment (b1, b2 , b3 , b4) and one *between-subjects* factor with two levels (a1 and a2). The number of subjects in each **ab** cell is 4 (i.e. $n = 4$). The total number of subjects is 8, not 64 (as would be the case in a completely randomised factorial design).

		b1	b2	b3	b4	$\sum_1^q AS$	$\frac{(\sum_1^q AS)^2}{q}$
a1	s1	3	4	7	7	21	110.25
	s2	6	5	8	8	27	182.25
	s3	3	4	7	9	23	132.25
	s4	3	3	6	8	20	100.00
a2	s1	1	2	5	10	18	81.00
	s2	2	3	6	10	21	110.25
	s3	2	4	5	9	20	100.00
	s4	2	3	6	11	22	121.00

Table 4.1. *Hypothetical data from an 'experiment' conducted using a split-plot factorial design* (From Kirk, 1968, p.249).*

The computational procedures that are required to analyse this hypothetical data are given below.

Step 1. An AB Summary Table is generated like this:

n=4	b1	b2	b3	b4	$\sum A$	$\frac{\left(\sum_1^q A\right)^2}{nq}$
a1	15	16	28	32	91	517.56
a2	7	12	22	40	81	410.06
$\sum B$	22	28	50	72		
$\frac{\left(\sum_1^q B\right)^2}{np}$	60.5	98.0	312.5	648.0		

Step 2. The following intermediate values are computed:

(1). $\sum_1^q \sum_1^N ABS = 3 + 6 + 3 + \ldots + 11 = \mathbf{172.000}$

(2). $\sum_1^q \sum_1^N (ABS)^2 = [\mathbf{ABS}] = (3) + (6)(3) + \ldots + (11) = \mathbf{1160.000}$

* ***Where:*** ***p***=levels of the between-subjects factor (i.e. 2), ***q***=levels of the within-subjects factor (i.e. 4), ***n*** = number of cases per cell.

(3). $\frac{\left(\sum_1^q \sum_1^N\right)^2}{qN}$ = [X] = $\frac{(172)^2}{(4)(8)}$ = **924.500**

(4). $\sum_1^N \frac{\left(\sum_1^q AS\right)^2}{q}$ }= [AS] = 110.25 + 182.25 + ... + 121.00 = **937.000**

(5). $\sum_1^p \frac{\left(\sum_1^q A\right)^2}{nq}$ = [A] = 517.5625 + 410.0625 = **927.625**

(6). $\sum_1^q \frac{\left(\sum_1^p B\right)^2}{np}$ = [B] = 60.5 + 98.0 + ... + 648.0 = **1119.000**

(7). $\sum_1^p \sum_1^q \frac{(AB)^2}{n}$ = [AB] = $\frac{(15)^2}{4} + \frac{(16)^2}{4} + \ldots + \frac{(40)^2}{4}$ = **1141.500**

Step 3. The Sum of Squares are calculated like this:

SS_{total} = [ABS] - [X] = **235.500**	SSws = [ABS] - [AS] = **223.000**
SS_{bs} = [AS] - [X] = **12.5000**	SS_B = [B] = [X] = **194.5000**
SS_A = [A] - [X] = **3.125**	SS_{AB} = [AB] - [A] - [B] + [X] = **19.375**
SS_{swg} = [AS] - [A] = **9.375**	$SS_{BX\ swg}$ = [ABS] - [AB] - [AS] + [A] = **9.125**

Step 4. An ANOVA table is built up like this:

Effect	**SS**	**df**	**MS**	**F**
Between Subjects				
A	3.125	1 *(p-1)*	3.125	2.0000
swg	9.375	6 *(p(n-1)*	1.563	
Within Subjects				
B	194.500	3 *(q-1)*	64.83	127.8*
AB Interaction	19.375	3 *(p-1)(q-1)*	6.458	12.74*
B X swg	9.125	18 *p(n-1)(q-1)*	.507	

The final ANOVA table shown in step 4 above shows that the main effect of the between-subjects factor (A) is not significant. However, the interaction between this factor and the within-subjects factor is significant. Also, the main effect of the within-subjects factor (B) is significant. In the present thesis, a distinction is drawn between multiple comparison tests and tests of simple main effects. Multiple comparison tests are tests that are used to compare condition means regardless of whether or not the overall F value is significant. Tests of simple main effects are tests that are used to compare condition means as part of the process of breaking down a significant interaction between two or more variables.

4.3.3. Multiple Comparison (MC) Tests

There is a wide range of MC tests to choose from (see Rosenthal & Rosnow, 1991; Winer, Brown & Michels, 1990 and Howell, 1989). Before deciding to use any one particular MC test, the investigator must answer one or all of the following questions: (1) Is the comparison a planned one or is it a post-hoc analysis? (2) Is the comparison based on a significant or a non-significant overall F value? (3) Are the two condition means to be compared based on equal or unequal **n**s? Planned comparisons are comparisons that test specific predictions that an experiment is designed to investigate. Because these predictions are made before conducting the experiment, planned comparisons are also called a priori comparisons. Multiple comparisons that are conducted as part of 'data snooping' following a significant overall *F* are called posterior comparisons or post-hoc tests. In the present thesis, planned comparisons are made using the *t* formulae recommended by Kirk (1968, p.266-267). The computational procedure for this *t* value depends on the type of comparison that is to be made. It will be recalled that in a split-plot factorial design, two types of factors are manipulated in the same experiment: a between-subjects factor and a within-subjects factor.

(1). In cases where the planned comparison involved mean scores from two different groups as defined by the between-subjects factor, the following formula was used:

$$t = \frac{C_1(\overline{X}_1) + C_2(\overline{X}_2)}{\sqrt{2MS_{swg}/nq}} \quad , \quad df = p(n - 1) \qquad \textbf{(4.1)}$$

Where, ***C*** is a *coefficient*, $\overline{X}_1$ is mean for group 1 in condition 1, $\overline{X}_2$ is the mean for group 2 in the same condition, ***df*** is degrees of freedom, ***MS*** is the mean square, *swg* is subject within groups error variance, ***p*** is the number of levels for the between-subjects factor, ***q*** is the number of levels for the within-subjects factor, and ***n*** is the number of valid cases per cell.

(2). In cases where the comparison involved two means from the <u>same</u> group of subjects as defined by the within-subjects, factor, the following formula is used:

$$t = \frac{C_1(\overline{X}_1) + C_3(\overline{X}_3)}{\sqrt{2MS_{BXswg}/np}} \quad , \quad df = p(n-1)(q-1) \qquad \textbf{(4.2)}$$

Where: ***C*** is a *coefficient*, $\overline{X}_1$ is the mean for group 1 in condition 1 and $\overline{X}_3$ is the mean for the same group in condition 2, and ***df*** is degrees of freedom. ***MS*** is the mean square, ***swg*** is subject within groups error variance, ***p*** is the number of levels for the between-subjects factor, ***q*** is the number of levels for the within-subjects factor, and ***n*** is the number of valid cases per cell, ***BXswg*** = pooled error variance

Formulas 4.1 and 4.2 differ in two ways. First, in formula 4.1., the degrees of freedom are calculated by multiplying the number of levels of the between-subjects factor by n-1 while in formula 4.2., the degrees of freedom are calculated by multiplying the number of levels of the between-subjects factor by the product of (n-1) and (q-1). Secondly, while in formula 4.1. the denominator that is used in calculating the **t** value is $\sqrt{2MS_{swg}/nq}$, in formula 4.2., the divisor is $\sqrt{2MS_{Bxswg}/np}$. This difference arises from differences in the computational procedures that are used to calculate error variances in between-subjects designs compared to within-subject designs.

The preceding discussion has focused only on planned multiple comparisons tests. In cases where unexpected differences arise from the data collected during an experiment, these tests are not appropriate. The appropriate tests, which take into account the probability that these differences could indeed be spurious include Fisher's (1949) *LSD test*, Tukey's (1949) *HSD test*, Scheffe's (1953) *S test*, the *Newman-Keuls* (1952) test, and Duncan's (1955) W_r *test* and several others (see Winer, 1990). There are no clear statistical guidelines as to which of these tests is most ideal. In the present thesis, all posterior multiple comparisons of means were made using the Tukey's HSD test (Tukey, 1953, denoted by q in the present thesis). The statistical computations that are used in this thesis for obtaining q depended on whether the comparisons involved two means from the between-subjects factor or two means from the within-subjects factor.

In cases where the comparison involved two means from the between-subjects factor, the following formula is used:

$$q = \frac{C_j(A_1) + C_{j'}(A_2)}{\sqrt{MS_{Swg}/nq}} \qquad \textit{Where: } df = p,\ p(n-1)$$

In cases where the comparison involved means from the within-subjects factor, the following formula is used:

$$q = \frac{C_j(B_1) + C_{j'}(B_3)}{\sqrt{MS_{BXSwg}/np}} \qquad \textit{Where: } df = q,\ p(n-1)(q-1).$$

It will be recalled that at the beginning of this section, it was pointed out that multiple comparison tests are different from tests of simple main effects. Multiple comparison tests are used to test differences between means regardless of whether or not the overall interaction is significant. Tests of simple main effects are designed to assist the experimenter in making sense of significant interactions. A significant interaction simply tells the investigator that "... one treatment behaves differently under different levels of the other factor" (Kirk, 1968, p.263). However, this information is not particularly useful unless the experimenter can specify which factor is behaving differently at which levels of the other factor. This is where tests of simple main effects are relevant.

4.3.4. Tests of Simple Main Effects

An analysis of the data from our hypothetical experiment showed a significant interaction between factor **A** and factor **B**. To compare condition means as part of breaking down this overall interaction the following computational procedures are recommended by Kirk (1968) [p.264 - 266]:

Step 1. An AB Summary Table is prepared like this:

n=4

	b1	b2	b3	b4	ΣA
a1	15	16	28	32	91
a2	7	12	22	40	81
ΣB	22	28	50	72	

Step 2. Compute the following preliminary values.

$$\text{SSA at } b_1 = \sum_1^p \frac{(AB_{i1})^2}{n} - \frac{\left(\sum_1^p B_{i1}\right)^2}{np} = \frac{(15)^2}{4} + \frac{(7)^2}{4} - \frac{(22)^2}{8} = 8.0$$

$$\text{SSA at } b_2 = \sum_1^p \frac{(AB_{i2})^2}{n} - \frac{\left(\sum_1^p B_{i2}\right)^2}{np} = \frac{(16)^2}{4} + \frac{(12)^2}{4} - \frac{(28)^2}{8} = 2.0$$

$$\text{SSA at } b_3 = \sum_1^p \frac{(AB_{i3})^2}{n} - \frac{\left(\sum_1^p B_{i3}\right)}{np} = \frac{(28)^2}{4} + \frac{(22)^2}{4} - \frac{(50)^2}{8} = 4.5$$

$$\text{SSA at } b_4 = \sum_1^p \frac{(AB_{i4})}{n} - \frac{\left(\sum_1^p B_{i4}\right)}{np} = \frac{(32)^2}{4} + \frac{(40)^2}{4} - \frac{(72)^2}{8} = 8.0$$

$$\text{SSB at } a1 = \sum_1^q \frac{(AB_{i1})^2}{n} - \frac{\left(\sum_1^q A_{1j}\right)}{nq} = \frac{(15)^2}{4} + \frac{(16)^2}{4} + \ldots \frac{(32)^2}{4} - \frac{(91)^2}{16} = 54.69$$

$$\text{SSB at } a2 = \sum_1^q \frac{(AB_{2j})^2}{n} - \frac{\left(\sum_1^q A_{2j}\right)}{nq} = \frac{(7)^2}{4} + \frac{(12)^2}{4} + \ldots \frac{(40)^2}{4} - \frac{(81^2)}{16} = 159.19$$

Step 3. Decide on what error term to use.

As a rule of thumb, Kirk (1968) suggests that "if the treatment and interaction which equal the sum of simple main effects have different error terms, ... the two error terms should be *pooled* in testing for simple main effects ...". The formula for computing the pooled error term is:

$$pet = \frac{SS_{swg} + SS_{Bxswg}}{(dfSS_{swg}) + (dfSS_{Bxswg})}$$

Where: *pet* is the 'pooled error term'.

The *pooled error term* is used to test simple main effects of factor A at various levels of factor B. However, the error term for testing simple main effects of factor B at various levels of factor A remains MS_{BXswg}. (see Kirk, 1968, p.265). Dividing the SS by the appropriate error term gives the F-value that can be checked for significance in the usual way.

Part II

EXPERIMENTAL WORK I

CHAPTER FIVE

Do Individual Differences in Spatial Ability Affect Visual Memory and Recognition of Faces?

5.1. INTRODUCTION

Vernon (1950) proposed that an individual's intelligence is made up of two major factors, namely, a *verbal reasoning factor* and a *spatial reasoning factor*. Vernon also argued that each of these factors consists of several other specific abilities. For example, verbal reasoning ability is often thought to include word fluency, word memory, grammar, and inductive reasoning while spatial reasoning ability is thought to involve numerical reasoning, perceptual accuracy and visual memory performance. Empirical support for the verbal-visual distinction in human cognitive capacity has come from two main sources. First, correlational studies have shown that people's performance on tests of word fluency, word memory, grammar and inductive reasoning correlate more highly with one another than they correlate with tests of perceptual speed and numerical reasoning. Thus, when correlational data of this kind are subjected to principal component analysis, two *orthogonal* factors are often reported, one involving verbal reasoning and the other involving spatial reasoning.

The second source of evidence for the 'verbal-visual' distinction in human cognitive functioning has come from experimental studies that have examined the encoding and representational processes involved in verbal memory and visual memory[11]. This research has shown that human memory operates in two

[11] See Paivio, 1990 for a review.

representational modes, a visual mode and a verbal mode, hence the use of the term 'dual coding theory'. The dual coding theory suggests that information presented visually is encoded and represented in memory by a 'functionally independent' module from that which is responsible for processing verbal material such as words, phrases or sentences.

Laboratory experiments have shown that recognition of faces correlates significantly with recognition pictures of objects and other complex visual stimuli but not with recognition of words or phrases (Woodhead, Baddeley & Simmonds, 1979; Woodhead & Baddeley, 1981; Baddeley & Woodhead, 1983; Church & Winograd, 1985; Phillips & Rawles, 1979). Two conclusions have been drawn from these results. First, it has been argued that these results '...strongly support the hypothesis that there exist two sets of encoding processes, one associated with words and one associated with pictures, each of which is mediated by different abilities.' (Church & Winograd, 1985, p.76). This interpretation is consistent with the dual coding theory of mental representations (see Paivio, 1971; 1986; 1990)[12]. Secondly, the significant correlation between face recognition and picture memory performance has been interpreted as evidence that faces are processed in the same way as other complex visual stimuli and not by a face-specific mechanism that is entirely dedicated to face processing as proposed by Yin (1969; 1970). However, significant correlations between face recognition scores and performance on general visual memory tasks have only been reported in studies in which the *same* pictures of target faces were shown during presentation and at test.

12 Although Paivio popularised the dual coding theory, early neuropsychological work by Milner in the 1950's and 1960's had provided strong support for separate verbal and visual memory stores.

Since in real life we rarely see people's faces in exactly the same pose, view or facial expression, Hay and Young (1982), Bruce (1982: 1988) and Young and Bruce (1991) have pointed out that experiments in which the same pictures of target faces are shown during presentation and at test do not assess 'face recognition proper'. Face recognition proper is thought to involve recognition of *different* photographs of previously presented faces. In discussing their results, Church and Winograd (1985) acknowledged that the correlation between memory for faces and memory for pictures may have been inflated by the use of identical pictures of target faces during study and at test. Thus, Church and Winograd (1985) concluded that:

> "It would be interesting to know if evidence for face uniqueness would be found with an individual differences paradigm when the faces shown at study and test are not identical but, instead, show different poses of the same person" (p.77).

There is a substantial body of literature which suggests that subjects who score highly in tests of spatial ability also score highly in visual memory tasks (see Eysenck, 1977; 1983 and Salthouse, Babcock, Mitchell, Palmon & Skovronek, 1990 for detailed reviews). These studies are consistent with Lohman (1988)'s *representational-quality hypothesis* of individual differences in spatial ability. Lohman and his associates have shown that high spatial ability subjects encode visual information more accurately and generate more detailed visual representations than low spatial ability subjects. It has also been shown that high spatial ability subjects are better than low spatial ability subjects in their recognition of transformed visual stimuli (Lohman, 1979; Mumaw & Pelligrino, 1984; Lohman, Pelligrino, Alderton, & Regian, 1987; Lohman & Kyllonen, 1983). Thus, it has been argued that high spatial ability subjects are better than low spatial ability subjects at retaining in memory a more accurate representation of one stimulus while viewing another stimulus (Lohman, 1988).

The experiments that are reported in this chapter examined: (i) the effect of individual differences in spatial ability on recognition of visual and verbal stimuli, and (ii) the effect of individual differences in spatial ability on recognition of transformed and untransformed photographs of target faces. In experiment 1, the dual coding theory of memory (Paivio, 1971; 1986; 1990) is tested by comparing 'high' and 'low' spatial ability subjects on their recognition of pictures of houses and high imagery words.

In subsequent experiments, the interaction between individual differences in spatial ability and recognition of 'transformed' and 'untransformed' photographs of faces is explored. In experiment 2, high and low spatial ability subjects are tested for their recognition of faces that are either changed or unchanged in facial expression at test while in experiment 3, the same subjects are tested for their recognition of upright and upside-down faces. The critical factor in all the experiments that are described in this chapter is individual differences in spatial ability.

Subjects were classified as 'high' or 'low' in spatial ability on the basis of their performance on Part II of the AH5 Test of High Grade Intelligence (Heim, 1968). First, fifty-four undergraduates aged between 18 and 38 years (*mean age=20.74, sd=3.48*) were administered the AH5 Test during a psychology practical class. The AH5 test is divided into two parts. Part I of the test consists of 36 items which measure 'verbal reasoning ability' (see Appendix A1 for examples). Part II is made up of 36 items which measure 'spatial reasoning ability' (see Appendix A2 for examples).

The mean scores for the entire sample were as follows: *verbal ability*=16.01 (*sd=3.82*), *spatial ability*=20.06 (*sd=3.88*). Sixteen 'high-spatial' and sixteen 'low-spatial' ability subjects were selected from the 54 subjects who were originally tested. High spatial ability (HSA) subjects were operationally defined as any subject whose score on Part II of the AH5 test was above 23. Low spatial ability (LSA) subjects were defined as any subject whose score on Part II of the AH5 test was below 17. Table 5.1 shows the descriptive data for the subjects who participated in all the experiments that are presented in this chapter. Subjects participated in the experiments in the order in which they are reported.

Table 5.1. *Descriptive statistics for 'high' and 'low' spatial ability subjects who participated in experiments 1, 2 and 3.*

	Minimum	*Maximum*	*Mean*	*Std Dev*
GROUP				
HSA Ss				
Spatial ability	21.00	29.00	23.80	2.37
Verbal ability	9.00	21.00	15.67	3.52
LSA Ss				
Spatial ability	12.00	18.00	16.27	1.62
Verbal ability	13.00	26.00	17.53	3.23

HSA Ss = High Spatial Ability Subjects, **LSA Ss** = LSA Spatial Ability Subjects.

5.2. EXPERIMENT 1

The aim of this experiment was to replicate previous findings regarding the effect of individual differences in spatial ability on visual recognition memory performance and to test Paivio's dual coding theory of mental processes (Paivio, 1971; 1986). Previous studies have shown that individual differences in spatial ability correlate significantly with visual memory performance while Paivio's dual coding theory suggests that visual and verbal memory are functionally independent. Therefore, in the present experiment, it was predicted that HSA subjects would be significantly more accurate in their recognition of pictures than LSA subjects and that individual differences in spatial ability would not significantly affect word recognition performance.

5.2.1. Method

Half of the subjects from each group were tested for their recognition pictures of houses first while the other half of the subjects were tested for their recognition of words first. The order in which the study and test items were presented to the subjects was randomised for each group separately.

5.2.1.1. Picture Memory Task

Stimuli and Apparatus

The stimuli consisted of forty photographs of houses that were prepared as 35 mm slides. These were the same pictures that were used by Valentine and Bruce (1986a). Twenty pictures were used as targets and the other 20 were used as distractors. A computer-controlled Kodak (Model 1010) carousel projector was used to present the slides onto a white screen.

Design and Procedure

Subjects were tested in two groups, each group consisting of 8 LSA and 8 HSA subjects. Each group was shown an initial list of 20 pictures and instructed to study each picture carefully in preparation for a subsequent recognition test.

Each picture was shown for 7 seconds. The inter-stimulus interval was 2 seconds. Approximately 2 minutes after the initial list had been shown, a test list consisting of 20 targets and 20 distractors in a random order was presented to the subjects. Each picture was shown for 5 seconds. The interval between slides was 3 seconds. Subjects were instructed to decide for each picture whether it was "old" (seen in the previous list) or "new" (*not* seen in the previous list) and to indicate their choice by ticking the appropriate box on individual response forms.

5.2.1.2. Word Memory Task

Stimuli and Apparatus

One hundred and fifty high-imagery words (e.g. apple, ticket, mountain, football, blanket) were selected from Gilhooly and Logie's (1980) list. These were randomly divided into 100 words for the study list and 50 distractors. An Apple IIe microcomputer was used to present the words to the subjects.

Design and Procedure

Subjects were tested in small groups of up to four. Subjects were shown an initial list of 100 words and instructed to try and remember each word for later recognition. Each word was shown for 1 second. The inter-stimulus interval was 1 second. Approximately 2 minutes after the initial list had been shown, a test list of 100 words (comprising 50 targets that were randomly selected from the one hundred words previously shown and 50 distractors) was presented to the subjects on the same computer screen. Each word was shown for 2 seconds. The inter-stimulus interval was 3 seconds. Subjects responded to each word by ticking on individual response forms either a "Yes" box for targets or a "No" box for distractors.

5.2.2. Results and Discussion

For each subject, hit and false positive rates on each memory task were calculated and combined in A' scores. An A' score of 0.5 is chance performance, the maximum value of A' is 1. The mean number of hits, mean false positives, and mean A' scores that were obtained by HSA and LSA subjects on each memory task are shown in table 5.2. Separate one-way ANOVAs were carried out on hits, false positives and A' scores for each task. (F ratios from each analysis are referred to as F_{hits}, $F_{f.p.}$, and $F_{A'}$ respectively)

Table 5.2. *Mean number of hits, mean false positives and mean A' scores obtained in experiment 1·*

	SPATIAL ABILITY GROUP			
	HSA Subjects		LSA Subjects	
	Mean	*Std Deviation*	*Mean*	*Std Deviation*
WORD MEMORY TASK				
Hits	32.47	6.20	36.73	6.30
False Positives	10.13	5.66	10.40	4.48
A' scores	.82	.07	.81	.08
PICTURE MEMORY TASK				
Hits	13.93	1.62	12.73	1.94
False Positives	5.20	1.82	6.73	2.12
A' Scores	.80	.07	.72	.09

The results of this analysis showed that while HSA subjects were significantly more accurate in their recognition of pictures than were LSA subjects[F_{hits}(1,30)=10.65, p=.0002; $F_{f.p.}$ (1,30) = 8.80, p=.0005; $F_{A'}$ (1,30) = 16.72, p=.0003], individual differences in spatial ability did not significantly affect recognition of words [All F ratios < 1.33] (see Appendices B1 through to B6).

These results are consistent with the dual coding theory which suggests that visual memory is functionally independent of verbal memory (Paivio, 1971; 1986; 1990). Individual differences in spatial ability have been shown to affect performance in a visual memory task but to have no effect on verbal memory. Also, the significant difference between HSA and LSA subjects on recognition of pictures could be evidence that the mental skills that enable some subjects to score more highly than others in spatial ability tests also mediate visual memory. In the next two experiments, the effect of individual differences in spatial ability on recognition of 'transformed' and 'untransformed' photographs of faces is examined.

5.3. EXPERIMENT 2

In the previous experiment, HSA subjects were significantly more accurate in their recognition of pictures of houses than were LSA subjects. The present experiment examined whether individual differences in spatial ability significantly affect subjects' recognition of faces that are shown either (i) in the *same facial expression* during presentation and at test, or (ii) in *different facial expressions* between study and test. Three predictions were tested in this experiment. First, it was hypothesised that if recognition of pictures and faces involve similar encoding and memory processes, the main effect of spatial ability that was found on recognition of pictures in experiment 1 should be replicated in this experiment.

However, if recognition of faces involves *face-specific* processes that are independent of spatial and general visual memory abilities, individual differences in spatial ability should not significantly affect recognition of faces. Secondly, a significant main effect of condition was predicted. Subjects were expected to make a significantly greater number of false positives and fewer hits on recognition of faces in the 'different-expression' test condition than on recognition of faces in the 'same expression' test condition (Bruce, 1982). Thirdly, it was hypothesised that if HSA subjects are better than LSA subjects in their recognition of transformed pictures (Lohman, 1979; Lohman & Kyllonen, 1983; Mumaw & Pelligrino, 1984), and faces are processed in the same way as other complex visual stimuli, recognition accuracy by LSA subjects should be more impaired by a change in the stimulus between study and test than recognition accuracy by HSA subjects.

5.3.1. Method

5.3.1.1. Subjects

Fifteen of the sixteen high spatial ability subjects and fifteen of the sixteen low spatial ability subjects who participated in experiment 1 acted as subjects in this experiment. Subjects were kept unaware of the group to which they belonged.

5.3.1.2. Stimuli and Apparatus

Two sets of monochrome photographs of faces were used. For the 'same-expression' test condition, 32 Caucasian faces that had been photographed in full-front view were prepared as 35mm slides. Sixteen of these faces were used as targets and the other 16 faces were used as distractors. For the 'different-expression' test condition, a different set of photographs was used.

This set consisted of two views of 32 Caucasian faces displaying a smiling and an unsmiling expression that were also prepared as 35mm slides. Sixteen faces were used as targets (8 smiling and 8 unsmiling) and the other sixteen faces were used as distractors (8 smiling and 8 unsmiling). Slides were presented to the subjects using a computer-controlled Kodak (1010) carousel projector. The microcomputer controlled the exposure duration for each slide and at test, also logged subjects' responses and reaction time to each test face.

5.3.1.3. Design

A 2 X 2 split-plot factorial design was used in this experiment. Spatial ability was a *between-subjects* factor and type of task (i.e. test condition) was a *within-subjects* factor. The dependent variables were: recognition accuracy and response latencies of hits and of correct rejections.

5.3.1.4. Procedure

Subjects were tested individually in a dimly-lit room. For half of the subjects in each group, the 'same-expression' test condition preceded the 'different-expression' test condition while for the rest of the subjects in each group, the 'different-expression' test condition preceded the 'same-expression' test condition. In each test condition, subjects were initially presented with a list of 16 faces and instructed to study each face carefully in preparation for a subsequent recognition test. Each face was shown for 5 seconds with 2 seconds interval between slides.

The recognition test followed immediately after each study list. Each test list consisted of 32 faces, 16 of which were targets and 16 were distractors. In the 'same-expression' test condition, the same photographs of target faces were presented during study and at test. In the 'different-expression' test condition, faces that were shown in a smiling pose during study were presented in an unsmiling pose at test while faces that were shown in an unsmiling pose during study were shown in a smiling pose at test. In each test condition, two random orders were used at test such that half of the subjects in each group saw each test list in one random order and the rest of the subjects in each group saw each test list in a different random order. Subjects responded to each face by pressing either a 'Yes' button for target faces or a 'No' button for distractors. Subjects were instructed to respond to all the faces as quickly but as accurately as possible and to guess if unsure.

5.3.2. Results

For each subject, hit and false positive rates in each condition were calculated and combined in A' scores (Rae, 1976). The maximum number of hits or false positives in each condition is 16. Mean A' scores, mean number of hits and false positives obtained by HSA and LSA subjects on each memory task are shown in table 5.3.

Table 5.3. *Mean number of hits, mean false positives and mean A' scores obtained in experiment 2.*

	SPATIAL ABILITY GROUP			
	HSA Subjects		LSA subjects	
	Mean	*Std Deviation*	*Mean*	*Std Deviation*
IDENTICAL TARGET FACES				
Hits	13.27	1.75	10.20	2.68
False Positives	.53	.74	1.80	1.08
A' Scores	.94	.04	.86	.06
DIFF. EXPRESSION FACES				
Hits	10.47	2.42	10.13	2.00
False Positives	3.33	1.68	3.33	1.84
A' Scores	.80	.11	.79	.10

5.3.2.1. Recognition Accuracy

Separate 2 X 2 split-plot ANOVAs were carried out on hits, false positives and A' scores. In each analysis, spatial ability was a between-subjects factor and condition was a within-subjects factor. The full results of these analyses are given in Appendices B7 through to B9.

Hits

The main effect of spatial ability was significant (F(1,28)=9.26, p=.005). HSA subjects made a significantly greater number of hits than LSA subjects. Also, a significantly greater number of hits were made in the 'same-expression' test condition than were made in the 'different expression' test condition (F(1,28)=5.77, p=.023). The interaction between spatial ability and test condition was also significant (F(1,28)=5.24, p=.030) [see Figure 5.1].

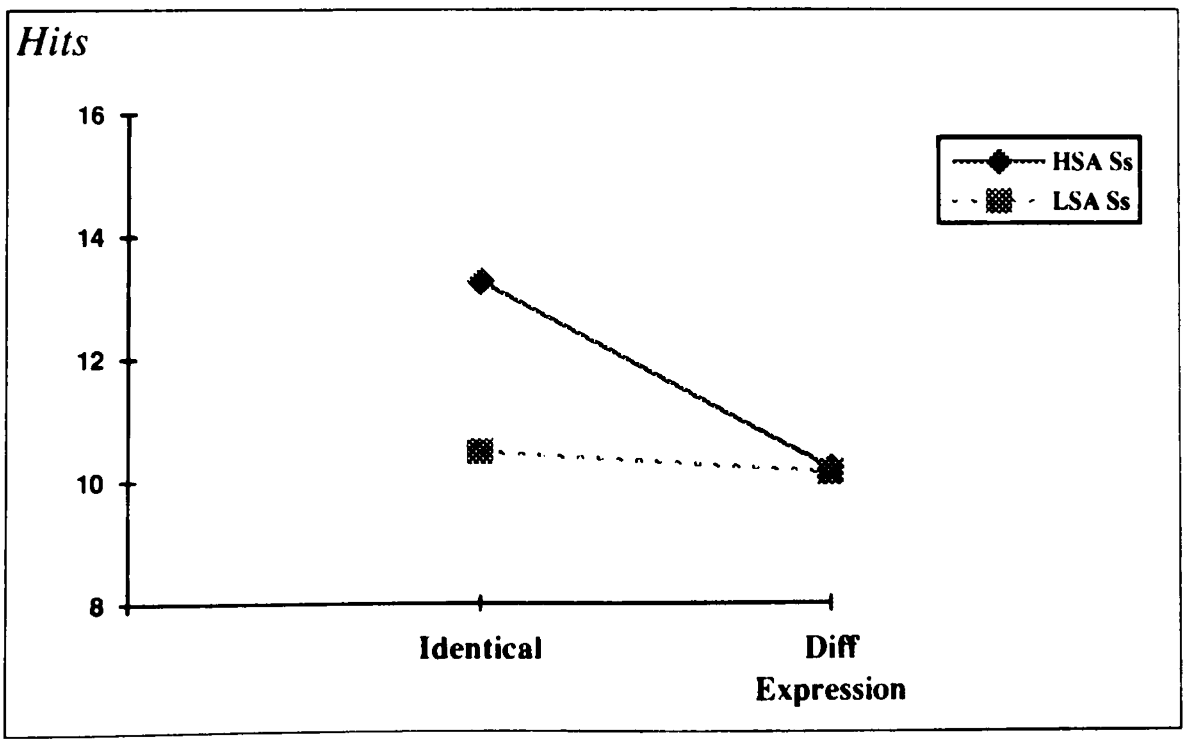

Figure 5.1. *A graph showing a significant interaction between spatial ability and test condition obtained from an analysis of hits in experiment 2.*

Tests of simple main effects showed that HSA subjects made a significantly greater number of hits than LSA subjects in the 'same-expression' test condition (F(1,28)=24.75, p=.05) but not in the 'different-expression' test condition (F(1,28)=0.30, p>.05).

False Positives

Because many of the data points were (or were close to) zero, the false positives data were first transformed before an ANOVA was carried out. The results of the analysis revealed a significant main effect of spatial ability (F(1,28)=7.97, p=.009). LSA subjects made a significantly greater number of false positives than HSA subjects. The main effect of test condition was highly significant (F(1,28)=37.70, p=.0001). More false positives were made to recognition of faces in the 'different-expression' test condition than were made on recognition of faces in the 'same-expression' test condition. The interaction between spatial ability and test condition was also significant (F(1,28)=6.72, p=.015) [see Figure 5.2].

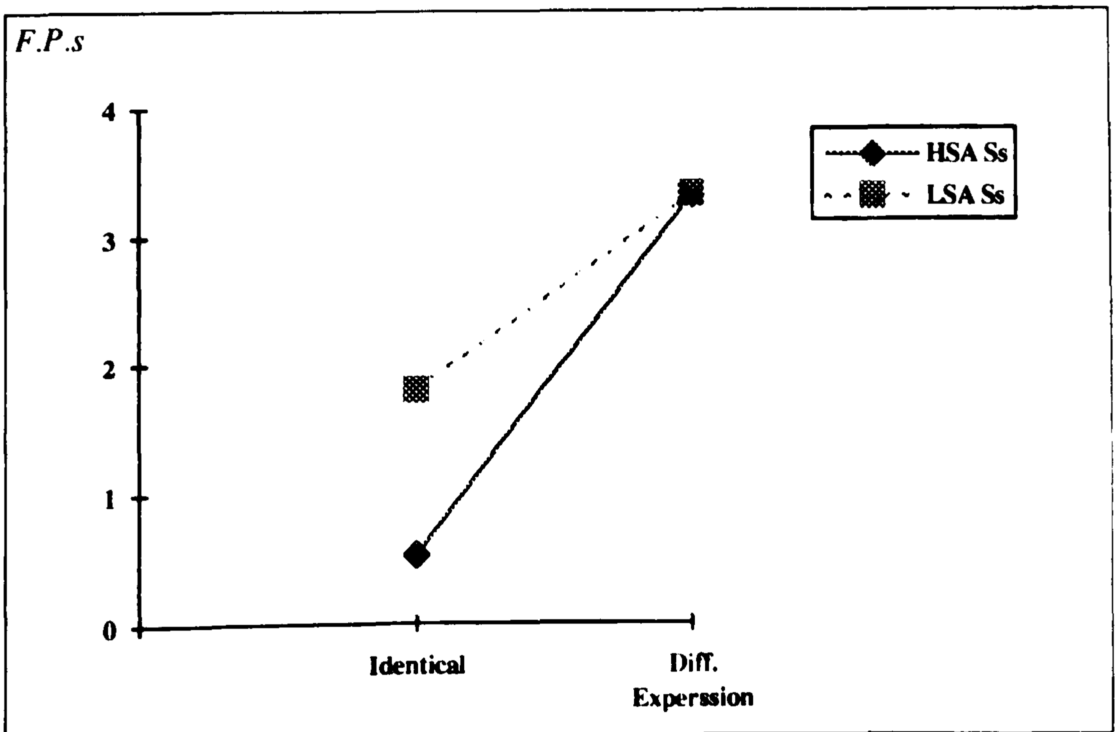

Figure 5.2. *A graph showing a significant interaction between spatial ability and test condition obtained from an analysis of false positives in experiment 2.*

Tests of simple main effects showed that in the 'same-expression' test condition, LSA subjects made a significantly greater number of false positives than were made by HSA subjects (F(1,28)=11.74, p=.05) but, in the 'different-expression' test condition, the difference in the number of false positives between HSA and LSA subjects was not significant (F(1,28)=0.006, p>.05).

A' Scores

On the whole, HSA subjects recognised faces more accurately than LSA subjects (F(1,28)=10.33, p=.003). The main effect of test condition was highly significant (F(1,28)=23.00, p=.0001). Recognition memory for faces in the 'same-expression' test condition was significantly more accurate than recognition of faces in the 'different-expression' test condition. The interaction between spatial ability and type of task was also significant (F(1,28)=5.54, p=.06) [see Figure 5.3].

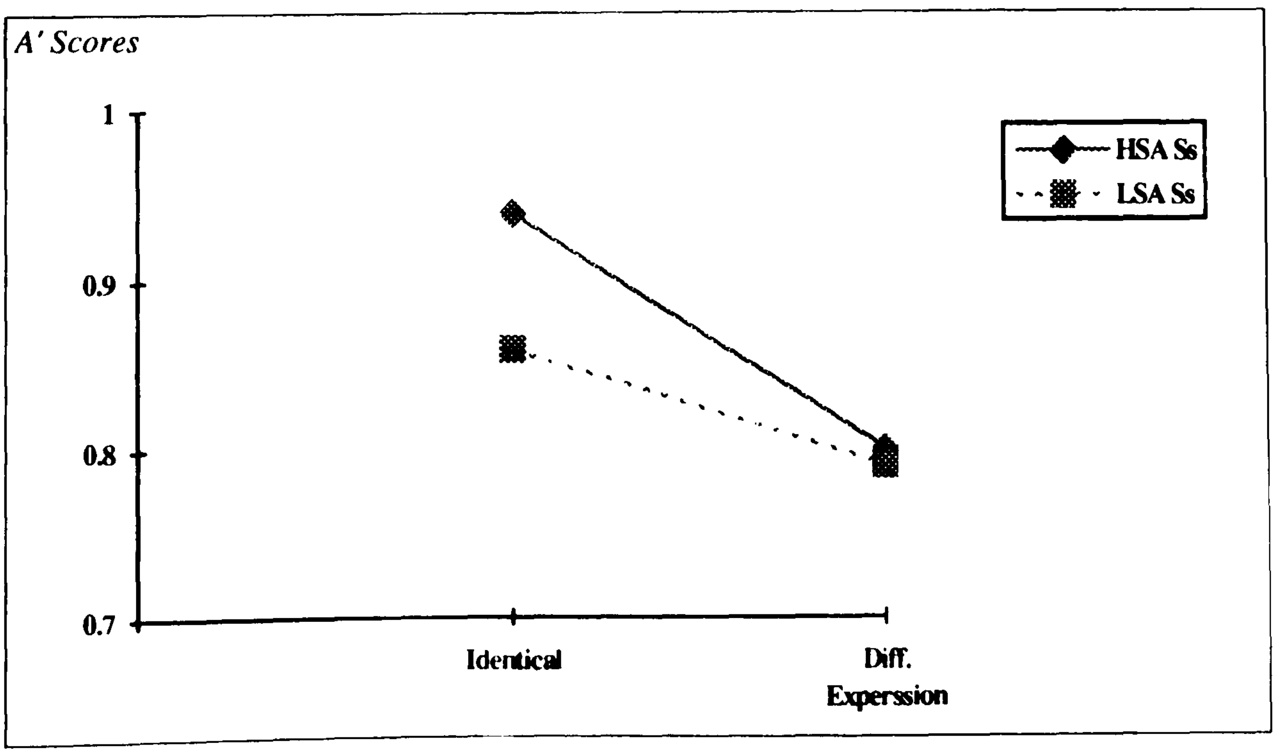

Figure 5.3. *A graph showing a significant interaction between spatial ability and test condition obtained from an analysis of A' scores in experiment 2.*

Tests of simple main effects showed that HSA subjects were significantly more accurate than LSA subjects in their recognition of faces in the 'same-expression' test condition ($F(1,28)=17.50$, $p=.05$) but not in their recognition of faces in the 'different-expression' test condition ($F(1,28)= 2.50$, $p>.05$).

5.3.2.2. Response Latencies

Separate 2 X 2 split-plot ANOVAs were carried out on response latencies of hits and of correct rejections. In each analysis, spatial ability was a between-subjects factor and type of task was a within-subjects factor. The full results obtained from this analysis are shown in Appendices B10 and B11. The mean RT data obtained from this analysis are shown in table 5.4.

Table 5.4. *Mean response latencies (in milliseconds) of hits and of correct rejections obtained in experiment 2.*

	SPATIAL ABILITY GROUP			
	HSA Subjects		LSA Subjects	
	Mean	*Std Deviation*	*Mean*	*Std Deviation*
IDENTICAL TARGET FACES				
RT to Hits	1194.27	434.94	1707.53	394.25
RT to Correct rejections	1600.60	568.17	1989.40	552.75
DIFF. EXPRESSION FACES				
RT to Hits	1258.53	436.54	1806.27	451.79
RT to Correct Rejections	1550.73	629.49	2035.07	646.63

Response latencies of hits

A significant main effect of spatial ability was found (F(1,28)=11.70, p=.002). HSA subjects responded more quickly than LSA subjects. Also, the main effect of test condition was significant (F(1,28)=11.18,p=.002). Subjects responded more quickly to target faces in the 'same-expression' test condition than they responded to target faces in the 'different-expression' test condition. The interaction between spatial ability and test condition was not significant (F(1,28)=0.50, p=.485).

Response latencies of correct rejections

The main effect of spatial ability was significant (F(1,28)=4.11, p=.05). LSA subjects were significantly slower to reject Distractor faces than were HSA subjects. The main effect of test condition was not significant (F(1,28)=0.001, p=.960). Spatial ability did not interact significantly with type of task (F(1,28)=1.30, p=.265).

5.3.3. Discussion

The predicted main effect of spatial ability was significant on hits, false positives, A' scores and on both measures of response latencies. On the whole, HSA subjects recognised faces more accurately and more quickly than did LSA subjects. Also, the predicted main effect of type of task was significant on hits, false positives, A' scores and on response latencies of hits. Recognition of faces in the 'different-expression' test condition was significantly slower and less accurate than recognition of faces in the 'same-expression' test condition.

It will be recalled that in the previous experiment where the same target pictures of houses were shown during presentation and at test, HSA subjects recognised pictures more accurately than did LSA subjects. In the present experiment, HSA subjects also recognised faces that were untransformed at test more accurately than did LSA subjects. This consistency suggests that when the task involves recognition of the *same* pictures of target items, similar encoding and memory processes may be involved regardless of whether the stimuli are faces or pictures of houses.

However, the predicted interaction between spatial ability and type of task, although significant, revealed an opposite effect to the one we predicted. Individual differences in spatial ability had a significant effect on recognition of faces in the 'same-expression' test condition but did not significantly affect recognition of faces in the 'different-expression' test condition. These results suggest that the correlation between general visual memory and face recognition reported by Church and Winograd (1985) may have been inflated by the use of identical target stimuli to test face recognition performance. This result was rather surprising since previous studies have shown that high spatial ability subjects recognise transformed visual stimuli more accurately than low spatial ability subjects (see Salthouse *et al*, 1990 for a review). Perhaps, since changes in expression can only be attributed to faces, the analysis of facial expression may be a specialised mental function that is unrelated to individual differences in spatial ability and general visual analytical skills. Other transformations of the face may not be so specialised.

5.4. EXPERIMENT 3

In the previous experiment, individual differences in spatial ability did not significantly affect recognition of faces that were transformed in *facial expression* at test. In the present experiment, the same 'high' and 'low' spatial ability subjects who participated in experiment 2 were tested for their recognition of upright and upside down faces. It has been shown that turning a face upside down makes it considerably more difficult to recognise than showing it in its upright orientation (see Valentine, 1988 for a detailed review). This is also true for other visual stimuli that are often seen upright. However, several studies have shown that recognition of faces is disproportionately affected by inversion. Yin (1969; 1970) claimed that the disproportionate effect of inversion on recognition of faces is evidence that face recognition is a *specialised process*. Although much attention has been paid to this hypothesis over the past 20 or so years, the source of this effect is still unclear. One hypothesis is that inversion disrupts the encoding of spatial information from a face, making it considerably harder to recognise an upside down face (Diamond & Carey, 1986; Ellis, 1986).

Previous studies (e.g. Poltrock & Brown, 1984; Just & Carpenter, 1985; Lansman, 1981; Lansman, Donaldson, Hunt & Yanis, 1982) have shown that HSA subjects recognise rotated visual stimuli more accurately than LSA subjects (see Salthouse, *et al*, 1990 for a detailed review). The question that is investigated in the present experiment is whether a similar result can be obtained on recognition of rotated pictures of faces. If faces are not 'special' in that they are processed in the same way as other complex visual stimuli, HSA subjects should show a smaller effect of inversion in face recognition than LSA subjects. Three hypotheses were tested in this experiment.

First, it was predicted that the main effect of spatial ability would be significant. High spatial ability subjects were expected to be more accurate and faster in their recognition of faces than low spatial ability subjects. Secondly, recognition of upside down faces was expected to be significantly less accurate and slower than recognition of upright faces. Third and most importantly, it was predicted that the interaction between spatial ability and face orientation would be significant. The effect of inversion on recognition of faces was expected to be significantly smaller for HSA subjects than for LSA subjects.

5.4.1. Method

5.4.1.1. Subjects

The same subjects who took part in experiment 2 acted as subjects in this experiment.

5.4.1.2. Stimuli and Apparatus

The stimulus set consisted of 40 photographs of Caucasian faces that were prepared as 35mm slides. These were different photographs from the ones that were used in experiment 2. Twenty faces were used as targets and the other 20 were distractors. Stimuli were presented using the same apparatus that was used in experiment 2.

5.4.1.3. Design

A split-plot factorial design was used in this experiment. Spatial ability was a between-subjects factor and face orientation was a within-subjects factor. The dependent measures were recognition accuracy and reaction time.

5.4.1.4. Procedure

Subjects were tested individually in a dimly-lit room. The slides were projected onto a white screen that was placed 1.5 metres in front of the subject. During initial presentation, subjects were shown a list of 20 photographs of faces in an upright orientation. Each face was shown for 5 seconds. The inter-stimulus interval was 2 seconds. Subjects were told to study each face carefully in preparation for a subsequent recognition test. Half of the subjects in each group were shown the study faces in one random order while the rest of the subjects in each group were shown the same faces in a different random order.

At test, subjects were presented with a random list of 40 faces of which 20 were targets and 20 were distractors. Half of the targets and half of the distractors were presented upright while the other 10 targets and 10 distractors were presented upside down. Half of the subjects in each group saw the test list in one random order while the rest of the subjects in each group were shown the same test list in a different random order. The same exposure and interval times as those used during study were used at test. Subjects responded by pressing either a 'Yes' button for targets or a 'No' button for distractors, regardless of whether the face was upright or upside-down. Subjects were instructed to respond as quickly but as accurately as possible to each slide and were encouraged to guess if unsure. Accuracy and reaction time scores were logged for each subject by the microcomputer.

5.4.2. Results

For each subject, hit and false positive rates in each condition were calculated and combined in A' scores. The mean number of hits and false positives, mean A' scores and mean latencies of hits and of correct rejections that were obtained by HSA and LSA subjects on recognition of upright and upside down faces are shown in table 5.5.

5.4.2.1. Recognition Accuracy

Separate split-plot ANOVAs were performed on hits, false positives and A' scores with spatial ability as a between-subjects factor and face orientation as a within-subjects factor. The full results of these analyses are shown in Appendices B12 through to B14.

Hits

The main effect of spatial ability was not significant ($F(1,28)=0.15$, $p=.69$). However, the main effect of face orientation was highly significant ($F(1,28)=61.25$, $p=.0001$). Subjects made a significantly greater number of hits to upright faces than they made to inverted faces. The interaction between spatial ability and face orientation was not significant ($F(1,28)=0.00$, $p=1.00$).

Table 5.5. *Mean number of hits, mean false positives, mean A' scores and mean latencies of hits and of correct rejections obtained in experiment 3.*

	SPATIAL ABILITY GROUP			
	HSA Subjects		LSA Subjects	
	Mean	*Std Deviation*	*Mean*	*Std Deviation*
UPRIGHT FACES				
Hits	8.47	.74	8.67	1.76
False Positives	.80	.77	1.27	1.79
A' Scores	.93	.04	.91	.11
RT to Hits	1397.87	462.62	1519.13	384.96
RT to Correct Rejections	1384.87	390.91	1737.87	462.69
UPSIDE DOWN FACES				
Hits	6.13	1.73	6.33	1.95
False Positives	2.27	1.71	4.20	2.34
A' Scores	.79	.07	.65	.14
RT to Hits	1898.60	627.93	2315.33	713.41
RT to Correct Rejections	1861.47	562.68	2771.80	723.35

False Positives

A significant main effect of spatial ability was found (F(1,28)=5.07, p=.03). LSA subjects made a significantly greater number of false positives than HSA subjects. The main effect of face orientation was highly significant (F(1,28)=39.60, p=.0001). A significantly greater number of false positives were made to inverted faces than were made to upright faces. The interaction between spatial ability and face orientation was also significant (F(1,28)=4.40, p=.04) [see Figure 5.4].

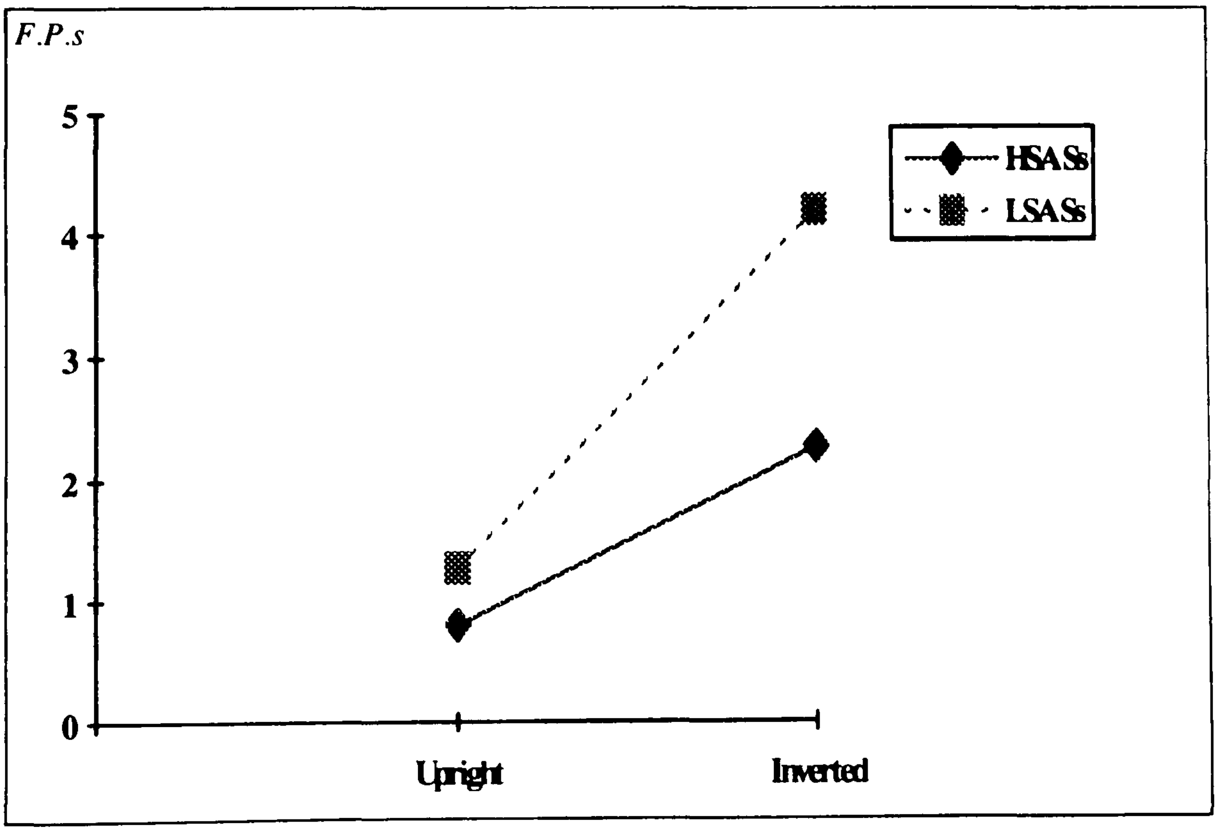

Figure 5.4. *A graph showing a significant interaction between spatial ability and face orientation obtained from an analysis of false positives in experiment 3.*

Tests of simple main effects showed that LSA subjects made a significantly greater number of false positives than HSA subjects on recognition of upside down faces (F(1,28)=12.25, p=.05) but, differences in spatial ability did not significantly affect recognition of upright faces (F(1,28)=1.43, p>.05).

A' Scores

An analysis of the transformed A' scores showed a significant main effect of spatial ability (F(1,28)=6.72, p=.015). HSA subjects recognised faces more accurately than LSA subjects. The main effect of face orientation was highly significant (F(1,28)=148.99, p=.0001). Subjects were significantly less accurate in their recognition of upside down faces than they were in their recognition of upright faces. The interaction between spatial ability and face orientation was also significant (F(1,28)=9.31, p=.005) [see Figure 5.5].

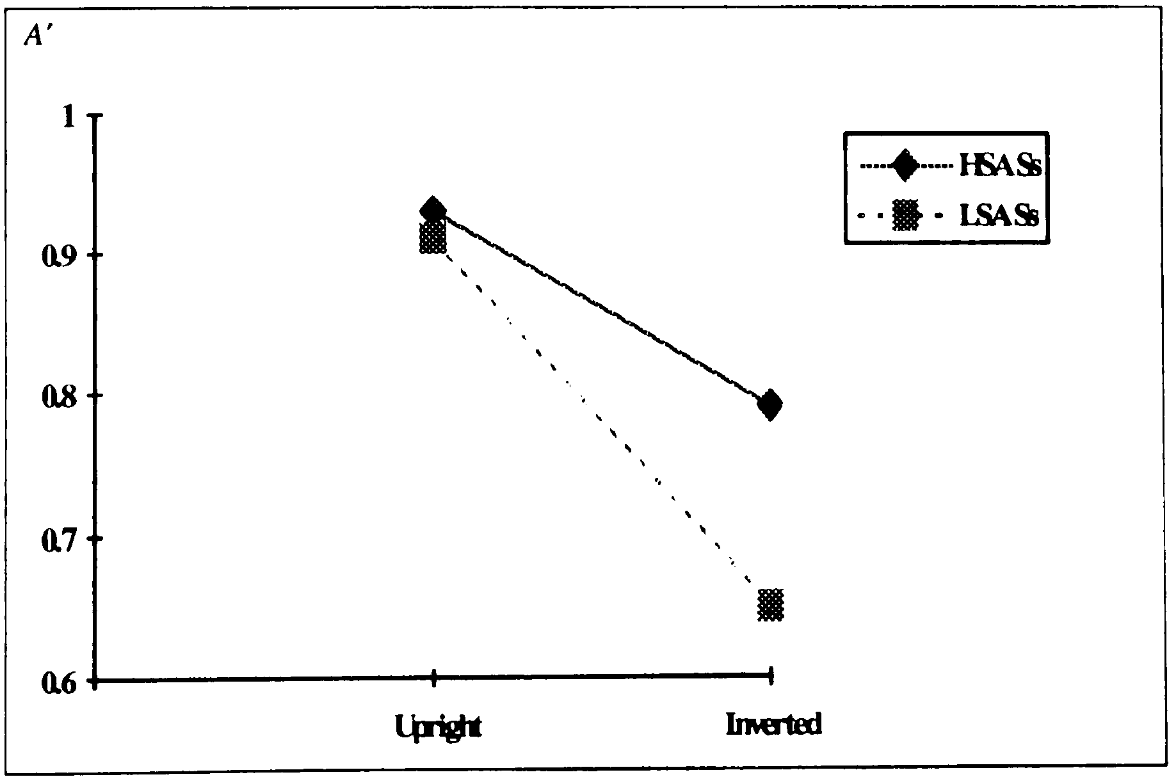

Figure 5.5. *A graph showing a significant interaction between spatial ability and face orientation obtained from an analysis of A' scores in experiment 3.*

Tests of simple main effects showed that HSA subjects were significantly more accurate than LSA subjects in their recognition of upside down faces

(F(1,28)=18.75, p=.05). Differences in spatial ability did not significantly affect recognition of upright faces (F>l).

5.4.2.2. Response Latencies

Separate split-plot ANOVAs were performed on the response latencies of hits and of correct rejections. In each analysis, spatial ability was a between-subjects factor and face orientation was a within-subjects factor. The full results of these analyses are shown in Appendices B15 and B16.

Response latencies of hits

HSA subjects recognised target faces more quickly than did LSA subjects (F(1,28)=5.46, p=.02). The main effect of orientation was highly significant (F(1,28)=33.13, p=.001). Subjects were significantly faster to recognise upright target faces than they were to recognise upside down target faces. Spatial ability did not interact significantly with face orientation (F(1,28)=1.72, p=.20).

Response latencies of correct rejections

LSA subjects were significantly slower to reject Distractor faces than were HSA subjects (F(1,28)=12.93, p=.001). The main effect of face orientation was highly significant (F(1,28)=60.91, p=.0001) in the predicted direction. The interaction between spatial ability and face orientation was also significant (F(1,28)=8.29, p=.008) [see Figure 5.6].

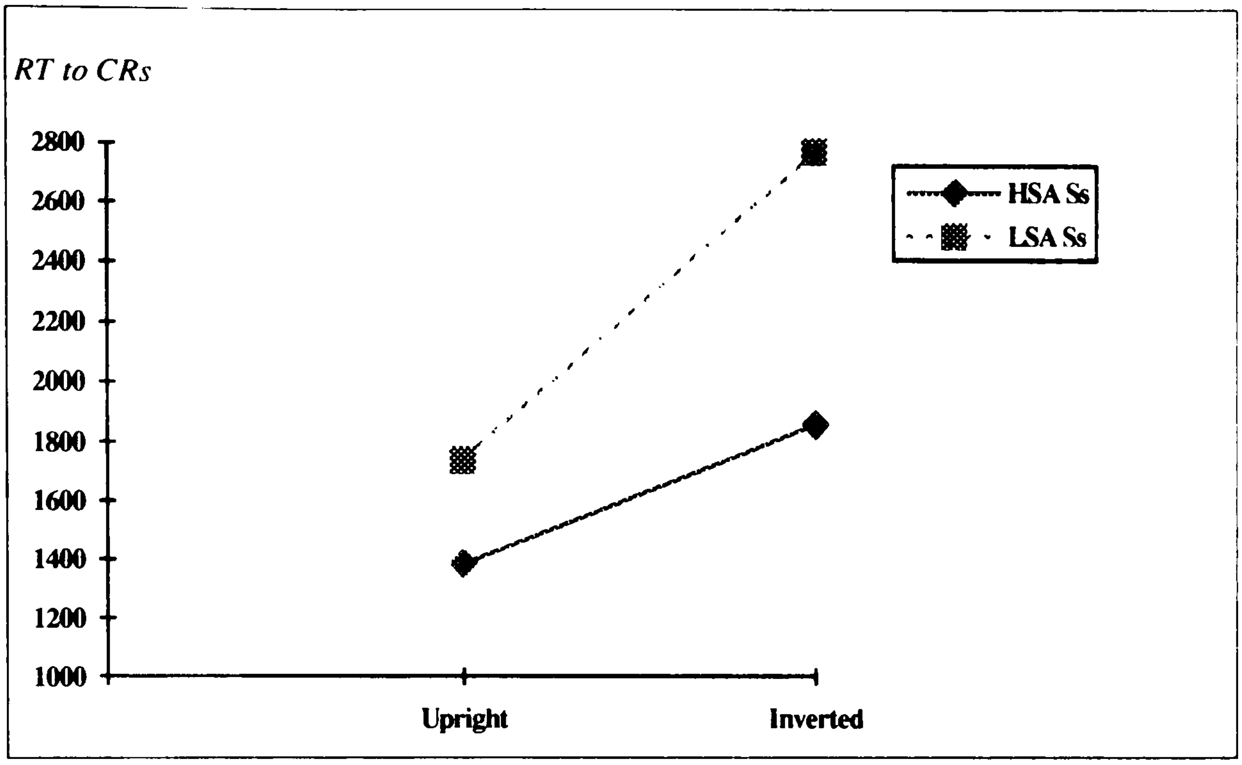

Figure 5.6. *A graph showing a significant interaction between spatial ability and face orientation obtained from an analysis of response latencies of correct rejections (CRs) in experiment 3.*

An analysis of simple main effects showed that HSA subjects were significantly faster to reject inverted Distractor faces than were LSA subjects (F(1,28)=27.36, p=.05). Differences in spatial ability did not significantly affect subjects' response latencies of correct rejections to upright faces (F(1,28)=3.12, p=.10).

5.4.3. Discussion

First, it should be noted that unlike in the previous experiment where individual differences in spatial ability significantly affected recognition accuracy and response latencies of hits and correct rejections in the 'identical' test condition, in the present experiment, the effect of spatial ability on recognition of identical upright target faces was not significant. However, in the present experiment, the 10 upright target faces were presented in *three-quarter view* during study and at test while in experiment 2, the 16 identical target faces were presented in *full-face view* during study and at test. Previous studies have reported a three-quarter view advantage in face recognition (see Bruce, Valentine & Baddeley, 1987). Thus, differences in *task difficulty* might account for the failure to find a significant difference between high and low spatial ability subjects in their recognition of identical upright faces. This interpretation is supported by the fact that while both high and low spatial ability subjects were close to ceiling in their recognition accuracy for upright faces in experiment 3, performance on recognition of faces in the 'same-expression' test condition of experiment 2 was not at ceiling.

The main predictions in this experiment were: (1) that recognition of upside down faces would be significantly less accurate and slower than recognition of upright faces, and (2) that LSA subjects would show a significantly greater effect of inversion in face recognition than HSA subjects. The results supported these predictions. Significant main effects of inversion in face recognition were found on hits and false positives, on A' scores and on both measures of response latencies. The interaction between spatial ability and face orientation was significant on false positives, A' scores and on response latencies of correct rejections. LSA subjects were significantly less accurate and slower in their recognition of upside down faces than were HSA subjects. This is consistent with the literature on the effect of spatial ability on recognition of rotated visual stimuli (Poltrock & Brown, 1984; Just & Carpenter, 1985; Lansman, Donaldson, Hunt & Yanis, 1982) and suggests that upside down faces are processed in the same way as other rotated visual stimuli.

5.5. GENERAL DISCUSSION

The experiments that are reported in this chapter examined two main hypotheses: (1) that individual differences in spatial ability would significantly affect recognition of pictures and faces but not recognition of words, and (2) that individual differences in spatial ability would interact significantly with recognition of faces following a change in facial expression and a change in orientation. The results of the first experiment supported hypothesis 1 in that while HSA subjects were significantly more accurate than LSA subjects in their recognition of pictures of houses, recognition memory for words was not significantly affected by individual differences in spatial ability. It has been argued that these results are consistent with the *dual coding theory* of mental processes (Paivio, 1971; 1986; 1990) and with Lohman's (1988) *representational quality hypothesis* of individual differences in spatial ability.

In experiments 2, HSA subjects were significantly more accurate and faster than LSA subjects in their recognition of *identical* photographs of target faces. This finding replicates the significant main effect of spatial ability that was found on recognition of *identical* pictures of houses in experiment 1. Also, the results of this experiment suggest that when the *same* target items are used during study and at test, similar encoding and memory processes may be used regardless of whether the stimuli are faces or pictures of other objects. However, when recognition of faces was tested using faces that were changed in facial expression at test, individual differences in spatial ability did not affect subjects' recognition accuracy and response latencies.

Thus, the significant correlation that has been reported in previous studies between face recognition and general visual memory performance (Woodhead

& Baddeley, 1981; Baddeley & Woodhead, 1983; Church & Winograd, 1985) is most likely to have been inflated by the use of identical targets pictures and faces during presentation and at test. The results of the third experiment showed that LSA subjects are significantly less accurate and slower in their recognition of upside down faces than are HSA subjects. This finding is consistent with results from previous studies that have examined the effect of spatial ability on recognition of rotated pictures of objects (Poltrock & Brown, 1984; Just & Carpenter, 1985; Lansman, Donaldson, Hunt & Yanis, 1982). This suggests that recognition of upside down faces involves similar encoding and memory processes to recognition of other rotated complex visual stimuli.

In conclusion, the results of the present study show that individual differences in spatial ability affect recognition of *untransformed* pictures of houses and faces as well as recognition of faces that are changed in *orientation* but do not affect recognition of faces that are changed in *facial expression* at test. Of the two stimulus changes that are used in the present study, a change in facial expression is a more naturally occurring transformation of the face. The results of the present study suggest that while individual differences in spatial ability may be important in recognition of rotated pictures of faces, recognition of faces that are transformed in facial expression is not significantly affected by individual differences in spatial or general visual memory abilities. Perhaps, spatial ability measures the ability to perform rigid transformations (e.g. rotation and change of pose) but non-rigid transformations (e.g. expression and ageing require different skills.

It would be of interest to know whether individual differences in spatial ability affect recognition of faces that are shown in different *views* between study and test. Also, an individual differences approach might shed more light on the perceptual and cognitive processes that differentiate recognition of identical faces and faces that are changed in view, facial expression and orientation. For example, instead of selecting subjects on spatial ability, subjects may be selected on their ability to recognise faces that are presented in different views between study and test. Good and poor face recognisers selected in this way can then be tested for their recognition of faces following various kinds of stimulus transformations.

Part III

EXPERIMENTAL WORK 2

CHAPTER SIX

Differences in Recognition of Male and Female Faces by 11-year old, 12-year old, and 13-year old Male and Female Subjects Across Two Delay Conditions

6.1. INTRODUCTION

The experiments described in the previous chapter examined the effect of individual differences in spatial ability on recognition of pictures, faces and words. In the present chapter, an experiment which investigated sex differences and age differences in recognition of male and female faces across two delay conditions using adolescent subjects aged 11, 12 and 13 years is reported. There is some evidence which suggests that for adult subjects, a delay of one week between initial presentation and test does not significantly affect recognition accuracy of the same pictures of target faces (e.g. Laughery, Fessler, Lenorovitz & Yoblick, 1974; Deffenbacher, Carr & Leu, 1981; Shepherd, Ellis & Davies, 1982; Podd, 1990; Shepherd, Gibling & Ellis, 1991). However, recent experimental work has shown that children in their early adolescent years show a significant fall in recognition of identical photographs of target faces following a delay of one week. For example, Flin (1983), Ellis (1990), Ellis and Flin (1990) found that ten-year-olds were significantly less accurate in their recognition of identical pictures of target faces following a delay of one week compared to their recognition of a comparable set of faces in an immediate-test condition. This finding supports the generally held view that children forget strangers' faces more quickly than adults. Perhaps, it is for this reason that in most western societies, judges and juries are often advised not to base convictions on uncorroborated face identification evidence supplied by children under the age of 14 years (Wilson, 1980).

However, while the results obtained by Flin (1983), Ellis (1990) and Ellis and Flin (1990) offer some support for this precautionary practice[13], little is known about whether 11-year olds, 12-year olds and 13-year olds also show a significant fall in their recognition of previously unfamiliar faces when a delay of one week is introduced between initial presentation of target faces and test. Also, it is at present unclear whether male and female adolescents of this age show similar effects of delay in their recognition of both male and female faces.

A review of the literature on sex differences in face recognition presented in chapter two of this thesis (section 2.2.1.) showed that there is no clear evidence to suggest that male subjects differ significantly from female subjects in their recognition of previously unfamiliar faces. However, most of the studies that have examined sex differences in face recognition have tended to use adults as subjects. As such, little is known about whether male and female subjects aged between 10 and 14 years differ significantly in their recognition of male and female faces. It is also unclear whether such differences (if any) interact significantly with the effect of delay discussed in the preceding paragraph.

The experiment to be described in this chapter investigated sex differences in recognition of male and female faces across two delay conditions using male and female subjects aged 11, 12 and 13 years. All the subjects were tested for their recognition of both male and female faces in each of the following delay conditions: (i) immediately after initial presentation of target faces and (ii) one

[13] Ellis and Flin did not draw this conclusion from their results.

week later. The experiment was designed to test a number of predictions. First, a significant main effect of delay was predicted: subjects were expected to show poorer face recognition accuracy scores in the one-week delay condition compared to their face recognition accuracy in the immediate-test condition. This prediction was expected to be significant for both male and female subjects on recognition of both male and female faces. Secondly, it was predicted that the main effect of age of subject would be significant: 12-year olds were expected to be significantly less accurate in their recognition of faces compared to 11 and 13-year olds. The latter prediction was based on results reported in previous studies that have explored the developmental trend in face recognition. These studies have shown that 12-year olds are often less accurate in their recognition of faces compared to 11-year olds and 13-14 year olds (see section 2.2.2. of Chapter Two of this thesis). However, it is unclear from this research whether both male and female adolescents aged 12 years show a developmental dip in their recognition of both male and female faces.

It is also not clear at present whether the developmental dip in face recognition that has been reported among 12-year olds is consistent across different delay intervals. To the extent that the developmental dip in face recognition among 12-year olds is robust, this effect should be found not only when subjects are tested immediately after studying a set of target faces (as is often the case) but also after a relatively long delay interval between study and test. Therefore, it was predicted that 12-year olds would be significantly less accurate than 11 and 13-year olds in their recognition of faces in both delay conditions. However, it was not possible to make any precise predictions regarding the extent to which sex of subject, age and delay might (or might not) interact with one another. In spite of this, it was considered an important goal in designing the present study to ensure that such interactions (if present) could be explored from the resulting data.

EXPERIMENT 4

6.2. METHOD

6.2.1. Subjects

Ninety adolescents who attended a local school in Central Manchester acted as subjects in this experiment. Thirty of these subjects were eleven-year-olds (15 males, 15 females), thirty were twelve-year-olds (15 males, 15 females) and thirty were thirteen-year-olds (15 males, 15 females).

6.2.2. Design

A split-plot factorial design in which age and sex of subject were between-subjects factors and delay and sex of face were within-subjects factors was used in the present study. The dependent variable was recognition accuracy.

6.2.3. Stimuli

Seventy-two photographs of adult Caucasian faces were selected from a pool of 216 faces and prepared as 35mm slides. Thirty-six faces (18 male and 18 female) were used as targets and the other 36 faces (18 male and 18 female) were used as distractors. The target faces were randomly divided into two sets: **Set A** faces (n=18, 9 male and 9 female) and **Set B** faces (n=18, 9 male and 9 female). An equal number of Distractor faces were prepared for use with each set of target faces.

6.2.4. Apparatus

A computer-controlled Kodak (1010) carousel projector was used to present the slides. The microcomputer controlled the exposure duration for each slide and the inter-stimulus interval.

6.2.5. Procedure

Subjects were tested at their school in a dimly-lit room. They were tested in small groups of up to eight. During study, subjects were shown a random list of 18 male and 18 female faces and asked to try and remember each face for later recognition. Each face was shown for 5 seconds. The inter-stimulus interval was 2 seconds. The test phase of the experiment was conducted in two stages: (1) approximately five minutes after presenting the study list and (2) one week later. In each delay condition, identical pictures of target faces were used at test.

In the immediate-test condition, half of the subjects (called Group 1) were tested for their recognition of Set A target faces and the other half of the subjects (called Group 2) were tested for their recognition of Set B target faces. An equal number of Distractor faces were included in each test list. Before each test list was shown, subjects were given individual response forms and the appropriate instructions were read out. In the immediate-test condition, the following instructions were read out to the subjects:

> *I am now going to show you a list of 36 faces. Eighteen of these faces have been randomly selected from among the faces which you have just seen. The rest of the faces are 'New'. The Old and the New faces will be presented in random order. Each face will be shown for 5 seconds. The time between the faces will be 2 seconds. I want you to decide for each face, whether it is 'Old' or 'New' and to enter your answer on the answer sheets which I have just given you. If you think that the face on the screen is 'Old', tick the 'Yes' box against the correct number. If you think that the face is 'New', then tick the 'No' box. Remember to enter your responses as quickly but as accurately as possible. You will have up to 5 seconds during which to respond.*

Subjects were encouraged to guess if unsure and not to consult with one another. Before presenting the test list, subjects were given time to ask questions and the experimenter proceeded only after he was sure that the subjects had clearly understood the instructions. In the one-week delay condition, subjects were tested in the same room at the same time, one week later. Group 1 subjects were tested for their recognition of Set B target faces and Group 2 subjects were tested for their recognition of Set A faces. The following instructions were read out to the subjects:

> *You will remember that last week I showed you 36 photographs of faces. I then tested your memory for only 18 of those faces. Today, I want to see whether you can identify the other 18 faces which I did not test you on last week. (Answer sheets were distributed to the subjects at this point). I will now show you a mixed list of 36 faces comprising 18 faces which you saw last week and 18 'New' faces. I want you to tick the 'Yes" box if you think that the face shown on the screen is one of the faces which you saw last week. If you think that the face shown on the screen is 'New', then tick the 'No' box.*

The test list was then presented. Each face was shown for 5 seconds. The inter-stimulus interval was 2 seconds.

6.3. RESULTS

Hits, false positives and A' scores were calculated for each subject on recognition of male faces and female faces in each delay condition. Separate analyses were carried out on hits, false positives and A' scores. In each analysis, a split-plot factorial ANOVA in which age and sex of subject were between-subjects factors and delay and sex of face were within-subjects factors was carried out. The full results of these analyses are shown in Appendices B17 through to B19.

6.3.1. Hits

The mean number of hits that were obtained by male and female subjects on recognition of male and female faces in each delay condition are shown in tables 6.1. and 6.2. respectively.

Table 6.1. *Mean number of hits obtained by male and female subjects aged 11, 12, and 13 years on recognition of male and female faces in the immediate-test condition of experiment 4.*

	SEX OF SUBJECT			
	Males		Females	
	Mean	*Std Deviation*	*Mean*	*Std Deviation*
AGE				
Eleven-year olds				
Male Faces	5.40	.99	5.33	.98
Female Faces	5.60	.93	6.40	1.30
Twelve-year olds				
Male Faces	5.73	1.03	5.13	1.19
Female Faces	6.13	.99	6.13	.83
Thirteen-year olds				
Male Faces	5.87	1.25	5.60	.91
Female Faces	6.53	.92	7.67	1.29

Table 6.2. *Mean number of hits obtained by male and female subjects aged 11, 12, and 13 years on recognition of male and female faces in the one week delay condition of experiment 4.*

	SEX OF SUBJECT			
	Males		Females	
	Mean	*Std Deviation*	*Mean*	*Std Deviation*
AGE				
Eleven-year olds				
Male Faces	5.07	1.44	5.07	1.16
Female Faces	4.53	1.41	5.33	1.18
Twelve-year olds				
Male Faces	4.67	.98	5.00	.85
Female Faces	4.53	1.13	4.87	.99
Thirteen-year olds				
Male Faces	4.93	1.10	4.87	.92
Female Faces	4.33	.98	4.93	1.16

Main Effects

The predicted main effect of delay was highly significant (F(1,84)=93.03, p=.0001). On the whole, subjects made a significantly smaller number of hits in the one week-delay condition than they made in the immediate-test condition. Also, the main effect of sex of subject was significant (F(1,84)=5.08, p=.027). Female subjects made a significantly higher number of hits than were made by male subjects. The predicted main effect of age was only marginally significant in the predicted direction (F(2,84)=3.02, p=.054). There was however, a significant but unexpected main effect of sex of face (F(1,84)=9.76, p=.002). Overall, subjects made a significantly greater number of hits on recognition of female faces than they made on recognition of male faces. While these main effects indicated some general trends in the data, they were moderated by a number of significant interactions as discussed below.

Interactions

First, the effect of delay interacted significantly with age of subject (F(2,84)=6.00, p=.004). Tests of simple main effects (see Appendix C1) showed that the effect of delay was significant among 11-year olds (F(1,84) = 8.32, p=.05), among 12-year olds (F(1,84)=15.80, p=.05) and among 13-year olds (F(1,84)=30.69, p=.05). However, while differences in age significantly affected the number of hits obtained by subjects in the immediate-test condition (F(2,86)=6.34, p=.05), age differences did not significantly affect the number of hits that were obtained after a delay of one week (F(2,86)=1.74, p>.05). These conclusions are readily apparent from Figure 6.1. An inspection of Figure 6.1. shows that the data on hits did not support the prediction of a developmental dip in face recognition among 12-year olds.

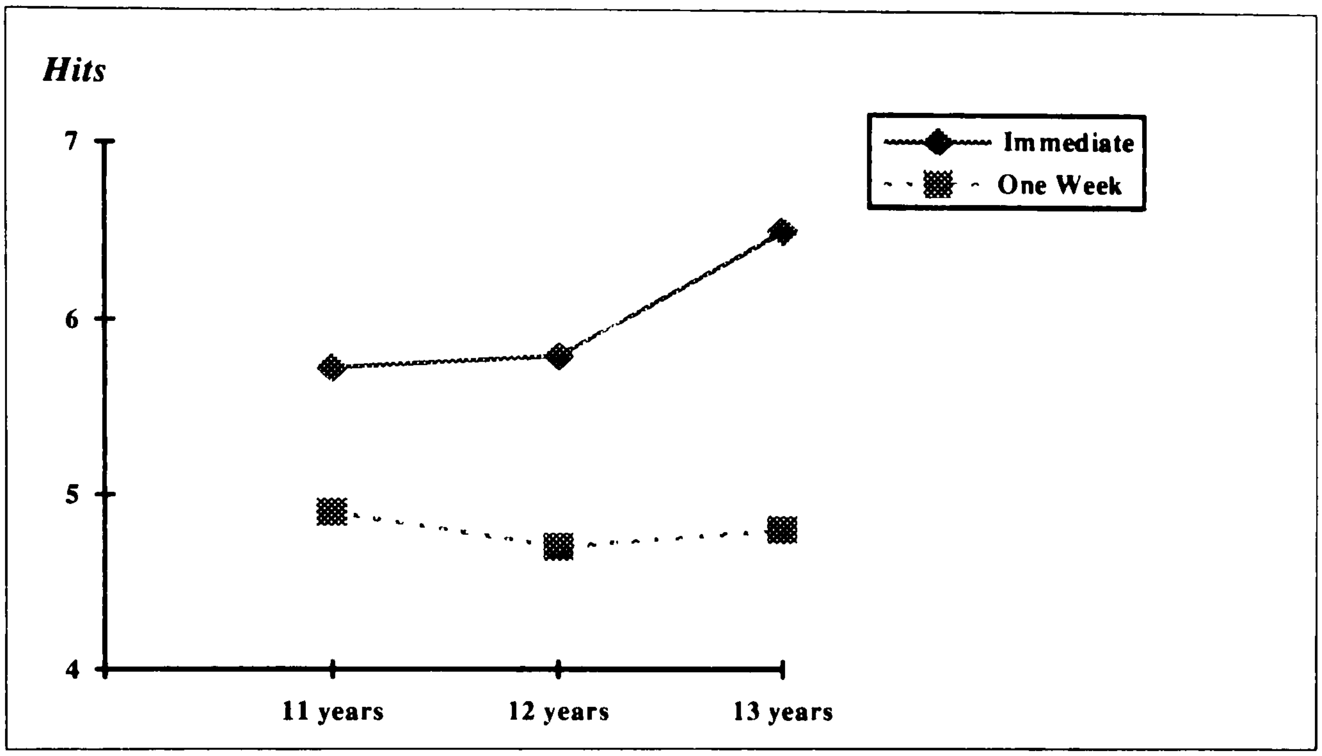

Figure 6.1. *A graph showing a significant interaction between age and delay obtained from an analysis of hits in experiment 4.*

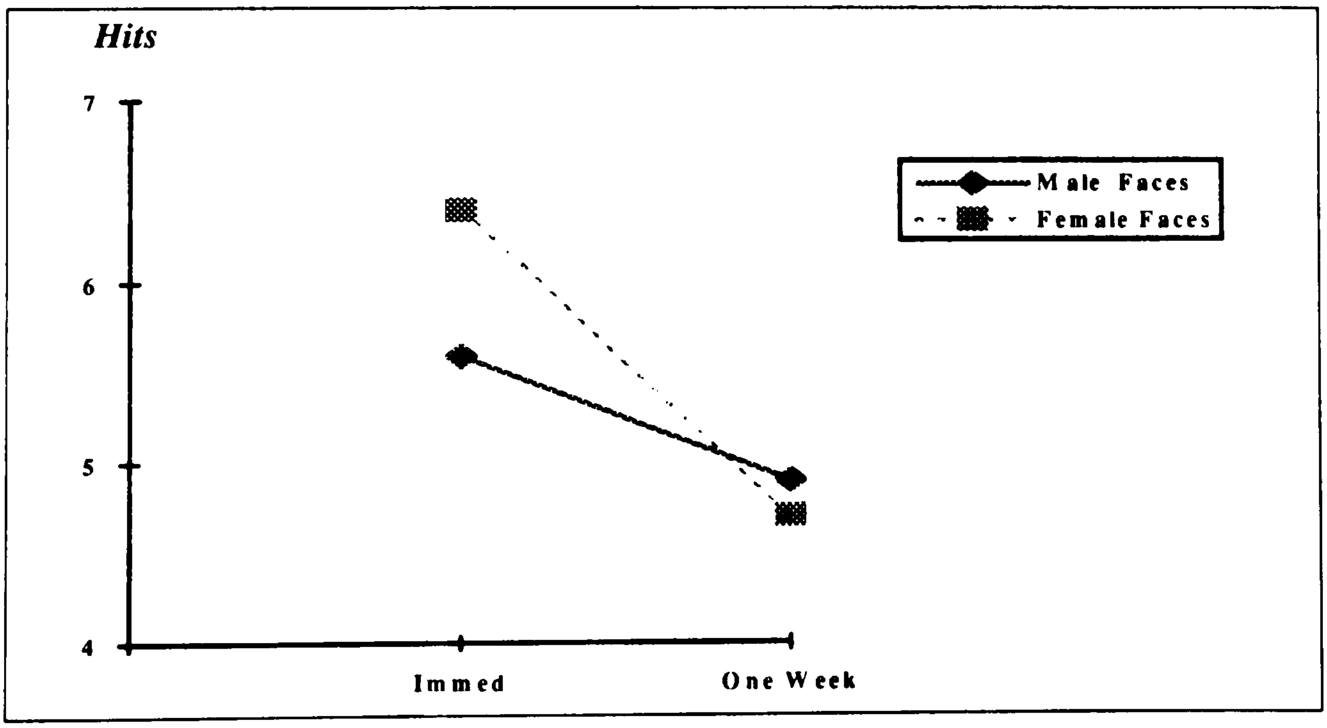

Figure 6.2.*A graph showing a significant interaction between delay and sex of face obtained from an analysis of hits in experiment 4.*

The effect of delay also interacted significantly with sex of face ($F(1,84)=22.42$, $p=.0001$). Tests of simple main effects (see Appendix C2) showed that the effect of delay was greater on recognition of female faces ($F(1,84)=106.2$, $p=.01$) than it was on recognition of male faces ($F(1,84)=18.01$, $p=.05$). However, the effect of sex of face was significant only in the immediate test condition ($F(1,84)= 23.52$, $p=.05$) but not in the one week delay condition ($F(1,84)=1.47$, $p>.05$). These conclusions are evident from figure 6.2.

There was also a significant interaction between sex of subject and sex of face ($F(1,84)=9.76$, $p=.002$). Tests of simple main effects (see Appendix C3) showed that while male subjects did not differ significantly from female subjects in the number of hits that they made on recognition of male faces ($F(1,85)=0.17$, $p>.05$), female subjects made a significantly higher number of hits than did male subjects on recognition of female faces ($F(1,85)=10.39$, $p=.05$). Also, female subjects made a significantly higher number of hits in their recognition of female faces than they made in their recognition of male faces ($F(1,84)=11.20$, $p=.05$). The mean numbers of hits obtained by male and female subjects on recognition of male faces were identical ($F=0$). These conclusions are apparent from Figure 6.3.

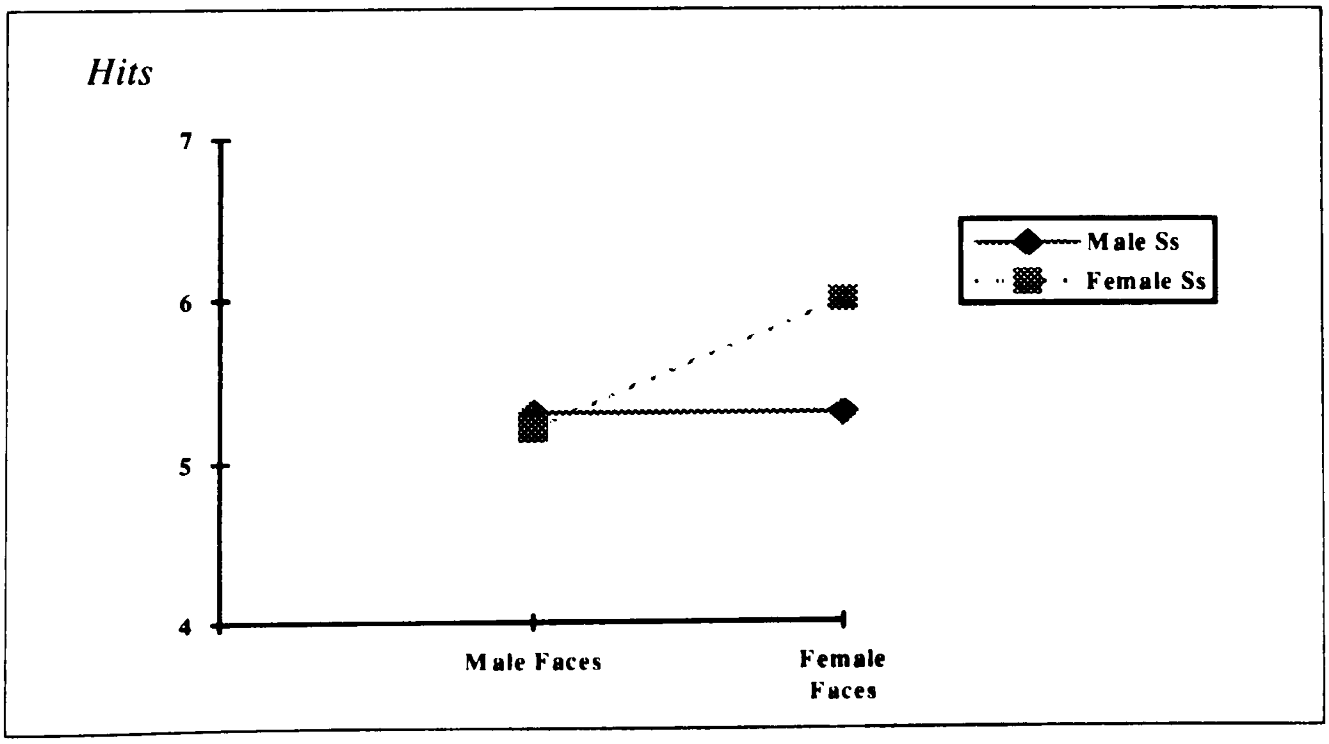

Figure 6.3. *A graph showing a significant interaction between sex of subject and sex of face obtained from an analysis of hits in experiment 4.*

6.3.2. False positives

The mean number of false positives that were made by male and female subjects on recognition of male and female faces in the immediate-test condition and in the one-week delay condition are shown in tables 6.3. and 6.4. respectively.

Table 6.3. *Mean number of false positives obtained by male and female subjects aged 11, 12, and 13 years on recognition of male and female faces in the immediate-test condition of experiment 4.*

	SEX OF SUBJECT			
	Males		Females	
	Mean	*S.D.*	*Mean*	*S.D.*
AGE				
Eleven-Year olds				
Males	2.40	1.06	3.07	1.22
Females	2.53	.74	1.67	1.05
Twelve-Year olds				
Males	2.80	1.26	4.27	1.16
Females	3.33	1.23	3.40	1.06
Thirteen-Year olds				
Males	2.80	.94	2.87	.83
Females	3.40	1.40	2.07	1.10

Table 6.4. *Mean number of false positives obtained by male and female subjects aged 11, 12, and 13 years on recognition of male and female faces in the one-week delay condition of experiment 4.*

	SEX OF SUBJECT			
	Males		Females	
	Mean	*S.D.*	*Mean*	S.D.
AGE				
Eleven-Year olds				
Male faces	3.73	1.44	4.27	1.28
Female faces	3.40	1.40	2.93	1.10
Twelve-Year olds				
Male faces	3.07	.70	4.60	.83
Female faces	3.13	1.06	3.47	1.13
Thirteen-Year olds				
Male faces	3.40	1.06	3.40	.83
Female faces	2.80	.94	2.00	.76

Main Effects

The predicted main effect of age was significant (F(2,84)=10.26, p=.0001). Twelve-year olds made a significantly higher number of false positives than were made by 11 and 13-year olds. The main effect of sex of subject was not significant (F(1,84)=2.95, p=.09). However, the predicted main effect of delay was significant (F(1,84)=70.07, p=.0001). A significantly higher number of false positives were made in the one-week delay condition than were made in the immediate-test condition. Also, there was a significant but unexpected main effect of sex of face (F(1,84)=360.06, p=.0001). A significantly smaller number of false positives were made on recognition of female faces than were made on recognition of male faces. These main effects were moderated by two significant interactions as discussed below.

Interactions

First, age of subject interacted significantly with delay (F(2,80)=10.28, p=.0001). Tests of simple main effects (see Appendix C4) showed that the effect of delay was significant among 11-year olds (F(1,84)=17.23, p=.05) but not among 12 and 13-year olds (F<1) (see Figure 6.4.). Secondly, an inspection of Figure 6.4. suggests that the significant main effect of age on the number of false positives in the immediate-test condition was due to more false positives made by 12-year olds compared to the other two groups of subjects. These results provide partial support for a developmental dip in recognition of faces among 12 year olds. However, this effect was only present in the immediate-test condition.

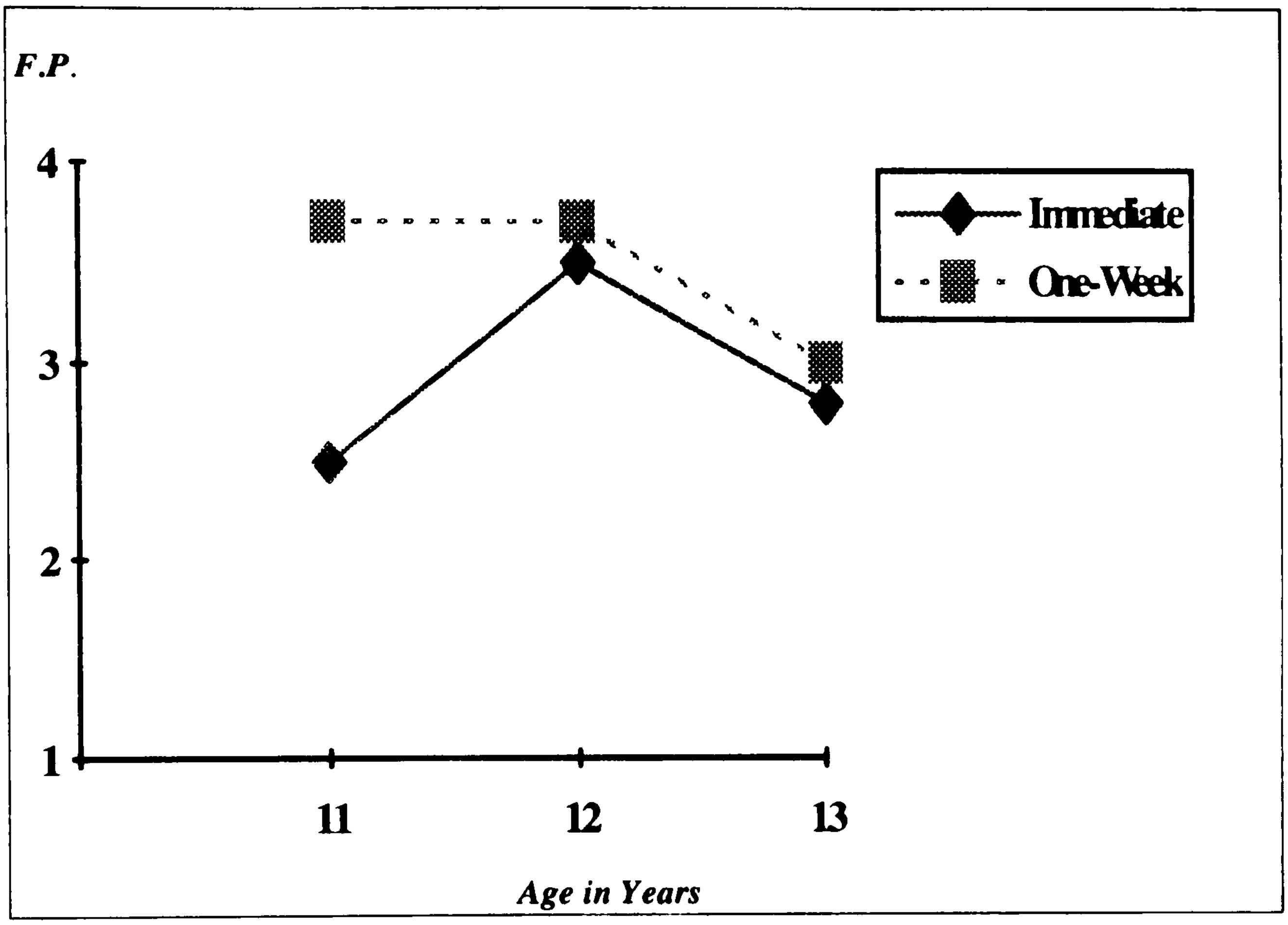

Figure 6.4. *A graph showing the interaction between age and delay obtained from an analysis of false positives in experiment 4.*

The interaction between sex of subject and sex of face was highly significant (F(1,84)=30.64, p=.0001). Tests of simple main effects (see Appendix C5) showed that female subjects made a significantly smaller number of false positives than were made by male subjects on recognition of female faces (F(1,85)=3.39, p=.05) while male subjects made a significantly smaller number of false positives than female subjects on recognition of male faces (F(1,85)=4.98, p=.05). However, while male subjects did not differ significantly in the number of false positives that they made on recognition of male vs. female faces(F=0), female subjects made a significantly greater number of false positives on recognition of male faces than they made on recognition of female faces (F(1,84)=25.53, p=.05). These conclusions can readily be ascertained from Figure 6.5.

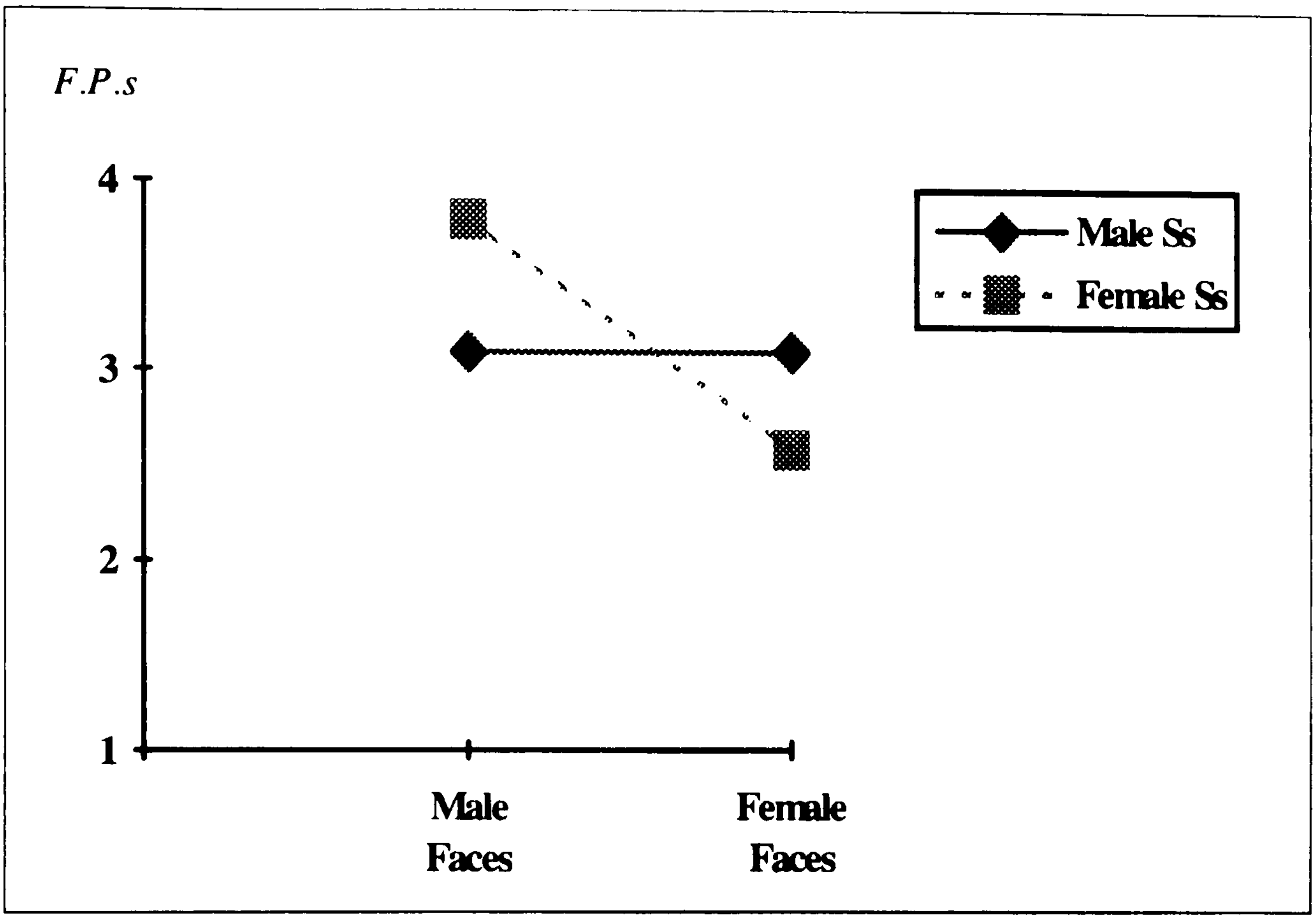

Figure 6.5. *A graph showing a significant cross-over interaction between sex of face and sex of subject obtained from an analysis of false positives data in experiment 4.*

6.3.3. A' scores

The mean A' scores that were obtained by male and female subjects on recognition of male and female faces across the two delay conditions of experiment 4 are shown in tables 6.5 and 6.6 respectively. The A' data were subjected to a split-plot ANOVA in which delay and sex of face were within-subjects factors and age and sex of subject were between-subjects factors. The full results of this analysis are shown in Appendix B19.

Table 6.5. *Mean A' scores obtained by 11-year olds, 12-year olds and 13-year olds on recognition of male and female faces in the immediate-test condition of experiment 4.*

	SEX OF SUBJECT			
	Males		Females	
	Mean	*S.D.*	*Mean*	*S.D.*
AGE				
Eleven-Year olds				
Male Faces	.76	.03	.71	.04
Female Faces	.76	.03	.85	.04
Twelve-Year olds				
Male Faces	.75	.04	.59	.07
Female Faces	.74	.03	.74	.04
Thirteen-Year olds				
Male Faces	.76	.04	.74	.05
Female Faces	.77	.03	.89	.04

Table 6.6. *Mean A' scores obtained by 11-year olds, 12-year olds and 13-year olds on recognition of male and female faces in the one-week delay condition of experiment 4.*

	SEX OF SUBJECT			
	Males		Females	
	Mean	*S.D.*	*Mean*	*S.D.*
AGE				
Eleven-Year olds				
Male Faces	.64	.04	.59	.04
Females	.62	.06	.72	.04
Twelve-Year olds				
Male Faces	.65	.06	.54	.08
Female Faces	.64	.06	.64	.06
Thirteen-Year olds				
Male Faces	.65	.04	.64	.04
Female Faces	.65	.05	.76	.03

Main Effects

The predicted main effect of delay was highly significant (F(1,84)=705.96, p=.0001). Subjects were significantly more accurate in their recognition of faces in the immediate-test condition than they were in the one-week delay condition. There was also a significant main effect of age of subject (F(2,84)=52.40, p=.0001). This main effect is shown in Figure 6.6.

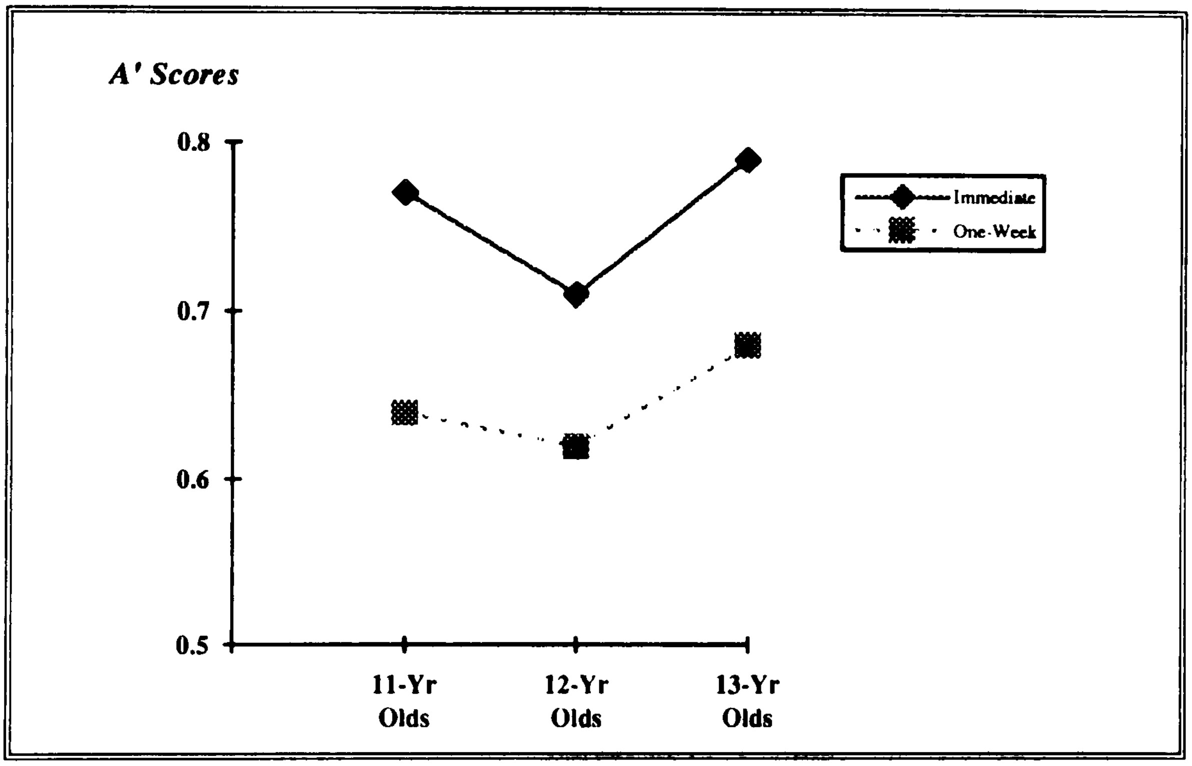

Figure 6.6. *A graph showing a significant main effect of age obtained from an analysis of A' scores in experiment 4.*

Planned comparison tests were performed to explore whether the dip in recognition accuracy among 12-year olds that is apparent in Figure 6.6. was significant. These tests showed that in both delay conditions, 11-year olds and 13-year olds were significantly more accurate in their recognition of faces than were 12-year olds (see Appendix C6).

Interactions

The interaction between sex of subject and sex of face was significant (F(1,84)=169.14, p=.0001). This interaction is shown in Fig 6.7.

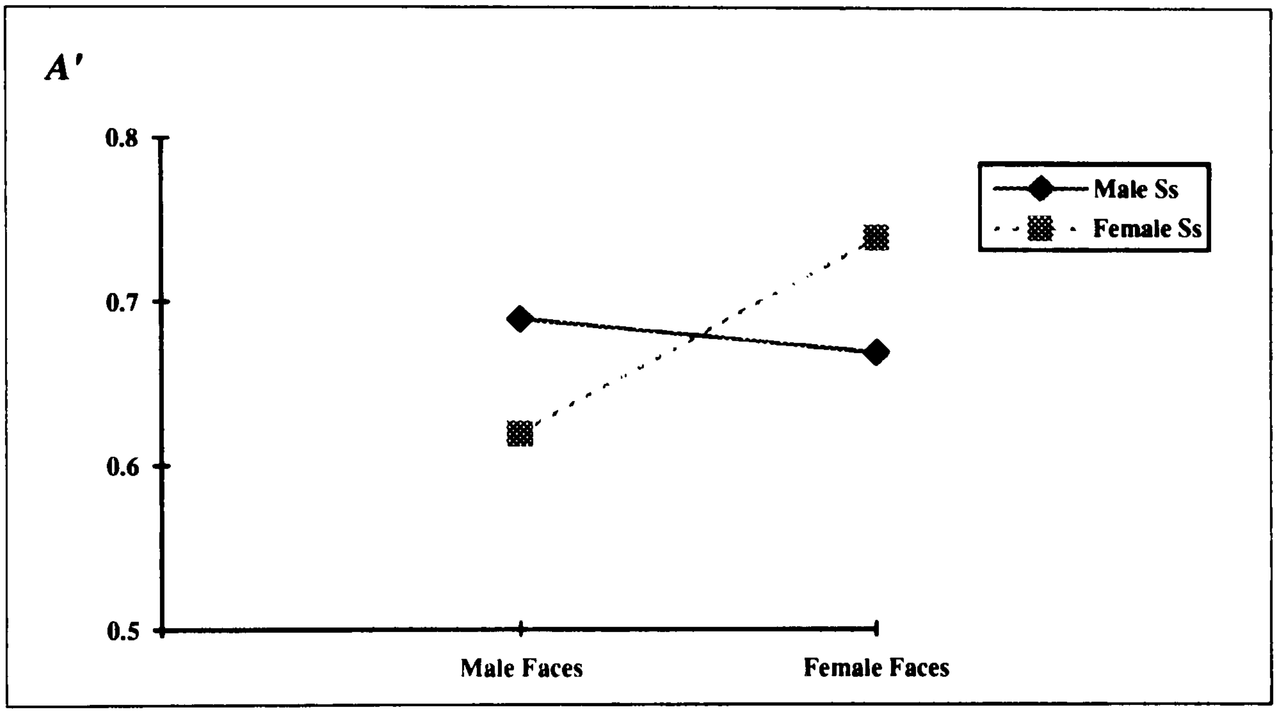

Figure 6.7. *A graph showing a significant interaction between sex of subject and sex of face obtained from an analysis of A' scores in experiment 4.*

Tests of simple main effects showed that while male subjects did not differ significantly in their recognition of male vs. female faces (F(1,84)=0.087,p>.05), female subjects recognised female faces more accurately than they recognised male faces (F(1,84)=13.6,p=.05). Furthermore, female subjects recognised male faces less accurately than did male subjects (F(1,85)=12.02, p=.05). It will be recalled that one of the questions raised in the introduction to this experiment was whether the developmental dip in face recognition accuracy that has been reported in previous studies among 12-year olds occurs with the same magnitude for both male and female subjects on their recognition of both male and female faces. Another question that was also of interest in the present study is whether this developmental dip in face recognition is consistent across different delay intervals. Even though the four-way interaction involving age of subject, sex of subject, sex of face and delay was not significant, an inspection of the mean A' scores suggested some interesting trends in the data regarding both these questions. Figures 6.8a - 6.8d show the mean A' scores that were obtained by 11-year old male and female subjects, 12-year old male and female subjects, and 13-year old male and female subjects on recognition of male and female faces in each of the two delay conditions of the present experiment.

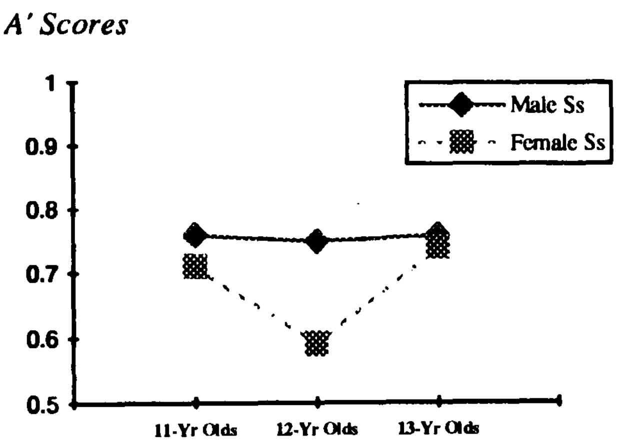

Figure 6.8a. *Mean A' scores obtained by male and female Ss on recognition of male faces in immediate-test condition of experiment 4.*

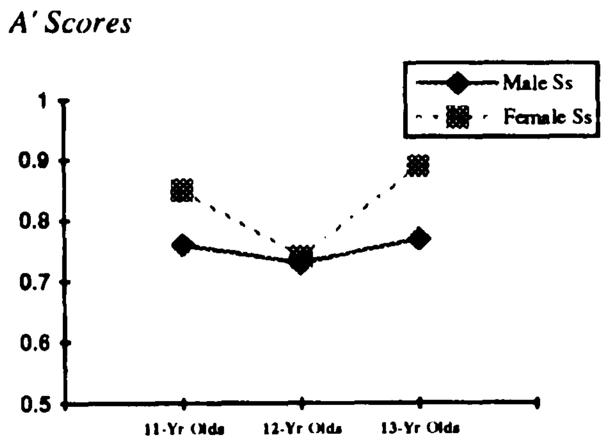

Figure 6.8b. *Mean A' scores obtained by male and female Ss on recognition of female faces in the immediate-test condition of experiment 4.*

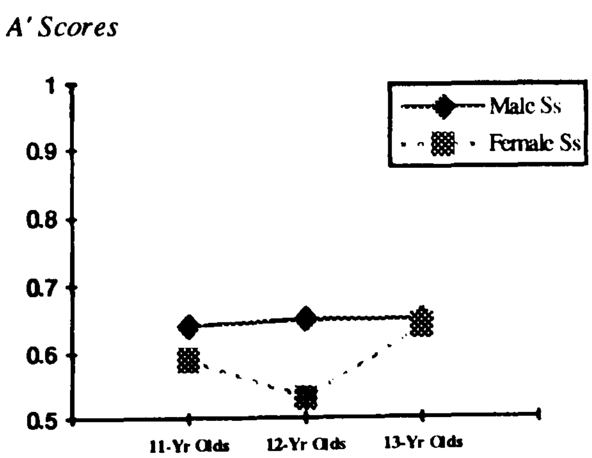

Figure 6.8c. *Mean A' scores obtained by male and female Ss on recognition of male faces in the week delay one-week delay condition of experiment 4.*

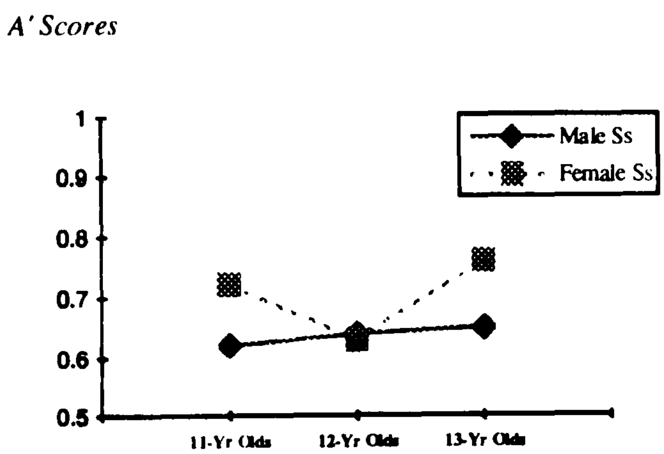

Figure 6.8d. *Mean A' scores obtained by male and on recognition of female faces in the one- condition of experiment 4.*

Figure 6.8. *Graphs showing the mean A' scores obtained by male and female subjects on recognition of male and female faces in each delay condition of experiment 4.*

It is apparent from Figures 6.8a - 6.8d that male subjects did not show a developmental dip in their recognition of either male faces or female faces. This was true for both delay conditions. Therefore, although the overall four-way interaction is not significant, the developmental dip in recognition of faces that was reported as part of the main effect of age was due to female subjects who showed a developmental dip at the age of 12 years in their recognition of both male and female faces in both delay conditions.

6.4. DISCUSSION

This experiment was designed to investigate a number of questions. First, it was hypothesised that unlike adults, children in their early adolescent years would be significantly less accurate in their recognition of faces in the one week delay condition than they would be in the immediate-test condition. This prediction was supported by significant main effects of delay on hits, on false positives and on A' scores. Flin (1983), Ellis (1990) and Ellis and Flin (1990) showed a similar drop in face recognition performance among 10-year olds. In the present experiment, it was shown that both male and female subjects aged 11, 12, and 13 years also experience a significant fall in their recognition of both male and female faces in a one-week test condition compared to their recognition of male and female faces in an immediate-test condition. While laboratory experiments such as the present one do not incorporate many of the factors that may be in operation in children's everyday memory for unfamiliar people's faces, it could be argued that taken together with Ellis and Flin's (1990) findings, the results obtained in this experiment provide some support for the current legal practice of treating children's face identification evidence with caution (Wilson, 1980).

Secondly, the results of the present experiment showed that on the whole, adolescent females aged 11, 12 and 13 years recognise female faces more accurately than they recognise male faces. This conclusion is supported by significant interactions between sex of face and sex of subject that were obtained on hits, on false positives and on A' scores. In each of these interactions, male subjects did not differ significantly in their recognition of male vs. female faces while female subjects showed superior recognition of female faces compared to their recognition of male faces. It is difficult to provide an uncontroversial explanation for this result. However, one hypothesis that has been suggested for this effect is the 'social comparison' hypothesis (Hoyenga & Hoyenga, 1979). Proponents of this hypothesis argue that females tend to look at female faces more than they look at male faces because of their greater tendency to compare themselves with other females. Perhaps, this tendency is stronger among adolescent girls than it is among adolescent boys particularly in Western societies where "good looks" are constantly being brought to the fore in the media. If this were indeed the case, this may lead to deeper encoding of female faces and to superficial analysis of male faces by female adolescents. However, appealing as this explanation may be, not all researchers would agree that this is the case (see McKelvie's (1978) review).

It would be of interest to explore this hypothesis further. One way in which this could be done would be to test male and female adolescents for their recognition of both male and female faces under different encoding conditions, one involving making attributional judgements to each face during initial presentation of study faces and the other involving superficial judgements during encoding. If the own-sex bias in face recognition displayed by female subjects in this experiment is related to deeper encoding during initial presentation of target faces, then, this bias should disappear in the first condition but be present in the second condition.

The third question that was investigated in the present experiment involved the developmental dip in face recognition accuracy that has been reported among 12-year olds. While this effect was present on false positives and on A' scores, a closer examination of the mean A' scores suggested that there were clear differences between male and female subjects. Twelve-year old male subjects did not show a developmental dip in their recognition of either male faces or female faces while female subjects aged 12 years were significantly less accurate than 11-year olds and 13-year olds in their recognition of both male and female faces. This result was significant in both delay conditions, suggesting that it was quite a robust effect. Perhaps, the onset of puberty (and the hormonal changes that this may bring to bear on face recognition tasks) may occur earlier for females (i.e. at about 12 years of age) and later for males.

In conclusion, although the effect of delay on adolescents' recognition of faces was strong and consistent on all the three measures of recognition accuracy, two questions remained unanswered. First, there is need to examine further the own-sex bias in face recognition displayed by female adolescents in this experiment. Secondly, it could be of interest to examine why the developmental dip in recognition of faces that was found to be significant in both delay conditions of this experiment was confined to recognition of faces by female adolescents. Experiments on the nature and quality of the face encoding processes among male and female adolescents may shed more light on both these questions.

Part IV

EXPERIMENTAL WORK 3

CHAPTER SEVEN

A Cross-cultural Investigation of The Contact Hypothesis of the Own-race Bias in Face Recognition

7.1. Introduction

As the evidence discussed in Chapter three of this thesis demonstrated, both laboratory and field studies have consistently shown that subjects recognise faces of their own-race more accurately, more quickly and more confidently than they recognise other-race faces (see Lindsay & Wells, 1983 and Bothwell, Brigham & Malpass, 1989 for detailed reviews). However, as Brigham (1986) and Valentine (1991b) point out, the theoretical basis of this effect is not clearly understood at present. Four hypotheses have been proposed. First, faces of one race may be inherently more difficult to recognise than faces of another race. This hypothesis has not been supported by empirical findings (Goldstein, 1979a, 1979b; Shepherd & Deregowski, 1981).

Second, it has been suggested that racial prejudice might account for the own-race bias in face recognition. According to this hypothesis, racially prejudiced attitudes lead to poorer recognition of other-race faces. However, Brigham and Barkowitz (1978), Lavrakas, Buri and Mayzner (1976) and Yarmey (1979) did not find a significant correlation between inter-racial attitudes and subjects' recognition of other-race faces. A third hypothesis proposed by Chance and Goldstein (1981) suggests that superficial orienting to other-race faces at encoding may cause poorer recognition of faces of that race. However, Devine and Malpass (1985) found a significant own-race bias in face recognition under both superficial and inferential encoding conditions.

The fourth hypothesis, which is the focus of the present study, proposes that the own-race bias in face recognition might be due to limited contact with multiple exemplars of other-race faces. As Valentine (1991b) suggests, current evidence for the contact hypothesis is mixed. Cross, Cross and Daley (1971) found that Caucasian children from segregated neighbourhoods show a greater own-race bias in face recognition than Caucasian children from integrated neighbourhoods. However, Cross *et al* (1971) did not find a similar difference among black children. Although Feinman and Entwistle (1976) replicated Cross *et al*'s results, Brigham (1986) points out that the results of this study were not entirely consistent.

More recently, Brigham, Maas, Snyder and Spaulding (1982) reported a weak but significant correlation between subjects' self-reported degree of cross-racial experience and their recognition of other-race faces. However, other researchers have reported contradictory findings. For example, Brigham and Barkowitz (1978), Luce (1974), and Malpass and Kravitz (1969) did not find a significant relationship between self-reported degree of cross-racial experience and recognition of other-race faces. Valentine (1991b) points out that inadequate cross-racial controls might account for these inconsistencies. Brigham (1986) also notes that "... measures of contact and experience which more accurately assess the quality and depth of contact, as well as its frequency, may help us identify the relationship between experience and a cross-race effect if indeed one exists" (p.175).

Another problem often encountered in neighbourhood and correlational studies of the own-race bias in face recognition is that it is often difficult to control for demand characteristics. For example, the desire to present oneself as *non-racist* may significantly influence subjects' ratings of their own degree of cross-racial interaction. Also, living in an integrated neighbourhood does not necessarily result in more cross-racial interaction. Mobility between neighbourhoods, the influence of television and the nature and context of one's employment are all factors that are known to affect an individual's degree of cross-racial experience.

In order to avoid these problems and investigate the contact hypothesis more directly, it was considered critical in designing the present study to test groups of subjects whose degree of cross-racial experience could be more objectively specified. Owing to the multi-racial nature of most contemporary societies, such groups are difficult to find. However, in some parts of Africa (particularly in the remote rural villages), it is possible to locate individuals whose degree of contact with Caucasian faces is either very low or non-existent. However, finding a comparable group of Caucasian subjects whose degree of contact with black-African faces is either very low or non-existent is comparatively more difficult.

In the present study, the effect of individual differences in degree of contact with 'other-race' faces on subjects' recognition of distinctive and typical own-race and other-race faces was investigated. Distinctiveness was included as a factor in this study for two reasons. First, Bothwell, Brigham and Malpass (1989) have pointed out that in cross-racial studies involving face recognition, it is vital to ensure that the stimuli are equated in terms of distinctiveness to prevent spurious interactions that may result from differences in the range of distinctiveness of the faces that are used in the experiment. Secondly, including distinctiveness as a factor in this experiment made it possible to test specific theoretical predictions that were derived from Valentine's (1991b) multidimensional space (MDS) framework of face encoding.

Valentine's MDS framework of face encoding suggests that faces are encoded as points in a multidimensional space. Assuming that the location of individual faces in the multidimensional space is based on experience with faces of one's own race, the dimensions on which individual other-race faces will be encoded may be those that are important for encoding own-race faces. Ellis, Deregowski and Shepherd (1975) and also Shepherd and Deregowski (1981) found that different features are used to describe black-African faces and Caucasian faces and that different features are used to judge similarities between simultaneously presented African and Caucasian faces. On the basis of these and other findings, Valentine (1991b) proposed that a population of other-race faces encoded in the multidimensional space will have a central tendency that is located at a different point in the multidimensional space from the central tendency of own-race faces.

According to the MDS framework of face encoding, the difficulty that is experienced in recognition of typical own-race faces is because of the increased exemplar density close to the central tendency which leads to greater interference effects in memory than when recognition of distinctive faces is involved. Distinctive faces are thought to suffer less interference effects in memory because they are encoded further away from the central tendency in regions of the space with low exemplar density. Also, Valentine

(1991b) argues that although other-race faces are encoded further away from the central tendency of own-race faces, as a group, they are more difficult to recognise because they occupy a *more densely clustered space* within the multidimensional space. This proposition is based on the assumption that the effect of distinctiveness in recognition memory for faces can only be defined in relation to a specific population of faces and that in order for subjects to show this effect, they must be sufficiently familiar with the population of faces on which the recognition task is based. Thus, subjects with a low degree of contact with faces of another race are less likely to identify the features that make individual faces of that race either typical or distinctive than subjects who are highly familiar with faces of that race.

In the experiment that is reported in this chapter, four groups of subjects were tested for their recognition of distinctive and typical own-race and other-race faces. Subjects were either black-Africans or British-Caucasians. In each racial group, half of the subjects were deemed to be highly 'familiar' with faces of both races (high contact subjects) and the other half of the subjects in each racial group had little or no exposure to faces of the opposite race (low contact subjects). Therefore, the experiment employed a split-plot factorial design in which race of subject (Africans vs. Caucasians) and contact group (high vs. low) were between-subjects factors and race of face (own-race vs. other-race) and distinctiveness (typical vs. distinctive) were within-subjects factors. The dependent variables were recognition accuracy and confidence ratings.

The following predictions were tested. First, a significant crossover interaction between race of subject and race of face was predicted. This result would show a replication of the advantage for recognition of own-race faces that has been reported in previous studies[14]. African subjects were expected to be significantly more accurate and more confident in their recognition of African faces than in their recognition of Caucasian faces while Caucasian subjects were expected to be significantly more accurate and more confident in their recognition of Caucasian faces than in their recognition of African faces. Secondly, subjects in the 'high-contact' groups were expected to show a significantly smaller own-race bias in face recognition than subjects in the 'low contact' groups. Thus, a significant three-way interaction involving race of subject, contact group and race of face was predicted. The third prediction was that the main effect of distinctiveness would be significant. Overall, subjects were expected recognise distinctive faces more accurately and more confidently than typical faces.

Finally, on the basis of the MDS framework of face encoding, a significant four-way interaction involving race of subject, contact group, race of face and distinctiveness was predicted. High contact subjects of both races were expected to show a significant effect of distinctiveness in their recognition of faces of both races while low contact subjects were expected to show an effect of distinctiveness only in their recognition of own-race faces. This prediction was based on the assumption that the effect of distinctiveness in recognition memory for faces is a function of subjects' degree of contact with faces of a given population of faces (Valentine, 1991b).

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[14] See section 3.3. of Chapter Three of this thesis.

7.2. EXPERIMENT 5

7.2.1. METHOD

7.2.1.1. Subjects

Sixty-eight subjects (34 Caucasians and 34 black-Africans) acted as subjects in this experiment. Half of the subjects in each racial group had a 'high' degree of contact with faces of the opposite race (HC subjects) and the other half of the subjects in each racial group had a 'low' level of contact with faces of the opposite race (LC subjects). Subjects were all male.

High Contact Subjects. Two groups of adolescents were selected to serve as the HC subjects. These were students at a privately-run multi-racial college in Harare[15]. Seventeen of the subjects were Caucasian (*mean age*=16.02 years, *s.d.*=1.66) and 17 were black-Africans (*mean age*=16.10 years, *s.d.*=1.52). The college from which these subjects were selected was chosen because it enrols students from both racial groups. This made it an appropriate source of subjects who had a high degree of contact with faces of both races.

Low Contact Subjects. Two groups of adolescents were selected to serve as the LC subjects. One group consisted of 17 black-Africans (*mean age*=16.15 years, *s.d.*=1.37) who attended a privately-run boarding school located in a remote rural village in Southern Zimbabwe. There are no televisions in the village and, except for the village priest who is Caucasian, these students were unlikely to have seen many other Caucasians. The second group consisted of 17 Caucasians (*mean age*=16.73, *s.d.*=1.33) who were students at a college in North East England.

[15]Harare is the capital city of Zimbabwe.

It must be pointed out that although the LC group of Caucasian subjects were deemed to be 'low' in their degree of contact with faces of an African origin, they were not an entirely comparable sample to the LC group of rural Zimbabweans since, owing to the influence of television and other media, these subjects were undoubtedly familiar with many of the black British celebrities in sport, art and theatre. However, it was assumed that their overall degree of contact with African faces was substantially lower than that of Caucasians who were born and educated in Zimbabwe where black Africans constitute more than 90% of the entire population.

7.2.1.2 Stimuli

The stimuli set consisted of 32 slides of Caucasian faces and 32 slides of black-African faces. Two slides of each face were prepared: one in full-face smiling pose and the other in full-face unsmiling pose. Distinctiveness ratings were collected for each face in an unsmiling pose. Caucasian faces were rated for distinctiveness by 16 Caucasian postgraduate students at the University of Manchester. Black-African faces were rated by 16 African postgraduate students at the University of Zimbabwe.

The procedure that was used to obtain distinctiveness ratings for each set of faces was similar to the one described in Valentine and Endo (1991). Each subject was given a response form with a scale of 1 - 9 for each of the original 53 Caucasian faces (for Caucasian raters) or 48 black-African faces (for black-African raters). The raters were asked to imagine they had to meet "each of these people at a busy railway station" and to rate each face for how easy it would be to pick out in a crowd by circling the appropriate number on the 1 - 9 scale. They were instructed to rate 'unusual' or distinctive faces which they thought would be easy to spot as 9, and typical faces which they thought would be very difficult to pick out as 1. Raters were encouraged to make use of the entire range of the scale and proceeded through the list of faces at their own pace. Different random orders were used for each set of 4 consecutive subjects of each race.

Mean distinctiveness ratings for each face were calculated and used as a basis of stimulus classification. Sixteen of the most distinctive faces of each race were selected and divided into two sets of 8 targets and 8 distractors. Similarly, 16 of the most typical faces of each race were selected and divided into two sets of 8 targets and 8 distractors. The mean distinctiveness ratings for each set of faces are shown in Table 7.1.

Table 7.1. *Mean distinctiveness ratings for African and Caucasian faces used in experiment 5. (The maximum score in each cell is 9. The minimum score is 1).*

	AFRICAN FACES		CAUCASIAN FACES	
	Typical	**Dist**	**Typical**	**Dist**
Mean	4.35	6.15	4.40	6.60
s.d.	0.40	1.04	0.50	0.80

Key: s.d. = standard deviation.

Paired t-tests confirmed that the mean ratings of distinctive faces were significantly higher than the mean ratings for typical faces [for African faces[$t(30)=5.91, p=.0001$]; for Caucasian faces [$t(30)=9.62, p=.0001$]].

7.2.1.3. Apparatus

A Saville PROslide projector fitted with an external Elmo-T2 timer was used to present the slides. The external timer controlled the exposure duration for each slide as well as the inter-stimulus interval.

7.2.1.4. Procedure

Two study lists of 16 faces each were constructed. One list consisted of typical faces. The other list consisted of distinctive faces. Each study list consisted of 8 slides of black African faces and 8 slides of Caucasian faces. Half of the subjects in each of the four contact groups were tested for their recognition of distinctive faces first and the rest of the subjects in each group were tested for their recognition of typical faces first. During the study phase of the experiment, subjects were instructed to examine each face carefully in preparation for a subsequent recognition memory test. Each face was shown for 8 seconds. The inter-stimulus interval was 2 seconds. In each study list, half of the faces of each race showed a smiling pose and the other half of the faces of each race showed an unsmiling pose.

The recognition test followed immediately after each study list. A random list of 16 targets and 16 distractors was presented to the subjects. Target faces were presented in a different facial expression at test. Thus, faces that were shown in a smiling pose during study were shown in an unsmiling pose at test and vice versa. Half of the targets and distractors were smiling and half were unsmiling. The timing was the same as that used during study. Subjects responded to each face by ticking on individual response forms either a 'Yes' box (for targets) or a 'No' box (for distractors). Subjects also rated their confidence to each response on a scale of 1 - 7. They were encouraged to respond to all the faces that were included in the test list and to guess if unsure.

7.2.2. RESULTS

7.2.2.1. Recognition Accuracy

For each subject, hit and false positive rates in each condition were calculated and combined in A' scores. An $F_{max.}$ test of homogeneity of variance was applied to the raw data before conducting all of the analyses reported in this chapter. Although the data on hits and on false positives did not violate the principle of homogeneity of variance for ANOVA, the A' scores did. Therefore, A' scores were subjected to an $arcsin\sqrt{A'}$ transformation (Kirk, 1968) before being analysed. Hits, false positives and A' scores were analysed separately. The full results obtained from these analyses are shown in appendices B20, B21, and B22 respectively.

Hits

The mean number of hits that were obtained by HC and LC subjects of each race in recognition of distinctive and typical own race and other race faces are shown in Table 7.2. (*overleaf*).

A 2 X 2 X 2 X 2 split-plot ANOVA in which race of subject and contact group were between-subjects factors and race of face and distinctiveness were within-subjects factors was carried out on hits.

Table 7.2. *Mean number of hits obtained by HC and LC subjects in recognition of distinctive and typical own race and other race faces in experiment 5. [The maximum score is 8. The minimum score is 0. Standard deviations are in parentheses].*

	AFRICAN FACES		CAUCASIAN FACES	
	Dist	**Typ**	**Dist**	**Typ**
Race of Ss				
Africans				
HC(n=17)	5.59(1.37)	5.82(1.47)	6.29(0.99)	6.00(1.23)
LC(n=17)	7.35(0.71)	5.52(1.23)	6.00(1.23)	5.23(1.44)
Es (n=34)	6.47(1.04)	5.55(1.58)	6.15(1.11)	5.62(1.34)
Caucasians				
HC(n=17)	5.59(1.06)	5.47(1.70)	6.06(1.30)	6.29(0.85)
LC(n=17)	5.77(1.48)	5.35(1.50)	6.71(1.36)	6.94(1.25)
Es (n=34)	5.68(1.27)	5.41(1.60)	6.39(1.33)	6.62(1.05)
Overall (n=68)	6.07(1.39)	5.54(1.46)	6.27(1.22)	6.11(1.15)

Key: Ss=Subjects, HC=High contact, LC=Low contact, Es=Entire sample, Dist=Distinctive, Typ=Typical.

The predicted interaction between race of face and race of subject was significant (F(1,64)=13.15, p=.001). Overall, black-African subjects made a significantly greater number of hits in their recognition of African faces than in their recognition of Caucasian faces while Caucasian subjects made a significantly greater number of hits in their recognition of Caucasian faces than they made in their recognition of black-African faces. The predicted main effect of distinctiveness was also significant (F(1,64)=6.52, p=.01). Subjects made more hits to distinctive faces than they made to typical faces (see table 7.2).

The predicted three-way interaction involving race of subject, contact group and race of face was also significant (F(1,64)=8.85, p=.004). Subjects in the HC groups showed a smaller own-race bias in face recognition than subjects in the LC groups. Furthermore, the interaction involving race of subject, contact group and distinctiveness was significant (F(1,64)=4.45, p=.039). On the whole, HC subjects showed a significantly greater effect of distinctiveness than LC subjects. However, the predicted four-way interaction involving race of subject, contact group, race of face and distinctiveness was not significant ($F(1,64)=1.73$, $p=.19$).

False positives

The mean number of false positives that were obtained by HC and LC subjects in each condition are shown in Table 7.3. A split-plot ANOVA performed on the false positives showed a significant main effect of race of face ($F(1,64)=11.59$, $p=.001$). More false positives were made to black-African faces than were made to Caucasian faces. In spite of this main effect, the interaction between race of subject and race of face was highly significant ($F(1,64)=116.76$, $p=.0001$). Subjects made a significantly smaller number of false positives in their recognition of own race faces than they made in their recognition of other-race faces.

Table 7.3. *Mean number of false positives obtained by HC and LC subjects in recognition of distinctive and typical own race and other race faces in experiment 5. [The maximum score is 8. The minimum score is 1. Standard deviations are in parentheses].*

	AFRICAN FACES		CAUCASIAN FACES	
	Dist	**Typ**	**Dist**	**Typ**
Race of Ss				
Africans				
HC(n=17)	1.82(1.74)	2.41(1.18)	0.77(1.44)	3.12(1.22)
LC(n=17)	0.94(1.09)	1.24(1.09)	3.65(1.12)	3.29(0.92)
Es(n=34)	1.38(1.42)	1.83(1.14)	2.21(1.28)	3.21(1.07)
Caucasians				
HC(n=17)	2.65(1.22)	3.24(0.83)	0.53(0.94)	1.24(1.25)
LC(n=17)	2.17(1.74)	2.94(1.56)	0.18(1.53)	1.59(1.33)
Es(n=34)	2.41(1.48)	3.09(1.20)	0.36(0.74)	1.42(1.29)
Overall (n=68)	2.15(1.43)	2.46(1.17)	1.28(1.24)	2.31(1.48)

Key: Ss=Subjects, HC=High contact, LC=Low contact, Es=Entire sample, Dist=Distinctive, Typ=Typical

The predicted main effect of distinctiveness was highly significant (F(1,64)=20.20, p=.0001). Fewer false positives were made to distinctive faces than were made to typical faces [see table 7.3]. The three-way interaction involving race of subject, contact group and race of face was also significant (F(1,64)=20.16, p=.0001). High contact subjects showed a smaller own-race bias in face recognition than did low contact subjects. Also, the predicted four-way interaction involving race of subject, contact group, race of face and distinctiveness was significant (F(1,64)=17.13, p=.0001). High contact subjects showed a significantly greater effect of distinctiveness in their recognition of other-race faces than did low contact subjects.

A prime scores

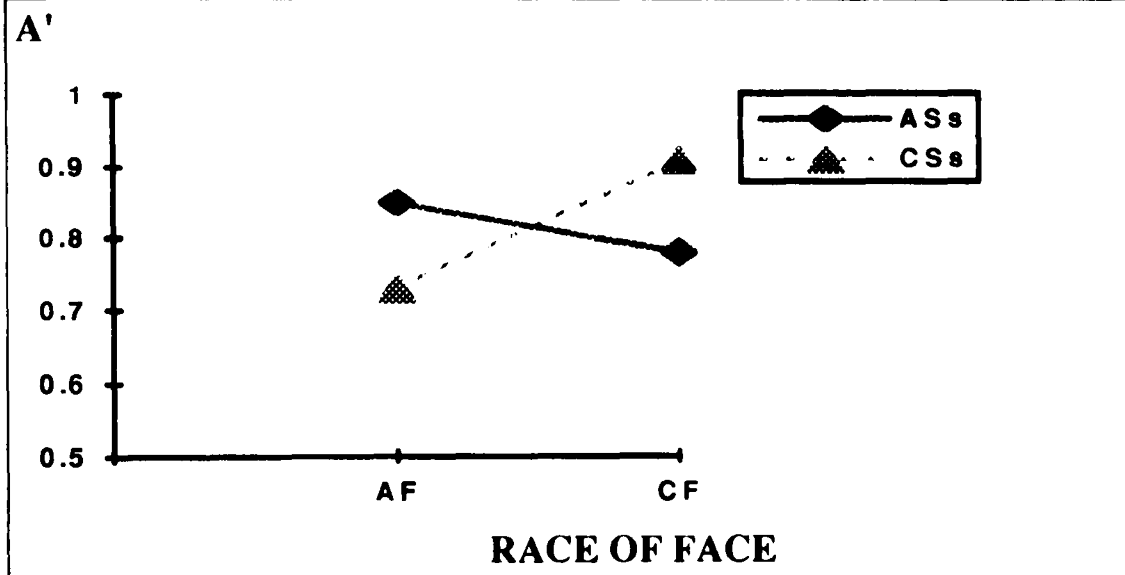
The mean A' scores for this experiment are shown in Table 7.4.

Table 7.4. *Mean A' scores obtained by HC and LC subjects in recognition of distinctive and typical own-race and other-race faces in experiment 5. [The maximum score is 1. The minimum score is 0. A score of .5 is chance performance. Standard deviations are in parentheses].*

	AFRICAN FACES		CAUCASIAN FACES	
	Dist	Typ	Dist	Typ
Race of Ss				
Africans				
HC(n=17)	.84(0.07)	.79(0.12)	.90(0.05)	.76(0.12)
LC(n=17)	.95(0.04)	.85(0.10)	.73(0.12)	.70(0.13)
Es(n=34)	.89(0.05)	.81(0.10)	.82(0.10)	.73(0.13)
Caucasians				
HC(n=17)	.76(0.11)	.70(0.15)	.91(0.09)	.88(0.09)
LC(n=17)	.73(0.17)	.71(0.15)	.96(0.05)	.87(0.13)
Es(n=34)	.75(0.15)	.71(0.13)	.93(0.07)	.88(0.10)
Overall (n=68)	.82(0.14)	.76(0.15)	.88(0.12)	.81(0.14)

Key: Ss=Subjects, HC=High contact, LC=Low contact, Es=Entire sample, Dist=Distinctive, Typ=Typical

An ANOVA performed on transformed A' scores showed a significant main effect of race of face (F(1,64)=16.55, p=.0001). Caucasian faces were recognised more accurately than were black-African faces. However, in spite of this main effect, the predicted interaction between race of subject and race of face was highly significant (F(1,64)=97.17, p=.0001). Subjects of both races showed a strong own-race bias in their recognition of faces (see figure 7.1).

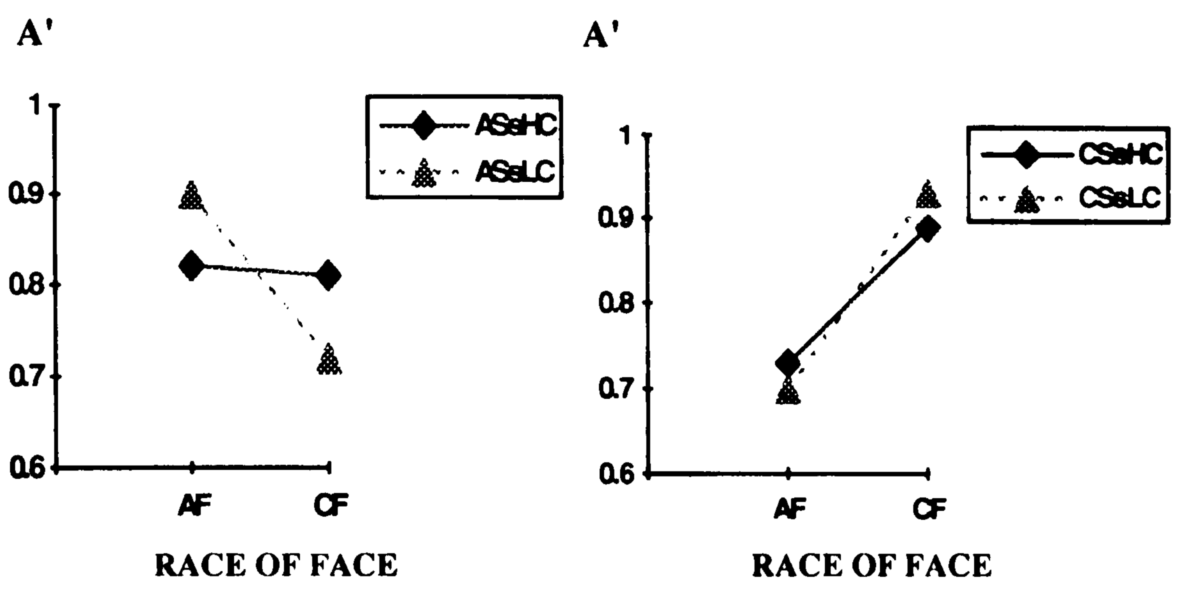


ASs = African subjects, CSs = Caucasian Subjects, AF = African faces, CF= Caucasian faces.

Figure 7.1. *A graph showing a significant interaction between race of face and race of subject obtained from an analysis of A' scores in experiment 5.*

The predicted three-way interaction involving race of subject, contact group and race of face was significant (F(1,64)=22.98, p=.0001). The nature of this interaction is shown in Figure 7.2. A close examination of figure 7.2a shows that while high contact black-African subjects did not show a significant own-race bias in face recognition, low contact black-African subjects found it disproportionately harder to recognise Caucasian faces. However, although a similar trend was present for Caucasian subjects (see Figure 7.2b), this effect was not significant. Both the high contact and the low contact Caucasian subjects showed a strong own-race bias in face recognition.

Figure 7.2.a. Mean A' scores for African Ss **Figure 7.2.b.** Mean A' scores for Caucasian Ss



Key: AF= African faces, CF=Caucasian faces, ASsHC=African subjects, high contact group, ASsLC=African subjects, low contact group, CSsHC=Caucasian subjects, high contact group, CSsLC=Caucasian subjects, low contact group.

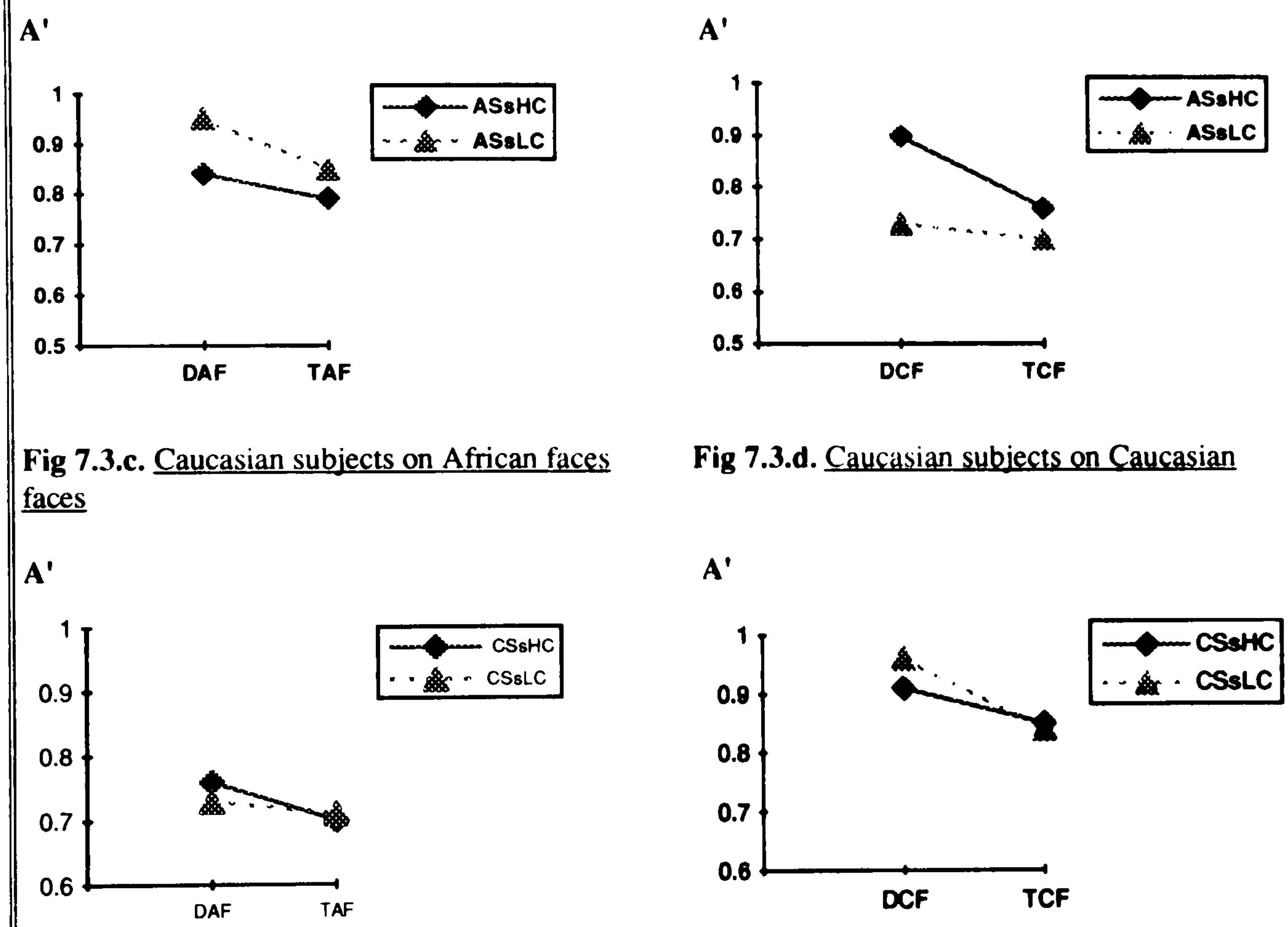
Figure 7.2. *Graphs showing a significant three-way interaction involving race of subject, contact group and race of face obtained from an analysis of A' scores in experiment 5.*

The main effect of distinctiveness was highly significant (F(1,64)=22.46, p=.0001). Overall, distinctive faces were recognised more accurately than were typical faces. It will be recalled that the key prediction in this experiment regarding the effect of distinctiveness was that the high contact subjects from both racial groups would show a stronger effect of distinctiveness in their recognition of own-race *as well as* other-race faces than the low contact subjects (i.e. for the LC subjects, the effect of distinctiveness was expected to be stronger on recognition of own-race faces but weak or absent on recognition of other-race faces whose defining characteristics were unknown to them). The results obtained in this experiment supported this hypothesis. First, the four-way interaction involving race of subject, contact group, race of face and distinctiveness was significant (F(1,64)=11.45, p=.001). The nature of this interaction is shown in Figure 7.3.

Figure 7.3. *Graphs showing a significant four-way interaction involving race of subject, contact group, race of face and face distinctiveness obtained from an analysis of A' scores in experiment 5.*

Fig 7.3.a. African subjects on African faces

Fig 7.3.b. African subjects on Caucasian faces



Key: DAF=Distinctive African faces, TAF=Typical African faces, DCF=Distinctive Caucasian faces, TCF=Typical Caucasian faces, CSsHC=Caucasian subjects, high contact group, CSsLC=Caucasian subjects, low contact group, ASsHC=African subjects, high contact group, ASsLC=African subjects, low contact group.

A close examination of Figures 7.3a and 7.3b shows that while the low contact African subjects showed a significant effect of distinctiveness on recognition of African faces, they did not show a similar effect on recognition of Caucasian faces. The data obtained from LC Caucasian subjects (see Figures 7.3c and 7.3d) also showed a significant effect of distinctiveness on recognition of own-race faces and no effect of distinctiveness on recognition of African faces while the HC Caucasian subjects showed significant effects of distinctiveness on recognition of faces of both races. Similarly, HC African subjects showed significant effects of distinctiveness on recognition of own-race faces as well as on recognition of other-race (Caucasian) faces.

7.2.2.2. Confidence Ratings

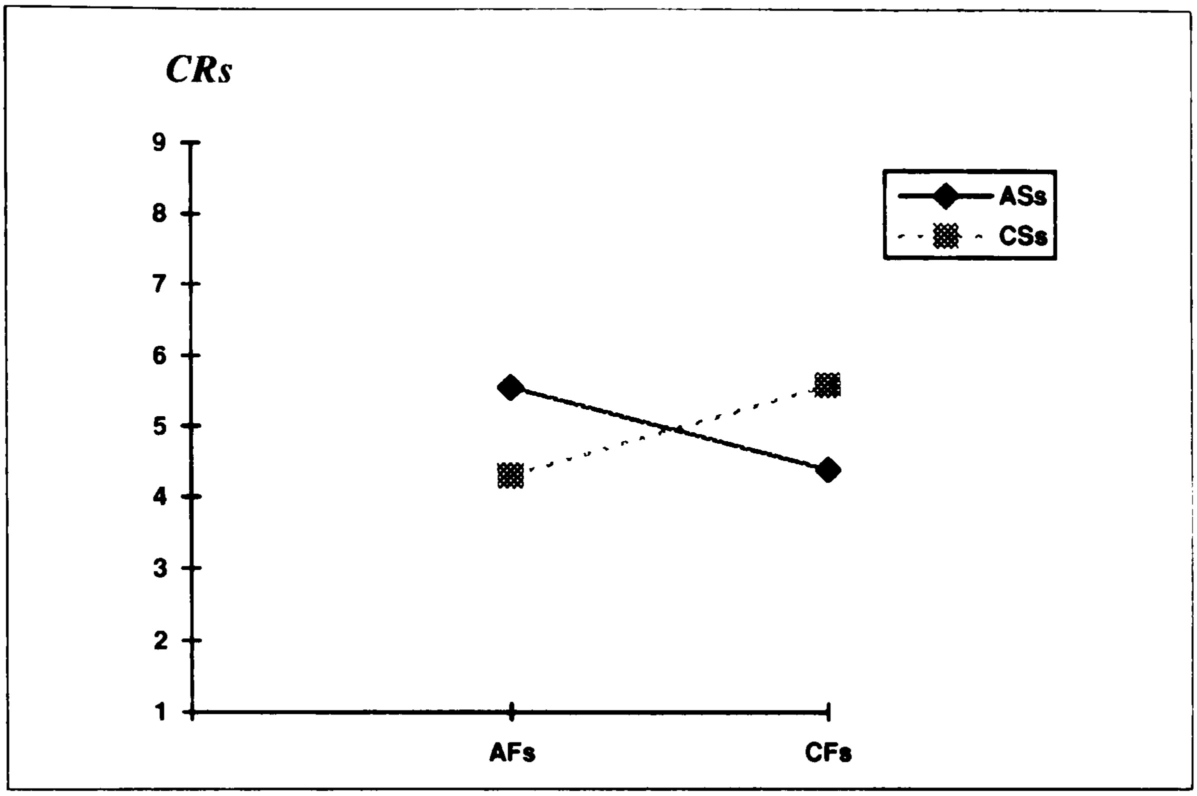
Mean confidence ratings to hits were calculated for each subject on recognition of each category of faces. The mean scores obtained in this experiment are shown in Table 7.5.

Table 7.5. *Mean and standard deviation scores on confidence ratings to hits obtained by HC and LC subjects of each race in experiment 5. [The maximum score is 7. The minimum score is 1. Standard deviations are in parentheses].*

	AFRICAN FACES		CAUCASIAN FACES	
Race of Ss	Dist	Typ	Dist	Typ
Africans				
HC(n=17)	5.69(0.99)	4.21(1.02)	5.19(0.94)	4.32(0.77)
LC(n=17)	5.41(0.65)	4.76(0.85)	4.14(0.90)	3.94(0.79)
Es(n=34)	5.55(0.82)	4.49(0.93)	4.67(0.92)	4.13(0.78)
Caucasians				
HC(n=17)	4.41(0.81)	4.07(1.35)	5.32(0.85)	4.37(0.86)
LC(n=17)	4.90(0.56)	4.60(0.83)	6.41(0.73)	6.43(0.55)
Es(n=34)	4.66(0.69)	4.33(1.09)	5.87(0.79)	5.40(0.71)
Overall	5.10(0.96)	4.66(1.18)	5.27(1.17)	4.76(1.23)

Key: Ss=Subjects, HC=High contact, LC=Low contact, Es=Entire sample, Dist=Distinctive, Typ=Typical

A 2 X 2 X 2 X 2 split-plot ANOVA in which race of subject and contact group were between-subjects factors and race of face and distinctiveness were within-subjects factors was carried out on the mean confidence data. The predicted interaction between race of subject and race of face was significant ($F(1,64)=22.95$, $p=.0001$). This interaction is shown in Figure 7.4.

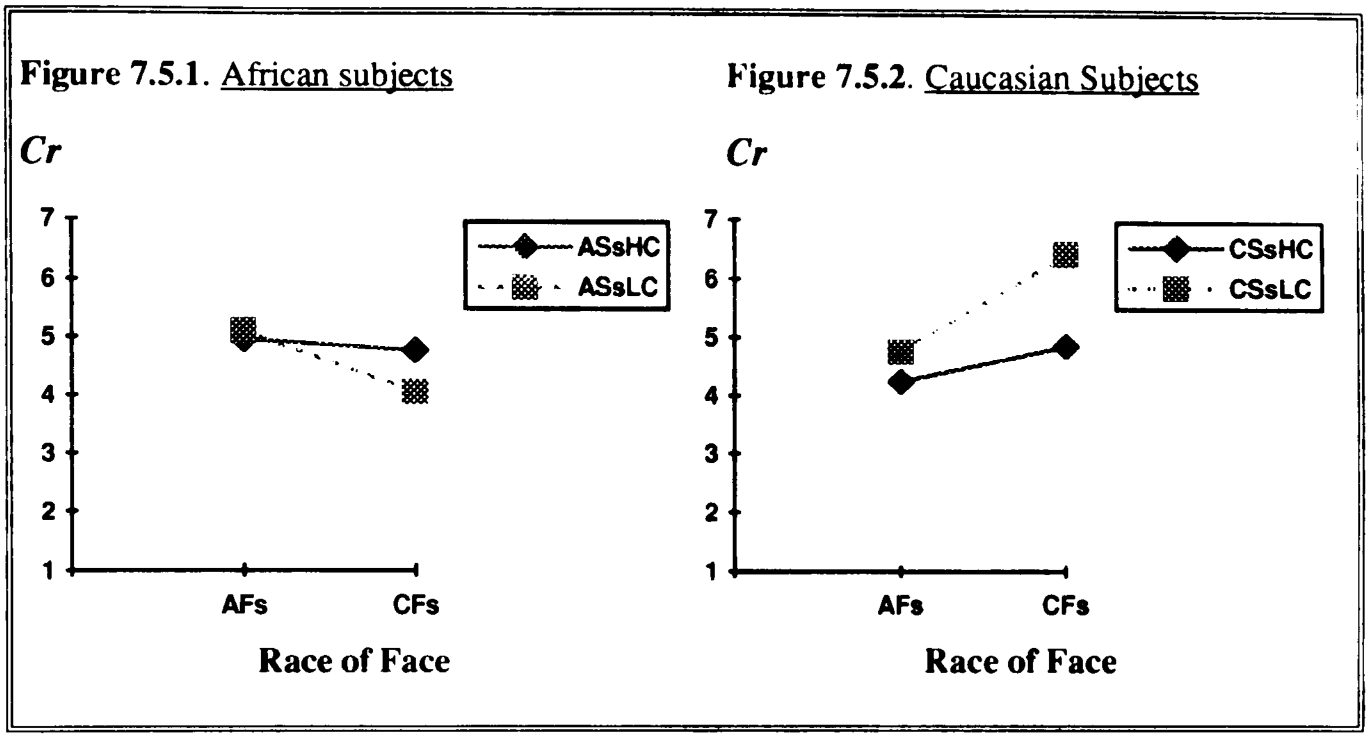


ASs = African subjects, CSs = Caucasian subjects, AFs = African faces
CFs = Caucasian faces, CRs = Confidence ratings.

Figure 7.4. *A graph showing a significant interaction between race of face and race of subject obtained from an analysis of confidence ratings to hits in experiment 5.*

Subjects were significantly more confident in their correct responses to own-race target faces than they were in their correct responses to other-race target faces. The main effect of distinctiveness was significant (F(1,64)=22.32, p=.0001). Subjects were significantly more confident in their correct responses to distinctive faces than they were in their correct responses to typical faces. Also, the predicted three-way interaction involving race of subject, contact group, and race of face was significant (F(1,64)=10.41, p=.002). This interaction is shown in Figure 7.5.

Figure 7.5. *Graphs showing a significant three-way interaction involving race of subject, contact group and race of face obtained from an analysis of confidence ratings in experiment 5.*



Key: AFs= African faces, CFs=Caucasian faces, ASsHC=African subjects, high contact group, ASsLC=African subjects, low contact group, CSsHC=Caucasian subjects, high contact group, CSsLC=Caucasian subjects, low contact group, Cr = Confidence ratings.

It is apparent from figure 7.5.1 above that while the low contact African subjects were significantly more confident in their correct responses to African faces than to Caucasian faces, the high contact African subjects showed comparable levels of confidence in their correct responses to both African and Caucasian faces. However, the HC Caucasian subjects were significantly more confident in their correct responses to own-race faces than they were in their correct responses to African faces while the low contact Caucasian subjects showed an even stronger own-race bias in their confidence ratings to correct responses to targets (see Figure 7.5.2.).

7.2.3. DISCUSSION

The main objective of this study was to test the contact hypothesis of the own-race bias in face recognition and to establish whether the effect of distinctiveness in recognition memory for faces interacts significantly with race of subject, contact group and race of face. Four predictions were tested: (i) a significant crossover interaction between race of subject and race of face, (ii) a significant three-way interaction involving race of subject, contact group and race of face, (iii) a significant main effect of distinctiveness, and (iv) a significant four-way interaction involving race of subject, contact group, race of face and distinctiveness.

The predicted cross-over interaction between race of subject and race of face was significant on all the three measures of recognition accuracy and on confidence ratings. Black-African subjects were significantly more accurate and more confident in their recognition of African faces than they were in their recognition of Caucasian faces. Similarly, Caucasian subjects were significantly more accurate and more confident in their recognition of Caucasian faces than they were in their recognition of African faces. Thus, a significant own-race bias in face recognition was found among subjects of both races. This result is consistent with previous studies that have investigated the own-race bias in face recognition (Brigham & Barkowitz, 1978; Ellis & Deregowski, 1981; Barkowitz & Brigham, 1982; Brigham & Malpass, 1985; Caroo, 1986, 1987; Bothwell, Brigham & Malpass, 1989; Valentine & Endo, 1991).

The predicted three-way interaction involving race of subject, contact group and race of face was significant on hits, on false positives, on A' scores and on confidence ratings. Evidence for the contact hypothesis of the own race bias in face recognition was particularly strong among black-African subjects. HC African subjects were significantly more accurate and more confident in their recognition of Caucasian faces than were LC African subjects. However, HC African subjects showed an unexpectedly lower level of recognition performance on African faces.

The predicted four-way interaction involving race of subject, contact group, race of face and distinctiveness was significant on false positives and on A' scores. For the LC African subjects, the effect of distinctiveness was confined to recognition of own-race faces while for HC African subjects, a significant effect of distinctiveness was found on recognition of faces of both races. Also, while for the LC Caucasian subjects the effect of distinctiveness was confined to recognition of own-race faces, HC Caucasian subjects showed a significant effect of distinctiveness on recognition of faces of both races. This interaction supported Valentine's (1991b) proposition that the effect of distinctiveness in recognition memory for faces is a function of subjects' degree of contact with faces of a given population of faces.

It should be noted that in this experiment, there was a significant main effect of race of face on false positives and on A' scores. Overall, Caucasian faces were better remembered than black-African faces. This result is not altogether surprising. Valentine and Endo (1991) also found a significant main effect of race of face in a study involving recognition of Caucasian and Japanese faces by Caucasian and Japanese subjects. This may be evidence that African faces and Oriental faces are inherently more difficult to recognise than Caucasian faces. However, such a conclusion cannot be justified on the basis of the results of the present study. First, the interaction between race of subject, contact group and race of face was significant on false positives, on hits and on A' scores. A closer examination of the data revealed that this interaction resulted from the fact that HC African subjects were significantly more accurate than LC African subjects in their recognition of Caucasian faces but significantly less accurate than LC African subjects in their recognition of African faces and no effect of contact was observed for Caucasian subjects. Thus, the significant main effect of race of face could be explained in terms of this rather unexpected result.

In conclusion, these results clearly support the existence of an own-race bias in face recognition. They also support the contact hypothesis of the own-race bias in face recognition especially in the case of black African subjects. However, the reduction in the own-race bias demonstrated by HC African subjects on recognition of Caucasian faces appears to have been achieved at a cost of reduced recognition accuracy for own-race (African) faces. Although this effect was not predicted, it might follow from an implementation of the multidimensional space framework in terms of connectionist models using distributed representations. According to these models, after having learnt faces of the own race, if a large number of faces from a different population are encoded within the same network, the statistical structure of the sample of all faces stored in the network might change (*see* Valentine & Ferrara, 1991; O'Toole, Abdi, Deffenbacher & Bartlett, 1991; O'Toole, Deffenbacher, Abdi & Bartlett, in press). This change might benefit recognition of the 'minority' race of faces encountered but be less optimal for encoding faces of the 'majority' race which existed previously.

The present study is, to my knowledge, the first to examine the effect of contact with other-race faces on recognition of distinctive and typical own-race and other-race faces using a multifactor cross-cultural design. Future experimental work on the own-race bias in face recognition could produce clearer results if RT data are also collected. This would enable the investigator to check whether or not the obtained results are affected by a speed-for-accuracy trade-off. Reaction time data could have been collected in the present study had the power supply unit which controlled the external digital clock not blown off during the first few trials in Zimbabwe. Replacements could not be obtained and the digital clock could not be repaired in time.

Part V

EXPERIMENTAL WORK 4

CHAPTER EIGHT

DIFFERENCES BETWEEN GOOD AND POOR FACE RECOGNISERS

8.1. Introduction

Experiments on face recognition can be divided into two categories: (i) experiments in which the *same* photographs of target faces are presented during study and at test, and (ii) experiments in which *different* photographs of target faces are shown at test. According to Hay and Young (1982), the first category of experiments assess 'stimulus recognition of faces' (i.e. memory for a specific photograph of a face). Hay and Young (1982) argued that these experiments do not measure face recognition 'proper' (i.e. a subject's ability to recognise a face in different views or in different facial expressions).

Theoretically, this distinction is important in differentiating 'pictorial' encoding of faces from 'structural' encoding of faces (Bruce & Young, 1986). Bruce and Young (1986) describe a *pictorial* code of a face as one which 'captures the static pose and expression portrayed in a face'. While the creation of pictorial codes of faces is vital in early visual processing of faces, the ability to recognise a face in different views and in different facial expressions requires subjects to successfully create view-independent and expression-independent representations of the face in memory. These representations, which take a more abstract form, mediate recognition of familiar faces in everyday life. Thus, Bruce and Young (1986) point out that:

> 'Studies of face memory which use the same pictures at presentation and at test may tell us as much about picture memory generally as about face recognition. Pictorial coding is of little importance in everyday life, where faces are seldom encountered under identical conditions' (p.307).

The distinction between 'stimulus' recognition of faces and 'true' face recognition is now widely accepted among most experimental psychologists working on face memory (see Bruce's 1988 and Young & Bruce's 1991 reviews). As Bruce and Young (1986) pointed out, the relevance of this distinction lies '... in the interpretation of much of the research literature on face recognition, and in the design of future experiments' (p.307). However, it is not exactly clear whether in testing 'true' face recognition, the target faces should be changed in facial expression, in view, or in both facial expression and in view at test.

In some studies, test lists in which the target faces are shown in different facial expressions between study and test have been used (e.g. Valentine & Bruce, 1986b; Valentine, 1991b; Valentine & Endo, 1991) while in other studies, investigators have changed either the target face's view, or both its view and facial expression at test (e.g. Baddeley & Woodhead, 1983). In many other experiments, investigators have continued to use the <u>same</u> photographs of target faces at test (e.g. Church & Winograd, 1985; Mueller & Thomson, 1985). These inconsistencies pose a major problem as results from one study cannot easily be compared with those of another.

One reason why these inconsistencies still exist in contemporary face recognition research might be the absence of clear experimental evidence to guide researchers towards the choice of 'an appropriate' transformation. Two questions must be addressed before deciding to change a target face's expression, its view, or both its facial expression and view at test. First, it is important to specify more clearly the nature of the internal cognitive processes that make recognition of the same photographs of target faces computationally different from recognition of different photographs of target faces. Secondly, it is critical to know whether recognition of faces following a change in facial expression involves the same or different computational processes from recognition of faces that are shown in different views between study and test.

If different perceptual and memory processes are involved in recognition of faces following a change in facial expression from recognition of faces following a change in view, then, the practical and theoretical implications of using either of these transformations must be carefully examined in designing experiments on face recognition especially under laboratory conditions. There is evidence which suggests that the analysis of facial expression proceeds independently of and in parallel to the determination of the familiarity of a face. Evidence for this comes from neuropsychological dissociations between impairments of identity and expression processing (Bornstein, 1963; Kurucz & Feldmar, 1979) and from experiments which have shown that expression judgements by 'normal' subjects are unaffected by familiarity of the faces (Bruce, 1986; Young, McWeeny, Hay & Ellis, 1985).

The experiments to be described in this chapter investigated individual differences in recognition of transformed and untransformed faces. In experiment 6, the inter-correlations between stimulus recognition of faces, face-matching ability, recognition of faces in different views and recognition of faces in different facial expressions between study and test were explored. In subsequent experiments, an extreme groups design was used to investigate the extent to which individual differences in recognition of faces following a change in view affect recognition of faces that were shown in different facial expressions and in different orientations between study and test.

8.2. EXPERIMENT 6

8.2.1. Aim

The present experiment investigated two questions. First, it was hypothesised that deciding whether two simultaneously presented faces are identical pictures of the same person or not may involve similar computational processes to recognition of the same photographs of target faces at test. To the extent that this hypothesis is correct, subjects' performance on a face-matching task should correlate significantly with their recognition of the same target faces at test.

A linear positive correlation between these two abilities would suggest that stimulus recognition of faces is probably accomplished through a process of matching each face that is shown at test against direct copies of view-dependent *pictorial* representations of faces already held in memory. Recognition of different photographs of target faces at test (e.g. faces changed in view or in facial expression) is unlikely to be accomplished through such a simple matching procedure. Instead, recognition of transformed faces is more likely to require the use of 3D representations of each target face at test. Therefore, while a significant correlation was predicted between face-matching performance and recognition of untransformed photographs of target faces, neither of these two measures were expected to correlate significantly with recognition of faces following a change in facial expression or a change in view.

A second question that is investigated in this experiment is whether recognition of faces following a change in view correlates significantly with recognition of faces following a change in facial expression. If recognition of faces following a change in facial expression requires subjects to make use of the same cognitive skills as recognition of faces in different views, we might expect performance on these two tasks to correlate significantly with one another. However, if recognition of faces in different views requires the use of different perceptual and memory skills from recognition of faces following a change in facial expression (Ellis, 1983, 1986; Calis & Mens, 1986; Bruce, 1986; Young, et al, 1985), performance on these two tasks should not correlate significantly with one another.

8.2.2. Method

8.2.2.1. Subjects

Forty-two high school students who were selected from among the subjects who participated in experiment 4 acted as subjects in this experiment. Twenty-one of the subjects were female and 21 were male.

8.2.2.2. Face Matching Task

Subjects were tested individually in a dimly-lit room. They were shown a series of 16 monochrome slides, each containing two photographs of faces that were mounted side by side. The faces were projected onto a white screen that was placed approximately 2 metres away in front of the subjects. Eight of the slides showed two identical photographs of the *same* face and the other 8 slides contained two photographs of *different* but highly similar faces. The faces were presented in different random orders for every four consecutive subjects. Each slide was shown for up to 5 seconds. The inter-stimulus interval was 2 seconds. Subjects were instructed to respond to each pair of faces by pressing either a "Yes" button for faces which they thought were "of the same person" or a "No" button for faces which they thought were "of two different people". Subjects were instructed to respond to each pair of faces as quickly but as accurately as possible. Each subject's responses were logged by a microcomputer.

8.2.2.3. Face Recognition Tasks

Stimuli. The stimuli set consisted of 96 photographs of Caucasian faces that were mounted on 35mm slides. All the faces that were used in this experiment were unfamiliar to the subjects. For use in the 'same-face' (SF) test condition, a set of 32 faces was used. Each face had been photographed in full-front, unsmiling pose. Sixteen of these faces were used as targets and the other 16 were used as distractors. For use in the 'different-view' (DV) test condition, a different set of 32 faces was used, 16 of which were targets and 16 were distractors. Two slides were prepared for each of the 16 target faces, one in full-face, unsmiling pose and the other in full-profile, unsmiling pose. Sixteen Distractor faces in a full-profile view were also prepared. For use in the 'different-expression' (DE) test condition, another set of 32 faces was used. Two photographs of each face were available, one in a full-front, smiling pose and the other in a full-front, unsmiling pose.

Apparatus. A Kodak (1010) carousel projector was used to present the stimuli to the subjects. The projector was controlled by a BBC (model B) microcomputer which also logged subjects' responses to each face at test.

Procedure. Subjects were tested individually in a dimly-lit room. Separate input lists and test lists were used for each of the three test conditions described above. During study, subjects were shown a list of 16 faces and instructed to study each face carefully in preparation for a subsequent recognition test. Each face was shown for 5 seconds. The inter-stimulus interval was 2 seconds. The recognition test followed immediately after each study list. Each test list consisted of 32 faces, 16 of which were targets and the other sixteen were distractors. The order in which the three tasks were presented was balanced across subjects.

In the SF test condition, the same photographs of target faces were shown during study and at test. In the DV test condition, target faces that were shown in full-front view during study were shown in full-profile view at test and vice versa. In the DE test condition, faces that were shown in a smiling pose during study were shown in an unsmiling pose at test while faces that were shown in an unsmiling pose during study were shown in a smiling pose at test. Each face was shown for 5 seconds. The inter-stimulus interval was 2 seconds. In each test condition, subjects responded by pressing either a "Yes" button for faces which they thought were targets or a "No" button for faces which they thought were distractors. Subjects were instructed to respond to each face as quickly but as accurately as possible. Subjects' responses to each face were logged by the microcomputer.

8.2.3. Results

Four response accuracy scores were calculated for each subject: an *index** of face-matching (FM) performance, an *A'* score on recognition of faces in the SF test condition, an *A'* score on recognition of faces in the DV test condition, and an *A'* score on recognition of faces in the DE test condition. A correlational analysis[16] was performed on this data. The results of this analysis are shown in table 8.1.

Table 8.1.*Correlation coefficients obtained in experiment 6.*

	FMI	ID	DV	DEx
FMI	1.00	.87	.13	.25
ID		1.00	.06	.25
DV			1.00	-.1
DEx				1.00

FMI = Face matching index, **ID** = Recognition of identical target faces, **DV** = Recognition of faces in different views, **DEx** = Recognition of faces in different facial expressions.

The predicted correlation between face-matching performance and recognition of identical photographs of target faces was highly significant ($r=.87$, $p=.0001$). As can be seen quite clearly from Figure 8.1, this relationship was positive and linear. In other words, good face-matching skills tended to be closely associated with high A' scores on recognition of untransformed photographs of target faces while poor face matching skills were closely associated with poorer performance on recognition of untransformed pictures of target faces.

* Total number of correct responses divided by the maximum number of correct responses.

16 The Pearson Product Moment Correlation Coefficient was used.

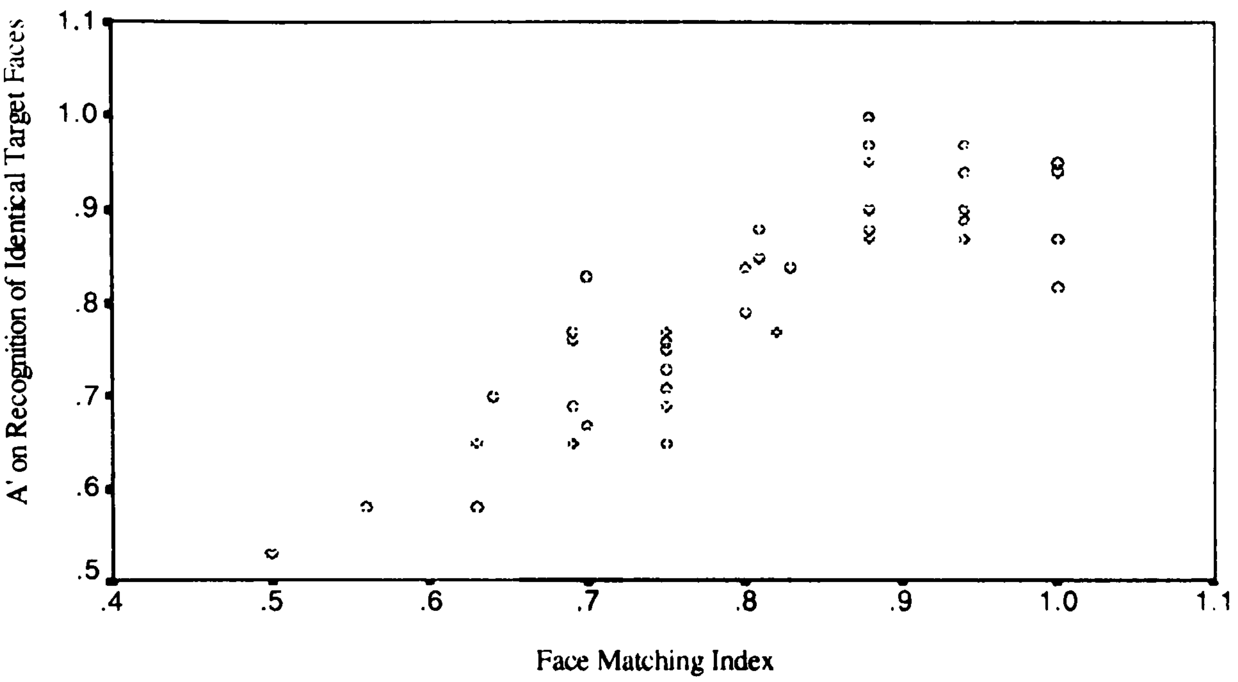


Figure 8.1. *A scatter plot of the correlation between face matching performance and recognition of identical photographs of faces at test obtained in experiment 6.*

However, the correlation between recognition of faces following a change in facial expression and recognition of faces following a change in view was not significant (r=-.10, p=.510). Furthermore, recognition of identical photographs of target faces did not correlate significantly with recognition of faces following either a change in view or a change in facial expression (see figures 8.2 and 8.3).

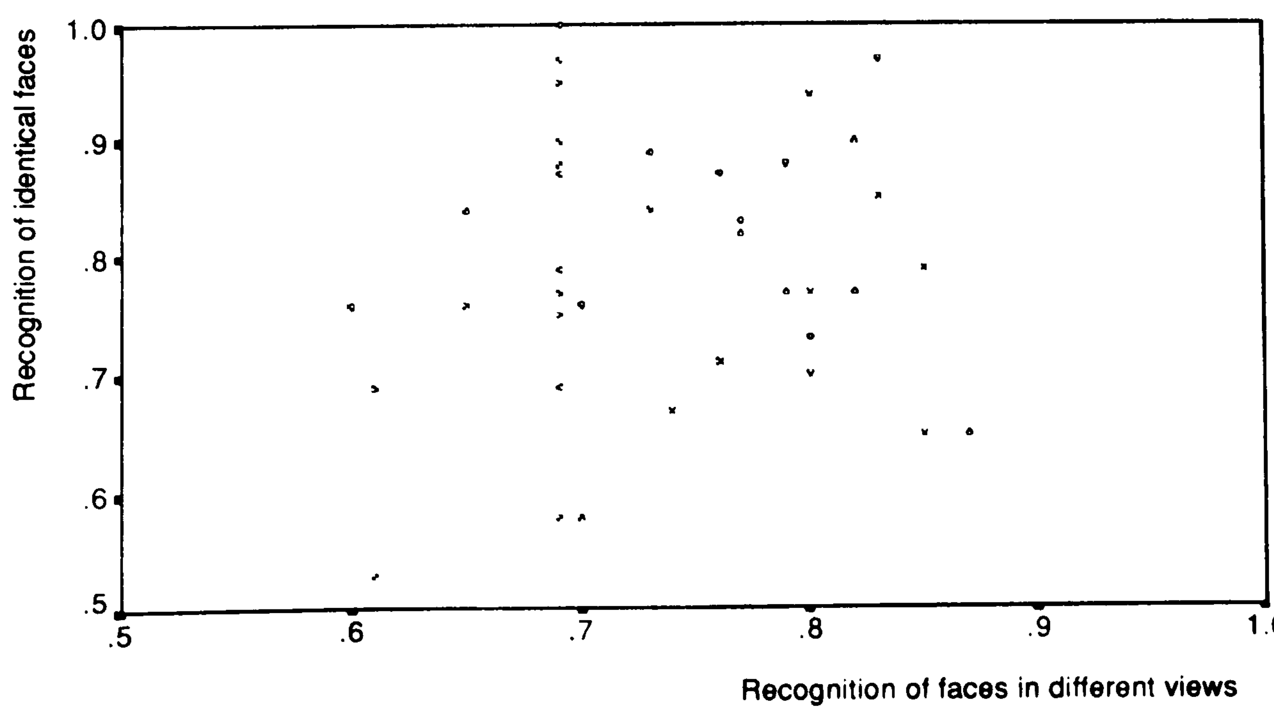


Figure 8.2. *A scatter plot of the correlation between recognition of identical faces and recognition of faces following a change in view obtained in experiment 6.*

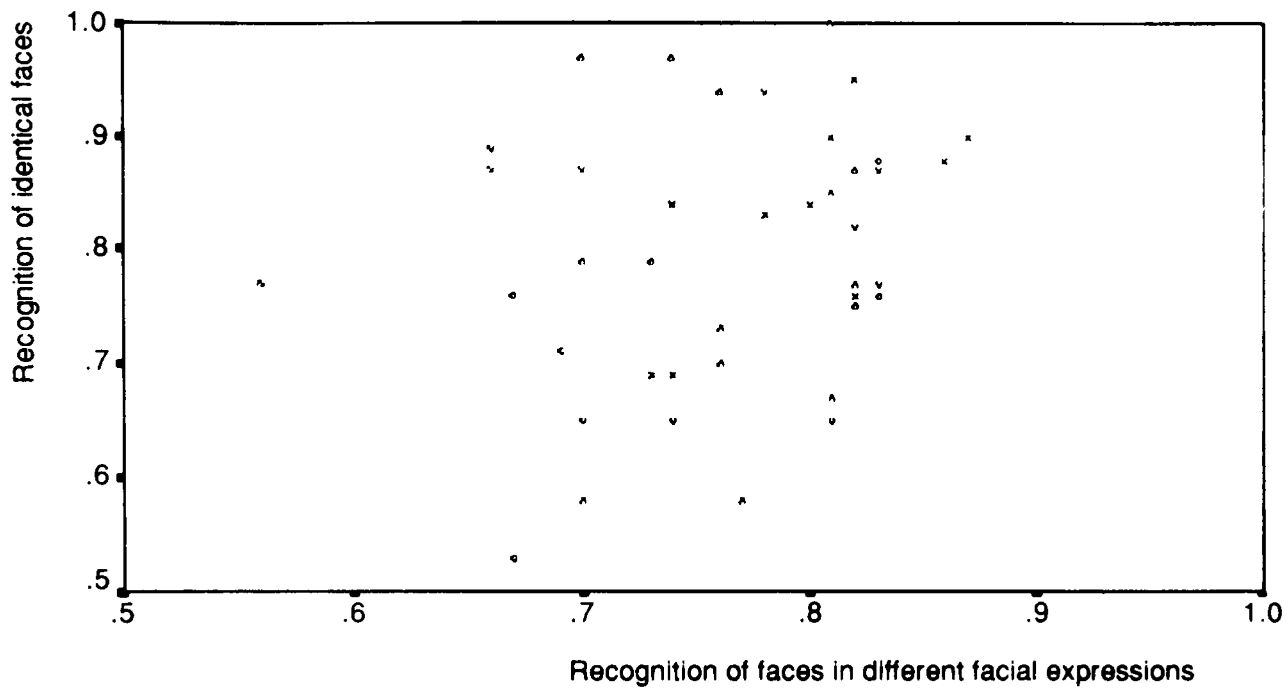


Figure 8.3. *A scatter plot of the correlation between recognition of identical faces and recognition of faces following a change in facial expression obtained in experiment 6.*

8.2.4. Discussion

The main purpose of this experiment was to find out whether subjects' performance on a face matching task would correlate significantly with their recognition of identical photographs of target faces, and whether recognition of faces following a change in facial expression would correlate significantly with recognition of faces following a change in view. The results showed a significant positive linear relationship between face matching performance and recognition of identical pictures of target faces at test. It could be argued, therefore, that this result supports the hypothesis that stimulus recognition of faces might be achieved through a process of matching each face that is shown at test against "direct copies" of view-dependent representations of target faces already held in memory. Also, the results of the present experiment showed no evidence of a significant relationship between face-matching performance and recognition of faces that were shown in different views between study and test, nor did face matching performance correlate significantly with recognition of faces following a change in facial expression. These findings are consistent with Hay and Young's (1982) distinction between recognition of specific photographs of faces and recognition of different photographs of target faces.

The results from the present study also showed that recognition of faces that were shown in different facial expressions between study and test did not correlate significantly with recognition of faces that were shown in different views between study and test. This finding suggests that recognition of faces following a change in view does not involve the same computational processes as recognition of faces following a change in facial expression. This conclusion is consistent with Bruce and Young's (1986) functional model of face processing. According to Bruce and Young (1986), the analysis of facial expression proceeds independently of and in parallel to the creation of view-independent descriptions of the face.

The lack of a significant correlation between recognition of identical target faces and recognition of faces in different views may have been due to the fact that much of the information that is present in a full-front view of a face is unlikely to be available in a full-profile view of the same face (Bruce, Valentine & Baddeley, 1987). As such, it would not be unreasonable to suggest that recognition of faces following a change in view may require subjects to use view-independent representations of the target faces at test while recognition of faces following a change in facial expression requires subjects to encode expression-independent representations of faces. This interpretation suggests that recognition of faces following different kinds of changes to the target face may each involve the use of different skills and/or abilities. In the next experiment, an extreme-groups design is used to examine this issue in more detail.

8.3. EXPERIMENT 7

8.3.1. AIM

The present experiment was designed to replicate and extend the results that were obtained in the previous experiment using a different design, namely, an extreme-groups design. First, eighty-one undergraduates from the University of Manchester were tested for their recognition of a set of 12 target faces that were shown in full-face view during study but in a three-quarter view in a test list in which a further 12 faces in 3/4 view were included as distractors[17].

From these subjects, 16 'good face recognisers' and 16 'poor face recognisers' were selected to take part in this (and the next) experiment. Table 8.2 shows the descriptive statistics for the entire sample of 81 subjects from which the 16 good face recognisers and 16 poor face recognisers were selected. Table 8.3 shows the descriptive statistics for the 32 subjects who participated in the present experiment. Good and poor face recognisers were matched as well as possible in age, spatial ability and verbal ability.

[17] The exposure time for each face was 5 seconds during study and at test. The inter-stimulus interval was 2 seconds.

Table 8.2. *Descriptive statistics for the 81 subjects from whom 16 good face recognisers and 16 poor face recognisers were selected (Verbal Ability and Spatial Ability scores are from the AH5 test of High Grade Intelligence).*

Variable	Minimum	Maximum	Mean
Age	18	45	21.34 (5.82)
Verbal Ability (max=36)	5	20	16.11 (4.80)
Spatial Ability (max=36)	4	29	17.31 (5.16)
Word Memory (A')	.43	.91	00.78 (0.09)
Face Memory (A')	.50	.96	00.81 (0.07)

Table 8.3. *Descriptive data for the 16 good face recognisers and the 16 poor face recognisers who acted as subjects in experiments 7 & 8.*

Variable	Good Face Recognisers	Poor Face Recognisers
Age	19 years (s.d. = 2.34)	20 years (s.d. = 2.43)
Spatial Ability (max=36)	26.56 (s.d. = 4.32)	27.32 (s.d. = 3.98)
Verbal Ability (max=36)	23.45 (s.d. = 3.99)	24.01 (s.d. = 4.01)
Face Memory (A')	00.94 (s.d. = 0.03)	00.67 (s.d. = 0.04)

8.3.2. METHOD

8.3.2.1. Design

A split-plot factorial design in which group was a between-subjects factor and test condition was a within-subjects factor was used in this experiment. Subjects from each group were tested for their recognition of faces under three conditions: (i) recognition of identical photographs of target faces, (ii) recognition of faces that were shown in full-face view at presentation and in full-profile view at test, and (iii) recognition of faces that were shown in an upright orientation during study but in an upside-down orientation at test. The dependent variables were recognition accuracy and response latencies of hits and of correct rejections. It was predicted that while differences in recognition of faces following a change in view would not significantly affect recognition of identical photographs of target faces, 'good face recognisers' would be significantly more accurate and faster than 'poor face recognisers' in their recognition of faces that were shown in full-profile view and in an upside down orientation at test. Therefore, a significant interaction was predicted between group and test condition.

8.3.2.2. Apparatus

Same as for previous experiment.

8.3.2.3. Procedure

Subjects were tested individually in a dimly-lit room. They were informed that they would be shown three sets of faces to try and remember, each followed by a recognition test. Thus, separate input lists and test lists were used for each of the three test conditions described above.

During study, subjects were instructed to study each of the 16 faces carefully in preparation for a subsequent recognition test. Each face was shown for 5 seconds and the inter-stimulus interval was 2 seconds. Each test list contained 32 faces, 16 of which were targets and the other 16 were distractors.

Targets and distractors from each set were shown in different random orders to half of the subjects from each group. In each test condition, subjects responded by pressing either a 'Yes' button for targets or a 'No' button for distractors. Subjects' responses and reaction time to each face were logged by the microcomputer.

8.3.3. RESULTS

8.3.3.1. Recognition Accuracy

Table 8.4 shows the mean number of hits, mean false positives and mean A' scores obtained by good and poor face recognisers in each of the three test conditions of this experiment.

Table 8.4. *Mean number of hits (max=16), mean false positives (max=16) and mean A' scores obtained by good and poor face recognisers in experiment 7.*

	GROUP			
	Good Face Recognisers		Poor Face Recognisers	
	Mean	*S.D.*	*Mean*	*S.D.*
Identical Faces				
Hits	11.69	2.41	12.69	2.73
False Positives	2.81	1.87	2.81	1.83
A'	.84	.09	.86	.08
Different Views				
Hits	10.88	1.36	10.25	1.24
False Positives	3.31	1.78	5.56	1.63
A'	.80	.06	.71	.07
Upside Down Faces				
Hits	10.75	2.05	9.81	1.52
False Poistives	2.25	1.29	3.63	1.63
A'	.84	.06	.77	.07

Hits, false positives and A' scores were analysed separately. In each analysis a split-plot factorial ANOVA in which group was a between-subjects factor and test condition was a within-subjects factor was carried out.

Hits

The main effect of group was not significant (F(1,30)=0.20, p=.65). However, the main effect of task was significant (F(1,30)=9.09, p=.0001). This main effect is shown in figure 8.4.

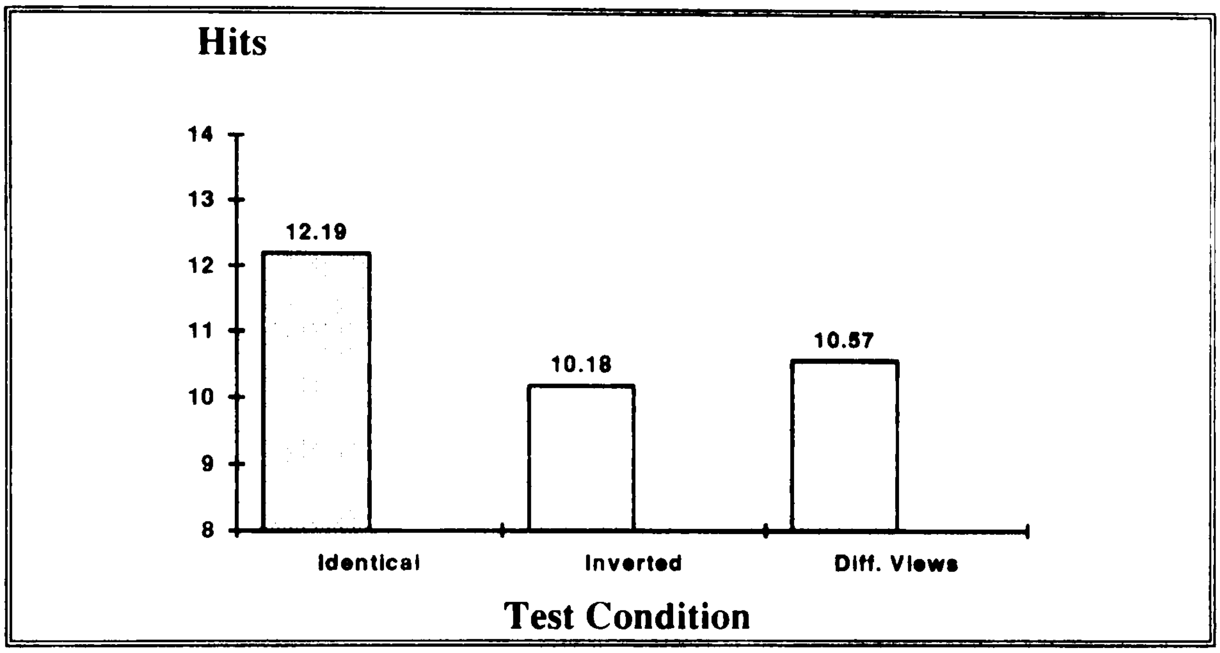


Figure 8.4. *A graph showing a significant main effect of test condition obtained from an analysis of hits in experiment 7.*

A significantly smaller number of hits were made on recognition of transformed target faces than were made on recognition of the same pictures of target faces. The interaction between group and task was not significant (F(1,30)=2.32, p=.11).

False positives

The main effect of group was highly significant (F(1,30)=16.45, p=.0001). Overall, poor face recognisers made a significantly greater number of false positives than were made by good face recognisers. The main effect of task was also significant (F(1,30)=8.22, p=.001). This main effect is shown in Figure 8.5.

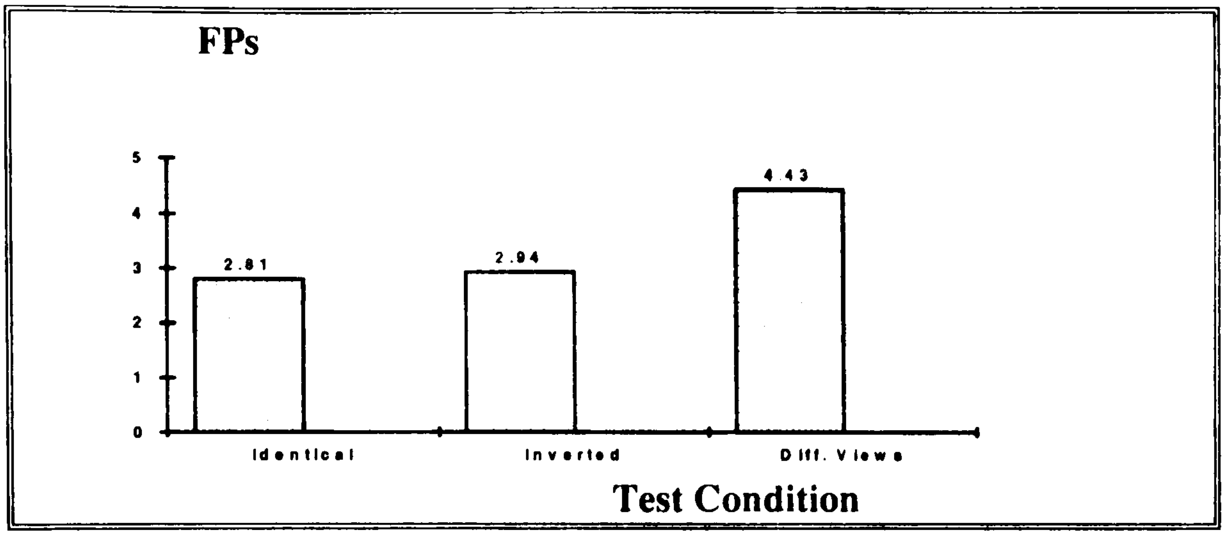
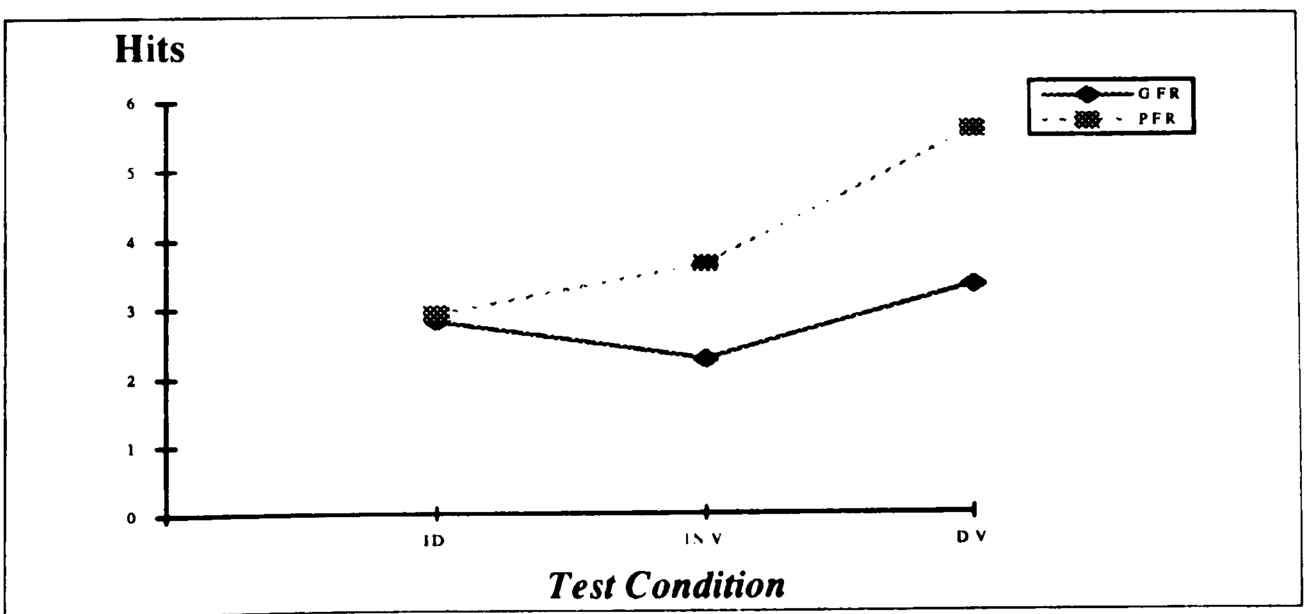


Figure 8.5. *A graph showing a significant main effect of test condition obtained from an analysis of false positives in experiment 7.*

Figure 8.5. shows that fewer false positives were made on recognition of identical target faces than were made on recognition of transformed faces. The interaction between group and test condition was significant (F(1,30)=3.23, p=.04). This interaction is shown in Figure 8.6. It is clear from figure 8.6 that there was no significant difference between good and poor face recognisers in the number of false positives which they made on recognition of identical target faces. However, poor face recognisers made a significantly greater number of false positives than good face recognisers on recognition of transformed faces.



ID = Identical, **INV** = Inverted faces, **DV** = Different view faces

Figure 8.6. *A graph showing a significant interaction between group and test condition obtained from an analysis of false positives in experiment 7.*

A' scores

A significant main effect of group was found (F(1,30)=9.91, p=.004). Good face recognisers were, on the whole, significantly more accurate in their recognition of faces than were poor face recognisers. However, the main effect of test condition was also highly significant (F(1,30)=12.00, p=.0001). This main effect is shown in Figure 8.7.

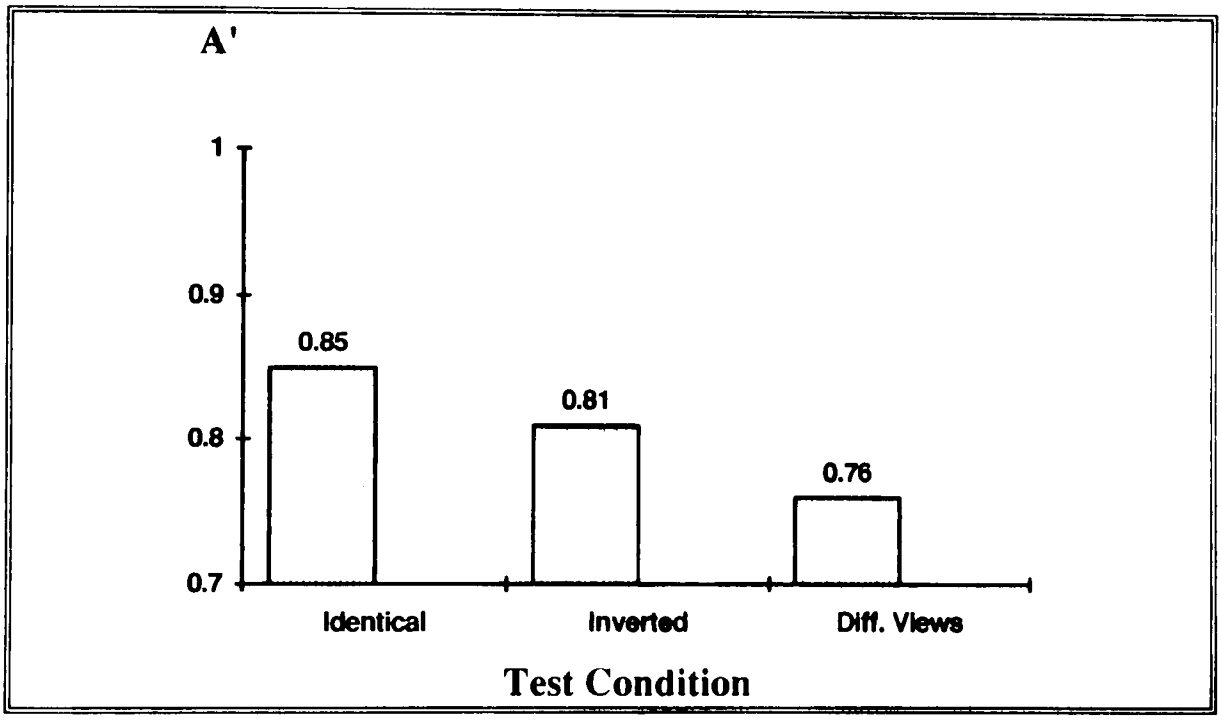
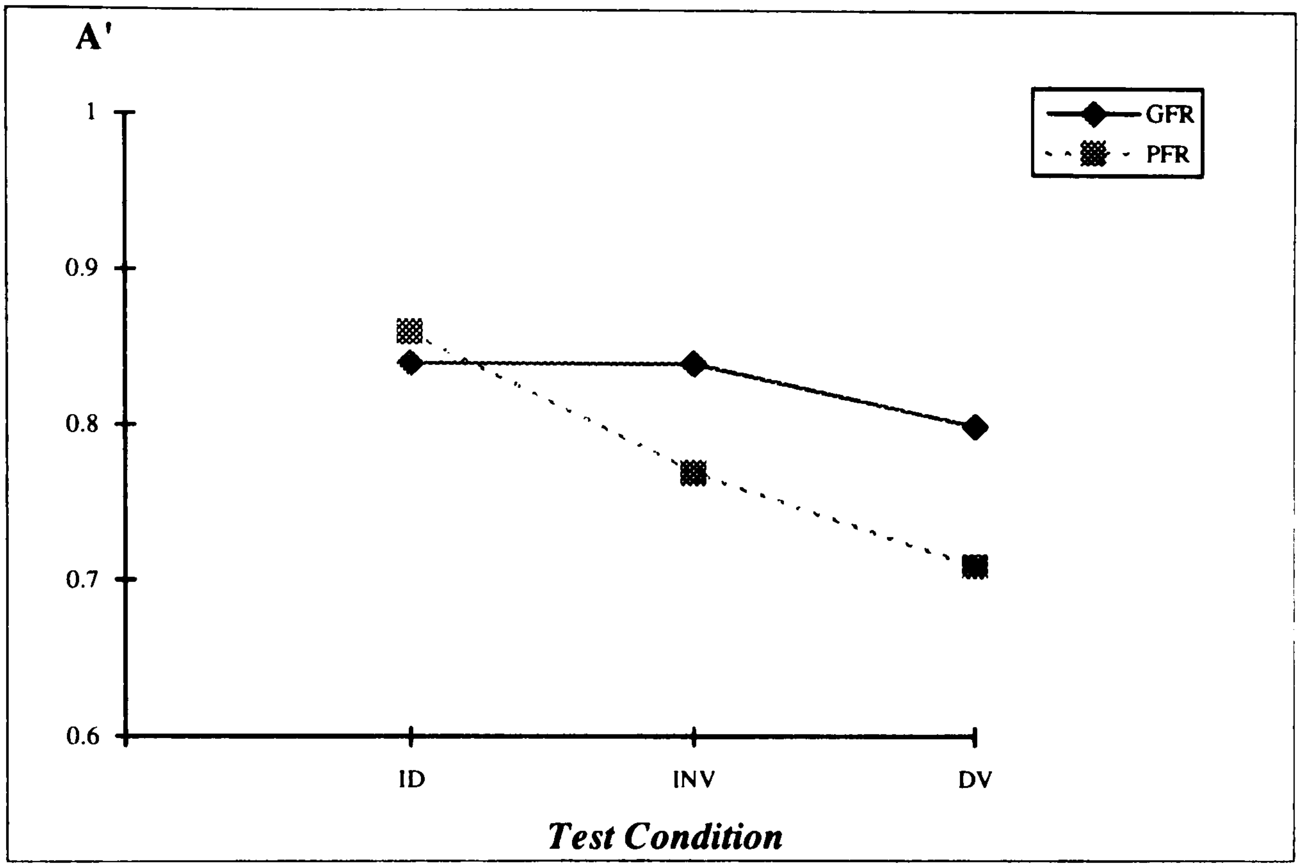


Figure 8.7. *A graph showing a significant main effect of test condition obtained from an analysis of A' scores in experiment 7.*

It clear from figure 8.7 that recognition of transformed faces was significantly less accurate than was recognition of untransformed target faces. Most importantly, group interacted significantly with test condition (F(1,30)=5.17, p=.008). This interaction is shown in Figure 8.8.



ID = Identical, INV = Inverted faces, DV = Different view faces

Figure 8.8. *A graph showing a significant interaction between group and test condition obtained from an analysis of A' scores in experiment 7.*

It can be seen from figure 8.8 that while good and poor face recognisers did not differ significantly in their recognition of identical target faces, good face recognisers were more accurate than poor face recognisers on recognition of faces that were changed either in view or in orientation at test.

8.3.3.2. Response Latencies

Separate split-plot ANOVAs were performed on response latencies of hits and of correct rejections. In each analysis, face recognition ability was a between-subjects factor and test condition was a within-subjects factor. The mean reaction times to correct responses obtained by good and poor recognisers are shown in table 8.5.

Table 8.5. *Mean response latencies of hits and of correct rejections obtained by good face recognisers and poor face recognisers in experiment 7.*

	GROUP			
	Good Face Recognisers		Poor Face Recognisers	
	Mean	*S.D.*	*Mean*	*S.D.*
Reaction Time to Hits				
Identical Faces	991.63	228.27	895.69	113.03
Different Views	1343.13	221.49	1916.63	139.52
Upside Down Faces	1266.19	159.44	1993.19	80.73
Reaction time to CRs				
Identical Faces	1046.13	269.69	955.50	177.11
Different Views	1407.56	196.20	1935.63	108.95
Upside Down Faces	1292.06	146.32	1988.13	125.57

Response latencies of hits

The main effect of group was highly significant ($F(1,30)=114.22$, $p=.0001$). Overall, good face recognisers responded to targets more quickly than did poor face recognisers. The main effect of test condition was also highly significant ($F(1,30)=205.81$, $p=.0001$). This main effect is shown in figure 8.9. It is clear from figure 8.9. that subjects were significantly slower in their correct responses to identical target faces than they were in their correct responses to target faces that were changed in view or in orientation at test.

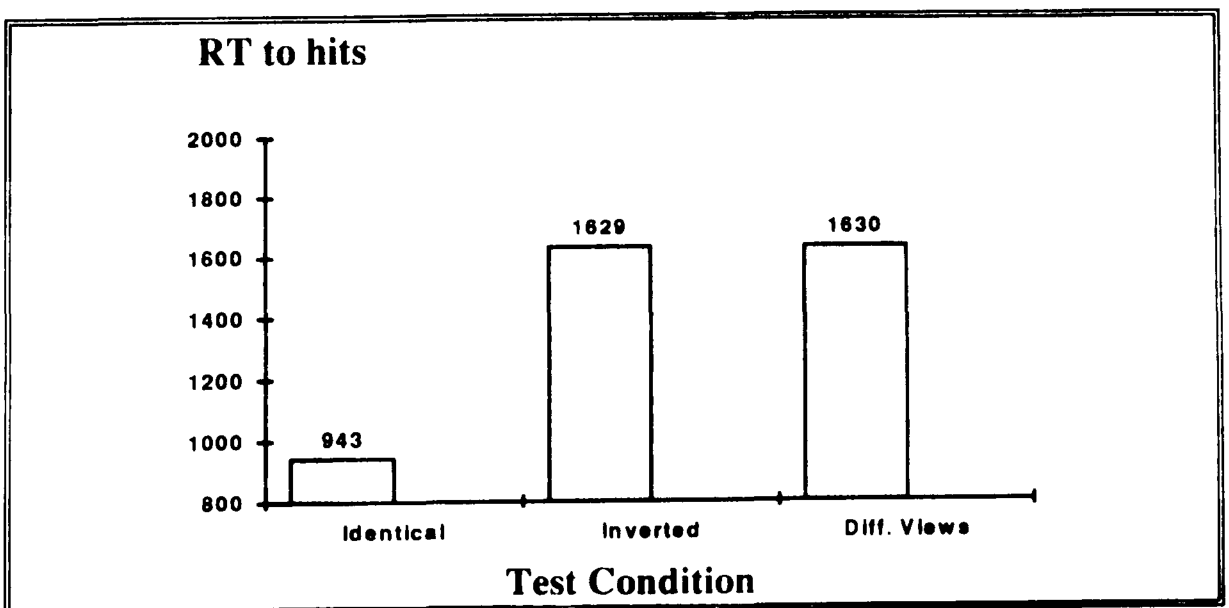


Figure 8.9. *A graph showing a significant main effect of test condition obtained from an analysis of response latencies of hits in experiment 7.*

The interaction between face recognition ability and test condition was also significant (F(1,30)=62.79, p=.0001). This interaction is shown in Figure 8.10.

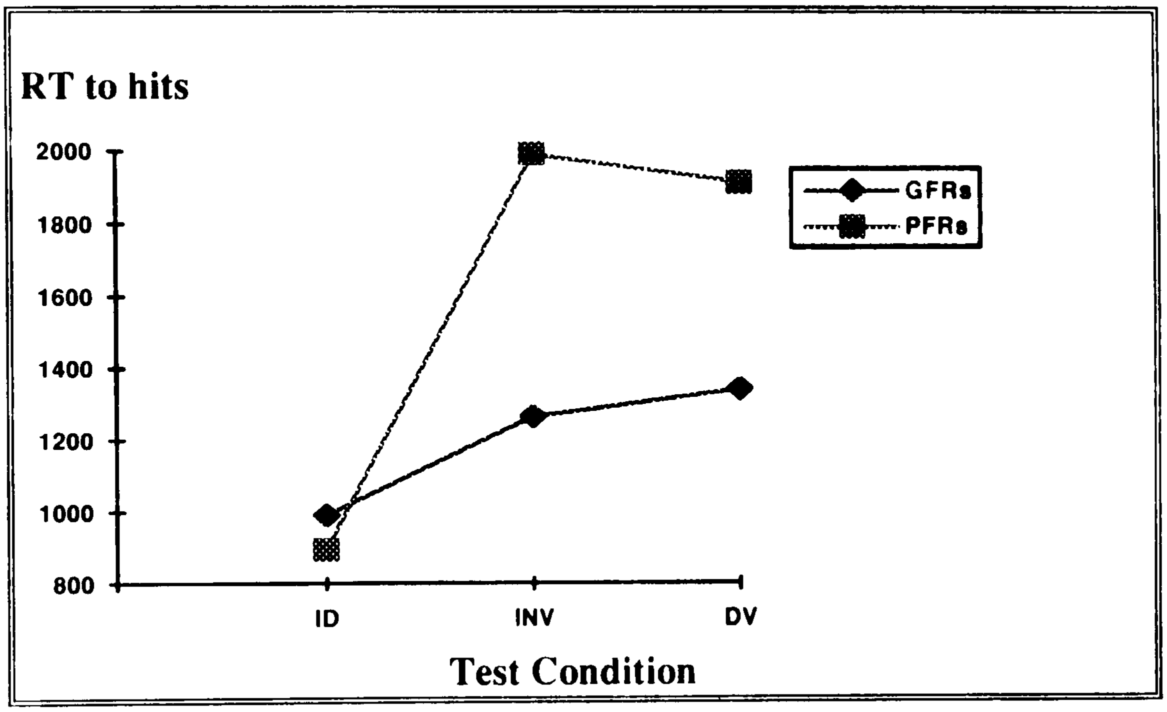


Figure 8.10. *Graphs showing a significant interaction between face recognition ability and test condition obtained from an analysis of response latencies of hits in experiment 7*

It is clear from Figure 8.10 that while the difference in RT to hits was not significant on recognition of identical target faces, good face recognisers responded to transformed target faces more quickly than did poor face recognisers.

Response latencies of correct rejections

The main effect of group was highly significant (F(1,30)=105.77,p=.0001). Correct responses to distractors were made more quickly by good face recognisers than by poor face recognisers. Also, the main effect of test condition was significant (F(1,30)=144.56, p=.0001). This main effect is shown in figure 8.11.

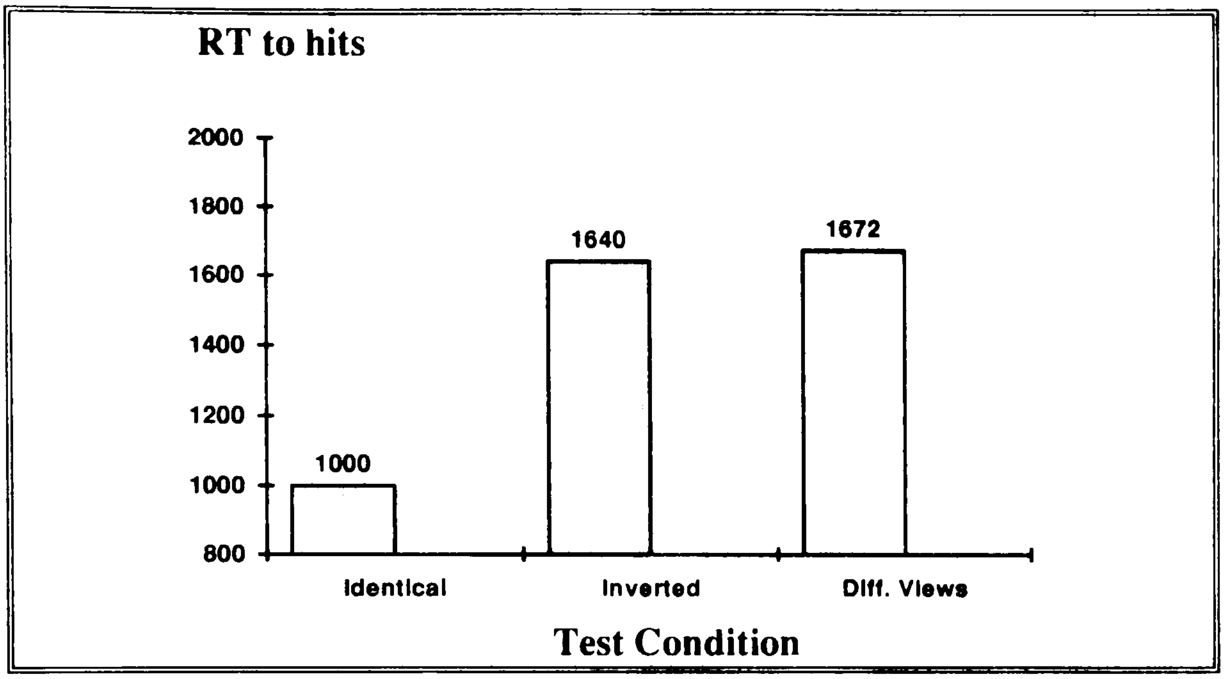


Figure 8.11. *A graph showing a significant main effect of test condition obtained from an analysis of response latencies of hits in experiment 7.*

Subjects were faster to reject distractors in the 'identical targets' test condition than they were to reject distractors in either the 'different views' test condition or in the 'different orientations' test condition. Face recognition ability interacted significantly with test condition ($F(1,30)=43.30$, $p=.0001$). This interaction is shown in figure 8.12.

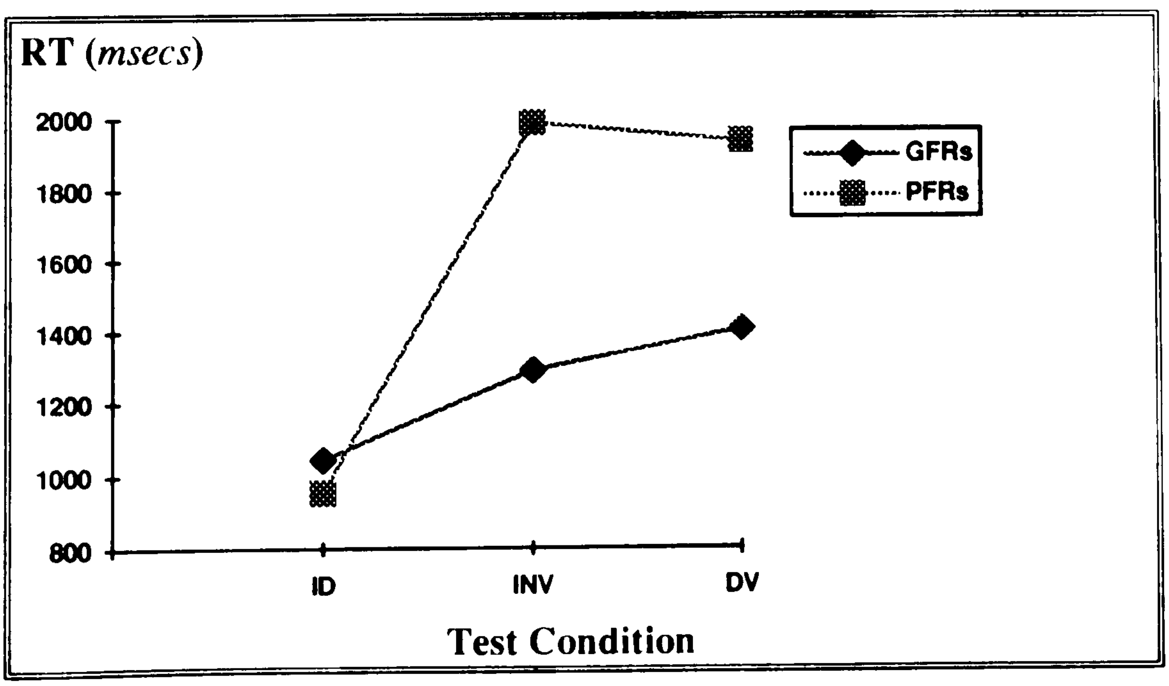


Figure 8.12. *Graphs showing a significant interaction between face recognition ability and test condition obtained from an analysis of response latencies of correct rejections in experiment 7*

While the difference between good and poor face recognisers in their response latencies of correct rejections was not significant in the 'identical targets' test condition, poor face recognisers correctly rejected distractors in the other two conditions more slowly than did good face recognisers.

8.3.4. Discussion

The results of the present experiment replicate and extend the results that were obtained in experiment 6. First, individual differences in recognition of faces following a change in view did not significantly affect subjects' recognition of identical target faces. This is consistent with the lack of a significant correlation between recognition of identical pictures of faces and recognition of faces in different views that was obtained in the previous experiment. Secondly, the results obtained in this experiment showed that individual differences in recognition of faces following a change in view are consistent across tasks. It will be recalled that in the present experiment, subjects were selected on the basis of their recognition of faces that were shown in full-front view at presentation and in three-quarter view at test. Subjects who were 'good' in their recognition of these faces were significantly more accurate and faster to recognise target faces that were shown in full-profile view at test. Furthermore, individual differences in recognition of faces following a change in view also had a significant effect on subjects' recognition of faces that were shown in an upside down orientation at test. These results suggest that recognition of faces following a change in view and a change in orientation may both involve the ability to handle *rigid transformations* of faces. However, recognition of faces following a change in facial expression may require different skills. In the next experiment, the same subjects who participated in the present experiment were tested for their recognition of faces that were shown in different facial expressions between study and test.

8.4. EXPERIMENT 8

8.4.1. AIM

This experiment examined whether subjects who differ significantly in their recognition of faces following a change in view also differ significantly in their recognition of faces following a change in facial expression. It will be recalled that in experiment 6, the correlation between recognition of faces in the DV test condition and recognition of faces in the DE test condition was not significant. Therefore, if this result is robust, individual differences in recognition of faces in different views should not significantly affect recognition of faces that are shown in different facial expressions between study and test.

8.4.2. METHOD

8.4.2.1. Stimuli

The same faces that were used in the DE test condition of experiment 6 were used in the present experiment.

8.4.2.2. Apparatus

The same apparatus that was used in the previous experiment was used in this experiment.

8.4.2.3. Design

An independent groups design in which face recognition ability (group) was a between-subjects design was used in this experiment. The dependent variables were recognition accuracy and response latencies (in milliseconds).

8.4.2.4. Procedure

Subjects were tested individually in a dimly-lit room. During study, 16 faces were presented to the subjects. Eight of these faces showed a smiling expression and the other eight were unsmiling. Each face was shown for 5 seconds. The inter-stimulus interval was 2 seconds. The recognition test followed immediately after initial presentation of target faces. A total of 32 faces were included in the test list. Sixteen of these faces were targets and the other 16 faces were distractors. Targets and distractors were presented in different random orders to half of the subjects in each group. Target faces that were initially presented in a smiling pose were presented in an unsmiling pose at test and vice versa. Half of the Distractor faces in the test list were smiling and the other eight Distractor faces were unsmiling. Each face was shown for 5 seconds. The inter-stimulus interval was 2 seconds. Subjects were instructed to respond to each face by pressing a 'Yes' button for targets or a 'No' button for distractors. Each subject's responses were logged by a microcomputer.

8.4.3. Results and Discussion

The mean data for this experiment are shown in Table 8.6. Separate one-way ANOVAs were carried out on hits, on false positives, on A' scores and on response latencies of hits and of correct rejections.

Table 8.6. *Mean number of hits, mean false positives, mean A' scores, mean response latencies of hits and of correct rejections obtained by good face recognisers and poor face recognisers in experiment 8.*

	GROUP			
	Good Face Recognisers		Poor Face Recognisers	
	Mean	*Std Deviation*	*Mean*	*Std Deviation*
Hits	12.75	1.95	12.94	1.69
False Positives	2.44	1.55	2.44	1.59
A'	.88	.09	.87	.08

It will be recalled that the main purpose of this experiment was to examine whether individual differences in recognition of faces following a change in view would significantly affect recognition of faces that were changed in facial expression at test. Results from the analysis of hits, false positives and A' scores showed no significant main effect of group in this experiment (see Appendices B30, B31 and B32 for ANOVA results). This finding is consistent with the results that were obtained in experiment 6 where a non-significant correlation was found between recognition of faces following a change in view and recognition of faces following a change in facial expression. It could therefore be argued that the results of the present experiment, taken together with the results obtained in experiments 2 and 6 strongly support the view that the analysis of facial expression may indeed involve different perceptual and memory processes from recognition of faces following either a change in view or a change in orientation.

However, the RT data suggested the possibility of a significant trade-off between accuracy and response latencies in the present experiment. The mean response latencies of hits and of correct rejections obtained in this experiment are shown in table 8.7.

Table 8.7. *Mean response latencies obtained by good and poor face recognisers in experiment 8.*

	GROUP			
	Good Face Recognisers		**Poor Face Recognisers**	
	Mean	*Std Deviation*	*Mean*	*Std Deviation*
RT to Hits	1316.81	310.26	1953.47	317.60
RT to Correct Rejections	1910.06	415.38	2819.16	526.88

The main effect of group was significant on RT to hits and on RT to correct rejections (see Appendices B33 and B34). It is therefore possible that poor face recognisers were able to achieve a comparable level of performance to that of good face recognisers by responding more cautiously than good face recognisers. However, a post-hoc correlational analysis performed in order to check whether subjects who took longer before responding tended to be more accurate than subjects who responded more quickly showed no significant correlation between the number of hits and RTs to hits ($r=.02$, $p>.05$) and between the number of correct rejections and RTs to correct rejections ($r=.12$, $p>.05$). Thus, although as a group, poor face recognisers responded to targets and to distractors more slowly than did good face recognisers, there is no evidence that taking longer to inspect each test item actually led to better recognition of targets and rejection of distractors.

8.4.4. GENERAL DISCUSSION

It will be recalled that the purpose of the experiments reported in this chapter was (i) to examine the inter-correlations between subjects' performance in a face-matching task and their performance on *(a)* recognition of the same pictures of target faces at test, *(b)* recognition of faces following a change in *view* and *(c)* recognition of faces following a change in *facial expression*, and (ii) to find out whether individual differences in recognition of faces that were shown in different views between study and test would significantly affect recognition of faces that were shown in different orientations and in different facial expressions between study and test.

In experiment 6, it was hypothesised that deciding whether two simultaneously presented photographs of faces are identical pictures of the same person or not may involve similar encoding processes as recognition of the same pictures of target faces at test. In other words, it was assumed that *stimulus* recognition of faces may, in terms of its computational demands, be just a different form of a 'delayed face-matching' task which, in addition to the perceptual processes necessary for performing a face matching task also involves a small component of memory. It was therefore predicted that subjects' performance in a face-matching task would correlate significantly with their recognition of the same pictures of target faces at test. This hypothesis was supported by a strong positive correlation that was obtained in this experiment between subjects' performance in the face-matching task and their performance on recognition of faces in the 'identical-test' condition. Neither face matching performance nor subjects' recognition of identical target faces correlated significantly with recognition of faces following a change in view or a change in facial expression. These results suggest that recognition *different* photographs of target faces at test require the use of different perceptual and memory skills from recognition of the same pictures of target faces at test, a conclusion that is consistent with Hay and Young's (1982) distinction between *stimulus* recognition of faces and face recognition *proper*.

However, the results obtained in experiment 6 also showed that recognition of faces following a change in *facial expression* did not correlate significantly with recognition of faces following a change in *view*. Furthermore, in experiment 8, subjects who had demonstrated an exceptionally 'good' memory for faces in different views did not differ significantly from subjects who had initially shown 'poorer' recognition of these faces when these two groups of subjects were tested for their recognition of faces that were shown in different facial expressions during study and at test. However, in experiment 7, the 'good' face recognisers were significantly more accurate than the 'poor' face recognisers in their recognition of faces that were shown in different *orientations* between study and test. These findings are consistent with the hypothesis that the analysis of facial expression may operate independently of and in parallel to the determination of the familiarity of a face (Bruce & Young, 1986). Perhaps, while recognition of faces in different views and in different orientations involve the ability to handle rigid transformations by encoding *view-independent* representations of faces, recognition of faces following a change in facial expression may involve a different set of skills.

It is likely that recognition of faces in different facial expressions requires subjects to pay attention to the *invariant* characteristics of a face that remain unaffected when the face changes from an unsmiling expression to a smiling one and vice versa. Changes in facial expression alter a face's configuration due to the 'plasticity' of the muscles and features of the face while changes in view or orientation are rigid transformations which simply alter the kinds of information that can be accessed by the subject. In the case of a change in view (e.g. from full-face to full-profile view) the *type and quantity* of available information changes dramatically while in the case of a change in orientation, the *configuration* of the face's features is altered making it considerably more difficult to determine whether or not a face has been seen before. Therefore, while encoding *expression-independent* representations of faces may be important for recognition of faces that are shown with different facial expressions, it is the *view-independent* representations that are important for recognition of faces following a change in view.

Taken together, the results obtained in this experiment suggest that what Hay and Young (1982) termed face recognition 'proper', while involving different skills from recognition of the same pictures of target faces at test, may itself comprise a number of separate abilities. The experiments reported in this chapter clearly show that a distinction must be made between experiments in which the target faces are changed in view at test and experiments in which the target faces are shown in different facial expressions between study and test.

Part VI

SUMMARY AND CONCLUSION

CHAPTER NINE

Summary and Conclusions

9.1. Introduction

Contemporary laboratory research on memory for faces has tended to disregard individual differences. This trend is not unique to face recognition experiments. The same can also be said for other branches of human experimental psychology[18]. However, there seems to be no empirical justification for this practice, especially in experimental situations where the stimuli that are used are 'socially relevant'. Human faces constitute one such category. There is strong empirical evidence which suggests that people differ substantially is their ability to recognise faces not only in laboratory experiments but also in everyday situations[19]. These differences should, in my view, be taken seriously since they have considerable practical applications[20]. Furthermore, ignoring individual differences in psychological performance in any task fails to acknowledge the diversity in human cognitive abilities that has been demonstrated consistently in psychometric research. Thirdly, our theoretical understanding of the psychological processes that may be involved in human memory for faces can be enhanced by carefully examining differences in face recognition performance that are characteristic of

[18] See section 1.3. of Chapter One of this thesis.
[19] See section 1.3 of Chapter One of this thesis.
[20] See sections 1.4.1 and 1.4.2. in Chapter One of this thesis.

individuals who either possess or do not possess certain specific cognitive attributes or who, through their background and/or social experience, lack or possess exceptional qualities that are rare in the general population[21]. A number of empirically acceptable approaches can be used in this exercise[22]. In the present thesis, individual differences in recognition of faces were studied using standard laboratory experimental techniques.

The purpose of this chapter is to summarise the main empirical findings that emerged from the experiments reported in this thesis and to discuss the theoretical implications of these findings. In section 9.2, experiments which investigated the effect of individual differences in spatial ability on recognition of pictures, faces and words are summarised and discussed. The experiment on adolescents' recognition of male and females faces across two delay conditions which is reported in Chapter Six of this thesis is discussed in section 9.3. Following that, in section 9.4, the cross-cultural study on recognition of distinctive and typical own-race and other-race faces reported in Chapter Seven of this thesis is discussed. Experiments on differences between 'good' and 'poor' face recognisers reported in Chapter Eight are discussed in section 9.5. The limitations of the experiments described in the present thesis and suggestions on how future experimental work on individual differences in face recognition could benefit from the lessons learnt in designing and running these experiments are discussed in each of these sections.

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[21] See section 1.4.2. of Chapter One of this thesis.
[22] See Introduction to Chapter Two of this thesis.

9.2. Spatial Ability Experiments

The experiments reported in Chapter Five investigated the effect of individual differences in spatial ability on recognition of pictures, faces and words. First, 16 high spatial ability (HSA) subjects and 16 Low Spatial Ability (LSA) subjects were selected from a pool of 54 undergraduates who had taken the AH5 Test of High Grade Intelligence (Heim, 1968). These two groups of subjects were then asked to participate in experiments 1, 2, and 3. Experiment 1 showed that HSA subjects were significantly more accurate in their recognition of pictures of houses than were LSA subjects but recognition of high-imagery words was not significantly affected by individual differences in spatial ability. It was argued that these findings support Paivio's dual coding theory of memory according to which different representational processes are thought to mediate visual and verbal memory (Paivio, 1970; 1986; 1990). Having demonstrated that individual differences in spatial ability significantly affect recognition memory for pictures, experiments 2 and 3 were designed and run to test whether recognition of photographs of people's faces is also significantly affected by individual differences in spatial ability.

In experiment 2, high and low spatial ability subjects were tested for their recognition of faces that were either unchanged or showed a different facial expression at test. On the basis of the results obtained in the previous experiment, it was predicted that on the whole, HSA subjects would recognise target faces more quickly and more accurately than would LSA subjects. The results showed significant main effects of spatial ability on hits, on false positives, on A' scores and on response latencies of hits and of correct rejections. High spatial ability subjects recognised target faces and rejected distractors more accurately and more quickly than did low spatial ability subjects.

Secondly, on the basis of Lohman's representational quality hypothesis of individual differences in spatial ability[23], a significant interaction between spatial ability and test condition was predicted in experiment 2. Low spatial ability subjects were expected to be disproportionately impaired in their recognition of faces that were shown in different expressions between study and test compared to HSA subjects. However, the opposite result was obtained. Although the predicted interaction between spatial ability and test condition was significant on hits, on false positives, and on A' scores, tests of simple main effects showed that HSA did not differ significantly from LSA subjects in their recognition of faces that were shown in a different facial expressions at test but that HSA subjects were significantly more accurate than LSA subjects in their recognition of target faces that were unchanged at test. This result was particularly surprising because previous studies[24] have shown that high spatial ability subjects recognise transformed visual stimuli more accurately than low spatial ability subjects.

Therefore, in experiment 3, the same 'high' and 'low' spatial ability subjects who participated in experiment 2 were tested for their recognition of (i) *identical* target faces and (ii) faces that were changed in *orientation* at test. The results of this experiment showed significant main effects of spatial ability and significant interactions between spatial ability and face orientation on false positives, on A' scores and on response latencies of correct rejections. Tests of simple main effects performed on the mean false positives and on

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[23] See Introduction to Chapter Five of this thesis.
[24] See Introduction to Chapter Five of this thesis.

mean A' scores showed that recognition accuracy of upside-down faces was significantly better among HSA subjects than it was among LSA subjects. However, because recognition accuracy of upright unchanged target faces was close to ceiling in this experiment[25], the differences between HSA and LSA subjects were not significant. However, an analysis of the RT data suggested that there may have been a speed-for-accuracy trade-off among the LSA subjects. While the LSA subjects obtained comparable hits, false positives, and A' scores to HSA subjects on recognition of identical upright faces, they were significantly slower to reject distractors than were HSA subjects.

Taken together, these experiments showed that while individual differences in spatial ability had little effect on recognition of words, HSA subjects recognised unchanged pictures of houses and unchanged photographs of faces more accurately and more quickly that did LSA subjects. Also, HSA subjects recognised faces that were shown in an upside-down orientation at test more accurately and more quickly than did LSA subjects. However, individual differences in spatial ability did not significantly affect subjects' recognition of faces that were changed in facial expression at test. It was argued that perhaps, individual differences in spatial ability affect subjects' facility to handle rigid transformations (e.g. a change in orientation, view etc.) but not the ability to process faces that are changed in *facial expression* between study and test.

It would be of interest to investigate more thoroughly the effect of individual differences in spatial ability on recognition of faces following changes in facial expression, changes in view (e.g. from full-face view to 3/4 and full profile views) and changes in age possibly using a correlational design in

[25] (a smaller number of target faces were used in each condition of this experiment than were used in experiment 2 to avoid floor effects on recognition of upside-down faces)

which more than one test of spatial ability is used. Such a study could also include various picture memory tasks and word memory tasks. In a correlational study of this kind, it would be possible to subject the data to a principal component analysis or cluster analysis in order to identify the underlying ability groupings. If this were to be done, it would also be ideal to use larger stimulus sets than were used in the experiments described in this thesis. This would serve to limit the possibility of 'stimulus-sampling' errors either masking robust effects or exaggerating what may, in effect, be quite modest factor loadings.

9.3. Sex and Age Differences in Adolescents' Recognition of Male and Female Faces Across Two Delay Conditions.

Having investigated the effect of individual differences in spatial ability on recognition of pictures and faces in experiments 1, 2, and 3, experiment 4 was designed and run to examine (i) whether male and female adolescents aged 11, 12, and 13 years differ significantly in their recognition of male and female faces across two delay conditions, (ii) whether the developmental dip in face recognition that has been observed among 12-year olds is consistent over a delay of one week, (iii) whether both male and female adolescents aged 12 years show a developmental dip in their recognition of faces of both sexes, and (iv) whether there is a significant own-sex bias in recognition memory for faces among young adolescents.

The Developmental Dip in Face Recognition.

It was hypothesised in experiment 4 that if the developmental dip in face recognition is due to some significant change that occurs to adolescents aged 12 years, this inflection in face memory performance should not only be found when subjects are tested immediately after studying a set of target faces (as is often the case) but should also be present even when a delay of one week is introduced between initial presentation of target faces and test. The results obtained from an analysis of A' scores showed significant main effects of age in both the 'immediate-test' and the 'one-week' delay conditions of experiment 4, suggesting that the developmental dip in face recognition among 12-year olds was present in both delay conditions.

However, a closer examination of the mean A' scores revealed that the developmental dip in face recognition among 12-year olds was confined to female subjects in both delay conditions. Twelve-year old female adolescents were significantly less accurate in their recognition of both male and female faces in both delay conditions than were 11-year olds and 13-year olds[26]. Therefore, although an overall analysis of the A' data obtained in experiment 4 suggested that the developmental dip was significant in both delay conditions, this conclusion was only true for female subjects. The basis of this finding cannot be ascertained from the results obtained in experiment 4. However, one possible explanation could be that if the developmental dip in face recognition is linked to maturational factors such as the onset of puberty (and the hormonal changes that maturation may bring to bear on face encoding[27]), then, perhaps female adolescents mature earlier than male adolescents. It would be of interest in future experiments to test whether this result can be replicated using different subjects and different sets of male and female faces. Also, a review of the current literature on the developmental trend in face recognition could be conducted using techniques such as 'meta-analysis' in order to examine whether the conclusions arrived at in Chapter Six could have been

[26] See Figures 6.8a - 6.8d in Chapter Six of this thesis.
[27] See section 2.2.1. of Chapter Two of this thesis.

deduced from previous studies had the data been analysed separately for male and female subjects.

The Own-Sex Bias In Face Recognition Among Adolescents.

The data that were obtained in experiment 4 showed significant cross-over interactions between sex of subject and sex of face on hits, on false positives and on A' scores. Tests of simple main effects showed that while male subjects did not differ significantly in their recognition of male vs. female faces, female subjects recognised female faces more accurately than they recognised male faces[28]. This was true for both delay conditions. Therefore, it was concluded that the significant interaction between sex of subject and sex of face that was observed in experiment 4 was due to the fact that recognition of female faces was significantly more accurate among female subjects than was recognition of male faces. Male subjects did not show an own-sex bias in their recognition of faces. As pointed out in Chapter Six, it is difficult to provide an uncontroversial theoretical account for this result. However, the social comparison theory[29] proposed by Hoyenga and Hoyenga (1979) could account for this finding.

Proponents of the social comparison theory have suggested that females tend to be more interested in other females' faces because of their greater tendency to compare themselves with other females. It is argued in this thesis that perhaps this tendency might be particularly strong among adolescent females due to the social pressure on 'good looks' exerted on them by their peers, parents and the media in general. If this were indeed the case, one might

[28] See Figures 6.3.,6.5., and 6.7 in Chapter Six of this thesis.

[29] See section 2.2.1. of Chapter Two of this thesis.

expect deeper encoding of female faces among adolescent girls than among adolescent boys of this age. Superficial analysis of both male and female faces by male adolescents may, therefore, account for the comparable but generally poorer performance observed among male subjects on recognition of both male and female faces[30].

Future experimental work could examine this hypothesis further by investigating whether male and female adolescents of this age differ significantly in their recognition of male and female faces under different encoding conditions. For example, in one condition, two comparable groups of adolescent male and female subjects could be asked to make judgements of attractiveness on equal sets of male and female faces during study while in condition two, another two groups of comparable male and female adolescent subjects could be asked to make superficial judgements (e.g. a sex discrimination task) during encoding of the same sets of male and female faces. If the own-sex bias displayed by adolescent female subjects in experiment 4 is due to deeper encoding of female faces during study as a result of more elaborate analysis of female target faces, this effect should be weaker in condition one than in condition two. Furthermore, female subjects in condition one may also show a smaller own-sex bias in face recognition due to their being required to process male faces more elaborately than they otherwise would in an uncontrolled situation.

At a more general level, the results obtained in experiment 4 provide a clear example of how failure to examine sex differences as part of data analysis could lead to incomplete interpretations of results obtained from experiments

30 The main effect of sex of subject was significant on hits.

designed to investigate robust effects such as the developmental dip in face recognition. For instance, if the analysis had been performed simply to test whether or not there is a developmental dip in recognition of faces among 12-year olds, the results obtained in experiment 4 would have confirmed the presence of this effect but it would have remained unknown to the experimenter that this effect is only confined to female subjects and does not generalise to male subjects. Future investigators who may not be interested in the issues raised in the present discussion could also benefit from designing their experiments in such a way as to ensure that there is adequate control over their choice of stimuli and subjects.

9.4. The Own-Race Bias in Face Recognition

Although it has been shown in several studies that subjects recognise faces of their own race more accurately than they recognise faces of other races[31], the theoretical basis of this robust effect has eluded many scientists and philosophers. However, one long-standing hypothesis but one which has not been tested systematically in previous studies of the own-race bias in face recognition is the *contact hypothesis*. Some investigators[32] have sought support for the contact hypothesis of the own-race bias in face recognition by comparing subjects from racially segregated neighbourhoods and subjects from racially integrated neighbourhoods on their recognition of own-race and other-race faces[33]. These studies have often suffered from a number of limitations. First, living in either of these neighbourhoods does not necessarily

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[31] See section 3.3. of Chapter Three of this thesis.
[32] See section 3.3. of Chapter Three of this thesis.
[33] See Introduction to Chapter Seven of this thesis (and also section 3.3 of Chapter Three).

lead to differences in cross-racial experience. Secondly, groups 'created' on the basis of demographic characteristics of an estate where a person lives cannot possibly provide an accurate basis for determining people's cross-racial experience as such categorisation fails to take into account the influence of television, differences in modes of employment and mobility of individuals over time.

In the present thesis, Experiment 5[34] was designed and conducted as a cross-cultural study to circumvent some of these problems and to test the contact hypothesis using groups whose degree of contact with faces of the opposite race could be more objectively specified. The main aim of experiment 5 (in addition to replicating the own race-bias in face recognition) was to find out whether subjects who had a high degree of contact with faces of the opposite race (HC subjects) would show a smaller own-race bias in their recognition of faces than subjects who had a low degree of contact with faces of the opposite race (the LC subjects). A second hypothesis investigated in experiment 5 concerned the extent to which face distinctiveness would interact with race of face, race of subject and contact group.

It has been shown in previous studies[35] that faces that are rated as being 'distinctive' are often remembered more accurately than faces rated to be 'typical'. However, it is not clear from this research whether subjects who have little or no exposure to faces of a given racial group also show an effect of distinctiveness in their recognition of faces of that group. It is also not clear whether this effect is stronger or weaker among subjects who have a high degree of contact with faces of the opposite race than it is among subjects who

[34] described in Chapter Seven of this thesis.

[35] See section 3.4. of Chapter Three of this thesis.

have a low degree of contact with faces of the other race. In designing experiment 5, it was considered an important goal to ensure that answers to these questions could also be obtained from the results as such answers may tell us something about how people learn to recognise individual faces of a different race from that of their own.

High contact African subjects and high contact Caucasian subjects were drawn from a multi-racial college situated in Harare, Zimbabwe. Low contact African subjects were drawn from a rural school located in Southern Zimbabwe, in a remote village where the students at this school were unlikely to have seen a large number of white people. It was much more difficult to obtain a comparable sample of LC Caucasian subjects in the England owing to the large number of Africans who presently live in the United Kingdom. Besides, the popularity of black celebrities in football, athletics and theatre in England (and the West in general) makes them not such a rarity. However, a college located in a small village in North East England was used as a source of subjects who were thought to have a low degree of contact with many black-African people. All the subjects were tested for their recognition of distinctive and typical own-race and other-race faces under comparable experimental conditions.

The results obtained from this study showed a strong overall own-race bias in face recognition among both races of subjects. Significant cross-over interactions were found on hits, on false positives, on A' scores and on confidence ratings to hits. These interactions showed that Caucasian subjects recognised Caucasian faces more accurately and more confidently than they recognised African faces while African subjects recognised African faces more accurately and more confidently than they recognised Caucasian faces.

However, the critical question regarding the effect of *contact* with faces of the opposite race on the own-race bias in face recognition was answered by a significant three-way interaction involving race of subject, contact group and race of face. An examination of the mean A' scores showed that evidence for the contact hypothesis of the own race bias in face recognition was stronger among the African subjects than it was among the Caucasian subjects. LC African subjects were significantly more accurate in their recognition of African faces than they were in their recognition of Caucasian faces (indicating a strong own-race bias in face recognition) while HC subjects showed no significant difference in their recognition of African vs. Caucasian faces. Thus, a high degree of contact with Caucasian faces appeared to have removed the own-race bias among the HC African subjects. However, more accurate recognition of Caucasian faces by the HC African subjects was achieved at a *cost* of reduced recognition accuracy for own-race (African) faces. Although this result was not predicted in experiment 5, it is argued in this thesis that it could be explained by an application of the multidimensional space (MDS) framework of face encoding using connectionist models of distributed representations (O'Toole, *et al*, 1991; O'Toole *et al*, in press).

If we assume that Valentine's MDS framework of face encoding is a reasonable approximation of how faces are encoded in memory, then, it is possible that as one learns to discriminate individual faces of another race, the parameters that are necessary for discriminating own-race faces may be sacrificed, particularly if the racial group whose faces are to be learned exerts a disproportionately more 'powerful' influence on the everyday life of the learner. This was indeed the case at the college from which the HC African subjects were obtained. At that college, nearly four-fifths of the academic and secretarial staff are Caucasians. The demographic characteristics of this college could also explain why Caucasian subjects who were drawn from this college were no better than Caucasian subjects drawn from a village college in England in their recognition of African faces because only a minority of the African members of staff at the college had positions of influence. More direct evidence for this comes from a recent study conducted by Malpass and his associates in South Africa (1993).

Using subjects who were drawn from among employees of a large private bank in South Africa, Malpass and his associates compared administrative (who were all white) and junior clerical staff and cleaners (who were all black South Africans) on their recognition of faces of white and black members of the bank's staff. Malpass and his associates found that in spite of the need to know the individual origins of clerical errors, white managers and senior executives did not recognise their African clerical staff as well as the African juniors recognised their white bosses. It seems to me reasonable, therefore, to suggest that contact alone is not enough. The nature of the contact, the social context within which this contact occurs as well as the *power dynamics* involved need to be closely examined if we are to test the contact hypothesis of the own-race bias in face recognition more precisely.

It will be recalled that experiment 5 also investigated the extent to which face distinctiveness would interact with race of face, race of subject and contact group. The results obtained in experiment 5 showed significant four-way interaction involving race of subject, contact group, race of face and face distinctiveness on false positives and on A' scores[36]. A close examination of the mean A' scores revealed that LC African subjects showed a strong effect of distinctiveness on recognition of own-race (African) faces but no effect of distinctiveness on recognition of other-race (Caucasian) faces while the HC African subjects showed a significant effect of distinctiveness in their recognition of faces of both races. HC Caucasian subjects also showed significant effects of distinctiveness in their recognition of faces of both races while LC Caucasian subjects showed a significant effect of distinctiveness in their recognition of own-race (Caucasian) faces. On the basis of these results, it was argued that the effect of distinctiveness may indeed be a product of learning the parameters that discriminate individual faces of a given population of faces as suggested by Valentine (1991b). Without this knowledge, the LC subjects could not employ the skills necessary for differentiating between distinctive and typical Caucasian faces but the HC subjects could, hence the significant effect of distinctiveness demonstrated by the latter group on recognition of faces of both races. In my view, future experimental work on the own-race bias in face recognition could benefit from a shift of emphasis away from replicating the effect (as has often been the case in many previous studies) to developing and testing theoretical models of how this effect comes about and whether it can be reduced through training people to use appropriate cues when looking at faces of other races. In order that this can be done effectively, it is necessary to know more about the features and/or characteristics of the faces that are used by subjects when they memorise own-race faces. In the case of recognition of African vs. Caucasian faces, the

[36] The effect of distinctiveness was also significant on hits, on false positives, on A' scores and on confidence ratings.

studies conducted by Shephered and Deregowski[37] could provide a reasonable starting point. There is also some work on this currently being conducted by Takashi[38] and his colleagues in Japan.

In conclusion, the results obtained in experiment 5 replicated the own-race bias in face recognition, provided evidence which supported the contact hypothesis particularly in the case of African subjects, and also demonstrated that the effect of distinctiveness in recognition memory for faces may be a product of *learning* the defining characteristics of given population of faces.

9.5. Differences Between Good and Poor Face Recognisers

Since Hay and Young (1982) drew a conceptual distinction between experiments in which the same target faces are shown during study and at test (*stimulus* recognition of faces) and experiments in which *different* photographs of target faces are shown between study and test (face recognition *proper*), there has been a slow but determined shift towards the use of the latter approach by psychologists working on memory for faces in laboratory situations[39]. This distinction is important for distinguishing 'pictorial' from 'structural' encoding of faces (Bruce & Young, 1986). However, there has been little experimental work done on why stimulus recognition of faces should be thought to involve different perceptual and memory skills from recognition of different photographs of target faces at test. Also, it is not clear at present whether the two most commonly used changes in the target faces between study and test (i.e. a change in *view* and a change in *facial expression*) involve the same perceptual and memory skills in standard

[37] See Introduction to Chapter Five of this thesis.
[38] This work has not yet been published.
[39] See Introduction to Chapter Eight of this thesis.

recognition memory experiments. In Chapter Eight of this thesis, an individual differences approach was used to examine both these questions.

Experiment 6 examined the inter-correlations between subjects' performance in a face-matching task and their performance on *(a)* recognition of the same pictures of target faces at test, *(b)* recognition of faces that were changed in *view* at test and *(c)* recognition of faces that were changed in *facial expression* at test. Experiments 7 and 8 were conducted to find out whether individual differences in recognition of faces that were shown in different views between study and test would significantly affect recognition of faces that were shown in different *orientations* and in different *facial expressions* between study and test.

In experiment 6, it was hypothesised that deciding whether two simultaneously presented photographs of faces are identical pictures of the same person or not may involve similar computational processes as recognition of the same pictures of target faces at test. In other words, it was assumed that *stimulus* recognition of faces may, in terms of its computational demands, be just a different form of a 'delayed face-matching' task which, in addition to the perceptual processes necessary for performing a face matching task also involves a small component of memory. It was therefore predicted that subjects' performance on the face-matching task would correlate significantly with their recognition of the same pictures of target faces at test. This hypothesis was supported by a strong positive correlation that was obtained in this experiment between subjects' performance on the face-matching task and their performance on recognition of faces in the 'identical-test' condition. Neither face matching performance nor subjects' recognition of identical target faces correlated significantly with recognition of faces following a change in view or a change in facial expression. It was argued that these results suggest that recognition of *different* photographs of target faces at test require the use of different perceptual and memory skills from recognition of the same pictures of target faces at test, a conclusion that is consistent with Hay and Young's (1982) distinction between *stimulus* recognition of faces and face recognition *proper*.

However, the results obtained in experiment 6 also showed that recognition of faces following a change in *facial expression* did not correlate significantly with recognition of faces following a change in *view*. Furthermore, in experiment 8, subjects who had demonstrated an exceptionally 'good' memory for faces in different views did not differ significantly from subjects who had initially shown 'poorer' recognition of these faces when these two groups of subjects were tested for their recognition of faces that were shown in different facial expressions during study and at test. However, in experiment 7, 'good' face recognisers were significantly more accurate than the 'poor' face recognisers in their recognition of faces that were shown in different *orientations* between study and test. These findings are consistent with the hypothesis that the analysis of facial expression operates independently of and in parallel to the determination of the familiarity of a face (Bruce & Young, 1986). Perhaps, while recognition of faces in different views and in different orientations involve the ability to handle rigid transformations by encoding *view-independent* representations of faces, recognition of faces following a change in facial expression may involve a different set of skills.

It is likely that recognition of faces in different facial expressions requires subjects to pay attention to the *invariant* characteristics of a face that remain unaffected when the face changes from an unsmiling expression to a smiling one and vice versa. Changes in facial expression alter a face's configuration due to the 'plasticity' of the muscles and features of the face while changes in view or orientation are rigid transformations which simply alter the kinds of facial information that can be accessed by the subject. In the case of a change in view (e.g. from *full-face* to *full-profile*), the *type and quantity* of available information changes dramatically while in the case of a change in orientation, the *configuration* of the face's features is altered making it considerably more difficult to determine whether or not the face has been seen before. Therefore, while encoding *expression-independent* representations of faces may be important for recognition of faces that are shown in different facial expressions, it is the *view-independent* representations that appear to be important for recognition of faces following a change in view.

Taken together, the results reported in Chapter Eight suggest that what Hay and Young (1982) termed face recognition 'proper', while involving different skills from recognition of the same pictures of target faces at test, may itself comprise a number of separate abilities. The evidence from the experiments reported in Chapter Eight clearly show that a distinction must be made between experiments in which the target faces are changed in view at test and experiments in which the target faces are shown in different facial expressions between study and test. However, on the basis of these findings alone, it is not possible to make any specific recommendations as to whether experimenters must use a change in facial expression or a change in view at test. More work needs to be done to establish whether changing *both* facial expression and view (perhaps from *full-face* to *three-quarter* view and vice versa) between study and test has the same effect as making only one of these changes[40].

[40] Experiments on this are currently being run.

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APPENDICES

APPENDIX A

Examples of Test Items from the AH5 Test of High Grade Intelligence

A1. Examples of items included in Part I of the AH5 Test of High Grade Intelligence (Heim, 1968).

AH5
Part I

1. Which one of the five words on the right bears a similar relation to each of the two words on the left?

Just. Blonde 1. Light. 2. Only. 3. Unjust. 4. Fair. 5. Brunette.

2. *Hear* is to see as *listen* is to ....1. touch. 2. audit. 4. see. 4. feel 5. look.

3. *Backwards* is to *reversed* as *upside-down* is to ....
1. forwards 2. inside-out 3. right-side-up 4. converse 5. inverted.

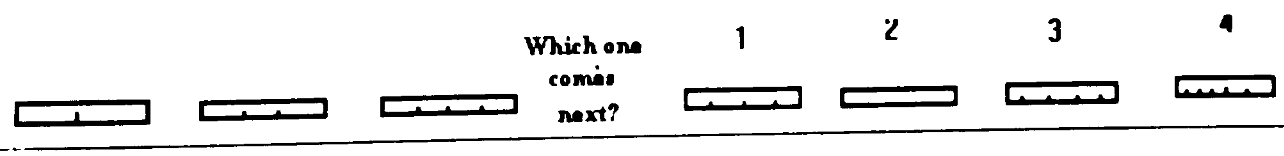
4. Write down the number of the word that would come sixth if the following words were arranged in order, with the longest period on the extreme left:

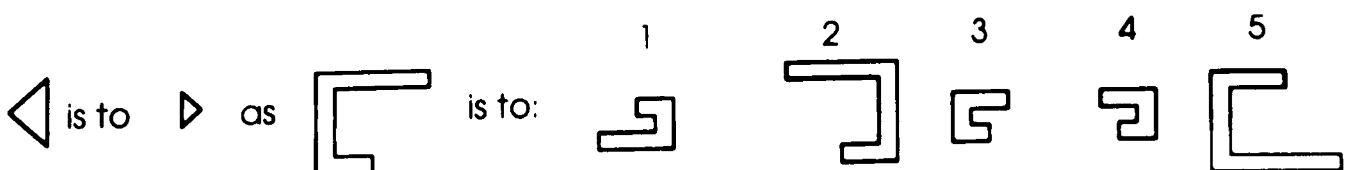
1.Week 2.Year. 3.Hour. 4. Decade 5. Minute. 6. Day. 7.Century. 8. Second. 9. Month.

A.2. Examples of items included in Part II of the AH5 Test of High Grade Intelligence (Heim, 1968).

AH5
Part II

1.


2.


3.


APPENDIX B

Analysis of Variance Tables

Experiment 1 - Anova Tables

B1. A one-way ANOVA table obtained from an analysis of hits on the word memory task in experiment 1.

----- O N E W A Y -----
Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	10.1250	10.1250	.2782	.6017
Within Groups	30	1091.7500	36.3917		
Total	31	1101.8750			

B2. A one-way ANOVA table obtained from an analysis of F.P.s on the word memory task in experiment 1.

----- O N E W A Y -----
Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	.7813	.7813	.0313	.8608
Within Groups	30	749.1875	24.9729		
Total	31	749.9688			

B3. A one-way ANOVA table obtained from an analysis of A's on the word memory task in experiment 1.

----- O N E W A Y -----
Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	.0006	.0006	.1041	.7492
Within Groups	30	.1765	.0059		
Total	31	.1771			

B4. A one-way ANOVA table obtained from an analysis of hits on the picture memory task in experiment 1

----- O N E W A Y -----
Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	36.1250	36.1250	10.6511	.0027
Within Groups	30	101.7500	3.3917		
Total	31	137.8750			

B5. A one-way ANOVA table obtained from an analysis of F.P.s on the picture memory task in experiment 1.

----- O N E W A Y -----
Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	28.1250	28.1250	8.8005	.0059
Within Groups	30	95.8750	3.1958		
Total	31	124.0000			

B6 . A one-way ANOVA table obtained from an analysis of A's on the picture memory task in experiment 1.

- - - - - O N E W A Y - - - - -

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	.1024	.1024	16.7199	.0003
Within Groups	30	.1837	.0061		
Total	31	.2861			

Experiment 2 - Anova Tables

B7. A split-plot ANOVA table obtained from an analysis of hits in experiment 2

```
     * * * * * * A n a l y s i s   o f   V a r i a n c e * * * * * *

Tests of Between-Subjects Effects.

 Tests of Significance for T1 using UNIQUE sums of squares
 Source of Variation          SS      DF        MS         F  Sig of F

 WITHIN CELLS             131.13      28      4.68
 SAG                       43.35       1     43.35      9.26      .005

Tests involving 'COND' Within-Subject Effect.

 Tests of Significance for T2 using UNIQUE sums of squares
 Source of Variation          SS      DF        MS         F  Sig of F

 WITHIN CELLS             149.67      28      5.35
 COND                      30.82       1     30.82      5.77      .023
 SAG BY COND               28.02       1     28.02      5.24      .030

 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
```

B8. A split-plot ANOVA table obtained from an analysis of transformed false positives in experiment 2

```
     * * * * * * A n a l y s i s   o f   V a r i a n c e   * * * * * *

Tests of Between-Subjects Effects.

 Tests of Significance for T1 using UNIQUE sums of squares
 Source of Variation          SS      DF        MS         F  Sig of F

 WITHIN CELLS                .00      28       .00
 SAG                         .00       1       .00      7.97      .009

Tests involving 'COND' Within-Subject Effect.

 Tests of Significance for T2 using UNIQUE sums of squares
 Source of Variation          SS      DF        MS         F  Sig of F

 WITHIN CELLS                .00      28       .00
 COND                        .00       1       .00     37.70      .000
 SAG BY COND                 .00       1       .00      6.72      .015

 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
```

B9. A split-plot ANOVA table obtained from an analysis of transformed A' scores in experiment 2

```
      * * * * * * A n a l y s i s   o f   V a r i a n c e * * * * * *

Tests of Between-Subjects Effects.

 Tests of Significance for T1 using UNIQUE sums of squares
 Source of Variation          SS      DF       MS         F  Sig of F

 WITHIN CELLS               1.41      28      .05
 SAG                         .52       1      .52     10.33      .003

Tests involving 'COND' Within-Subject Effect.
 Tests of Significance for T2 using UNIQUE sums of squares
 Source of Variation          SS      DF       MS         F  Sig of F

 WITHIN CELLS               1.59      28      .06
 COND                       1.30       1     1.30     23.00      .000
 SAG BY COND                 .31       1      .31      5.54      .026

 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
```

B10. A split-plot ANOVA table obtained from an analysis of RT to hits in experiment 2

```
      * * * * * * A n a l y s i s   o f   V a r i a n c e * * * * * *

Tests of Between-Subjects Effects.

 Tests of Significance for T1 using UNIQUE sums of squares
 Source of Variation          SS      DF       MS         F  Sig of F

 WITHIN CELLS        10100537.40      28 360733.48
 SAG                  4221453.75       1 4221453.7     11.70      .002

Tests involving 'COND' Within-Subject Effect.

 Tests of Significance for T2 using UNIQUE sums of squares
 Source of Variation          SS      DF       MS         F  Sig of F

 WITHIN CELLS          249441.93      28   8908.64
 COND                   99633.75       1  99633.75     11.18      .002
 SAG BY COND             4454.82       1   4454.82       .50      .485

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```

B11. A split-plot ANOVA table obtained from an analysis of RT to correct rejections in experiment 2

* * * * * * A n a l y s i s   o f   V a r i a n c e * * * * * *

Tests of Between-Subjects Effects.

Tests of Significance for T1 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	19458961.53	28	694962.91		
SAG	2858856.82	1	2858856.8	4.11	.052

Tests involving 'COND' Within-Subject Effect.

Tests of Significance for T2 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	739275.53	28	26402.70		
COND	66.15	1	66.15	.00	.960
SAG BY COND	34224.82	1	34224.82	1.30	.265

\- -

Experiment 3 - Anova Tables

B12. A split-plot ANOVA table obtained from an analysis of hits in experiment 3

```
      * * * * * * A n a l y s i s   o f   V a r i a n c e * * * * * *

Tests of Between-Subjects Effects.

 Tests of Significance for T1 using UNIQUE sums of squares
 Source of Variation            SS       DF        MS         F  Sig of F

 WITHIN CELLS               108.80       28      3.89
 SAG                           .60        1       .60       .15      .697

Tests involving 'COND' Within-Subject Effect.

 Tests of Significance for T2 using UNIQUE sums of squares
 Source of Variation            SS       DF        MS         F  Sig of F

 WITHIN CELLS                37.33       28      1.33
 COND                        81.67        1     81.67     61.25      .000
 SAG BY COND                   .00        1       .00       .00     1.000

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```

B13. A split-plot ANOVA table obtained from an analysis of false positives in experiment 3

```
      * * * * * * A n a l y s i s   o f   V a r i a n c e * * * * * *

Tests of Between-Subjects Effects.

 Tests of Significance for T1 using UNIQUE sums of squares
 Source of Variation            SS       DF        MS         F  Sig of F

 WITHIN CELLS               119.33       28      4.26
 SAG                         21.60        1     21.60      5.07      .032

Tests involving 'COND' Within-Subject Effect.

 Tests of Significance for T2 using UNIQUE sums of squares
 Source of Variation            SS       DF        MS         F  Sig of F

 WITHIN CELLS                51.33       28      1.83
 COND                        72.60        1     72.60     39.60      .000
 SAG BY COND                  8.07        1      8.07      4.40      .045

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```

B14 . A split-plot ANOVA table obtained from an analysis of transformed A' scores in experiment 3

* * * * * * A n a l y s i s   o f   V a r i a n c e * * * * * *

Tests of Between-Subjects Effects.

Tests of Significance for T1 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	3.18	28	.11		
SAG	.74	1	.74	6.72	.072

Tests involving 'COND' Within-Subject Effect.

Tests of Significance for T2 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	.95	28	.03		
COND	5.07	1	5.07	148.99	.000
SAG BY COND	.32	1	.32	9.31	.005

\- -

B15 . A split-plot ANOVA table obtained from an analysis of RT to hits in experiment 3

* * * * * * A n a l y s i s   o f   V a r i a n c e * * * * * *

Tests of Between-Subjects Effects.

Tests of Significance for T1 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	12385791.73	28	442349.70		
SAG	2972590.00	1	2972590.00	6.72	.128

Tests involving 'COND' Within-Subject Effect.

Tests of Significance for T2 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	5330604.67	28	190378.74		
COND	6307635.27	1	6307635.3	33.13	.000
SAG BY COND	327377.07	1	327377.07	1.72	.200

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B16. A split-plot ANOVA table obtained from an analysis of RT to correct rejections in experiment 3

```
   * * * * * * A n a l y s i s   o f   V a r i a n c e * * * * * *

Tests of Between-Subjects Effects.

 Tests of Significance for T1 using UNIQUE sums of squares
 Source of Variation          SS      DF        MS         F  Sig of F

 WITHIN CELLS         12960487.33     28 462874.55
 SAG                   5985041.67      1 5985041.7     12.93      .001

Tests involving 'COND' Within-Subject Effect.

 Tests of Significance for T2 using UNIQUE sums of squares
 Source of Variation          SS      DF        MS         F  Sig of F

 WITHIN CELLS          3933762.27     28 140491.51
 COND                  8556416.07      1 8556416.1     60.91      .000
 SAG BY COND           1164826.67      1 1164826.7      8.29      .008

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```

Experiment 4 - Anova Tables

B17. A split-plot ANOVA table obtained from an analysis of hits in experiment 4

* * * * * * A n a l y s i s   o f   V a r i a n c e * * * * * *

Tests of Between-Subjects Effects.

Tests of Significance for T1 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	93.07	84	1.11		
AGE	6.69	2	3.34	3.02	.054
SEX	5.62	1	5.62	5.08	.027
AGE BY SEX	2.47	2	1.23	1.11	.333

Tests involving 'DELAY' Within-Subject Effect.

Tests of Significance for T2 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	101.33	84	1.21		
DELAY	112.22	1	112.22	93.03	.000
AGE BY DELAY	14.47	2	7.23	6.00	.004
SEX BY DELAY	.63	1	.63	.52	.474
AGE BY SEX BY DELAY	2.60	2	1.30	1.08	.345

Tests involving 'FSEX' Within-Subject Effect.

Tests of Significance for T3 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	101.00	84	1.20		
FSEX	11.74	1	11.74	9.76	.002
AGE BY FSEX	1.62	2	.81	.67	.512
SEX BY FSEX	11.74	1	11.74	9.76	.002
AGE BY SEX BY FSEX	2.16	2	1.08	.90	.412

Tests involving 'DELAY BY FSEX' Within-Subject Effect.

Tests of Significance for T4 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	97.93	84	1.17		
DELAY BY FSEX	26.14	1	26.14	22.42	.000
AGE BY DELAY BY FSEX	3.49	2	1.74	1.50	.230
SEX BY DELAY BY FSEX	1.22	1	1.22	1.05	.308
AGE BY SEX BY DELAY BY FSEX	.47	2	.23	.20	.819

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B18 . A split-plot ANOVA table obtained from an analysis of false positives in experiment 4

* * * * * * A n a l y s i s o f V a r i a n c e * * * * * *

Tests of Between-Subjects Effects.

Tests of Significance for T1 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	73.23	84	.87		
AGE	17.88	2	8.94	10.26	.000
SEX	2.57	1	2.57	2.95	.089
AGE BY SEX	19.08	2	9.54	10.94	.000

Tests involving 'DELAY' Within-Subject Effect.

Tests of Significance for T2 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	77.39	84	.92		
DELAY	64.55	1	64.55	70.07	.000
AGE BY DELAY	18.94	2	9.47	10.28	.000
SEX BY DELAY	2.25	1	2.25	2.44	.122
AGE BY SEX BY DELAY	1.23	2	.61	.67	.517

Tests involving 'FSEX' Within-Subject Effect.

Tests of Significance for T3 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	72.49	84	.86		
FSEX	310.70	1	310.70	360.06	.000
AGE BY FSEX	4.20	2	2.10	2.43	.094
SEX BY FSEX	26.44	1	26.44	30.64	.000
AGE BY SEX BY FSEX	1.86	2	.93	1.08	.344

Tests involving 'DELAY BY FSEX' Within-Subject Effect.

Tests of Significance for T4 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	76.24	84	.91		
DELAY BY FSEX	218.47	1	218.47	240.70	.000
AGE BY DELAY BY FSEX	.38	2	.19	.21	.811
SEX BY DELAY BY FSEX	2.92	1	2.92	3.22	.076
AGE BY SEX BY DELAY BY FSEX	2.00	2	1.00	1.10	.337

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B19. A split-plot ANOVA table obtained from an analysis of A' scores in experiment 4

* * * * * * A n a l y s i s o f V a r i a n c e * * * * * *

Tests of Between-Subjects Effects.

Tests of Significance for T1 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	.24	84	.00		
AGE	.30	2	.15	52.40	.000
SEX	.00	1	.00	.00	.963
AGE BY SEX	.24	2	.12	42.37	.000

Tests involving 'DELAY' Within-Subject Effect.

Tests of Significance for T2 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	.13	84	.00		
DELAY	1.10	1	1.10	705.96	.000
AGE BY DELAY	.02	2	.01	7.94	.001
SEX BY DELAY	.00	1	.00	1.51	.223
AGE BY SEX BY DELAY	.00	2	.00	1.18	.314

Tests involving 'FSEX' Within-Subject Effect.

Tests of Significance for T3 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	.21	84	.00		
FSEX	.36	1	.36	143.35	.000
AGE BY FSEX	.00	2	.00	.61	.545
SEX BY FSEX	.43	1	.43	169.14	.000
AGE BY SEX BY FSEX	.00	2	.00	.26	.772

Tests involving 'DELAY BY FSEX' Within-Subject Effect.

Tests of Significance for T4 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	.13	84	.00		
DELAY BY FSEX	.01	1	.01	6.26	.014
AGE BY DELAY BY FSEX	.00	2	.00	.15	.865
SEX BY DELAY BY FSEX	.00	1	.00	2.28	.135
AGE BY SEX BY DELAY BY FSEX	.00	2	.00	.68	.509

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Experiment 5 - Anova Tables

B20. A split-plot ANOVA table obtained from an analysis of hits in experiment 5

* * * * * * A n a l y s i s   o f   V a r i a n c e * * * * * *

Tests of Between-Subjects Effects.

Tests of Significance for T1 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	140.62	64	2.20		
SRACE	.13	1	.13	.06	.807
CONTACT	3.31	1	3.31	1.51	.224
SRACE BY CONTACT	.94	1	.94	.43	.515

Tests involving 'FRACE' Within-Subject Effect.

Tests of Significance for T2 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	108.85	64	1.70		
FRACE	9.94	1	9.94	5.84	.018
SRACE BY FRACE	22.37	1	22.37	13.15	.001
CONTACT BY FRACE	1.78	1	1.78	1.05	.310
SRACE BY CONTACT BY FRACE	15.06	1	15.06	8.85	.004

Tests involving 'DIST' Within-Subject Effect.

Tests of Significance for T3 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	76.32	64	1.19		
DIST	7.78	1	7.78	6.52	.013
SRACE BY DIST	7.12	1	7.12	5.97	.017
CONTACT BY DIST	8.47	1	8.47	7.10	.010
SRACE BY CONTACT BY DIST	5.31	1	5.31	4.45	.039

Tests involving 'FRACE BY DIST' Within-Subject Effect.

Tests of Significance for T4 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	65.74	64	1.03		
FRACE BY DIST	2.49	1	2.49	2.42	.125
SRACE BY FRACE BY DIST	.24	1	.24	.23	.634
CONTACT BY FRACE BY DIST	3.76	1	3.76	3.67	.060
SRACE BY CONTACT BY FRACE BY DIST	1.78	1	1.78	1.73	.193

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B21. A split-plot ANOVA table obtained from an analysis of false positives in experiment 5

* * * * * * A n a l y s i s   o f   V a r i a n c e -- design 1 * * * * * *

Tests of Between-Subjects Effects.

Tests of Significance for T1 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	100.29	64	1.57		
SRACE	3.09	1	3.09	1.97	.165
CONTACT	1.62	1	1.62	1.03	.313
SRACE BY CONTACT	.62	1	.62	.40	.531

Tests involving 'FRACE' Within-Subject Effect.

Tests of Significance for T2 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	96.65	64	1.51		
FRACE	17.50	1	17.50	11.59	.001
SRACE BY FRACE	176.33	1	176.33	116.76	.000
CONTACT BY FRACE	25.33	1	25.33	16.77	.000
SRACE BY CONTACT BY FRACE	30.44	1	30.44	20.16	.000

Tests involving 'DIST' Within-Subject Effect.

Tests of Significance for T3 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	96.47	64	1.51		
DIST	30.44	1	30.44	20.20	.000
SRACE BY DIST	.18	1	.18	.12	.731
CONTACT BY DIST	10.33	1	10.33	6.85	.011
SRACE BY CONTACT BY DIST	8.83	1	8.83	5.86	.018

Tests involving 'FRACE BY DIST' Within-Subject Effect.

Tests of Significance for T4 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	61.65	64	.96		
FRACE BY DIST	8.83	1	8.83	9.16	.004
SRACE BY FRACE BY DIST	.44	1	.44	.46	.499
CONTACT BY FRACE BY DIST	.83	1	.83	.86	.358
SRACE BY CONTACT BY FRACE BY DIST	16.50	1	16.50	17.13	.000

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B22. A split-plot ANOVA table obtained from an analysis of A' scores in experiment 5

* * * * * * A n a l y s i s   o f   V a r i a n c e -- design 1 * * * * * *

Tests of Between-Subjects Effects.

Tests of Significance for T1 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	7.59	64	.12		
SRACE	.05	1	.05	.42	.519
CONTACT	.02	1	.02	.20	.659
SRACE BY CONTACT	.09	1	.09	.80	.374

Tests involving 'FRACE' Within-Subject Effect.

Tests of Significance for T2 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	6.32	64	.10		
FRACE	1.63	1	1.63	16.55	.000
SRACE BY FRACE	9.59	1	9.59	97.17	.000
CONTACT BY FRACE	.82	1	.82	8.34	.005
SRACE BY CONTACT BY FRACE	2.27	1	2.27	22.98	.000

Tests involving 'DIST' Within-Subject Effect.

Tests of Significance for T3 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	5.95	64	.09		
DIST	2.09	1	2.09	22.46	.000
SRACE BY DIST	.17	1	.17	1.81	.184
CONTACT BY DIST	.00	1	.00	.05	.825
SRACE BY CONTACT BY DIST	.03	1	.03	.33	.569

Tests involving 'FRACE BY DIST' Within-Subject Effect.

Tests of Significance for T4 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	4.10	64	.06		
FRACE BY DIST	.04	1	.04	.70	.407
SRACE BY FRACE BY DIST	.02	1	.02	.32	.574
CONTACT BY FRACE BY DIST	.18	1	.18	2.85	.096
SRACE BY CONTACT BY FRACE BY DIST	.73	1	.73	11.45	.001

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B23. A split-plot ANOVA table obtained from an analysis of confidence ratings in experiment 5

* * * * * * A n a l y s i s   o f   V a r i a n c e * * * * * *

Tests of Between-Subjects Effects.

Tests of Significance for T1 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	57.09	64	.89		
SRACE	36.05	1	36.05	40.41	.000
CONTACT	38.27	1	38.27	42.90	.000
SRACE BY CONTACT	42.90	1	42.90	48.09	.000

Tests involving 'FRACE' Within-Subject Effect.

Tests of Significance for T2 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	52.61	64	.82		
FRACE	1.20	1	1.20	1.46	.232
SRACE BY FRACE	17.22	1	17.22	20.95	.000
CONTACT BY FRACE	7.04	1	7.04	8.56	.005
SRACE BY CONTACT BY FRACE	8.56	1	8.56	10.41	.002

Tests involving 'DIST' Within-Subject Effect.

Tests of Significance for T3 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	43.58	64	.68		
DIST	15.20	1	15.20	22.32	.000
SRACE BY DIST	.44	1	.44	.64	.426
CONTACT BY DIST	2.39	1	2.39	3.51	.066
SRACE BY CONTACT BY DIST	.28	1	.28	.41	.525

Tests involving 'FRACE BY DIST' Within-Subject Effect.

Tests of Significance for T4 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	36.21	64	.57		
FRACE BY DIST	.06	1	.06	.11	.743
SRACE BY FRACE BY DIST	.14	1	.14	.24	.626
CONTACT BY FRACE BY DIST	3.34	1	3.34	5.90	.018
SRACE BY CONTACT BY FRACE BY DIST	.01	1	.01	.02	.890

- -

Experiment 7 - Anova Tables

B25. A split-plot ANOVA table obtained from an analysis of hits in experiment 7

```
* * * * * * A n a l y s i s   o f   V a r i a n c e * * * * * *

Tests of Between-Subjects Effects.

 Tests of Significance for T1 using UNIQUE sums of squares
 Source of Variation          SS      DF        MS         F  Sig of F

 WITHIN CELLS             123.48      30      4.12
 GROUP                       .84       1       .84       .20      .654

Tests involving 'CONDITION' Within-Subject Effect.

 AVERAGED Tests of Significance for MEAS.1 using UNIQUE sums of squares
 Source of Variation          SS      DF        MS         F  Sig of F

 WITHIN CELLS             223.58      60      3.73
 CONDITION                 67.77       2     33.89      9.09      .000
 GROUP BY CONDITION        17.31       2      8.66      2.32      .107

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```

B26. A split-plot ANOVA table obtained from an analysis of false positives in experiment 7

```
* * * * * * A n a l y s i s   o f   V a r i a n c e * * * * * *

Tests of Between-Subjects Effects.

 Tests of Significance for T1 using UNIQUE sums of squares
 Source of Variation          SS      DF        MS         F  Sig of F

 WITHIN CELLS              63.92      30      2.13
 GROUP                     35.04       1     35.04     16.45      .000

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Tests involving 'CONDITION' Within-Subject Effect.

 AVERAGED Tests of Significance for MEAS.1 using UNIQUE sums of squares
 Source of Variation          SS      DF        MS         F  Sig of F

 WITHIN CELLS             191.08      60      3.18
 CONDITION                 52.33       2     26.17      8.22      .001
 GROUP BY CONDITION        20.58       2     10.29      3.23      .046

 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
```

B27. A split-plot ANOVA table obtained from an analysis of A' scores in experiment 7

```
* * * * * * A n a l y s i s   o f   V a r i a n c e * * * * * *

Tests of Between-Subjects Effects.

 Tests of Significance for T1 using UNIQUE sums of squares
 Source of Variation              SS       DF        MS          F  Sig of F

 WITHIN CELLS                    .13       30       .00
 GROUP                           .04        1       .04       9.91      .004

Tests involving 'CONDITION' Within-Subject Effect.

 AVERAGED Tests of Significance for MEAS.1 using UNIQUE sums of squares
 Source of Variation              SS       DF        MS          F  Sig of F

 WITHIN CELLS                    .35       60       .01
 CONDITION                       .14        2       .07      12.00      .000
 GROUP BY CONDITION              .06        2       .03       5.17      .008

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```

B28. A split-plot ANOVA table obtained from an analysis of RT to hits in experiment 7

```
* * * * * * A n a l y s i s   o f   V a r i a n c e * * * * * *

Tests of Between-Subjects Effects.

 Tests of Significance for T1 using UNIQUE sums of squares
 Source of Variation              SS       DF        MS          F  Sig of F

 WITHIN CELLS             1016270.31       30   33875.68
 GROUP                    3869255.51        1  3869255.5     114.22      .000


Tests involving 'CONDITION' Within-Subject Effect.

 AVERAGED Tests of Significance for MEAS.1 using UNIQUE sums of squares
 Source of Variation              SS       DF        MS          F  Sig of F

 WITHIN CELLS             1463937.25       60   24398.95
 CONDITION               10043040.90        2  5021520.4     205.81      .000
 GROUP BY CONDITION       3063826.52        2  1531913.3      62.79      .000

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```

B29. A split-plot ANOVA table obtained from an analysis of RT to correct rejections in experiment 7

```
* * * * * * A n a l y s i s   o f   V a r i a n c e * * * * * *

Tests of Between-Subjects Effects.

 Tests of Significance for T1 using UNIQUE sums of squares
 Source of Variation          SS      DF        MS          F  Sig of F

 WITHIN CELLS           971762.67     30  32392.09
 GROUP                 3426192.67      1 3426192.7    105.77      .000


Tests involving 'CONDITION' Within-Subject Effect.

 AVERAGED Tests of Significance for MEAS.1 using UNIQUE sums of squares
 Source of Variation          SS      DF        MS          F  Sig of F

 WITHIN CELLS          1902845.46     60  31714.09
 CONDITION             9169282.69      2 4584641.3    144.56      .000
 GROUP BY CONDITION    2746334.52      2 1373167.3     43.30      .000

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Experiment 8 - Anova Tables

B30. A split-plot ANOVA table obtained from an analysis of hits in experiment 8

----- O N E W A Y -----
Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	.2813	.2813	.0844	.7734
Within Groups	30	99.9375	3.3313		
Total	31	100.2188			

B31. A split-plot ANOVA table obtained from an analysis of false positives in experiment 8

----- O N E W A Y -----
Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	.0000	.0000	.0000	1.0000
Within Groups	30	73.8750	2.4625		
Total	31	73.8750			

B32. A split-plot ANOVA table obtained from an analysis of A' scores in experiment 8

----- O N E W A Y -----
Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	.0008	.0008	.0302	.8631
Within Groups	30	.7940	.0265		
Total	31	.7948			

B33. A split-plot ANOVA table obtained from an analysis of RT to hits in experiment 8

----- O N E W A Y -----
Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	3242649.445	3242649.445	32.8982	.0000
Within Groups	30	2956983.172	98566.1057		
Total	31	6199632.617			

B34 . A split-plot ANOVA table obtained from an analysis of RT to correct rejections in experiment 8

- - - - - O N E W A Y - - - - -

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	6611611.570	6611611.570	29.3755	.0000
Within Groups	30	6752159.297	225071.9766		
Total	31	13363770.87			

APPENDIX C

Tests of Simple Main Effects

C1. Analysis of variance table for simple main effects involving delay and age of subject on hits obtained in experiment 4.

Source	SS	df	MS	F	p
Between subjects					
Age @ Immediate Test	15.96	2	7.98	6.34	p<.01*
Age @ One Week Delay	4.334	2	2.17	1.74	p>.01
Pooled Error Term [#]	107.5	86	1.25		
Within subjects					
Delay @ 11 years	10.07	1	10.07	8.32	p<.05*
Delay @ 12 years	19.13	1	19.13	15.80	p<.01*
Delay @ 13 years	37.13	1	37.13	30.69	p<.01*
B x subjects-within groups	101.3	84	1.21		

#*SSswg + SSbxswg /(dfSSswg) + (dfSSbxswg)*

C2. Analysis of variance table for simple main effects involving delay and sex of face.

Source	SS	df	MS	F	p
Within subjects					
Effect of Delay on Male Faces	21.07	1	21.07	18.01	p<.05*
Effect of Delay on Female Faces	124.27	1	124.27	106.2	p<.05*
Sex of Face @ Immediate Test	27.52	1	27.52	23.52	p<.05*
Sex of Face @ One Week Delay	1.72	1	1.72	1.47	p<.05
Within Cells	97.93	84	1.17		

C3. Analysis of variance table for simple main effects involving sex of subject and sex of face on hits.

Source	SS	df	MS	F	p
Between subjects					
Sex of Subject on Male Faces	0.21	1	0.21	0.17	p>.05
Sex of Subject on Female Faces	12.79	1	12.79	10.39	p<.05*
Pooled Error Term [#]	104.81	85	1.23		
Within subjects					
Sex of Face on Male Ss	0	1	0	-	p>.05
Sex of Face on Female Ss	13.44	1	13.44	11.20	p<.05*
B x swg	101.00	84	1.20		

C4. An ANOVA table for simple main effects involving age of subject and delay on false positives.

Source	SS	df	MS	F	p
Between subjects					
Age @ Immediate Test	15.38	2	7.69	5.49	p<.05*
Age @ One Week Delay	8.08	2	4.04	2.86	p>.05
Pooled Error Term [#]	120.2	86	1.40		
Within subjects					
Delay @ 11 years	20.16	1	20.16	17.23	p<.05*
Delay @ 12 years	0.15	1	0.15	0.13	p>.05
Delay @ 13 years	0.56	1	0.56	0.47	p>.05
B x subjects-within groups	98.10	84	1.17		

#SSswg + SSbxswg /(dfSSswg) + (dfSSbxswg)

C5. Analaysis of variance table for simple main effects involving sex of subject and sex of face on false positives.

Source	SS	df	MS	F	p
Between subjects					
Sex of Subject on Male Faces	7.82	1	7.82	4.98	p<.05*
Sex of Subject on Female Faces	5.33	1	5.33	3.39	p<.05*
Pooled Error Term [#]	133.6	85	1.57		
Within subjects					
Sex of Face on Male Ss	0	1	0	0	p>.05
Sex of Face on Female Ss	30.64	1	30.64	25.53	p<.05*
B x swg	99.83	84	1.20		

C6. A matrix showing the t-values obtained from MC tests performed to examine the significance of a developmental dip in face recognition obtained in experiment 4.

	11-year olds	**12-year Olds**	**13-year Olds**
11-year Olds			
Immediate	-	t(58)=7.5,p<.05*	t<0(not sig)
One Week	-	t(58)=2.5,p<.05*	t(58)=5.0,<.05*
12-year Olds			
Immediate	-		t(58)=10.0,p<.05*
One Week	-	-	t(58)=7.50,p<.05*
13-year Olds			
Immediate	-	-	-
One Week	-	-	-