The Effects of Age, Memory Load, and Stimulus Type on Facial Recognition

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ABSTRACT

An experiment was conducted to assess the effects of age, memory load, and stimulus type on facial recognition. As these three factors have been implicated as important determinants in facial recognition (see Bäckman, 1991; Fulton & Bartlett, 1991; Shapiro & Penrod, 1986), the potential interactive role of these variables was examined. Thirty-two young and 64 older adults completed a facial recognition task to determine whether there were differences in recognition memory for three factors. The between-groups factors included the age of the participant (<40, 60 - 75, and >75) and memory load (low vs. high). The within-group factor was the stimulus face type (young vs. old). Participants saw 20 or 40 stimulus faces and then immediately attempted to recognise these faces when they were randomly mixed with an equal number of distractor faces in a single-interval, forced choice task. Signal detection analyses indicated that facial recognition accuracy declined with age. Older adults showed consistently poorer recognition than young adults. A main effect for memory load emerged. Performance decrements accompanied increased memory load but as all age groups were similarly affected, memory load did not interact with age. Neither did memory load interact with stimulus face type. In contrast to prior findings, stimulus face age affected only older adults who showed a marked deficit in the recognition of young stimulus faces. Young adults, however, were equally adept at recognising young and older stimulus faces. Differences between groups were not attributable to changes in response criterion, as all groups demonstrated similar levels of response bias. Results were discussed in terms of the marked interaction between stimulus face age and participant age, and the methodological implications of the ways in which variables such as load, stimulus face age, and participant age can affect the outcome of facial recognition studies. Changes in performance were shown to be a real difference in recognition memory rather than being a tendency toward reporting faces as 'old' or 'new'.

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INTRODUCTION

Prologue

Undoubtedly, the ability to perceive and recognise many thousands of faces demonstrates the extraordinary sensitivity and power of human memory. Because we are able to recognise people from their faces, discern their mood, decide whether or not they are listening to us, and gain understanding of the spoken word through lip movement, the face mediates a wider variety of cognitive and social activities than any other visual object. All faces share the same global spatial structure; yet, in no more than a fraction of a second, we not only see a face as a face, but also note its individual uniqueness – age, gender, race, beauty, and emotional expression are all perceived (Calis & Mens, 1986).

The number of faces individuals are called upon to recognise accurately is staggering. Damasio (1989) speculates that when relatives, friends, colleagues, and celebrities are all counted across a lifetime it would be difficult to estimate the average number of faces an individual learns to identify, but even a conservative estimate will always place that number in the thousands.

Flin and Dziurawiec (1989, p.335) comment that face processing is "one of the most sophisticated and precocious skills of the young child's cognitive repertoire". Standard recognition memory paradigms have been utilised in the study of face perception in childhood (Carey, 1981), and it has been shown that while infancy is characterised by rapidly developing face encoding skills, increasing maturity is accompanied by a steady improvement in recognition performance. Children up to the age of 8 years of age tend to perform poorly on encoding unfamiliar faces, but by the age of 10, most children approach, if not reach, normal adult levels of recognition ability (Carey, 1981).

Less is known about how face recognition declines in the *later* years of life, the focus of the present study. Can older adults recognise a relatively large ensemble of faces as well as younger adults? Do older subjects recognise young faces as well as they do older faces? These are just two of the questions about aging and face recognition addressed by the present thesis.

Aging and Memory

The belief that memory performance declines with increasing age is generally supported by experimental studies (Sherwin, 1994). The ability to remember incoming information over time depends on many inter-related variables. One variable found to have a marked effect on memory is that of age. Aging is a process associated with a reduction in cognitive capacity (Hasher & Zacks, 1979). Decrements have been attributed to several causes. Schaie and Labouvie-Vief (1974) attribute the age-related decline in part to socio-cultural, generational cohort differences, suggesting each generation is exposed to different sets of historical and personal events such as improved educational opportunities, nutrition, and health care. Labouvie-Vief (1985) notes that while many cross-sectional studies document significant differences in cognitive performance with age, the findings of several longitudinal investigations indicate part of the apparent decline with age is due to generational, rather than age, differences. Banich (1997) points to the changes in brain functioning during the normal aging process that surely must underpin age-related changes in mental functioning. Although Birren (1964) and Salthouse (1985) assume there is such a neural basis to cognitive slowing, they point out that its precise nature is not yet fully understood.

Although the magnitude of the decline between young and older adults' performance on memory tasks varies as a function of task and participant characteristics (Madden et al., 1999), it is clear that changes do occur. Furthermore, it is well established that normal aging is accompanied by a decline in memory and learning capacity, particularly for tasks requiring substantial capacity (McEntee & Crook, 1990). McEntee and Crook suggest that the majority of people over the age of 50 will be affected, at least to some degree. Short-term memory, the extent to which items that have just been presented are still in the person's conscious awareness, does not seem to be substantially affected by aging (Sherwin, 1994), although if a decision-making activity is required at the same time, there are decreases in both accuracy and speed (Craik, 1971; Park, 1992). If an older person must remember material that has left conscious awareness from seconds ago to years ago, performance will depend on the efficacy of both acquisition and retrieval.

Salthouse (1985) argues that a general decline across all abilities is associated with aging, representing a slowing in the speed of cognitive processing. This slowing is found across a variety of tasks, particularly those which place more demands on central aspects of process such as memory search. Salthouse (e.g., 1993, 1996) has shown that cognitive slowing accounts for most of the age-related variance in a number of memory tasks.

An opposing view to that posited by Salthouse (1985), argues that age-related deficits are task-specific. For example, Wingfield, Stine, Lahar, and Aberdeen (1988) compared young and elderly people on three tests of short-term storage: digit span, word span, and loaded word span. In the latter task, participants read sentences and made the decision as to whether each one made sense, and at various points were required to read aloud the last word of each sentence. Age differences were minimal on the two simple tasks, but elderly participants performed much more poorly on the loaded span task. Research is equivocal as to whether age-related declines are task-specific or general across all cognitive abilities, but it has been consistently demonstrated that increasing task complexity is accompanied by a reliable, deleterious effect on older adults' performance when compared with younger adults (Salthouse, 1987).

It may be that elderly adults have memory traces present in the long-term store, but find it more difficult to gain access to the information. Buschke (1974) demonstrated this when young and elderly participants completed a study trial consisting of a 20-word free recall list, which was subsequently followed by repeated test trials. While for the young subjects there was consistency in retrieval and recall over trials, this was not the case for elderly subjects. Recall of a word on a given test trial indicates the presence of a memory trace for that word, but Buschke's elderly participants revealed many more retrieval failures than young participants. Similarly, Rabinowitz (1984) found older adults achieved lower scores on a recognition test for words than did the younger adults. However, Schonfield and Robertson (1966) demonstrated in several laboratory studies with verbal material, that older participants demonstrate no apparent deterioration in recognition memory when compared with young participants. In a study examining age differences in recognition memory, Lithgow (1998) studied the effects of stimulus type using verbal and non-verbal recognition tasks. Of particular interest, alongside the expected decline in recognition accuracy with age, Lithgow found that across the lifespan, recognition accuracy was more impaired for non-verbal (geometric shapes), as opposed to verbal, stimuli. In contrast, Smith and Winograd (1978) demonstrated that the age-related deficit found for the deep processing of words as study-list items applied equally well to the processing of pictures of faces.

Many studies have found that pictorial material is more recognisable to both younger and older adults than verbal material – the pictorial superiority effect (e.g., Park & Puglisi, 1985; Park, Puglisi, & Smith, 1986). For example, when Park, Puglisi, and Sovacool (1983) presented participants either pictures or words to remember, older adults recognised more pictures than words. Shepard (1967) tested participants immediately after studying a subset of 612 pictures. Three hours later another subset was studied and tested. Participants scored a hit rate of 96.7% and 99.7%, respectively. Participants were also tested immediately after studying a series of 540 words, resulting in a hit rate of 88.4%, well below the hit rate for pictures. Pavio (1971) has argued that pictures are typically remembered better than words because pictures are more likely to be stored in both verbal and imaginal codes. In contrast, Feenan and Snodgrass (1990) posit that verbal items are more polysemous than pictorial items. Pictures have only one semantic representation and, therefore, are less likely to be confused than words which may have many semantic representations.

Standing (1973) found that when assessed using a forced-choice recognition task, pictorial material shows an overall superiority compared with verbal material, a superiority maintained when the recognition task difficulty is increased by the presentation of more distractors. Park et al. (1986) conducted a series of studies aimed at providing information about young and elderly adults' responses to pictorial detail and older adults' memory for pictures. Results showed that both young and older participants' memory improved with increased elaboration, and that the performance of the young and older participants was comparable over a variety of conditions and stimuli.

An interesting study was conducted by Woodhead and Baddeley (1981) in which participants who had previously demonstrated either very good or poor performance in the recognition of faces were tested on their memory for faces, typewritten words, and reproductions of paintings. The purpose of the study was to ascertain if the performance of good face recognisers would apply to other forms of recognition memory. Woodhead and Baddeley concluded that, as good face recognisers proved to be better at recognising paintings but did not differ from poor recognisers in their verbal recognition score, there is something special about visual memory which separates it from verbal memory, but there is no indication of a clear distinction within visual memory between remembering faces and remembering pictures of objects and scenes.

However, there is growing evidence that faces are, indeed, a special stimulus. In a view opposing that of Woodhead and Baddeley (1981), Diamond and Carey (1986) suggest recognition of faces is unique in two ways. Firstly, memory for faces involves within-group discrimination because all faces have the same configuration, such as the eyes are always set above the nose, and the mouth is always below the nose. Consequently, relational properties such as distance between the eyes must be used to distinguish particular faces. Indeed, Damasio (1989) proposes that because of the sheer number of similar exemplars, the learning and recognition of faces becomes one of the greatest burdens for cognition and for the neural apparatus supporting it. Secondly, Diamond and Carey suggest that because people are able to recognise and distinguish between thousands of faces and are constantly exposed to new faces, familiarity becomes a factor and may explain the inversion effect. Yin (1969) found that although participants were more accurate at recognising faces than other types of objects, this did not hold when faces and objects were inverted. Face recognition is differentially impaired by inversion, compared with recognition of other objects that are customarily seen only in one orientation.

Neurological studies which demonstrate that face recognition can be selectively impaired relative to objects of equivalent difficulty, and single unit recordings in monkeys showing a population of cells in the temporal cortex that respond selectively to particular faces, support the idea that faces are special (Desimone, 1991; Farah, Wilson, Drain, & Tanaka, 1998). Sergent, Ohta, and MacDonald (1992), employing PET scanning techniques while normal participants performed both object and face recognition tasks, found some parts of the brain were activated during both tasks, but certain areas in the right hemisphere (e.g., anterior temporal cortex) were activated during face processing but not object processing. Thus, face and object processing appear to share common neural processing mechanisms, but at the same time draw on resources in different brain areas.

In attempting to answer the ongoing argument as to whether words and pictures are represented in separate memory systems, and whether faces might constitute a special class processed by yet a third memory system, Deffenbacher, Carr, and Leu (1981) compared recognition memory for concrete nouns, pictures of common objects, pictures of landscapes, and pictures of faces. Results showed that memory for nouns and objects was relatively immune to retroactive interference in a test given shortly after the study. However, memory for pictures of landscapes and faces was highly susceptible to interference at a short retention level, but pictures for faces showed decreased susceptibility at longer retention intervals, and there was generally little long-term forgetting of faces. In other words, it appears that pictures of faces are processed in such a way that retrieval for them is superior to other pictorial stimuli.

People are continually exposed to face stimuli and thus may possess high facial discriminatory skills making them more proficient with faces than other types of stimuli. In addition, faces come in many different formats such as two-dimensional representations in newspapers, on television, and in magazines, and in three dimensions in real life. Sergent (1989) suggests this may contribute to the observed superiority of face recognition over other recognition tasks in the laboratory.

Farah (1992) argues that because faces have strong configural properties, they are likely to be encoded as entire structures rather than as a series of features. Tanaka and Farah (1993) found evidence for this by showing facial features were better recognised when presented in their appropriate context rather than in isolation, an effect of context which did not extend to visual objects such as houses and individual features of houses.

In summary, short-term memory, concerned with items which have just been presented and are still in the person's conscious awareness, does not seem to be substantially affected by aging (Sherwin, 1994), but increasing the complexity of a task is accompanied by a reliable, deleterious effect on older adults' performance when compared with younger adults (Salthouse, 1987). It may be that learning and recognition of faces is one of the most neurologically complex cognitive tasks because the vast number of homogeneous exemplars which must be learned and recognised require individuals to possess a high level of discriminatory skills.

Of particular importance in inter-individual difference, is the relationship between age and facial recognition (Carey, Diamond, and Woods, 1980). Age-related differences in recognition memory for faces are apparent in laboratory studies (e.g., Ferris, Crook, Clark, McCarthy, & Rae, 1980; Smith & Winograd, 1978). Although hit rates for target faces were similar in these two studies, false alarms were higher for elderly participants. Similarly, in forensic eyewitness studies, the elderly, as a group, appear highly prone to false identifications (Yarmey, 1996). In a meta-analysis of facial identification studies, Shapiro and Penrod (1986) found participant age to be a factor that reliably affects face recognition performance. Wahlin et al. (1993) found that in healthy elderly adults between 75 and 96 years of age, the best predictor of face recognition performance was age. However, it should be noted that, to date, the majority of studies investigating age and facial recognition, have either compared groups of children, or children and young adults (Shapiro & Penrod, 1986; Yarmey, 1996).

Whilst memory performance can be assessed in a variety of ways, a typical comparison is between free recall and recognition, a dichotomy that has been intensively studied. While aging does bring about a decline in recognition memory, its effect on recall is generally much greater. Indeed, one study (Schonfield & Robertson, 1966) found no apparent deterioration with age in recognition, whereas recall resulted in a loss of almost 50% between the scores of young adults and adults over the age of 60 years. The following section distinguishes between recall and recognition memory and discusses the differential effects of aging.

Recall and Recognition Memory

Deese (1963) explains that in recall an individual must produce a set of responses, whereas in recognition the set of responses is produced for the individual. A recall task requires participants to generate the target items as specified in the study phase in the absence of cues, whereas a recognition test usually requires participants to accept or reject items which have been seen before (targets) from those which have not been seen before (distractors) (Lithgow, 1998). Therefore, it could be expected that a superior score would be attained on a recognition test compared with a recall test, as the act of recognition demands the matching of a stimulus to a stored trace rather than retrieval without pictorial or verbal cues. This prediction is well supported by research. People given items to remember perform better on a test of recognition (measured by response accuracy) than on a test of recall (Parkin, 1993). For example, Craik and McDowd (1987) devised a recognition task that equated, in difficulty, to a recall task. The purpose was to investigate whether the typical absence of a significant age effect in recognition was merely a function of recognition being an easier task. Young and elderly adults performed cued-recall and recognition tests while carrying out a choice reaction-time task. Age-related differences were not found on the recognition test, though the recall test did elicit better performance by the young adults compared with elderly adults. Many researchers concur that whilst large deficits in free recall are associated with aging, these differences are reduced or even eliminated in recognition (Craik, Byrd, & Swanson, 1987).

Parkin (1993) suggests that the superiority of recognition over recall is not due to qualitative differences in the underlying memory system, but occurs because recognition provides the most featural overlap with a target trace. Loftus and Loftus (1976) suggest that there are three primary reasons for recognition superiority. Recognition tests are usually comprised of the two-alternative, forced-choice test. Thus, participants have a 50% chance of guessing correctly, whereas a recall test may produce a zero score when guesswork is utilised. Secondly, a participant in a recognition test need only remember enough information to discriminate between target and distractor items, whereas the complete item, itself, must be remembered in a test of recall. Thirdly, recognition requires a less elaborate memory search. Furthermore, Ferris et al. (1980) suggest recognition is an easier task than recall, as the participant need not retrieve the stimuli independently. Thus, retrieval is largely bypassed because the presented stimulus itself serves as a powerful retrieval cue.

Shepherd and Ellis (1996) note that there are a number of differences between the problems implicit in recognising and recalling most types of information, including faces. Faces, for example, are normally perceived in a specific context, and although the observer may notice distinctive details, the face is processed holistically and a memory trace is formed which includes information about specific features, configural information, the relationship of the features to each other, and the specific context within which the face was earlier seen (Sergent, 1984). Shepherd and Ellis further suggest that when recognition is required, as in witness identification of a crime suspect, the participant matches presented faces against their store of faces until a response of 'familiar' is evoked. In contrast, face recall in a similar situation requires the witness to externalise the image in the form of a verbal or pictorial description of parts of the face, necessitating decomposition into the constituent parts of the face whilst still retaining the total image (Ellis, 1986a) – a task made difficult by the high inter-item similarity created by the homogeneous nature of faces.

Although many investigations have found that the large deficits in free recall associated with aging are reduced or eliminated in recognition (Craik et al., 1987), there is also evidence that recognition memory is, indeed, also affected negatively by increased age. Parkin and Walter (1992), using a procedure pioneered by Tulving (1985), asked participants about their recollective experience for items recognised. The results suggest that although recognition scores for young and older adults were similar, older adults who were asked whether they actually recollected an item's prior occurrence (an R response) or merely found it familiar without recollecting details (a K response), performed very differently. Interestingly, Parkin and Walter demonstrated that the likelihood of older adults reporting recollective experiences is associated with measures of their frontal lobe functioning. Perfect (1997) suggests that in terms of relative impairment on recall and recognition, older adults may perform similarly to people with frontal lobe dysfunction. While there is evidence that older adults perform reasonably well on recognition tasks, there is a suggestion that the quality of recollective experience is impaired to a degree usually associated with frontal lobe functioning. This is an interesting question that merits further investigation.

In sum, while many researchers have found recognition tests reduce or negate the age-related decrements demonstrated in recall tests, others have found that recognition memory is affected negatively by increasing age. The central focus of the present thesis is to further examine the nature of the decline (if any) in facial recognition as a person ages.

Face Recognition Research

Human society relies greatly on the ability of individuals to recognise the faces of those with whom they interact, thus requiring the capacity to identify individual members of a relatively homogeneous stimulus class (Young, 1998). Ellis (1981) considered that faces constitute a complex, multidimensional, meaningful, and natural class of stimuli, in contrast to the simple and artificial stimuli often employed in psychological research. Young further suggested that because all individuals are experts at face recognition, the face provides a rich, ecologically valid stimulus for research. The standard procedure for a facial recognition task is to present a series of pictures or photographs of faces and then test the memory with a mixture of old and new faces.

A plethora of face recognition studies appeared in the 1970s, with some 600 studies heralding a burgeoning interest during that decade (Ellis, 1981). Research continued during the following decades, and a voluminous body of literature has accumulated. A meta-analysis of studies, conducted by Shapiro and Penrod (1986), examined in excess of 100 studies utilizing almost 1000 experimental conditions in the attempt to isolate and examine the effects of many participant and stimulus characteristics. Of particular interest has been how faces are perceived, encoded, stored, and retrieved (Carey, 1981). Ellis (1975, p.409) described the process of retrieval as "identification of some previously experienced configuration or event". A variety of experimental methods have been employed in the study of these phenomena. In addition, there has been prolific research on the effect of variables within the individual's ability to identify faces, such as familiarity (Bartlett, Hurry, & Thorley, 1984), distinctiveness (Shepherd, Gibling, & Ellis, 1991; Wickham, Morris, & Fritz, 2000), typicality (Light, Kayra-Stuart, & Hollander, 1979), load (Metzger, in press; Podd, 1990), differential experience (Chance, Goldstein, & McBride, 1975), race (Bruck, Cavanagh, & Ceci, 1991; Davies, 1978; Ellis, Deregowski, & Shepherd, 1975; Shepherd, 1981), sex (Exline, 1963; Going & Read, 1974), the use of explicit and implicit knowledge (Bruce, Burton, & Craw, 1992), training in face recognition (Ellis, 1986b), prior knowledge (Bäckman, 1991; Wahlin et al., 1993), and the mental and neurobiological process underlying face recognition (Carey, 1992; Madden et al., 1999).

One interesting dichotomy within face research is the question of whether faces are encoded piecemeal as a series of features, or by configurational/ holistic processing strategies. Sergent (1989) suggests all features of a face are not equally useful, and it is the type of knowledge to be gathered about a person that determines the relative weight each feature is given: interplay between the stimulus face and the observer may determine which features are encoded. Ellis, Shepherd, and Davies (1979) postulate that recognition utilises different features depending on whether the faces are familiar or unknown. When faces are familiar, recognition depends on internal features such as eyes, nose, and mouth, whereas recognition for unfamiliar faces also depends on external features such as hair, ears, and contours. Jones (1977, cited in Shepherd, Davies, & Ellis, 1981) conducted a poll asking respondents: "What facial features draw your glance and hold your attention?" The overwhelming choice was eyes (62%) followed by hair (22%) and mouth (8%) with the other 8% distributed across all other features.

On the other hand, evidence for a configural process in face recognition comes from the demonstrated findings that recognition is more accurate following global evaluative judgements (Patterson & Baddeley, 1977). It appears that a configural encoding is more informative than individual features when evaluating traits such as honesty or personality. Carey and Diamond (1977) have argued that face processing by adults employs a configural strategy, although young children may adopt a piecemeal approach. However, in a series of experiments investigating the notion that face recognition is primarily based on configurational information, Cabeza and Kato (2000) compared the prototype effect for face prototypes that emphasised either featural or configural processing. Cabeza and Kato concluded that both configural and featural processing make important contributions to face recognition, and their effects are dissociable.

People appear to be very good at recognising photographs of unfamiliar faces under laboratory conditions, and Goldstein (1977) notes in a review of research that participants exposed to a set of 20 faces are immediately able to select them from distractors with up to 90% accuracy. Carey et al. (1980) demonstrated that normal adults have a prodigious capacity for making new faces familiar. Very brief exposure to previously unfamiliar faces permits participants to distinguish those faces from new ones at a high level of performance across inspection sets ranging from 20 to 72. The effect is robust, capable of surviving changes of expression and pose between the study and recognition phases (Patterson & Baddeley, 1977). In addition, the effect holds up well over time as demonstrated in the ability of professors to recognise photographs of contemporaries from undergraduate days (Bahrick, Bahrick, & Wittlinger, 1975). In a later study, Bahrick (1984) found that older professors in their 60s were as proficient at recognising the faces of students in an introductory class as young professors in their 30s and 40s.

Although there has been a great deal of research on face recognition over the past three decades, one clear, uniting theoretical framework has yet to emerge. Early research into the recognition of faces was conducted in the absence of any guiding theoretical framework at all (Bruce et al., 1992). Besides difficulties in extending results of laboratory tests to real-life recognition, laboratory data themselves fall short of the consistency required for practical implementation (Wells & Loftus, 1984). For example, Shepherd (1981) points out in a review that 17 experiments revealed a sex difference in face recognition, usually female superiority, but also cites 18 experiments where no sex difference was observed.

Several theories have been proposed to provide a framework within which the processes underlying face recognition might be understood. For example, Burton, Bruce, and Johnston (1990) developed a model of face recognition consisting of a number of "pools" linked by two-way connectors. The first pool contains facial recognition units (FRUs), or information about each familiar face. When sufficient visual information has been encoded to take an FRU above threshold, the Personal Identity Nodes (PINs) are activated. PIN units act as organising stations where semantic, acoustic, and visual information about a particular individual is accumulated. A PIN threshold activates items in the next pool, Semantic Information Units (SIUs), where particular faces are related to abstract information about an individual. This model has been successful in accounting for some phenomena, such as semantic priming of faces. Furthermore, Burton, Young, Bruce, Johnston, and Ellis (1991) assert damage to the links between pools may account for prosopagnosia, the inability to recognise faces.

Schreiber, Rousset, and Tiberghien (1991) argue that the main weaknesses of the functional models of Bruce and Young (1986) and Burton et al. (1990) are that they do not take account of the way identity nodes are constructed – they do not model the learning stage, and do not take into account the role of contexts in face identification. The Schreiber et al. model, Facenet, comprises four multi-cell layers which model the memory processes which lead to familiarity estimation and identification by giving rise to three indicators: familiarity feeling, identity feeling, and identity content. The Facenet model addresses the structuring of identity representations in varying learning conditions defined by the encoding context, and provides evidence of a significant interaction in identification performance between the variability and specificity factors of encoding context. Schreiber et al., argue that it is vital to any face recognition model to take cognisance of the way information is learned, and Facenet provides a theory of how identity representations are constructed in different encoding conditions.

Of all the models of face recognition, signal detection theory (SDT) is, perhaps, the most widely supported theory of recognition. SDT was developed during the late 1950s and early 1960s, and has become one of the most useful models of recognition memory (e.g., Banks, 1970; Green & Swets, 1966; McNicol, 1972), a model that can usefully be applied to face recognition.

Signal Detection Theory

Signal detection theory (SDT) is a sophisticated theory regarding the way choices are made (McNicol, 1972). SDT affords useful measures of performance in decision-making situations such as those of the present study. Of paramount importance are measures of sensitivity – how well a participant is able to make correct decisions and avoid incorrect decisions – and bias, the extent to which evidence is ignored in favour of a tendency toward a particular hypothesis (McNicol, 1972).

SDT is particularly applicable to facial recognition, as it enables recognisability to be distinguished from response bias. SDT as applied to face recognition memory proposes memory strength as the decision axis. The participant is assumed to set a cut-off point, x, on this decision axis such that if memory strength exceeds x (the criterion) the participant responds, "Yes, this is a previously seen face" (an "old" item); otherwise the response is "No, this is a "new" item". Hit rate (the probability of reporting an old item as old) and false alarm rate (the probability of reporting a new item as old) measures are central to SDT. Hit rate alone is not a sufficient measure of sensitivity to a stimulus; a perfect hit rate may be obtained by the artifice of saying "old" on all trials. Taking both hit rate and false alarm rate into consideration allows for both measures of sensitivity (or recognisability) and the criterion used by the individual to make a decision. For example, whilst a lax criterion may result in a high hit-rate it will be at the expense of an increased number of false alarms. When a participant makes a series of decisions using a range of decision criteria, it is possible to plot hit rate against false alarm rate, thus creating a function named the Receiver Operating Characteristic (ROC) curve. It is also possible to calculate the area under a ROC curve based on a single pair of hit and false alarms. The area under this curve, A', is a measure of recognisability, independent of the decision criterion, defined as $0.5 + [(H - F)(1 + H - F)] / [4H(1 - F)]$, where H is the hit rate, and F is the false alarm rate (Macmillan and Creelman, 1991).

A' is a non-parametric index of recognisability. SDT also proposes a parametric index, d', a criterion-free measure defined as the mean z-score of the false alarm rate minus the mean z-score of the hit rate, whilst assuming underlying normal-normal, equal variance distributions over the memory strength decision axis. The distance between the means of these distributions of old items and new items, and the amount of overlap, determine the difficulty of the task (Glanzer, Kim, Hilford, & Adams, 1999).

A further measure, *c*, captures the decision criterion of the participant – the response bias, or assessment of the participants' willingness to report a face as "old" or "new". The *c* statistic is defined as $-0.5\,[z(H) + z(F)]$, where z(H) and z(F) are the z-score hit and false alarm rates, respectively (Macmillan & Creelman, 1991). Positive scores indicate a bias to report faces as "new", whereas negative scores indicate a bias in favour of reporting faces as "old". The use of *c* helps determine whether any performance change is the result of a real difference in memory, or merely a bias toward reporting faces as "old" or "new". Ferris et al. (1980) highlight the importance of this measure by noting that failing to account for response criterion differences may conceal age-related decrements in recognition memory.

In summary, the main advantage of the SDT model is that it allows for a relatively criterion-free estimate of recognisability while at the same time allowing for response bias to be measured. It will be seen below that these two measures are well suited to assessing face recognition in laboratory-based research.

Typical Face Recognition Studies

Although some researchers, in an attempt to provide ecologically valid stimuli, present participants with simulated crime scenes or other 'real life' scenarios, the majority of face recognition studies utilise faces or pictures of faces in a laboratory setting. Participants then undergo a standard recognition test, as described below.

A typical face recognition study involves presenting participants with a number of photographs or pictures of faces, presented sequentially. Photographs may be presented from varying angles or show only a full-frontal view of the face, as in the present study. This is the "study phase", and generally participants are asked to pay close attention to the faces (known as "targets"), as they will later be attempting to recognise them.

Interestingly, Courtois and Mueller (1981) found that it made little difference to the results whether or not participants knew a recognition test would follow.

In the "recognition phase" or "test phase", which can take place immediately after the study phase or after a delay, the participants are shown the target faces again, this time randomly interspersed with other faces, defined as "distractors", which they have not seen before. Participants are asked to indicate which faces they think they have seen before, by rating them as "old" (previously seen) or "new" (not seen before). The ratio of targets to distractors used in different studies varies widely. For example, Laughery, Fessler, Lenorovitz, and Yoblick (1974) used only one target photograph, although participants viewed 149 distractors in their recognition task. In a meta-analysis of face identification studies, Shapiro and Penrod (1986) found a mean of 22 targets shown at study, then intermixed with a mean of 40 distractor photographs in the recognition phase. Memory load is imposed by the number of targets seen in the study phase, whilst recognition load is imposed by the number of faces (targets and distractors) shown in the test phase. Both may be manipulated in recognition studies (e.g., see Podd, 1990).

Typically, the faces used are of males only, or of males and females. An entire set of female faces is seldom used, in order to avoid the possibility of a sex of participant by sex of stimulus face interaction. Shepherd (1981) notes that this may occur because females show greater facility than males at recognising female faces.

The length of delay between the study and recognition phases varies greatly, with many studies using more than one retention interval for comparison (e.g., Podd, 1990). In an overview of literature on laboratory studies of face recognition, Deffenbacher (1986, p.63) reported a "vast range" of retention intervals from "one minute to 350 days". Shapiro and Penrod (1986) noted a mean delay of 4.5 days, with a standard deviation of 21 days.

The present study utilises full frontal, coloured photographs of male faces, and zero delay between the study and recognition phases.

Age Differences in Face Recognition Research

Adults can successfully encode large numbers of new faces from briefly inspected photographs and subsequently identify these from distractors at recognition rates of over 90% (Carey, 1992). However, age differences in memory for pictures of faces under laboratory conditions have been found to be rather pronounced (Kausler, 1994).

A considerable volume of research has accumulated on the question of whether there is, indeed, an age-related decline for facial recognition. Crook and Larrabee (1992) found that memory performance in face recognition, in contrast to other every-day memory tasks, does not decline in a linear fashion but accelerates after the age of 70, and furthermore, reported associations between age and facial recognition memory performance were not specific to methods of assessment. George and Hole (1995) sound a note of warning stating that care must be taken to note the prosaic possibility that observed differences are an artefact of the different ways young and older adults may respond to experimental demands.

With the goal of determining the point at which age-related changes in face recognition memory become apparent, Crook and Larrabee (1992) included 650 adults representing every decade between 18 and 80 years of age. Facial recognition tests were administered as part of a larger, computerised, everyday memory battery. Their interest, in addition to affirming the relationship between age and face memory, was to investigate whether the relationship would show a similar magnitude across two different methodologies: signal detection theory, and delayed nonmatching-to-sample. The results did converge, and confirmed the relationship between age and facial recognition memory. Significant age-related decrements were found as early as 50, although the largest decrements occurred over the age of 70, suggesting an acceleration of decline after the seventh decade of life. The index, *d'*, for example, declined from 3.16 to 2.21 between the 18-39 and 70+ groups, with the most rapid decline occurring over the age of 70. Furthermore, the Crook and Larrabee study demonstrated that false alarm rates are more strongly associated with increasing age than are hit rates. No response bias was found.

In a study comparing participants between 18 – 25 years of age and older adults between 50 – 80 years of age, Smith and Winograd (1978) found a more relaxed criterion for the older adults: this group were more willing to classify a test face as old when uncertain. In the Smith and Winograd study, hit rate remained stable across the age groups in all three instructional conditions (standard instructions, structural characteristic, friendliness), and the groups differed only by an increased false alarm rate for older adults, suggesting that these changes were due to recognisability differences and not response bias. (Both hit and false alarm rates would have increased if the changes had been due to bias.)

A similar increase for false alarm rate was found in a series of experiments conducted by Bäckman (1991). The experiments involved recognition of contemporary and dated famous faces, and a recognition test of familiar and unfamiliar faces. Bäckman, too, found an increase in false alarms across four age groups (19 - 27 years, 63 - 70 years, 76 year-olds and 85 year-olds). However, unlike many other researchers, he found a recognition test of unfamiliar faces to be accompanied by a significant decrease in hit rate, whether the target faces were of young or old faces. The age-related deficit in face recognition memory was most pronounced in the 85 year-olds.

A higher false alarm rate for elderly adults when compared with young adults was also demonstrated by Ferris et al. (1980). Since there was no significant difference in response bias between young and elderly adults in the Ferris et al. study, the higher false alarm rates were due primarily to the older adults' poorer ability to discriminate between target and distractor faces.

A practical implication of the increased false alarm rate for older adults is in eyewitness testimony. It is disturbing to note the possibility that elderly witnesses might be more likely than young adult witnesses to falsely identify an innocent person as the criminal. This potential problem is compounded by evidence indicating that the false alarm rate of elderly adults is greater for young stimulus faces than for old stimulus faces (Yarmey, 1984).

Contrary to the increased false alarm rate found in the Smith and Winograd (1978) and Bäckman (1991) studies, Yarmey and Rashid (1981, cited in Yarmey, 1984) found no reliable age differences in false alarm or hit rates when young and elderly adults were required to examine a photograph line-up and recognise an assailant previously observed in a simulated assault. In addition, there were no reliable differences in response bias. However, recognition performance, measured by *d'*, showed deficits in facial recognition, relative to young adults, when Yarmey and Rashid increased the number of assailants observed in the simulated assault. Yarmey (1984), in a review of literature pertaining to aging and facial recognition, concluded that younger adults perform better on facial memory tasks than the elderly.

In an effort to present stimuli that were considered more ecologically valid than single views of faces, Bartlett and Leslie (1986) presented either multiple views or single views of faces to groups of young and older adults. As expected, a higher level of recognition performance was achieved for the multiple views with no age difference between young and old adults, whereas for the single view pictures there were significant age differences.

In a sample of 368 healthy adults between 75 and 96 years of age (Wahlin et al., 1993), multiple regression analysis indicated that among a variety of demographic, psychometric, and biological variables age was the best predictor of face recognition performance. In their review of facial identification studies, Shapiro and Penrod (1986) list subject age as a variable that reliably impacts on recognition accuracy.

In sum, many studies concur with the robust finding that young and older adults exhibit similar hit rates for face recognition. However, the false alarm rate is elevated for older adults (Bartlett & Leslie, 1986; Ferris et al., 1980; Smith & Winograd, 1978). Although older adults are as able as younger adults to recognise a previously seen item, they are likely to respond to new items as 'old' at a higher rate. This increased false alarm rate does not appear to be due to a change in response bias. Rather, aging seems to be accompanied by a change in recognisability, but mainly as a result of an increased false alarm rate.

The Present Study

It has been established that increasing age does cause a decline in recognition memory for faces. However, little is known about the variables which might interact with age. The present study utilised SDT methodology to examine the effects of age, memory load, and stimulus face type on facial recognition memory. Whilst a body of literature has accumulated regarding the effect of age on face recognition, there is a dearth of research on the effect of both memory load and stimulus face type. The effect of memory load on facial recognition has been investigated by Podd (1990) and Metzger (in press). However, only one study has specifically investigated the effect of the age of stimulus faces x age of participants interaction, that of Fulton and Bartlett (1991). Bäckman (1991), as part of a series of experiments designed to investigate the effects of prior knowledge on recognition memory, found that while young adults (19 - 27 years of age) were better at recognising young unfamiliar faces than old unfamiliar faces, and young-old adults (63 - 70 years of age) there was no effect of age for old adult participants (one group of 76 year olds and one group of 85 year olds).

The Fulton and Bartlett (1991) study

Research has shown that age-related differences in face recognition are reflected by elderly participants exceeding young participants in false alarms. Fulton and Bartlett (1991) set out to determine if this difference between young and elderly participants might differ for young versus elderly stimulus faces. Half the young (M = 27.6 years of age) and half the elderly participants (M = 71.4 years of age) examined young and middle-aged faces, and the remainder studied and recognised middle-aged and elderly faces. Although the prime purpose of the investigation was to provide solid evidence on whether the age-related increase in false alarms was smaller with older faces than with younger faces, using the same middle-aged faces in both the young-middle and middle-elderly conditions was intended to reveal the presence of any effect of stimulus set age as opposed to individual item age: the nature of any Condition x Subject Age interaction would be clarified by the effects of Condition when only middle-aged faces were taken into account.

Fulton and Bartlett (1991) refer to the research findings of Bartlett and Fulton (1991) where it was shown that recognition accuracy (measured by A') in their young adult groups was generally better with young adult faces than with older faces, whereas recognition accuracy in their elderly groups showed no significant age effects. This led Fulton and Bartlett to speculate whether the use of older faces would reduce the age differences in false alarm rate.

Their results show that face recognition hit rates were virtually identical for young and elderly participants when results were collapsed over face age and condition. However, the hit rate was higher for young compared to elderly participants in the young-middle condition, and higher among elderly than among young participants in the middle-elderly condition. Fulton and Bartlett (1991) concluded that, because this pattern held for middle-aged faces, it represented a stimulus set age effect as opposed to an individual item effect. False alarm rates showed a substantial participant age effect between young (M = .29) and elderly (M = .46) participants.

It was also found that participant age differences in face recognition accuracy depend on face age and that the effect is asymmetric: young adults showed higher discrimination with young adult faces than with elderly faces, but elderly participants did not show this effect. It was proposed that if perceived familiarity affects recognition judgement in old age (Bartlett & Fulton, 1991), then this would tend to inflate the false alarm rate by elderly participants when elderly faces are tested, and to deflate the false alarm rate when younger faces are tested. The researchers note that elderly participants showed both high false alarm rates and a lax criterion, concluding that the elderly rely more heavily on perceived familiarity, compared to young adults.

A criticism of this study is that while there was clear evidence of differential amounts of response bias for the young compared to the elderly participants, Fulton and Bartlett (1991) fail to discuss bias in relation to their hit and false alarm rate measures. SDT requires that recognisability be assessed by *both* the hit and false alarm rates together (as is the case for measures such as d' and A'). However, it is frequently the case that face studies consider hit and false alarm rates independently. This is acceptable only if any effects of response bias can be ruled as the cause of the changes in these measures. It is not clear in the Fulton and Bartlett study whether bias (changes in c) played any part in the changed hit and false alarm rates.

Furthermore, Fulton and Bartlett's (1991) use of three response categories (*identical* to face previously viewed, *changed* from one previously viewed, or entirely *new*) may well have confounded the results as it cannot be known how each affects the others. Fulton and Bartlett may have tried to achieve too much in one study. The number of trials upon which *d′* calculations were based must have been very small in some cases. Small numbers equate to high levels of sampling error (Green & Swets, 1966).

The present study takes a more straightforward approach to investigating variables of age and face type, and includes memory load in the factors investigated. On intuitive grounds, one might expect that older participants might be more affected by an increased number of faces to remember than their younger counterparts. To date, the possible interactive effect of these variables has not been examined

Age

It is as yet unclear whether, and how, age might interact with the other variables associated with face recognition. An objective of the present study was to find out whether there would be an age-related decline in recognition memory using a task designed to examine the effect of stimulus face type and memory load. While it is clear that young adults perform better on certain tests of recognition than older adults, there is still little known about which specific aspects of face recognition are impaired, and under what conditions.

Several prior studies of face recognition have included the variable of age. However, many of these have included a wide range of ages within the category of 'elderly'. For example, Smith and Winograd (1978) included participants between 50 and 80 years of age in their older adult group, Fulton and Bartlett's (1991) elderly group encompassed participants from 59 to 82 years of age, and Lithgow, Podd, and Bunnell (1998), in their study of aging and recognition memory, include older adults between the ages of 60 and 88 years in a single group. Bartlett and Leslie (1986), in a study designed to assess differences in the ability of young adults and the elderly to recognise faces, studied only 18 year olds in their young adult group, yet the elderly group included a range of ages (*Mean* = 74.2 years, *SD* = 6.8).

The present study divided older adults into two groups: 60 to 75 years of age, and those over 75 years of age. There is considerable evidence that memory in general deteriorates more rapidly in those over 70 years of age compared to those a decade or so younger (Parkin, 1993). Thus, one might expect to find an age-related deficit in face recognition when comparing two 'elderly' groups having an approximately 15 year mean age difference, as in the present study. It is important to investigate this difference rather than to treat it as within-group variability. Similarly with memory load, the number of stimulus faces used in the recognition task.

Memory Load

Memory load is imposed by the number of targets seen in the study phase, whilst recognition load is imposed by the number of faces (targets and distractors) shown in the test phase. For example, it might be expected that participants seeing 40 faces during the test phase would have less of a recognition load than those seeing 80 faces. The additional recognition load is created because of the extra time faces are remembered and because there is a greater chance of misidentifying faces as target faces seen early in a long recognition sequence with target faces previously seen.

While there has been little work undertaken regarding memory load in face recognition, two studies are noteworthy. Podd (1990) examined memory load as a function of retention interval (delay). The number of target faces in the study phase varied between 20 and 50, chosen as representative of memory loads used in most face recognition studies available in 1990. The 90 participants in this study were aged between 18 and 60. (Age was not a variable considered in Podd's study.) Podd's study was designed to enable memory load (imposed by the number of target faces seen at study) to be assessed independently of the potentially confounding effects of recognition load (imposed by the number of target and distractor faces seen in the recognition phase), as will the present study. Podd found that reliable decreases in accuracy could be expected with only moderate increases in the number of targets, irrespective of the recognition index used. Furthermore, accuracy declined with increasing load for all three delays between the study and recognition phases (10 minutes, 1 week, and 2 weeks, respectively). This suggests that memory load is an important factor to take into account in making comparisons across face studies of recognition accuracy. Podd's results were due to the effect of hit rate more than false alarm rate, although the false alarm rate changed more than hit rate as the delay interval increased.

Metzger (in press) conducted an experiment to assess the interactive role of stimulus load and age in facial recognition. Load was comprised of 10, 20, or 30 target items presented at study, and 20, 40, or 60 items observed in the recognition phase, using an equal number of target and distractor faces. Metzger's study was the first to systematically examine the effects of stimulus load for participants of different ages, but was confined to a comparison of children (8 - 10 years, $M = 9.3$), college students (18 - 33 years, $M = 22.0$), and middle-aged adults (40-67 years, $M = 49.6$). Although statistical analysis of the hit rate yielded significant results for both stimulus load and age, no significant interaction between the two variables emerged, suggesting that all three groups were affected equally by the increase in stimulus load. In other words, in a replication of Podd's (1990) findings, increasing stimulus load produced a reliable performance decrement in all groups of participants. Of particular interest, when the 10-target and 30-target conditions are compared, there is a statistically significant greater false alarm rate in the 30-target group. This change occurred for both young and older participants. That is, age had no effect on false alarms but increased load did. Analyses of the response bias in Metzger's study provide evidence that the main effects of load and age can be interpreted as changes in memory function, rather than changes in decision criterion between the three groups.

In Shapiro and Penrod's (1986) meta-analysis of facial identification studies, as load increased hit rate also increased although the increase in false alarms was greater. These hit and false alarm rate changes produced an overall reduction in recognisability as measured by *d′*. This is tantamount to storing (or being able to retrieve) fewer facial cues. Thus, targets and distractors are more likely to be confused, resulting in higher false alarm rates. With fewer features to compare, it is more likely the limited set of features available will match with certain features when the participant sees a distractor face. This distractor may then be mistakenly identified as "old" (a false alarm). This notion espouses the theory that older adults do not encode or retrieve material as well as younger people. Research conducted over many years points to a clear age-related decrement in encoding processes (e.g., Craik, 1977; Kausler, 1982; Poon, 1985). Similarly, research investigating comparisons of performance using different types of retrieval, and comparisons of recall and recognition performances consistently indicate that older adults have more difficulty retrieving information than do younger adults (Craik, 1977; McEntee & Crook, 1990; Poon, 1985).

The primary question is "Does memory load interact with age?" It is a particularly pertinent factor to examine with age because it could be expected that as people age the loading on memory may have a greater effect than on their younger counterparts. If there is such a differential effect of memory load, a significant interaction between age and memory load should be apparent: if an increased load impairs older adults more than their younger counterparts, the performance of older adults should decline more rapidly than that of younger adults when load is increased. Conversely, if increasing the memory load affects both older and younger adults similarly, decreases in performance should be observed in all groups, showing no interaction between stimulus load and age.

Face Type

There has been a paucity of research on the effect of the age of stimulus face versus the age of participant. Although face processing has been researched intensively during the last three decades, this aspect has been largely ignored. Shepherd, as long ago as 1981, suggested that one of the most promising questions for future research concerns the interactions between participant characteristics and face characteristics (Shepherd, 1981).

Analogous to the question of the possible interaction between participant and stimulus face age, are the cross-race interactions which have been vigorously researched (e.g., Brigham & Barkowitz, 1978; Feinman & Entwisle, 1976; Shepherd, Deregowski, & Ellis, 1974). People generally find it easier to recognise faces of members of their own racial group than those of other racial groups (Shepherd, 1981). This effect is robust and has been demonstrated with American black and Caucasian students (Brigham & Barkowitz, 1978; Lavrakas, Buri, & Mayzner, 1976).

In an interesting study of older adults, Brigham and Williamson (1979) found elderly black participants showed much better recognition for black than white faces, but their elderly white participants performed equally well with faces of both races. Adding another dimension to other-race studies, O'Toole, Peterson, and Deffenbacher (1996), using brief presentations of faces, demonstrated that even the most salient of facial characteristics, face sex, is impaired for other-race faces. Caucasian observers discriminated male and female Caucasian faces more accurately than Oriental faces, and vice versa.

The reason most given for own-race bias is that through greater experience with members of one's own race, greater knowledge of within-race variation is required (Laughery & Wogalter, 1989), thus assuming important information cues for distinguishing within-race differences are not so well acquired by other-race members. It is possible that a similar effect may be found with age. George and Hole (1995) researched whether participants' own ages played a part in their estimations of other peoples' ages. They found participants were, indeed, better at judging the ages of faces which were similar in age to their own, and it may be speculated that this stems from differential familiarity with faces of different ages. In a further experiment, George and Hole's (1998) participants learned six faces which were later manipulated to look younger or older. Participants were able to cope well with facial changes induced by aging, but the reverse was not true: performance declined with young versions of the learned faces.

A further reason for the other-race phenomenon was suggested by Galper (1973), who found that white participants who held positive attitudes toward blacks displayed significantly better recognition of black faces than did white participants who held negative attitudes. Another possible factor contributing to own-race superiority suggested by Shepherd et al. (1974) was that of motivation of interest: presumably people more often have the need to recognise particular members of their own ethnic group, and thus learn the appropriate identifying cues. Himmelfarb (1966) conducted an interesting study in which it was demonstrated that anti-Semite participants exhibit a stronger stereotypical impression of 'Jew' than non-anti-Semite participants, and are thus more ready to identify faces as falling within that category.

Another factor which may be considered in the encoding of personal information, and thus have a bearing on the effect of stimulus face age in recognition, is that of self-reference. Self-reference is a rich and powerful encoding process. The self, defined as an abstract representation of past experience, appears to function as a superordinate schema deeply involved in the processing, interpretation, and remembering of personal information (Rogers, Kuiper, & Kirker, 1977).

Bäckman (1991), in a study of recognition memory across the life span, found that young adults (*M* = 23.8 years) showed better recognition for young than old unfamiliar faces. Conversely, Bäckman's younger-old (*M* = 68.5 years) group performed better with old than with young unfamiliar faces. In contrast to both of these groups, Bäckman's two oldest age groups (76 and 85 years of age, respectively) showed no effect of age of stimulus face. Newman-Keuls analysis revealed that young adults and young-old adults performed better with cohort-relevant faces than with cohort-irrelevant faces, although the two oldest age groups failed to show an effect of age for unfamiliar faces. In the few studies researching this topic (e.g., Bäckman, 1991; Fulton & Bartlett, 1991), elderly adults have been found to be no more accurate in the recognition of old faces as target items than in the recognition of young faces. How recognition accuracy varies for young adults with the age of stimulus faces is uncertain (Kausler, 1994). Bartlett and Leslie (1986) suggest the possibility that young adults have more knowledge of young faces, whereas older adults have equivalent knowledge of both young and old faces. Yarmey (1993), in a study of the recall of primary and secondary features of a woman previously met for 15 seconds, found young adults, in contrast to persons over 30, may be more familiar and interested in young people, and this age-orientation effect appeared to explain the same-age effect found in this age group.

Several possible lines of investigation have been reviewed above, each of which suggests that age of participant and age of stimulus face might interact in a face recognition study. Do older people particularly note and more easily recognise older people because there are more of them in their immediate environment? With a key feature like a face, do older people recognise older faces, those they are likely to interact with more readily than younger faces? Do they ignore young faces and concentrate on, and remember, faces of older people? Do older people conserve cognitive resources by attending more closely to own-age faces? Similar questions can be asked about the recognition accuracy of younger adults.

It is of some surprise that such questions remain unanswered. The present study addresses the important question of 'Does the age of the stimulus face interact with the age of the participant?' On the basis of the research outlined above, it is predicted that older people will have greater accuracy at recognising older faces and younger people, younger faces.

In summary, the aim of the present research is to investigate the effects of age, memory load, and stimulus face type on face recognition. Based on previous research, the key predictions are:

1. Face recognition performance will decline with age.

2. Memory load will interact with age such that the older the participants, the greater will be the effect of load. Furthermore, it is predicted that memory load will affect recognition performance, irrespective of age. That is, a main effect for memory load is predicted.

3. Although there is little previous research on the topic, it is expected that there will be an interaction between age and face type: older people will show greater accuracy at recognising older faces and younger people, younger faces. More specifically, participant age and stimulus face age will interact. This prediction is based on previous research that strongly suggests that the saliency of the stimulus face for a person is a major determinant of how well that face will be recognised.

4. Finally, using SDT methodology allows for the investigation of whether response bias is a function of age in the present study. Research evidence to date has been equivocal. For example, Ferris et al. (1980) did not find age-associated differences in response criterion, which contrasted with the finding of Smith and Winograd (1978) that older adults did, indeed, demonstrate a more relaxed decision criterion. The question of greatest interest is whether older participants adopt a stricter criterion in regard to deciding whether a face has been previously seen. In other words, does increasing age bring an increasing degree of

conservativism into deciding whether a face is “old” or “new”? Such criterion changes will be assessed using the *c* statistic, derived from SDT.

METHOD

Participants

Young participants

Thirty-two young people between 18 and 39 years (M = 25.93, SD = 5.85) volunteered to participate in the study. Of these 32 participants, 8 were male (age M = 26.40, SD = 3.91) and 24 were female (age M = 25.78, SD = 6.43). The participants were undergraduate students (n = 7) from the University of Canterbury, people in professional employment (n = 11), people employed in non-professional occupations (n = 12), or were mothers of young children and who were not employed outside the home (n= 2). All young people were recruited by word-of-mouth.

Middle-aged participants

Thirty-two people between 60 and 75 years (M = 66.84, SD = 4.69) volunteered to participate in the study. Of these 32 participants, 8 were male (age M = 68.56, SD = 4.77), and 24 were female (age M = 66.26, SD = 4.62). The majority of the middle-age group were retired (n = 23), although 6 males were employed (n = 4) or self-employed (n = 2), and three females were employed part-time. The middle-age group participants were recruited as a result of the researcher speaking to a church congregation and a service group, or by word of mouth.

Elderly participants

Thirty-two community dwelling people 76 years and over (M = 81.22, SD = 5.52) volunteered to participate in the study. Of these 32 participants, 8 were male (age M = 79.11, SD = 2.78) and 24 were female (age M = 81.93, *SD* = 6.06). All of the elderly participants were retired, although 5 (2 males and 3 females) were undertaking part-time voluntary work. The elderly participants were recruited by speaking to a church congregation, a craft and scrabble group, and by word of mouth.

All materials and procedures used in the present study were approved by the Massey University Human Ethics Committee, Palmerston North (Protocol 01/28).

Group Assignment

Participants within each age group were randomly assigned to either the low memory load group or the high memory load group, 16 participants to each group. Thus, six groups of equal numbers were utilised. The randomisation was provisional on maintaining the same gender balance across all groups (8 males and 24 females in each group).

Apparatus

An Acer Extensa 500DX lap top computer with a 12" colour, non-active matrix, screen was utilised. This was typically placed on a dining-room sized table to ensure the screen was approximately 50 cm away when the participant was seated. The angle of the screen was adjusted to allow optimum viewing for each participant.

Task and Stimuli

The task was a recognition memory task using photographs of young or older men. Photographs of target faces were presented sequentially one at a time both during the study phase and during the single-interval, forced-choice recognition phase. During the recognition phase, participants indicated whether they had seen the stimulus before. Participants were instructed to guess if they were not sure of the correct response.

Eighty stimulus photographs were used. These were of male university students (n = 40) and older males (n = 40) between 63 and 97 years (*M* = 78, *SD* = 7.48). The photographs of the young men were part of a set held by Massey University School of Psychology for research purposes. They were primarily of male, second-year psychology students aged approximately 20 years. The older men, who volunteered to have their photographs taken for the purposes of research, were recruited from the Papanui Returned Servicemen's Association and the Christchurch branch of the Star of Italy Association. The 40 photographs of young males were randomly assigned to be either a target or a distractor – 20 of each. The same procedure was repeated with the older male photographs, thus giving 40 target photographs (20 young and 20 old stimuli), and 40 distractors (20 young and 20 old). The photographs were presented by computer. (A sample stimulus can be seen in Appendix A.)

Photographs of male faces were used to eliminate confounding by a sex of participant by sex of face interaction. Shepherd (1981) reports that when this occurs it is usually attributable to females showing greater facility on women's faces. Vokey and Read (1988) concur, stating that the same-sex bias in recognition is often found with female, but not male, participants.

Manipulating the stimulus load varied the level of difficulty. Memory load refers to the load at study (20 or 40 faces). Recognition load, on the other hand, is the number of faces shown in the recognition phase (40 or 80 faces). Although the present study is interested in memory load, the extra faces (40 versus 80) in the recognition phase could confound the outcome. Thus, the sequence of faces was constructed so that memory load and recognition load could be independently evaluated. To construct the sequence of photographs shown to Low Memory Load (LML) and High Memory Load (HML) groups, the following procedure was used. For the LML group the first 20 target photographs (10 young and 10 old) were shown during the study phase, then mixed with the first 20 distractors (10 young and 10 old) and stored in random order to be shown during the recognition phase. This sequence of 20 targets shown at the study phase and 40 mixed targets and distractors at the recognition phase, constituted the first 20 (study phase) and 40 (recognition phase) photographs, respectively, for HML participants seeing 40 faces at study (80 at recognition). To complete the sequences for the HML participants an additional 20 targets (10 young and 10 old) were added to the study phase, and an additional 20 distractors to the recognition phase. Therefore, the stimulus sets were constructed so the first 20 faces shown at study and the first 40 at recognition were the same, and identically sequenced for both the LML and HML groups. In this way, only load at study was free to vary during the first 40 recognition trials. A comparison of recognition scores for the first 40 trials enabled the effects of memory load to be assessed independently of the potentially confounding effects of recognition load (Podd, 1990).

Any potential memory cues, apart from the faces themselves, were controlled by the photographs being taken with the model standing in front of a white screen and ensuring no model had facial hair, spectacles, jewellery, or unusual features. Clothing was obscured by a black cape draped around the neck and shoulders of all models. All photographs were taken full-face, with the model assuming a neutral expression and looking straight into the camera.

In both study and recognition phases, each stimulus face was centred on the computer screen as a colour photograph measuring 12 x 15 centimetres. Each stimulus was presented for 5 seconds with an inter-stimulus interval of 3 seconds during which the screen was blank. During the recognition phase a tone sounded at the end of the 5 second stimulus presentation as a reminder to participants that a decision must be made, if it had not already, within the 3 second inter-stimulus interval.

Design and Analysis

The design was a 3 x 2 x 2 mixed factorial design, in which Age (<40, 60 - 75, and >75) and Memory Load (low vs. high) were between-group factors and Face Type (young vs. old) was a within-groups factor (Table 1). Participants were randomly assigned to the memory load groups, with the provision that there was the same ratio of males (4) to females (12) in each group.

Table 1
A visual representation of the mixed design. Age (<40, 60 - 75, >75) and Memory Load (low and high) are between-group factors, and the within group factor, Face Type (young and old), is shown within the cells.

AGE GROUP	Face Type (Low)		Face Type (High)	
<40	Young	Old	Young	Old
60-75	Young	Old	Young	Old
>75	Young	Old	Young	Old
	Low		High	

MEMORY LOAD

The dependent variables were the scores on the recognition test, represented by hit-rate, false alarm rate, *d'*, *A'*, and *c*. The probability of reporting a face as old, given it was an old item, *p* ("old"|old), defines the hit rate. The false alarm rate is defined as reporting the item as old when it was in fact a new item, *p* ("old"|new). As well as reporting the usual statistics along with their level of statistical significance, the effect size (Cohen's *d*: Cohen, 1988), and the post hoc statistical power (*SP*) values are also reported for *t*-tests. It is this researcher's firm belief that the effect size and *SP* should always be reported along with the conventional significance level. The main reason is that a null result can come about in two ways: firstly, there may not be a real difference between groups thus leading to the null result, or secondly, there may be a real effect but insufficient statistical power to detect it. A presentation of effect size and *SP* allows for an evaluation of this issue. Cohen's (1988) conventions for effect size are utilised: small, $d = .20$; medium, $d = .50$; large, $d = .80$. *F* tests are reported using η^2 (calculated in SPSS), an estimate of the variance accounted for by the independent variable under consideration.

All statistical analyses were completed using the statistical package SPSS for Windows, version 10.0.5 (SPSS Inc., 1999). Only the *F* values and associated statistics are reported in the text. Full ANOVA tables can be found in Appendices E to I.

Procedure

Participants were tested in their own homes. Prior to testing, participants were requested to provide a quiet, distraction-free room where the testing would not be interrupted.

An information sheet about the study was given to participants to read, and a consent form was filled out and signed by the participants (see Appendices B and C). A visual acuity test was given to ensure that participants were able to clearly see the faces on the computer screen. Each participant was asked to read 18pt font sentences from *Reading Test Types* as approved by The Faculty of Ophthalmologists, London (1987). The vision test sheet was held at the same distance and angle as the computer screen. Because of the short duration of testing required, participants who were not able to see the test sheet clearly were still invited to complete the study and remained unaware their data could not be used, thus avoiding embarrassment or distress.

Participants were seated comfortably at a table on which the lap-top computer was placed. Adjustments to distance and angle of the screen were made to ensure comfortable and optimised vision for the participant. Because many of the participants were unfamiliar with computers, the use of the apparatus was explained carefully and all questions relating to it answered fully. Verbal instructions reiterated those on the information sheet previously read. Again, being cognisant of the advanced age of many of the participants, time was taken to explain procedures fully, and to answer any queries.

During the study phase, participants in the LML groups viewed 20 target photographs, consisting of the randomised ordering of 10 young faces and 10 old faces. At the completion of the study phase participants were requested to respond verbally as a target or distractor face appeared during the recognition phase of 40 photographs (the randomised ordering of 20 young and 20 old faces). Participants were requested to respond "old" to photographs previously seen, and "new" to photographs not previously seen. A forced-choice procedure was utilised, with participants instructed to guess if they were unsure of the correct response. In all, participants had eight seconds in which to make a response from the time each face appeared on the screen. The same procedure was carried out for the HML groups. These groups viewed 40 target faces at study (20 young and 20 old), and 80 target and distractor faces at recognition (40 young and 40 old).

When the recognition task had been completed, participants were thanked and debriefed. They were asked if they would like to know their results. These were interpreted in a positive light by the researcher.

RESULTS

Hit and false alarm rates were calculated for all 40 (LML) and all 80 (HML) trials. From these, values for *d′*, *A′*, and *c* were derived for each participant. Table 2 presents the means and standard deviations for all five statistics for each experimental group.

Table 2

Means and standard deviations (in parentheses) for d′, A′, hit rate, false alarm rate, and c as a function of Age, Memory Load, and Face Type for all trials.

Age		*d′*	*A′*	HR	FAR	*c*
		Face Type – Young				
<40						
	LML[a]	2.43(.96)	.91(.05)	.84(.12)	.13(.09)	.09(.40)
	HML[b]	1.62(.57)	.85(.07)	.75(.10)	.21(.13)	.10(.37)
60-75						
	LML	1.70(.73)	.84(.09)	.77(.15)	.26(.15)	-.07(.59)
	HML	1.48(.65)	.82(.10)	.75(.15)	.26(.13)	-.01(.40)
>75						
	LML	1.15(.75)	.77(.11)	.65(.18)	.28(.17)	.13(.47)
	HML	1.06(.59)	.76(.08)	.73(.19)	.39(.16)	-.23(.50)
		Face Type - Old				
<40						
	LML	2.32(.78)	.90(.05)	.79(.13)	.12(.08)	.16(.51)
	HML	2.17(.60)	.90(.04)	.79(.10)	.12(.08)	.21(.33)
60-75						
	LML	2.36(.86)	.90(.07)	.85(.18)	.19(.12)	-.20(.57)
	HML	2.06(.58)	.90(.05)	.83(.08)	.17(.11)	-.01(.33)
>75						
	LML	2.46(.98)	.90(.06)	.80(.19)	.14(.10)	.02(.64)
	HML	2.11(.88)	.88(.07)	.80(.15)	.18(.14)	.04(.52)

[a] LML - Low Memory Load
[b] HML – High Memory Load

d'

Looking first at the *d'* values, it can be seen that recognition accuracy declined as a function of age for the young stimulus faces, but not for the old stimulus faces. Thus, there was a strong interaction between Age and Face Type, $F\ (2,90) = 9.36$, $p < .001$, $\eta^2 = .17$, $SP = .97$, qualifying the two main effects for Age, $F\ (2,90) = 4.08$, $p = .02$, $\eta^2 = .08$, $SP = .71$, and Face Type, $F\ (1,90) = 53.98$, $p < .001$, $\eta^2 = .38$, $SP \approx 1.00$. This interaction is shown in Figure 1.

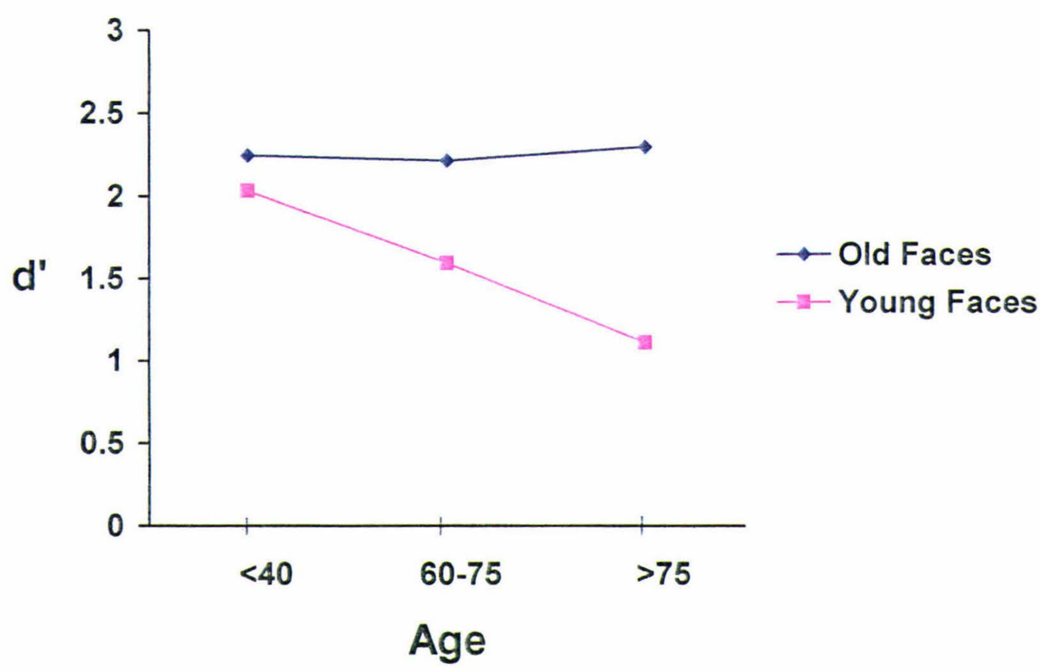

Figure 1

Interaction between Face Type and Age, collapsed over Load, for d'.

Figure 1 reveals that recognition accuracy was reasonably stable across all age groups for the old stimulus faces. However, for the young stimulus faces, recognition accuracy declined as a function of age, there being an especially large decline for the >75 group.

For the <40 groups there was no statistically significant difference in recognition accuracy for young and old stimulus faces (t (62) = 1.08, p = .28, d = .27, SP = .17). In contrast, there was a statistically significant difference in recognition rate between young and old stimulus faces for the 60 - 75 group (t (62) = 3.68, p < .001, d = .87, SP = .91). This group was better at recognising old (M = 2.21) compared to young (M = 1.59) faces. For the >75 group there was a very marked decline in recognition accuracy for the young compared to the old stimulus faces (t (62) = 5.82, p < .001, d = 1.44, $SP \approx 1.00$). While the recognition rate for old faces (M = 2.29) was comparable with the other two groups, accuracy for the young stimulus faces (M = 1.11) was considerably inferior. Thus, the Age x Face Type interaction was largely brought about by the comparatively poor recognition rate for young stimulus faces in the >75 group.

There was a main effect for Memory Load, F (1,90) = 6.35, p = .01, η^2 =.07, SP = .70. As expected, when Memory Load was high, accuracy (M = 1.75) fell below the level obtained (M = 2.07) for the LML condition. The effect of Load was particularly apparent in the <40 group when recognisability was markedly lower in the HML condition compared to the LML condition. However, this difference did not result in a statistically significant interaction between Age and Memory Load (F < 1).

Overall, the d' values indicate that recognition accuracy declined as age increased for the young stimulus faces, although recognition accuracy remained reasonably stable across all groups when participants observed old stimulus faces.

Hit Rate

The index, d', was decomposed into its component parts, hit rate and false alarm rate, to ascertain where the changes in d' occurred: Were the changes due mainly to changes in hit rate (correctly reporting a stimulus face as previously seen) or in false alarm rate (incorrectly reporting faces as previously seen)?

There was a main effect for Face Type, F (1,90) = 14.29, $p < .001$, $\eta^2 = .14$, $SP = .96$, but the effects of Age failed to reach significance, F (2,90) = 1.91, $p = .15$, $\eta^2 = .04$, $SP = .39$. However, as for d′, these two variables interacted, F (2,90) = 3.86, $p = .03$, $\eta^2 = .08$, $SP = .69$.

Simple main effects were again examined using *t*-tests. Collapsing over Memory Load, the Age x Face Type interaction showed hit rate did not vary across age for old stimulus faces (all *ps* > .05). For young faces, though, there was a statistically significant difference between the <40s and the >75s (t (62) = 2.60, $p = .01$, $d = .63$, $SP = .67$). However, there was no statistically significant difference between either the <40s and 60 - 75s (t (62) = .94, $p = .35$, $d = .25$, $SP = .13$) or between the 60 - 75s and >75s (t (62) = 1.67, $p = .10$, $d = .41$, $SP = .34$). It is of note that the statistical power for the last two *t* tests was low. Given the *d* values of .25 and .41, it seems likely that greater participant numbers would have produced statistically significant differences between these groups.

A statistically significant within-group difference between the hit rate for old faces and hit rate for young faces was shown for both the 60 - 75s (*Ms* = .84, .76; t (62) = 2.27, $p = .03$, $d = .57$, $SP = .58$) and the >75s (*Ms* = .80, .69; t (62) = 2.47, $p = .02$, $d = .59$, $SP = .64$). In contrast, the hit rate for the <40s was the same for both old and young faces ($M = .79$ for both groups). Memory Load had no consistent effect on hit rate, $F < 1$ (see Table 2, p.41).

In sum, the hit rate did not vary across the age groups for old stimulus faces. For young stimulus faces, in LML groups the hit rate decreased with increasing age, while in HML groups the hit rate was reasonably stable across all age groups, although performance was poorer than for old stimulus faces.

False Alarm Rate

There were main effects for false alarm rate for Age, F (2,90) = 8.28, p = .001, η^2 = .16, SP = .96, and Face Type, F (1,90) = 44.98, p = .001, η^2 = .33, $SP \approx$ 1.00 (see Table 2). Once again, these main effects were qualified by their interaction, F (2,90) = 5.97, p = .004, η^2 = .12, SP = .87.

Collapsing over Memory Load, for old stimulus faces there was a significant difference in false alarm rate for faces between <40 and 60 - 75 (t (62) = 2.38, p = .02, d = .60, SP = .66), whereas there was no statistically significant difference in the false alarm rate between <40 and >75 (t (62) = 1.41, p = .16, d = .40 , SP = .32) or between 60 - 75 and >75 (t (62) = .76, p = .45, d = .20, SP = .10). However, as for the hit rate, an effect size of d = .40 for the <40 and >75 groups, and a very low power value of .32 indicates that a more powerful test would have provided a statistically significant outcome. For young faces, though, there was a significant difference in false alarm rate between <40 and 60 - 75 (t (62) = 2.70, p = .009, d = .75, SP = .75), and <40 and >75 (t (62) = 4.32, p = .001, d = 1.14, SP = .99). The greatest increase in false alarm rate occurred between the <40 (M = .17) and the 60 - 75 (M = .26) groups, with a further increase between the 60 - 75 and >75 (M = .33) groups.

A within-groups examination of the false alarm rate between old and young stimulus faces revealed a statistically significant difference in all Age groups. The difference in the false alarm rate between old and young stimulus faces increased with age: the smallest difference occurred in the <40s (Ms = .12, .17; t (62) = 2.00, p = .05, d = .50, SP = .46), with an increase for the 60 - 75s (Ms = .18, .26; t (62) = 2.58, p = .01, d = .66, SP = .68), and the greatest difference was found in the >75 group (Ms = .16, .33; t (62) = 4.76, p < .001, d = 1.21, SP = .99).

In summary, the false alarm rate for young stimulus faces increased as age increased, with the oldest participants (over 75 years of age) having twice as many false alarms as the young adults (under 40 years of age). In contrast, for the old stimulus faces the greatest increase occurred between the <40 and 60 - 75 groups, with a further increase between the 60 - 75 and >75 groups.

A′

It will be recalled that the *A′* statistic provides an estimate of the area under the ROC curve. Like *d′*, it is a measure of recognisability independent of response bias. The index, *d′*, a parametric measure of recognisability, assumes underlying old and new distributions that are normal with equal variances. *A′* is a non-parametric measure, making no such assumptions. Thus, *A′* values were calculated to ensure that they produced the same results as d′. From Table 2 (p.41), it can be seen that, in general, *d′* and *A′* results are very similar. They both produce the same overall pattern of results. Hence, rather than reporting all of the ANOVAs based on *A′* here, these can be found in Appendix D.

In summary, while there was little difference in the ability of <40, 60 - 75, and >75 groups to recognise old faces, this did not hold true for the young faces. There was a declining ability to recognise young faces over the three groups: as the participants' age rose, young faces became less recognisable.

Response bias

The *c* measure, a measure of response bias, was calculated for each participant. It was of particular interest to ascertain if any of the age groups were especially biased to reporting faces as old or new. If so, then values of *c* would show up as being different from 0, the *c* value for a neutral criterion. From Table 3 it can be seen that there was a fairly even spread of positive (7) and negative (5) criterion values, with seven of the values deviating from 0 by .10 or less. However, for the larger mean deviations, it can be noted that the standard deviations were large, usually much larger than the mean deviation score itself. In the 60 - 75 LML group for old faces, one individual scored $c = .91$ and 2 individuals scored $c = -.91$, resulting in a standard deviation of .57. In the >75 HML group, the standard deviation of .50 was due to two participants: one producing a score of $c = 1.04$, and another with a score of -.97.

Table 3
Means and Standard Deviations (in parentheses) for c, as a function of Age, Memory Load, and Face Type.

Face Type		<40	60-75	>75
Young				
	LML[a]	.09(.40)	-.07(.59)	.13(.47)
	HML[b]	.10(.37)	-.01(.40)	-.23(.50)
Old				
	LML	.16(.51)	-.20(.57)	.02(.64)
	HML	.21(.33)	-.01(.33)	.04(.52)

LML[a] - Low Memory Load
HML[b] - High Memory Load

An ANOVA confirmed that there were no statistically significant main effects or interactions for *c*. (See Appendices E to I for the full ANOVA tables.)

Memory Load versus Recognition Load

The results thus far have been presented over all trials. It has been shown clearly that memory load (load at study) affects the outcome. However, the

HML groups had a higher recognition load (80 faces) compared with the LML groups (40 faces). The question arises as to whether this increased *recognition* load affected performance. To check on this possibility, the HML groups' results were calculated for the first 40 trials and the second 40 trials to separate out memory load, leaving it unconfounded by recognition load. As the first 40 trials of the HML task was comprised of the entire LML task, the effect of recognition load was expressed as a difference between the first 40 trials and the second 40 trials for the HML groups (Table 4). If recognition load is not imposing anything over and above memory load, which was manipulated by the number of faces at *study*, the statistics from the second 40 trials should be no different from those of the first 40 trials. This check on the effects of recognition load was conducted for *d'*, *A'*, hit rate, and false alarm rate (see Table 4).

Table 4
Mean difference scores between the first 40 trials and the second 40 trials for each Age group in the High Memory Load condition. Positive values indicate that scores were higher in the first 40 trials, and negative values that scores were lower in the first 40 trials.[1]

Age	**Face Type – Young**			
	d'	***A'***	**HR**	**FAR**
<40	.24	.05	.03	-.09
60-75	-.12	.00	-.02	.00
>75	-.08	-.01	-.03	.04
Mean	**.01**	**.01**	**-.01**	**-.02**
Face Type - Old				
<40	.41	.04	.07	-.05
60-75	.57	.05	.10	-.03
>75	.17	.02	.08	.05
Mean	**.38**	**.04**	**.08**	**-.01**

[1] A further analysis was conducted, comparing data from the 40 trials of the LML with the first 40 trials of the HML. As it added no new information this analysis has been omitted.

For the young stimulus faces, it can be seen that the overall mean values for all four measures barely deviate from 0.00 when the data are collapsed over Age. The only difference of note occurred for the <40 group whose recognition performance fell off in the second 40 trials, due mainly to a sharp increase in false alarms. However, overall, recognition load appeared to have little effect on the recognition of young faces.

The outcome was somewhat different for the old faces. When the data are collapsed over Age, the overall means for d' and A' show that recognition accuracy was *greater* in the first block of trials. These differences were due primarily to a marked decrease in hit rate for the second block of 40 trials. For the old faces, all Age groups had higher recognition rates in the first, compared to the second, 40 trials. The drop off in d' (and A') in the second 40 trials seemed to be due to quite a large decrease in the hit rate for all three Age groups. That is, in the second 40 trial block participants less frequently made a correct response of "yes, this is an old item". Put another way, the miss rate increased in the second 40 trials; previously seen faces were more likely to be identified as new faces. These results clearly demonstrate why it is necessary to differentiate between memory load and recognition load.

DISCUSSION

The present study aimed to find out if there is an age-related decline in face recognition memory, and if so, whether it was moderated by the age of the stimulus faces used or by memory load. More specifically, the present study asked four key questions about aging and face memory, and the results can be summarised as follows:

1. Does face recognition decline with age? On the basis of previous findings on the cognitive decline with age, it was expected that recognition performance would, indeed, decline with advancing age. As expected, older adults were generally less able to distinguish between target and distractor items, and were more prone to reporting new items as 'old' than were younger adults.

2. Does increasing memory load impose a greater burden on older participants compared to young participants? There have been few investigations of how memory load in the study phase affects performance. Previous research (e.g., Podd, 1990) has shown that an increased load at study does cause a decline in recognition accuracy. The present study was interested in finding out if memory load interacted with age of participant. It was expected that the >75 accuracy level would be inferior to that of either the <40 or the 60 - 75 year old groups, and this would be more pronounced in the high memory load condition as failure at one or more of the encoding, storage, or retrieval stages of memory becomes increasingly likely (Podd, 1990). The present data show that accuracy did decline as memory load increased. However, the prediction that memory load would interact with age such that the older the participants, the greater would be the effect of load was not supported. Although there was a main effect for Load, the latter did *not* interact with Age. Thus, load at study appears to affect older and younger participants in much the same way.

3. Does the age of the stimulus faces differentially impact on recognition accuracy with increasing participant age? It was expected that older people would have greater accuracy at recognising older faces and younger people, younger faces. Indeed, there was a progressive decline in the ability of older adults to recognise young faces: as age increased, participants became less able to distinguish young faces. The recognition accuracy of older adults was clearly moderated by the type of stimulus face presented. However, the converse did not hold true, and young adults were similarly adept at distinguishing young and old stimulus faces.

Memory load, also, was differentially affected by stimulus type: overall, for young stimulus faces there was little difference in performance between the first 40 trials and second 40 trials, whereas for old stimulus faces all age groups had lower recognition rates in the second, compared to the first, 40 trials. Thus, in the present study, over all trials, the decline in recognisability with age was primarily a function of an increase in the false alarm rate, although there was a small decline in hit rate for young stimulus faces.

4. The final research question was 'Is there any evidence of greater response bias with aging?' In the present study there were no statistically significant main effects or interactions for *c*. Thus, no age-associated response bias was found: changes in performance were shown to be a real difference in memory rather than merely being a bias toward reporting faces as 'old' or 'new'. Older adults were no more likely than young adults to employ a biased criterion in recognising faces in the present study.

Aging and Face Recognition

There was a significant main effect for Age when analysing d', A', hits, and false alarms. The decline in d' values for older adults compared to that of young adults highlighted the general difficulty older adults find with recognition memory. This result supports the findings of Gordon and Clark (1974) who conducted one of the few studies using a one-alternative, forced-choice procedure in prose recall and recognition tasks. Utilising the measure of *d′*, they also found that older adults produced lower recognition memory scores than young adults. The decreased level of performance was due to both a slight decrease in hit rate, and a larger increase in false alarm rate.

Decomposing *d′* to examine hit and false alarm rates independently is a valid procedure in the present study, because changes in hit and false alarm rates did not seem to be due to shifts in response criterion. A comparison of hits and false alarms across the three age groups produced interesting findings. Previous facial recognition memory studies (e.g., Crook and Larrabee, 1992) indicate there are few differences in hits but significant differences in the false alarm rate across the lifespan. The results of the present study suggest otherwise, as they demonstrate a marked decline in hit rate as well as increased false alarm rate when young stimulus faces were used. Other face recognition studies such as those of Podd (1990) and Rockel (1991) have yielded the same results using young stimulus faces. According to Podd (1990), assuming faces are stored in a piecemeal fashion (feature by feature), it is likely that when participants are presented with items in the recognition phase, they scan their memory for the encoded facial features. Those that were best encoded, or which were most memorable, are recovered. If an item's features match those already stored in memory, a response of 'old' is likely. Thus, a participant may recognise a distractor item as previously seen if it shares the same memorable features as a target face, thus leading to over-inclusiveness (Lithgow, 1998). For example, in a face recognition test, a participant may remember a particular face by a single attribute, such as the eyes. If presented with a distractor face which shares similar eyes to the target face already stored in memory, it may be incorrectly identified as having been seen before, thus resulting in a false alarm. When the actual target face is presented, the eyes should still be recognised, and the stimulus should be correctly identified as previously seen, thus maintaining the hit rate (see Podd, 1990). Such over-inclusiveness creates increasing confusion in distinguishing between targets and distractors. On the other hand, according to the piecemeal theory, a number of target cues may be lost whilst still leaving enough memorable features for recognition of a target stimulus, thus accounting for the little change in hit rate alongside increases in the false alarm rate.

For old stimulus faces there was no reliable difference in hit rate associated with aging, although there was an increase in the false alarm rate for the older participants compared to their younger counterparts. A similar result is reported by Yarmey (1984) who found, in a study of eyewitness testimony, that elderly adults demonstrated a higher false alarm rate than young adults, particularly for young stimulus faces. Crook and Larrabee (1992), in their study of 650 adults between 18 and 80 years of age, found that false alarm rates are more associated with advancing age than are hit rates. These results support the hypothesis that the false alarm rate increases with advancing age. Interestingly, some authors (e.g., Crook & Larrabee, 1992) do not report the age of their stimulus faces. Present results suggest that it is important to report this information.

The difference in recognition memory accuracy between young and older adults may be explained, at least in part, by a biological theory of aging. There is an abundant body of research demonstrating that the structures in the brain associated with memory deteriorate with age (Winocur, 1982). Bondareff (1985) posits the hippocampus is particularly vulnerable to physical changes during the aging process, and this may underlie the types of memory deficit observed in elderly adults. The presence in the brain of lipofuscin, neurofibrillary tangles, and neuritic plaques contribute to the degenerative process (Cavanaugh, 1997). It has been estimated that for every decade of life after the mid-40s, a 5% reduction in the number of cells in the hippocampus (a structure critical to the long-term store of information) occurs (Ball, 1977).

Parkin and Walter (1992) report that the recognition score may be similar for older and younger adults, possibly due to the older adults merely finding the item familiar without having any recollection of details, thus demonstrating a possible decline in frontal lobe functioning. If this were true, we would expect to find a larger recall than recognition deficit. Indeed, when Craik and McDowd (1987) compared reaction times on a secondary task performed alone or simultaneously with recall or recognition, they found that, compared to the alone condition, reaction times for elderly participants were markedly slower when recalling prior items, but were unaffected when recognising prior items. In contrast, young adult participants performed almost as well on the secondary task when recalling prior study items as when performing it alone (Kausler, 1994). Hasher and Zacks (1979) suggest that recall involves more effortful processing than recognition. Thus, older people are penalised when recall is required. It has been suggested by Craik (1983) that older people are less able than their younger counterparts to self-initiate the processing involved in recall, as few retrieval cues are provided and the person must initiate the appropriate mental operations in an effortful manner. In contrast, in a recognition task much of the required information is re-presented to the participant, with the appropriate mental operations driven largely by the stimuli associated with the task itself. While both recognition and recall of stimuli such as faces suffer with age, recall is more affected as age increases.

Memory Load and Age

Overall, replicating previous findings (Metzger, in press; Podd, 1990), the present investigation showed that increasing the memory load resulted in a reliable performance decrement in all groups of participants, irrespective of age. There was no statistically significant interaction between Memory Load and Age, and, hence, no support for the intuitively appealing hypothesis that cognitive decline with age would result in greater recognition deficits as load increased for the older participants compared to their younger counterparts. The fact that memory load affected young and old participants alike, is a particularly interesting result. While recognition accuracy *does* decline with age, older people seem just as capable as younger people when the stimulus ensemble is doubled in size. It would be especially interesting to ascertain if an even larger increase in load would cause a problem for the older participants. However, the present results strongly suggest that while age does cause an *overall* decline in recognition accuracy, it does not differentially affect the participants' ability to handle a doubling in memory load for faces.

It is possible differential age effects may have emerged had more stimuli been utilised during the study and recognition phases. During the design phase of the present study, using 40 faces at study (80 faces in the recognition phase) caused concern regarding possible attention and fatigue effects in the oldest group – some participants in this group were in the tenth decade of their lives. There was also some concern that as the number of target and distractor stimuli increased, it may have become increasingly difficult to discern the differences between a performance decrement caused by taxing a participant's memory and a participant becoming bored or fatigued by the task (Metzger, in press). However, fatigue did not appear to be the case in the present study and, in fact, the >75 groups demonstrated only a 0.22 difference in d' between the overall LML and HML conditions compared to the 0.48 difference for the <40 groups. This is an important issue. If older participants have poorer memories for recognising faces (e.g., Bäckman, 1991; Crook & Larrabee, 1992; Smith & Winograd, 1978), why does an increased memory load have little or no effect? It seems as if the elderly have sufficient *capacity* to deal with quite a large store (40) of target faces and are equally able to select from distractors almost immediately following the study phase. It would be interesting to increase the signal ensemble (at study) to, say, 80 faces to see if there is a point at which the elderly participants are more affected than the young by the increased load. It would also be of interest to examine the effects of varying the retention interval between study and test phases, along with memory load. Do the older participants have a greater rate of memory decay (see Podd, 1990) than younger ones, and is this rate of decay affected by the load? If performance for the elderly participants remained the same as for the young ones, we would have to conclude that memory *capacity* is not much affected by age, at least for facial recognition.

It is clear that memory load (load at study) has a detrimental effect on recognisability. However, the HML groups also had a higher recognition load of 80 faces, compared with the LML group which experienced a recognition load of only 40 faces. To check if recognition load was imposing anything over and above memory load, HML results were calculated separately for the first 40 trials and the second 40 trials. Following the design used by Podd (1990) and Metzger (in press), the first 40 trials of the HML task was comprised of the entire LML task. Thus, the effect of recognition load could be expressed as the difference between the first 40 trials and the second 40 trials for the HML groups. The results of this analysis show that for the young stimulus faces, the mean values for all four values (*d'*, *A'*, hit rate, and false alarm rate) barely deviated from 0.00 when the data are collapsed over age. However, for old stimulus faces all Age groups demonstrated lower recognition rates in the second, compared to the first, 40 trials, due to quite a large decrease in the hit rate for all three Age groups. This result strongly suggests that future research on face recognition must pay attention to the interaction between participant age and the age of the stimulus faces used.

It was notable that, in the second block of 40 trials, the <40 group demonstrated a sharp increase in false alarms during the recognition of young stimulus faces. This may have been due, in part, to lack of attention on a prolonged task self-reported by many of the <40 group participants as 'easy', leading to over-inclusion of similar stimulus faces. In contrast, when confronted with older stimulus faces, all Age groups demonstrated lower recognition rates in the second, compared to the first, 40 trials. This was due to quite a large decrease in the hit rate for all three age groups, suggesting that accuracy decreased because a smaller proportion of targets could be identified as memory load increased (Podd, 1990). It is clear that memory load and recognition load are factors which should be taken into account when making comparisons across face recognition studies as the number of stimulus faces used in the study and recognition phases varies considerably. For example, Laughery, Alexander, and Lane (1971) used only one face in four poses whereas Light et al. (1979) used 100 faces at study and 200 faces in the recognition phase. Memory load is an important factor to consider because it does change accuracy levels, although it does not appear to interact with age of participant.

Stimulus Face Type and Age

Recognition accuracy (d') declined as a function of age for the young stimulus faces, but not for the old stimulus faces. There was a clear, strong interaction between Age and Face Type. The <40 participants demonstrated they were equally able to distinguish both old and young stimulus faces. The 60 - 75 year old group were a little better at recognising old, compared to young, stimulus faces. However, it was the >75 group which showed a dramatic decline in the ability to recognise young stimulus faces. With young stimulus faces, older adults were more likely to fail to recognise target faces, and were also more likely to erroneously recognise new items as old when presented with older stimulus faces. Moreover, the result held for participants in both the low load and high load conditions.

Interestingly, the reverse pattern did not emerge. In the present study, young people were as adept at recognising old stimulus faces as were older adults. This finding appears inconsistent with previous reports of the Age x Face Type interaction (e.g., Bäckman, 1991; Fulton & Bartlett, 1991). In the few prior studies where the age of stimulus face versus age of participant has been investigated, an asymmetric pattern also emerged, but in the *opposite* direction. However, there are several important differences between these studies that may account for this difference in results. For example, Bäckman (1991) found that while young adults (M = 23.8 years of age) and younger-old adults (M = 68.5 years of age) performed better with cohort-relevant faces, the oldest participants (groups of 75- and 86-year olds) showed no effect of age of face when tested on the recognition of unfamiliar faces. In the second of two experiments investigating the effect of prior knowledge on recognition memory, Bäckman presented participants with 15 black and white photographs for each of four categories: dated famous people, contemporary famous people, unfamiliar young faces, and unfamiliar old faces. Each photograph was viewed for 5 seconds at study, and participants were required to discriminate the 60 target photographs which had been intermingled with 60 distractor photographs in an self-paced recognition test. Interestingly, in Bäckman's study young participants (19 - 27 years of age) demonstrated a drop in hit rate and an increase in false alarm rate when recognising unfamiliar old stimulus faces, compared to unfamiliar young stimulus faces. Conversely, younger-old participants (63 - 70 years of age) showed higher discrimination with elderly faces than with young faces, as did the 60 - 75 years of age group in the present study. Although the 85-year-old participants exhibited an overall drop in hit rate and an increase in false alarm rate when compared to the 76 year olds, both of these elderly groups performed equally well on the recognition of young and old unfamiliar stimulus faces.

It is notable that Bäckman (1991) does not appear to have investigated the criterion effects on the separate measures of hit and false alarm rates reported in this study. When the hit rate and false alarm rates are separately considered, it is vital to ascertain whether the changes in either are due to criterion shifts or genuine recognisability changes. Failing to account for response criterion differences may conceal age-related decrements in recognition memory (Ferris et al., 1980).

The data resulting from the present study also contradict those of Fulton and Bartlett (1991) who found that recognition accuracy in their young adult groups was generally better with young adult stimulus faces than with older faces, whereas recognition accuracy in their elderly groups showed no significant age effects, a result similar to that of Bäckman (1991). In contrast to both the present study and that of Bäckman, in Fulton and Bartlett's study, face age was varied between participants. That is, half of the young and elderly participants received a study list and recognition test containing only young and middle-aged faces, while the remaining young and elderly participants received a study list and recognition test containing only middle-aged and elderly faces. The middle-aged faces were the same in both conditions to allow for clarification of whether stimulus set age effects as opposed to item age effects, contributed to any effect of condition found to be present. Subsequent analysis indicated that though participant age differences were influenced by individual item age, they were not influenced by stimulus set age, thus indicating it is unlikely that different processing strategies are utilised for faces of different ages – a notion investigated in the Fulton and Bartlett study.

Several differences in the methodologies employed in the Fulton and Bartlett (1991) study, the Bäckman (1991) study, and in the present investigation, may account, at least in part, for the markedly different results found in the present study. For example, the age of the stimulus faces varied greatly across the three studies. In the Fulton and Bartlett (1991) study, independent age ratings of the young, middle-aged, and elderly stimulus photographs were 29.5, 44.3, and 62.7, respectively, giving a range of 33.2 years between young and old stimulus photographs. On the other hand, the age of young and old stimulus faces in Bäckman's (1991) study, averaged 29.5 and 76.2 years of age, respectively, with an age range of 46.7 years. In the present study, however, young stimulus photographs averaged 20 years whilst old stimulus photographs averaged 78 years of age, giving a range of 58 years between young and old photographs.

Secondly, the sex of stimulus photographs varied across the three studies. Whereas the Fulton and Bartlett (1991) study utilised 16 female and 8 male faces in each set of stimuli, Bäckman (1991) refers to stimulus faces as familiar or unfamiliar "individuals" and "people", without stating sex. The present study presented only male stimuli, taking cognisance of the body of literature (e.g., Shepherd, 1981; Vokey & Read, 1988) indicating that a same-sex bias is often found with female, but not male, participants. In the light of such prior literature, it is likely the sex of stimulus faces exerted some influence on the difference in findings between the Fulton and Bartlett study, the Bäckman study, and the present investigation.

Thirdly, differences also occurred in the pose utilised in stimulus photographs. In the Fulton and Bartlett (1991) study, stimulus faces were equally divided between four poses: smiling versus neutral, and L- and R-facing three-quarter views. Bäckman (1991) used black and white photographs of famous dated, famous contemporary, unfamiliar young, and unfamiliar old people. No information is given as to pose or expression. The present study presented coloured, frontal photographs of male faces assuming a neutral expression. Bartlett and Leslie (1986), in an effort to present ecologically valid stimuli, presented either multiple views, or single views of faces to groups of older and younger participants. The finding that multiple views resulted in no age difference between young and old adults, whereas in a standard single-view condition young adults perform better than elderly adults in distinguishing target photographs from distractor photographs, is indicative that studies utilising stimuli differing in pose and/or number of views of a single target presented, should be compared with caution.

Fourthly, an important methodological issue is whether the stimulus faces will be varied between groups or all participants will be presented with an intermingled set of young and old stimulus faces in a within-groups design. The participants in the Fulton and Bartlett (1991) study were presented only with young and middle-aged, or middle-aged and old stimulus faces. Conversely, both the Bäckman (1991) study and the present investigation treated stimulus face type as a within-groups factor, with all participants presented with an intermingled set of young and old faces.

Fifthly, very different methodologies were used in the three studies, regarding instructions given to, and the expectations of, participants. In the Fulton and Bartlett (1991) study, participants were given the task of rating the pleasantness of the stimulus faces during the study phase (1 = most pleasant and 5 = least pleasant) and to enter this on a response sheet. *No* forewarning of a subsequent test was given. For both study (48 stimuli) and recognition test (72 stimuli) phases stimulus faces were presented for 10 seconds with a 3 second inter-item interval. Bäckman (1991) presented each item for 5 seconds with a 2 second inter-item interval during the study phase. There was a 20-minute interval between the study and recognition phases, during which the participants completed a vocabulary test and a questionnaire concerning background information. In contrast to the two other studies under consideration, the recognition test in Bäckman's study was a self-paced task utilising 60 target faces intermingled with 60 distractor faces. No information is given by Bäckman regarding instructions to participants. In the present study, the 20 (or 40) stimulus faces at study, and the 40 (or 80) faces at recognition, were presented for 5 seconds each, with a 3 second inter-item interval. Participants were aware a recognition test would immediately follow the study phase. While Courtois and Mueller (1981) found it made little difference whether participants knew they would be tested or not, the introduction by Fulton and Bartlett of a decoy task in the absence of the information that a recognition test would follow presents a very different methodology from the present study.

Despite the different results obtained by Bäckman (1991), Fulton and Bartlett (1991), and the present study, it seems clear that age of participant and age of stimulus faces interact, an interaction that needs explaining. The possibility that young adults have greater knowledge of young faces, whereas older adults have knowledge of both young and old faces was discussed by Bartlett and Leslie (1986). Bäckman (1991), however, refutes this as an explanation for the results found in his investigation, and asserts that it is more likely that the lack of an effect of age among elderly participants is due to a failure to use prior knowledge in recognising unfamiliar faces. Bäckman suggests that this occurs because the recognition of an unfamiliar face is necessarily based on the physical and structural features of the faces to be remembered, thus lacking the rich representation (e.g., semantic, contextual, verbal, and multiple views) required by elderly adults in order to optimise remembering by utilising prior knowledge.

Fulton and Bartlett (1991) propose that it is tempting to argue that similar perceptual-learning differences may account for both participant age by face age interactions and the well-researched cross-race effect, where Subject Race x Face Race interactions do occur (e.g., Bothwell, Brigham, & Malpass, 1989; Shapiro & Penrod, 1986). Fulton and Bartlett suggest that this "makes sense" (p.629) if young adults are more practiced at perceiving and distinguishing young adult faces than old adult faces, whereas elderly adults are equally practiced with young and elderly faces. It is proposed, also, that the elderly, compared with young adults, rely more heavily on perceived familiarity in recognising faces, leading to both large numbers of face-recognition judgements and a lax criterion. Fulton and Bartlett further suggest that if perceived familiarity affects recognition judgements in old age, as shown by Bartlett and Fulton (1991), this would tend to increase the false alarm rate of elderly participants, relative to their younger counterparts, when elderly faces are tested. Conversely, it would tend to decrease the false alarm rate of elderly participants, relative to young participants when young faces are tested.

It is of particular interest that, in contrast to the Fulton and Bartlett (1991) and Bäckman (1991) studies, the present study produced clear data demonstrating that only older adults' performance was affected by the age of stimulus faces. The finding of the present study is consistent with those demonstrated in laboratory simulations of crimes (Yarmey, 1984). Elderly participants not only exhibited a markedly higher false alarm rate than younger participants, but the problems of the elderly adults were compounded by evidence indicating the false alarm rate for elderly participants was greater when the study-list faces were young rather than old: for Yarmey's elderly participants, young stimuli were markedly less distinguishable than old stimuli.

A robust finding that may be considered analogous to the stimulus face type versus age of participant, comes from the literature on the other-race effect. It is a commonplace observation that the faces of members of an unfamiliar race are more difficult to remember than own-race faces. A number of studies provide support for a cross-over interaction using Black versus White participants and target faces (e.g., Brigham & Barkowitz, 1978; Shepherd et al., 1974). Ellis (1984) asserts that under some circumstances individuals may attend to particular, discriminating facial features which are not usually as suitable for encoding faces of another race. The reason most often given for the own-race bias is that through greater experience with one's own race, greater knowledge of within-race variation is required (Shepherd, 1981). Thus, other-race members may not pay attention to relevant distinguishing features of members of a different racial group. Associated with the other-race phenomenon is the often reported feeling that other-race faces 'all look alike' (O'Toole et al., 1996).

Lavrakas et al. (1976) assert that quantity of contact with members of other races seems less important than the quality of such contact. For example, the number of black friends predicts the performance of white participants on cross-race tasks, whereas the sheer amount of inter-racial contact does not. While it may well be true that older adults are more likely to have a higher quality of contact with members of their own peer group, thus, at least in part, explaining the same-age superiority in recognition accuracy for older adults, it does not explain why the converse relationship did not occur. While it seems likely that young people will also have close friends amongst their own peer-group, in the present study the young adult group consisted of participants between the ages of 18 and 39 years (*M* = 26 years of age) with three quarters of the group having made the transition into working life. It is likely that the majority of the young adults in this study have moved beyond the adolescent need for close affiliation with peers into working and socialising with a wider cross-section of society (Peterson, 1989; Santrock, 1996). While the young adult groups in the Fulton and Bartlett (1991) and Bäckman (1991) studies exhibited a similar average age as the present study (*M* = 27.6 and *M* = 23.8, respectively), the Fulton and Bartlett group were all females with a range of 20 to 36 years, and the Bäckman participants were a somewhat younger group of males and females between the ages of 19 and 27 years. Such disparity in the definition of "young adult" renders definitive comparisons difficult.

Self-reference is a rich and powerful encoding process, and the self appears to function as a superordinate schema vitally involved in memory (Rogers et al., 1977). It is clear that for self-reference to be useful, the self must be a well-structured concept, a process involving an interaction between previous experience and incoming stimuli (Cantor & Mischel, 1977). Might this concept of the self have been achieved by the older adults, more so than for younger participants, some of whom were in late adolescence? In the light of self-reference, it appears reasonable to expect older adults to more easily encode the faces of adults similar to themselves, whereas younger adults as young as 18 years of age may not yet have acquired a uniform, well-structured concept of self posited by Cantor and Mischel as vital to the self-reference effect. Fulton and Bartlett (1991) noted elderly participants in their face recognition study exhibited both an inflated rate of false alarms and a more relaxed criterion, compared to younger adults. They concluded that the elderly rely more heavily on perceived familiarity, a notion consistent with self-reference.

Among several variables that have been suggested as related to the ability to recognise an other-race face, is that of experience. The experience hypothesis is predicated on the idea that the relative deficit in recognising other-race faces stems from a lack of personal experience with other-race individuals (Lavrakas et al., 1976). Galper (1973) argues it is an individual's attitude toward other-race individuals which acts as the important correlate of other-race recognition. It is entirely possible that both experience with cross-age target faces, and attitude towards cross-age members, influence recognisability. In present-day society, many older people are, indeed, isolated from wider society and older adults' social circle may consist primarily of other older people. In addition, conservation of cognitive resources may result in the older adults' attention being focused on those most salient to them – other older adults. Additionally, in a fast-moving society of rapid technological change, older adults may feel somewhat alienated from the 'young people's world', and thus be influenced by the outgroup homogeneity effect – the perception of other groups as being more similar to one another than are members of one's own ingroup (Franzoi, 1996). This proposal is supported by Malpass and Kravitz (1969) who found differential recognition performance by persons of one social group for members of another. While this may, in part, explicate the finding that older people are less able to distinguish between younger stimulus faces, the reason for the asymmetric nature of the decrement is as yet unclear. However, it is possible that younger people have more exposure to older people such as teachers, lecturers, or grandparents, for example, than the elderly do to the young. The elderly may well be more salient in a young person's life than is the *reverse* case. This 'saliency asymmetry' constitutes a worthwhile subject for future research.

In an experiment conducted by George and Hole (1998), participants viewed six faces for a total of 11 seconds each, consisting of an original viewing of 5 seconds, plus three additional 2-second presentations. Participants were prompted to provide a description of each face, and learn the name associated with each face. In a recognition task, participants were presented with twenty-four faces in random order. Six of these faces were either younger, older, the same age, or exactly the same photographic images that had been learnt previously. Interestingly, in view of the results of the present study, participants were able to cope well with facial changes induced by aging, but not with faces made younger. It must be left to future investigation to find if a similar mechanism underpins this result and the finding of the present study that older people have difficulty in distinguishing young faces. Shepherd (1981) suggests that interactions between participant characteristics and stimulus face characteristics constitute some of the most promising questions for future research, and that fine-grained study of participants' responses to stimulus faces is vital.

The present study sought to achieve this in relation to participants' response to same-age and cross-age stimulus faces. However, future theories of face recognition will need to take into account the fact that the age of the participant and the age of the people portrayed in stimulus materials interact. Thus, statements about face recognition that might be true for one group of participants and one set of stimulus faces, may not be true for another. Future studies must report the mean and standard deviation for the ages of the stimulus faces. It seems apparent from the comparison between Fulton and Bartlett (1991), Bäckman (1991), and the present study, that different sets of stimulus faces lead to different recognition rates.

In sum, age and type of stimulus face strongly interacted in the present study. Young adults were able to recognise old stimulus faces as well as young stimulus faces, but this was not true for the aged participants. This finding has implications for both a complete theory of face recognition and for the stimulus materials used in future studies of face perception.

Response Bias

The final research question was directed towards investigating any possible changes in criterion which might occur with age. In the present study there were no statistically significant main effects or interactions for *c*. Thus, no age-associated response bias was found; changes in performance were shown to be a real difference in recognition memory rather than merely being a bias toward reporting faces as 'old' or 'new'.

The response bias analysis suggests older adults utilised a similar strategy to young adults in performing the facial recognition task in the present study. These results lend support to those of Ferris et al. (1980) who found no response bias difference between young adults and two groups of older adults (normal and impaired). When compared to young adult participants, the older adults did not employ an overly conservative or cautious approach in the recognition of previously-seen target faces. Botwinick (1966) suggests older adults demonstrate an elevated level of cautiousness when responding to laboratory stimuli, and Bartlett, Leslie, Tubbs, and Fulton (1989) suggest older adults favour 'old' judgements rather than risk-taking. On the other hand, both Fulton and Bartlett (1991) and Smith and Winograd (1978) found that older adults exhibit a more relaxed criterion than their younger counterparts. The analysis of *c* in the present study did not support the presence of either an elevated level of cautiousness, or a more relaxed criterion for older adults when compared with young adults.

In sum, no definitive conclusion regarding response bias is at present possible. Clearly, more research is required to find out more about response bias in elderly, compared to young, participants.

Limitations of the Present Study and Suggested Further Research

As long ago as 1981, Goldstein and Chance asserted that memory load is a variable neglected by investigators. Apart from the finding of a small handful of investigators, this remains as true now as it was 20 years ago. Metzger (in press) has suggested that to gain a more complete understanding of how increasing stimulus loads affect diverse populations, an investigation of load effects on older participants (over the age of 65) is warranted. While the present study has sought to rectify this position, it may be that employing older age groups of 60 - 75 and >75 years of age was too coarse. Further delineating older adults into a greater number of sub-groups would be a valuable modification to this study, particularly within the >75 years of age group. Participants in this group ranged from 76 to 94 years of age, and the present study makes it clear that rapid decline in recognition memory for faces occurs within this group as age increases. In the light of these findings, increasing the number of participants and grouping older adults into decades would further clarify the onset, extent, and rate of decline. It is crucial to explanations of the recognition process that any systematic age differences in recognition memory are more fully understood.

With regards to the differences encountered by participants in the two memory load conditions (LML vs HML), a difficulty resulting from the high load condition is the longer list length during the recognition phase. Low load participants make judgements on 40 stimulus faces compared to 80 stimulus faces for the high load participants. This can pose a problem, as when participants are required to make judgments on 80 faces, confusion can occur as to whether an item, particularly near the end of the recognition phase, was seen during the study phase or near the beginning of the recognition phase. It is possible that when the recognition phase follows immediately after the study phase in one block, this results in an artificially high decline in *d'* due to confusion, fatigue, or both.

A further difficulty for participants in the HML condition was that a longer time elapsed between commencing the study phase and the commencement of the recognition phase. Observing 40 faces for 5 seconds with an inter-item space of a further 3 seconds plus 30 seconds for verbal instruction prior to the recognition phase, resulted in six minutes between the commencement of each phase. For participants in the LML groups only 3 minutes and 15 seconds elapsed between the commencement of each phase. The robust age-associated decrement in speeded tasks (e.g., Salthouse 1985,1993, 1996), exacerbated by the inexorable procession of faces appearing on the computer screen at 8 second intervals, may have contributed to the decline in face recognition for older adults overall. Participants in the HML groups were exposed to 120 faces over 16.5 minutes (inclusive of verbal instructions prior to the recognition phase), and this may well have constituted a more difficult task for older adults because of the pressure of the timed task.

The intriguing finding of a strong interaction between stimulus face type and the age of the participants promises a rich area for future research. In an interesting study, Feinman and Entwisle (1976) demonstrated that when children viewed pictures of children, a female superiority effect occurred only when looking at female child faces. This suggests the present study would benefit by extending both the age of stimulus faces and the age of participants across the lifespan, thus including children. It would be of great interest to discover if the decrements experienced by older participants in the recognition of young adult stimulus faces would extend to, or increase when confronted with, children's faces. Of equal interest would be an investigation of whether a symmetric cross-age relationship is present when the extremes of the life span are taken into account.

Manipulating the degree of target-distractor similarity could further enhance the present study. This may be achieved by such means as having stimulus photographs ranked for similarity (e.g., Rockel, 1991), or using computerised stimuli in order to produce stimulus photographs with controlled degrees of similarity (e.g., Podd, 1990). Controlling target-distractor similarity would allow future research to clarify at what point of similarity targets and distractors become indistinguishable to older adults.

Because of the cross-sectional nature of the present study, data must be interpreted with caution. Cross-sectional research tends to paint a bleak picture of aging (Cavanaugh, 1997), and cannot address issues of individual differences over time. The assumption is made that older adults had comparable recognition memory ability to the young participants in the study when they, too, were young. However, as long as the limitations of cross-sectional research are taken into account, such studies provide a 'snapshot' view of age differences of issues such as face recognition, which would benefit from future follow-up with research designs which are sensitive to age change and provide longitudinal data.

Although three decades of research have produced a plethora of studies pertaining to variables thought to affect facial recognition memory, interactions between many of these variables await investigation. Attention to interactions in both laboratory experiments and naturalistic studies would bolster the literature and lead to an increased understanding of the theoretical underpinnings of facial recognition memory.

Summary

The present study investigated two variables that could reasonably be expected to interact with the age of the participant: age of stimulus face, and memory load. In contrast to some previous findings (e.g. Craik & McDowd, 1987; Craik et al., 1987; Schonfield & Robertson, 1966), the present study found that recognition memory can, indeed, become impaired with age. Older adults showed a decrease in recognition accuracy due to both a small decrease in the hit rate and a more marked increase in false alarms. Any future theory of face recognition memory must be able to account for such an age-related decline.

The results emerging from the current study confirmed those of Podd (1990) in showing that increasing the memory load resulted in a reliable performance decrement in recognition accuracy. Somewhat surprisingly, this decrement in performance was independent of age. There was no statistically significant interaction between memory load and age, or memory load and face type in the present study. This result was obtained irrespective of the recognition index used, and with the potentially confounding effects of recognition load removed.

Adult efficiency for recognising pictorial material has been demonstrated in research such as that of Shepard (1967) where participants scored hit rates of 96.7% and 99.7%, respectively, on two subsets of 612 pictures in a test requiring participants to indicate if the old picture was on the left or right when a target and a distractor were presented side by side. Park et al.

(1986) showed that both young and older participants' memory improved with increased elaboration of pictorial material. However, it is clear from the results of the present study and that of Podd (1990) that there is a limit to the number of faces that can be recognised. This limit falls short of the recognition capacity for other pictorial material and may be accounted for by research utilising pictorial items other than faces, maximising stimulus heterogeneity, and enhancing memorability as in Shepherd (1967). Faces are unique because of the extent of within-group discrimination required for such homogeneous stimuli. Consequently, relational properties such as distance between the eyes must be used to distinguish particular faces (Diamond & Carey, 1986). As Damasio (1989) proposes, the similarity of exemplars is the reason for face recognition being one the greatest burdens for cognition and for the neural apparatus undergirding it.

The present study is the first to integrate memory load and stimulus face type into an investigation of the effects of aging on recognition memory for faces. A substantial finding was the strong interaction between age and stimulus face type. It is particularly intriguing that this interaction emerged only for older adults, and was most marked for the oldest adult participants, those over 75 years of age. Given that the present results conflict with the earlier findings of Bäckman (1991) and Fulton and Bartlett (1991), no definite conclusion is possible. It is strongly suggested that further research on this interaction is urgently required, for both methodological and theoretical reasons.

In conclusion, the presence of age-related decrements in facial recognition memory has been confirmed by the present study, and such decrements increase with advancing age. Most importantly, the present study has demonstrated the age of the stimulus face undoubtedly affects recognition accuracy of older adults, whereas young adults seem able to distinguish between target and distractor faces equally well whether they be young or older faces. The absence of an age-related response bias is noteworthy. The changes in performance were shown to be a real difference in memory rather than a tendency toward reporting faces as 'old' or 'new'.

The effects of memory load and the age of the stimulus faces in relation to the age of participants are factors that can confound the results of face recognition studies. Future research must take variables such as these into account, both in terms of developing a theory of face recognition and when comparing results across studies where different memory loads and different participant age/stimulus face age combinations may make comparisons invalid. As long as the memory load is held constant within a study, groups can be compared in terms of absolute performance levels.

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APPENDICES

Appendix A

Sample Stimulus Face

SAMPLE STIMULUS FACE

Permission was obtained from the above participant
to include his photograph in this thesis

Appendix B

Information Sheet

Massey University
COLLEGE OF HUMANITIES & SOCIAL SCIENCES

School of Psychology
Private Bag 11 222,
Palmerston North,
New Zealand
Telephone: 64 6 356 9099
Facsimile: 64 6 350 5673

The Effects of Age, Memory Load, and Stimulus Type on Facial Recognition Memory.

Information Sheet

The perception and recognition of faces demonstrates the extraordinary sensitivity and power of the human visual memory system. Because we are able to recognise people from their faces, discern their mood, decide whether or not they are listening to us, and gain understanding of the spoken word through lip movement, for example, the face mediates a wider variety of cognitive and social activities than any other visual object. People who lose the ability to recognise faces (prosopagnosia) experience a profound effect on their lives. The present research, for the Masterate of Allison Lamont, student at Massey University, will investigate the effects of age on face recognition, observing whether increasing the amount people are asked to remember impairs memory performance, and whether people are more accurate at recognising faces from their own age group. This research will be carried out under the supervision of Dr. John Podd, who may be contacted at the School of Psychology, Massey University, Private Bag 11 222, Palmerston North.

- In this study you will be asked to first read a few sentences to check your vision.

- You will then observe a number of photographs, one at a time, on the computer screen. You will see each face for five seconds and then have a three second break before the next face.

- On the recognition part of the session you will see twice as many photographs, and will be asked to say whether the faces are 'old' (you have seen it before) or 'new'.

- If you are unsure, please guess! Try to make your guesses as evenly spread over 'old' and 'new' as possible.

- All data from the study will be identified as a code only and will not be able to be linked to any individual. All information will be stored securely and will be destroyed after the holding period as outlined in the Massey University Policy on Research Practice, Section 2.2.

- It is anticipated the findings of the study will be published in a suitable scientific journal.

Your rights

You have the right:

- to decline to participate
- to withdraw from the study at any time
- to refuse to answer any particular question
- to ask any questions about the study at any time during participation
- to provide information on the understanding your name will not be used
- to be given access to a summary of findings at the conclusion of the study.

If you have any queries or concerns, please feel free to contact me on 352 9798.

Allison Lamont

Appendix C

Consent Form

Massey University
COLLEGE OF HUMANITIES & SOCIAL SCIENCES

School of Psychology
Private Bag 11 222,
Palmerston North,
New Zealand
Telephone: 64 6 356 9099
Facsimile: 64 6 350 5673

The Effects of Age, Memory Load, and Stimulus Type on Facial Recognition Memory.

CONSENT FORM

I have read the information sheet for this study and have had the details explained to me. My questions about the research have been answered to my satisfaction, and I understand I may ask further questions at any time.

I understand I have the right to withdraw from this study at any time, and to decline to answer any particular questions.

I agree to provide information to the researcher on the understanding that my name will not be used.

I understand that the information will be used only for this research and publications arising from this research project.

I agree to participate in this study under the conditions set out in the Information Sheet.

Signed: ....

Name: ....

Date: ....

Contact Address: ....

....

Date of Birth: ....

Please indicate if you would like to receive a summary of the results of this study YES / NO

This study has been approved by the Massey University Human Ethics Committee, Palmerston North (Protocol 01/28).

Appendix D

Results Analysis for the *A′* Measure

A′

Looking at the *A′* values, it can be seen that recognition accuracy declined as a function of age for the young stimulus faces, but not for the old stimulus faces. Thus, as can be seen in Figure D1, there was a strong interaction between Age and Face Type, $F\,(2,90) = 12.53$, $p < .001$, $\eta^2 = .22$, $SP \approx 1.00$, qualifying the two main effects for Age, $F\,(2,90) = 9.03$, $p < .001$, $\eta^2 = .17$, $SP = .97$, and Face Type, $F\,(1,90) = 71.10$, $p < .001$, $\eta^2 = .44$, $SP \approx 1.00$. These findings are the same as for the *d′* measure.

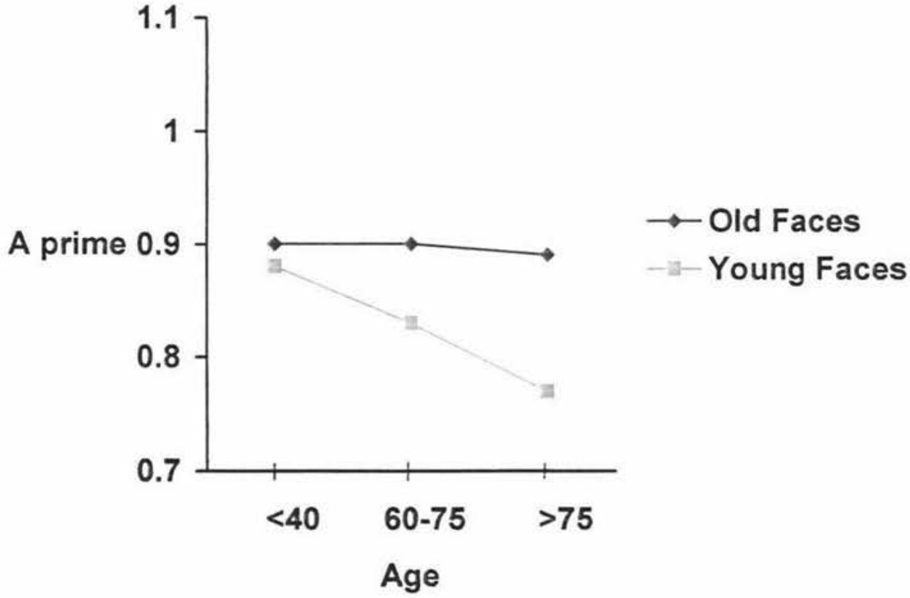

Figure D1:

The A′ interaction between Face Type and Age collapsed over Load.

Whereas Age did not interact with old stimulus faces, it did for the young faces (Figure D1). Participants in the <40 groups were able to distinguish both old and young stimulus faces ($M = .90, .88$; $t\,(62) = 1.61$, $p = .11$, $d = .33$, $SP = .34$). In contrast, there was a statistically significant difference in the ability to distinguish between old and young stimulus faces in both the 60 - 75 ($M = .90, .83$; $t\,(62) = 3.33$, $p < .001$, $d = 1.00$, $SP = .97$), and the >75 ($M = .89, .77$; $t\,(62) = 6.29$, $p < .001$, $d = 1.50$, $SP = 1.00$) groups.

Performance on old stimulus faces was unaffected by age. The difference for old stimulus faces between the <40 and >75 groups was (*M* = .90, .89; *t* (62) = .77, *p* = .45, *d* = .16, *SP* = .12). Within this range, differences between the <40 and 60 - 75 groups were (*M* = .90, .90; *t* (62) = .47, *p* = .64, *d* = 0), and for the 60 - 75 and >75 groups (*M* = .90, .89; *t* (62) = .30, *p* = .77, *d* = .14, *SP* = .10).

The overall result for *A′* was the same as for *d′* - there was no effect of Age.

In contrast, performance for young stimulus faces was markedly affected by Age with recognisability decreasing as age increased. Between the <40 (*M* = .88) and >75 (*M* = .76) groups the difference was statistically significant (*t* (62) = 5.72, *p* < .001, *d* = 1.50, *SP* = 1.00). There was also a statistically significant difference between both the <40 and 60 - 75 groups (*M* = .88, .83; *t* (62) = 2.39, *p* = .02, *d* = .63, *SP* = .73), and the 60 - 75 and >75 groups (*M* = .83, .76; *t* (62) = 2.93, *p* = .005, *d* = .78, *SP* = .87). As for *d′*, *A′* values showed a decline in recognisability with advancing age. While the recognition rate for old stimulus faces was identical with the other two groups (*M* = .90), accuracy for the young stimulus faces (*M* = .76) was considerably inferior. Thus, the Age x Face Type interaction, brought about by the comparatively poor recognition rate for young stimulus faces in the >75 group, paralleled that found for the *d′* measure.

In summary, whilst there was little difference in the ability of <40, 60 - 75, and >75 groups to recognise old faces, this did not hold true for the young faces. Clearly, as the *d′* measure also showed, there was a declining ability to recognise young faces over the three groups: as the age of participants rose, young faces became less recognisable. As the results were similar for both measures, it does not seem to matter whether a parametric recognisability measure (*d′*) or a non-parametric measure (*A′*) is used.

Appendix E

ANOVA for d' for All Trials

ANOVA for *d'* for All Trials

Tests of Within-Subjects Effects

Source	Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Power[a]
FACETYPE	21.755	1	21.755	53.981	.000	.375	1.000
FACETYPE * AGE	7.546	2	3.773	9.362	.000	.172	.975
FACETYPE * LOAD	.135	1	.135	.335	.564	.004	.088
FACETYPE * AGE * LOAD	1.916	2	.958	2.377	.099	.050	.469
Error(FACETYPE)	36.272	90	.403				

[a] Computed using alpha = .05

Tests of Between-Subjects Effects

Source	Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Power[a]
Intercept	701.161	1	701.161	926.204	.000	.911	1.000
AGE	6.180	2	3.090	4.082	.020	.083	.711
LOAD	4.810	1	4.810	6.354	.013	.066	.703
AGE * LOAD	.642	2	.321	.424	.656	.009	.117
Error	68.132	90	.757				

[a] Computed using alpha = .05

Appendix F

ANOVA for Hit Rate for All Trials

ANOVA for Hit Rate for All Trials

Tests of Within-Subjects Effects

Source	Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Power[a]
FACETYPE	.189	1	.189	14.290	.000	.137	.962
FACETYPE * AGE	.102	2	5.104E-02	3.864	.025	.079	.686
FACETYPE * LOAD	8.333E-06	1	8.333E-06	.001	.980	.000	.050
FACETYPE * AGE* LOAD	6.169E-02	2	3.085E-02	2.335	.103	.049	.462
Error(FACETYPE)	1.189	90	1.321E-02				

[a] Computed using alpha = .05

Tests of Between-Subjects Effects

Source	Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Power[a]
Intercept	116.906	1	116.906	3932.060	.000	.978	1.000
AGE	.114	2	5.692E-02	1.914	.153	.041	.388
LOAD	3.333E-03	1	3.333E-03	.112	.739	.001	.063
AGE * LOAD	5.907E-02	2	2.953E-02	.993	.374	.022	.218
Error	2.676	90	2.973E-02				

[a] Computed using alpha = .05

Appendix G

ANOVA for False Alarm Rate for All Trials

ANOVA for False Alarm Rate for All Trials

Tests of Within-Subjects Effects

Source	Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Power[a]
FACETYPE	.510	1	.510	44.984	.000	.333	1.000
FACETYPE * AGE	.136	2	6.777E-02	5.972	.004	.117	.870
FACETYPE * LOAD	3.797E-02	1	3.797E-02	3.346	.071	.036	.440
FACETYPE * AGE * LOAD	1.183E-02	2	5.917E-03	.521	.595	.011	.133
Error(FACETYPE)	1.021	90	1.135E-02				

[a] Computed using alpha = .05

Tests of Between-Subjects Effects

Source	Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Power[a]
Intercept	8.052	1	8.052	399.605	.000	.816	1.000
AGE	.334	2	.167	8.279	.001	.155	.957
LOAD	6.163E-02	1	6.163E-02	3.059	.084	.033	.409
AGE * LOAD	6.144E-02	2	3.072E-02	1.524	.223	.033	.317
Error	1.814	90	2.015E-02				

[a] Computed using alpha = .05

Appendix H

ANOVA for *A′* for All Trials

ANOVA for *A′* for All Trials

Tests of Within-Subjects Effects

Source	Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Power[a]
FACETYPE	.247	1	.247	71.099	.000	.441	1.000
FACETYPE * AGE	8.723E-02	2	4.361E-02	12.530	.000	.218	.996
FACETYPE * LOAD	5.033E-03	1	5.033E-03	1.446	.232	.016	.221
FACETYPE * AGE * LOAD	1.166E-02	2	5.832E-03	1.675	.193	.036	.345
Error(FACETYPE)	.313	90	3.481E-03				

[a] Computed using alpha = .05

Tests of Between-Subjects Effects

Source	Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Power[a]
Intercept	142.449	1	142.449	20521.77	.000	.996	1.000
AGE	.125	2	6.269E-02	9.031	.000	.167	.971
LOAD	1.482E-02	1	1.482E-02	2.135	.147	.023	.304
AGE * LOAD	4.977E-03	2	2.489E-03	.359	.700	.008	.106
Error	.625	90	6.941E-03				

[a] Computed using alpha = .05

Appendix I

ANOVA for *c* for All Trials

ANOVA for *c* or All Trials

Tests of Within-Subjects Effects

Source	Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Power[a]
FACETYPE	5.880E-02	1	5.880E-02	.346	.558	.004	.090
FACETYPE * AGE	.235	2	.117	.691	.504	.015	.163
FACETYPE * LOAD	.443	1	.443	2.607	.110	.028	.359
FACETYPE * AGE * LOAD	.258	2	.129	.761	.470	.017	.176
Error(FACETYPE)	15.287	90	.170				

[a] Computed using alpha = .05

Tests of Between-Subjects Effects

Source	Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Power[a]
Intercept	7.285E-02	1	7.285E-02	.249	.619	.003	.078
AGE	1.493	2	.747	2.554	.083	.054	.499
LOAD	3.008E-03	1	3.008E-03	.010	.919	.000	.051
AGE * LOAD	.701	2	.350	1.199	.306	.026	.256
Error	26.309	90	.292				

[a] Computed using alpha = .05

Appendix J

Raw Data for All Trials[2]

Raw Data for First 40 Trials

[2] Differences in z-score and *d′* statistics are due to rounding errors. Such rounding errors as do occur in raw data tables are due to the use of two sources of information. Z-scores were calculated according to Jones (2000), whereas Swets' (1964) tables were utilised in *d′* calculations. This applies to all appendices that include *d′*/z-score values.

Group 1: Under 40 - Low Memory Load - Young Faces – all trials

Participant	HR	FAR	Z-HR	Z-FAR	*d′*	*A′*	*c*
1	0.7	0.1	0.52	-1.28	1.8	0.881	0.38
2	0.6	0.1	0.25	-1.28	1.54	0.847	0.52
3	0.9	0.2	1.28	-0.84	2.12	0.913	-0.22
4	0.9	0.01	1.28	-2.33	3.6	0.972	0.53
5	0.8	0.2	0.84	-0.84	1.68	0.875	0.00
6	0.6	0.1	0.25	-1.28	1.54	0.847	0.52
7	0.99	0.01	2.33	-2.33	4.64	0.995	0.00
8	0.9	0.01	1.28	-2.33	3.6	0.972	0.53
9	0.9	0.2	1.28	-0.84	2.12	0.913	-0.22
10	0.9	0.1	1.28	-1.28	2.56	0.944	0.00
11	0.8	0.3	0.84	-0.52	1.36	0.835	-0.16
12	0.99	0.2	2.33	-0.84	3.16	0.946	-0.75
13	0.9	0.2	1.28	-0.84	2.12	0.913	-0.22
14	0.8	0.3	0.84	-0.52	1.36	0.835	-0.16
15	0.8	0.01	0.84	-2.33	3.16	0.946	0.75
16	0.9	0.1	1.28	-1.28	2.56	0.944	0.00
Mean	**0.84**	**0.13**			**2.43**	**0.911**	**0.09**
SD	**0.12**	**0.09**			**0.96**	**0.052**	**0.40**

Group 2: Under 40 - Low Memory Load - Old Faces – all trials

Participant	HR	FAR	Z-HR	Z-FAR	*d′*	*A′*	*c*
1	0.7	0.01	0.52	-2.33	2.84	0.921	0.91
2	0.9	0.1	1.28	-1.28	2.56	0.944	0.00
3	0.7	0.1	0.52	-1.28	1.8	0.881	0.38
4	0.99	0.1	2.33	-1.28	3.6	0.972	-0.53
5	0.8	0.1	0.84	-1.28	2.12	0.913	0.22
6	0.7	0.2	0.52	-0.84	1.36	0.835	0.16
7	0.99	0.2	2.33	-0.84	3.16	0.946	-0.75
8	0.9	0.1	1.28	-1.28	2.56	0.944	0.00
9	0.6	0.1	0.25	-1.28	1.54	0.847	0.52
10	0.8	0.2	0.84	-0.84	1.68	0.875	0.00
11	0.8	0.1	0.84	-1.28	2.12	0.913	0.22
12	0.7	0.3	0.52	-0.52	1.05	0.786	0.00
13	0.6	0.01	0.25	-2.33	2.58	0.895	1.04
14	0.99	0.1	2.33	-1.28	3.6	0.972	-0.53
15	0.7	0.01	0.52	-2.33	2.84	0.921	0.91
16	0.8	0.2	0.84	-0.84	1.68	0.875	0.00
Mean	**0.79**	**0.12**			**2.32**	**0.903**	**0.16**
SD	**0.13**	**0.081**			**0.78**	**0.051**	**0.51**

Group 3: Under 40 - High Memory Load - Young Faces - all trials

Participant	HR	FAR	Z-HR	Z-FAR	*d'*	*A'*	*c*
17	0.85	0.35	1.04	-0.39	1.42	0.839	-0.33
18	0.75	0.45	0.67	-0.13	0.8	0.736	-0.27
19	0.75	0.15	0.67	-1.04	1.72	0.876	0.19
20	0.75	0.35	0.67	-0.39	1.06	0.787	-0.14
21	0.6	0.2	0.25	-0.84	1.1	0.792	0.30
22	0.7	0.45	0.52	-0.13	0.66	0.703	-0.20
23	0.55	0.05	0.13	-1.65	1.77	0.859	0.76
24	0.85	0.25	1.04	-0.67	1.72	0.876	-0.19
25	0.85	0.2	1.04	-0.84	1.88	0.894	-0.10
26	0.75	0.1	0.67	-1.28	1.96	0.897	0.31
27	0.85	0.1	1.04	-1.28	2.32	0.929	0.12
28	0.9	0.25	1.28	-0.67	1.96	0.897	-0.31
29	0.65	0.01	0.39	-2.33	2.7	0.908	0.97
30	0.85	0.1	1.04	-1.28	2.32	0.929	0.12
31	0.65	0.2	0.39	-0.84	1.22	0.814	0.23
32	0.7	0.2	0.7	-0.84	1.36	0.835	0.07
Mean	**0.75**	**0.21**			**1.62**	**0.848**	**0.10**
SD	**0.10**	**0.13**			**0.57**	**0.067**	**0.37**

Group 4: Under 40 Under 40 High Memory Load OLD faces - all trials

Participant	HR	FAR	Z-HR	Z-FAR	*d'*	*A'*	*c*
17	0.85	0.1	1.04	-1.28	2.32	0.929	0.12
18	0.75	0.2	0.67	-0.84	1.52	0.855	0.09
19	0.6	0.05	0.25	-1.65	1.9	0.874	0.70
20	0.7	0.05	0.52	-1.65	2.16	0.903	0.57
21	0.85	0.15	1.04	-1.04	2.08	0.912	0.00
22	0.95	0.1	1.65	-1.28	2.92	0.960	-0.19
23	0.85	0.15	1.04	-1.04	2.08	0.912	0.00
24	0.65	0.15	0.39	-1.04	1.42	0.839	0.33
25	0.8	0.25	0.84	-0.67	1.52	0.855	-0.09
26	0.9	0.01	1.28	-2.33	3.6	0.972	0.53
27	0.75	0.05	0.67	-1.65	2.32	0.918	0.49
28	0.75	0.15	0.67	-1.04	1.72	0.876	0.19
29	0.8	0.01	0.84	-2.33	3.16	0.946	0.75
30	0.95	0.15	1.65	-1.04	2.68	0.946	-0.31
31	0.75	0.1	0.67	-1.28	1.96	0.897	0.31
32	0.8	0.3	0.84	-0.52	1.36	0.835	-0.16
Mean	**0.79**	**0.12**			**2.17**	**0.902**	**0.21**
SD	**0.10**	**0.08**			**0.6**	**0.043**	**0.33**

Group 5: Middle (60-75) Low Memory Load - YOUNG faces – all trials

Participant	HR	FAR	Z-HR	Z-FAR	*d'*	*A'*	*c*
33	0.9	0.1	1.28	-1.28	2.56	0.944	0.00
34	0.7	0.1	0.52	-1.28	1.8	0.881	0.38
35	0.7	0.3	0.52	-0.52	1.05	0.786	0.00
36	0.7	0.01	0.52	-2.33	2.84	0.921	0.91
37	0.9	0.3	1.28	-0.52	1.8	0.881	-0.38
38	0.9	0.2	1.28	-0.84	2.12	0.913	-0.22
39	0.9	0.3	1.28	-0.52	1.8	0.881	-0.38
40	0.99	0.5	2.33	0	2.32	0.869	-1.17
41	0.99	0.5	2.33	0	2.32	0.869	-1.17
42	0.6	0.3	0.25	-0.52	0.78	0.732	0.14
43	0.8	0.3	0.84	-0.52	1.36	0.835	-0.16
44	0.8	0.4	0.84	-0.25	1.1	0.792	-0.30
45	0.5	0.4	0	-0.25	0.26	0.592	0.13
46	0.6	0.2	0.25	-0.84	1.1	0.792	0.30
47	0.8	0.3	0.84	-0.52	1.36	0.835	-0.16
48	0.6	0.01	0.25	-2.33	2.58	0.895	1.04
Mean	**0.77**	**0.26**			**1.7**	**0.838**	**-0.07**
SD	**0.15**	**0.15**			**0.73**	**0.087**	**0.59**

Group 6: Middle (60-75) Low Memory Load - OLD faces – all trials

Participant	HR	FAR	Z-HR	Z-FAR	*d'*	*A'*	*c*
33	0.99	0.3	2.33	-0.52	2.84	0.921	-0.91
34	0.8	0.1	0.84	-1.28	2.12	0.913	0.22
35	0.8	0.2	0.84	-0.84	1.68	0.875	0.00
36	0.99	0.1	2.33	-1.28	3.6	0.972	-0.53
37	0.9	0.2	1.28	-0.84	2.12	0.913	-0.22
38	0.99	0.3	2.33	-0.52	2.84	0.921	-0.91
39	0.9	0.2	1.28	-0.84	2.12	0.913	-0.22
40	0.8	0.5	0.84	0	0.84	0.744	-0.42
41	0.9	0.3	1.28	-0.52	1.8	0.881	-0.38
42	0.99	0.2	2.33	-0.84	3.16	0.946	-0.75
43	0.99	0.1	2.33	-1.28	3.6	0.972	-0.53
44	0.99	0.2	2.33	-0.84	3.16	0.946	-0.75
45	0.3	0.1	-0.52	-1.28	0.76	0.722	0.90
46	0.8	0.1	0.84	-1.28	2.12	0.913	0.22
47	0.8	0.1	0.84	-1.28	2.12	0.913	0.22
48	0.7	0.01	0.52	-2.33	2.84	0.921	0.91
Mean	**0.85**	**0.19**			**2.36**	**0.899**	**-0.20**
SD	**0.18**	**0.12**			**0.86**	**0.070**	**0.57**

Group 7: Middle (60-75) HIGH memory Load for YOUNG faces - all trials

Participant	HR	FAR	Z-HR	Z-FAR	*d'*	*A'*	*c*
49	0.9	0.35	1.28	-0.39	1.66	0.864	-0.45
50	0.75	0.15	0.67	-1.04	1.72	0.876	0.19
51	0.7	0.05	0.52	-1.65	2.16	0.903	0.57
52	0.4	0.35	-0.25	-0.39	0.13	0.550	0.32
53	0.9	0.5	1.28	0	1.28	0.811	-0.64
54	0.6	0.3	0.25	-0.52	0.78	0.732	0.14
55	0.8	0.05	0.84	-1.65	2.48	0.932	0.41
56	0.6	0.3	0.25	-0.52	0.78	0.732	0.14
57	0.95	0.35	1.65	-0.39	2.02	0.889	-0.63
58	0.7	0.35	0.52	-0.39	0.91	0.760	-0.07
59	0.8	0.35	0.84	-0.39	1.22	0.814	-0.23
60	0.65	0.05	0.39	-1.65	2.02	0.889	0.63
61	0.95	0.25	1.65	-0.67	2.32	0.918	-0.49
62	0.8	0.2	0.84	-0.84	1.68	0.875	0.00
63	0.7	0.3	0.52	-0.52	1.05	0.786	0.00
64	0.8	0.25	0.84	-0.67	1.52	0.855	-0.09
Mean	**0.75**	**0.26**			**1.48**	**0.824**	**-0.01**
SD	**0.15**	**0.13**			**0.65**	**0.097**	**0.40**

Group 8: Middle (60-75) HIGH memory Load for OLD faces - all trials

Participant	HR	FAR	Z-HR	Z-FAR	*d'*	*A'*	*c*
49	0.99	0.1	2.33	-1.28	3.6	0.972	-0.53
50	0.85	0.15	1.04	-1.04	2.08	0.912	0.00
51	0.9	0.1	1.28	-1.28	2.56	0.944	0.00
52	0.9	0.2	1.28	-0.84	2.12	0.913	-0.22
53	0.75	0.4	0.67	-0.25	0.93	0.763	-0.21
54	0.75	0.05	0.67	-1.65	2.32	0.918	0.49
55	0.8	0.15	0.84	-1.04	1.88	0.894	0.10
56	0.95	0.35	1.65	-0.39	2.02	0.889	-0.63
57	0.8	0.1	0.84	-1.28	2.12	0.913	0.22
58	0.8	0.35	0.84	-0.39	1.22	0.814	-0.23
59	0.9	0.15	1.28	-1.04	2.32	0.929	-0.12
60	0.8	0.1	0.84	-1.28	2.12	0.913	0.22
61	0.8	0.15	0.84	-1.04	1.88	0.894	0.10
62	0.75	0.05	0.67	-1.65	2.32	0.918	0.49
63	0.85	0.25	1.04	-0.67	1.72	0.876	-0.19
64	0.7	0.1	0.52	-1.28	1.8	0.881	0.38
Mean	**0.83**	**0.17**			**2.06**	**0.896**	**-0.01**
SD	**0.08**	**0.11**			**0.58**	**0.049**	**0.33**

Group 9: Over 76 Elderly Low Memory Load - YOUNG faces – all trials

Participant	HR	FAR	Z-HR	Z-FAR	*d'*	*A'*	*c*
65	0.5	0.4	0	-0.25	0.26	0.592	0.13
66	0.8	0.5	0.84	0	0.84	0.744	-0.42
67	0.9	0.7	1.28	0.52	0.76	0.722	-0.90
68	0.3	0.2	-0.52	-0.84	0.32	0.615	0.68
69	0.5	0.2	0	-0.84	0.84	0.744	0.42
70	0.9	0.4	1.28	-0.25	1.54	0.847	-0.52
71	0.5	0.1	0	-1.28	1.28	0.811	0.64
72	0.7	0.1	0.52	-1.28	1.8	0.881	0.38
73	0.7	0.2	0.52	-0.84	1.36	0.835	0.16
74	0.6	0.3	0.25	-0.52	0.78	0.732	0.14
75	0.8	0.01	0.84	-2.33	3.16	0.946	0.75
76	0.9	0.3	1.28	-0.52	1.8	0.881	-0.38
77	0.7	0.1	0.52	-1.28	1.8	0.881	0.38
78	0.6	0.3	0.25	-0.52	0.78	0.732	0.14
79	0.6	0.3	0.25	-0.52	0.78	0.732	0.14
80	0.4	0.3	-0.25	-0.52	0.27	0.598	0.39
Mean	**0.65**	**0.28**			**1.15**	**0.768**	**0.13**
SD	**0.18**	**0.17**			**0.75**	**0.107**	**0.47**

Group 10: Over 76 Elderly Low Memory Load - OLD faces – all trials

Participant	HR	FAR	Z-HR	Z-FAR	*d*	*A'*	*c*
65	0.8	0.1	0.84	-1.28	2.12	0.913	0.22
66	0.9	0.1	1.28	-1.28	2.56	0.944	0.00
67	0.99	0.3	2.33	-0.52	2.84	0.921	-0.91
68	0.5	0.1	0	-1.28	1.28	0.811	0.64
69	0.99	0.3	2.33	-0.52	2.84	0.921	-0.91
70	0.99	0.01	2.33	-2.3	4.64	0.995	-0.02
71	0.9	0.2	1.28	-0.84	2.12	0.913	-0.22
72	0.5	0.1	0	-1.28	1.28	0.811	0.64
73	0.99	0.1	2.33	-1.28	3.6	0.972	-0.53
74	0.7	0.2	0.52	-0.84	1.36	0.835	0.16
75	0.99	0.3	2.33	-0.52	2.84	0.921	-0.91
76	0.7	0.01	0.52	-2.33	2.84	0.921	0.91
77	0.99	0.1	2.33	-1.28	3.6	0.972	-0.53
78	0.6	0.01	0.25	-2.33	2.58	0.895	1.04
79	0.7	0.1	0.52	-1.28	1.8	0.881	0.38
80	0.6	0.2	0.25	-0.84	1.1	0.792	0.30
Mean	**0.80**	**0.14**			**2.46**	**0.901**	**0.02**
SD	**0.19**	**0.10**			**0.98**	**0.061**	**0.64**

Group 11: Over 76 Elderly - HIGH Memory Load - YOUNG faces - all trials

Participant	HR	FAR	Z-HR	Z-FAR	*d'*	*A'*	*c*
81	0.8	0.3	0.84	-0.52	1.36	0.835	-0.16
82	0.55	0.1	0.13	-1.28	1.41	0.830	0.58
83	0.9	0.35	1.28	-0.39	1.66	0.864	-0.45
84	0.45	0.23	-0.13	-0.74	0.61	0.694	0.44
85	0.9	0.4	1.28	-0.25	1.54	0.847	-0.52
86	0.5	0.25	0	-0.67	0.68	0.708	0.34
87	0.95	0.65	1.65	0.39	1.26	0.793	-1.02
88	0.55	0.3	0.13	-0.52	0.66	0.703	0.20
89	0.75	0.55	0.67	0.13	0.54	0.678	-0.40
90	0.4	0.25	-0.25	-0.67	0.42	0.644	0.46
91	0.7	0.45	0.52	-0.13	0.66	0.703	-0.20
92	0.99	0.35	2.33	-0.39	2.7	0.908	-0.97
93	0.85	0.55	1.04	0.13	0.91	0.755	-0.59
94	0.8	0.6	0.84	0.25	0.58	0.688	-0.55
95	0.85	0.55	1.04	0.13	0.91	0.755	-0.59
96	0.8	0.4	0.84	-0.25	1.1	0.792	-0.30
Mean	**0.73**	**0.39**			**1.06**	**0.762**	**-0.23**
SD	**0.19**	**0.16**			**0.59**	**0.078**	**0.50**

Group 12: Over 76 Elderly - HIGH Memory Load - OLD faces - all trials

Participant	HR	FAR	Z-HR	Z-FAR	*d'*	*A'*	*c*
81	0.9	0.2	1.28	-0.84	2.12	0.913	-0.22
82	0.6	0.01	0.25	-2.33	2.58	0.895	1.04
83	0.9	0.05	1.28	-1.65	2.92	0.960	0.19
84	0.55	0.25	0.13	-0.67	0.66	0.736	0.27
85	0.95	0.1	1.65	-1.28	2.92	0.960	-0.19
86	0.6	0.1	0.25	-1.28	1.54	0.847	0.52
87	0.99	0.05	2.33	-1.65	3.96	0.985	-0.34
88	0.65	0.2	0.39	-0.84	1.22	0.814	0.23
89	0.8	0.5	0.84	0	0.84	0.744	-0.42
90	0.75	0.15	0.67	-1.04	1.72	0.876	0.19
91	0.75	0.01	0.67	-2.33	3	0.934	0.83
92	0.9	0.15	1.28	-1.04	2.32	0.929	-0.12
93	0.99	0.35	2.33	-0.39	2.7	0.908	-0.97
94	0.95	0.35	1.65	-0.39	2.02	0.889	-0.63
95	0.75	0.1	0.67	-1.28	1.96	0.897	0.31
96	0.75	0.25	0.67	-0.67	1.35	0.833	0.00
Mean	**0.80**	**0.18**			**2.11**	**0.882**	**0.04**
SD	**0.15**	**0.14**			**0.88**	**0.072**	**0.52**

Group 3: Under 40 - HIGH Memory Load - YOUNG faces – First 40 trials only

Participant	HR	FAR	Z-HR	Z-FAR	*d′*	*A′*	*c*
17	0.9	0.1	1.28	-1.28	2.56	0.944	0.00
18	0.8	0.2	0.84	-0.84	1.68	0.875	0.00
19	0.8	0.1	0.84	-1.28	2.12	0.913	0.22
20	0.9	0.1	1.28	-1.28	2.56	0.944	0.00
21	0.6	0.2	0.25	-0.84	1.1	0.792	0.30
22	0.9	0.3	1.28	-0.52	1.8	0.881	-0.38
23	0.5	0.1	0	-1.28	0.84	0.811	0.64
24	0.9	0.2	1.28	-0.84	2.12	0.913	-0.22
25	0.8	0.2	0.84	-0.84	1.68	0.875	0.00
26	0.7	0.2	0.52	-0.84	1.36	0.835	0.16
27	0.8	0.1	0.84	-1.28	2.12	0.913	0.22
28	0.9	0.2	1.28	-0.84	2.12	0.913	-0.22
29	0.6	0.01	0.25	-2.33	2.58	0.895	1.04
30	0.8	0.1	0.84	-1.28	2.12	0.913	0.22
31	0.7	0.3	0.52	-0.52	1.05	0.786	0.00
32	0.7	0.3	0.52	-0.52	1.05	0.786	0.00
Mean	**0.77**	**0.17**			**1.80**	**0.874**	**0.12**
SD	**0.13**	**0.09**			**0.58**	**0.055**	**0.34**

Group 4: Under 40 - HIGH Memory Load - OLD faces – First 40 trials only

Participant	HR	FAR	Z-HR	Z-FAR	*d′*	*A′*	*c*
17	0.9	0.1	1.28	-1.28	2.56	0.944	0.00
18	0.7	0.2	0.52	-0.84	1.36	0.835	0.16
19	0.6	0.01	0.25	-2.33	2.58	0.895	1.04
20	0.8	0.1	0.84	-1.28	2.12	0.913	0.22
21	0.9	0.2	1.28	-0.84	2.12	0.913	-0.22
22	0.9	0.1	1.28	-1.28	2.56	0.944	0.00
23	0.8	0.1	0.84	-1.28	2.12	0.913	0.22
24	0.7	0.1	0.52	-1.28	1.8	0.881	0.38
25	0.99	0.1	2.33	-1.28	3.6	0.972	-0.53
26	0.9	0.01	1.28	-2.33	3.6	0.972	0.53
27	0.8	0.1	0.84	-1.28	2.12	0.913	0.22
28	0.8	0.1	0.84	-1.28	2.12	0.913	0.22
29	0.8	0.01	0.84	-2.33	3.16	0.946	0.75
30	0.99	0.1	2.33	-1.28	3.6	0.972	-0.53
31	0.99	0.1	2.33	-1.28	3.6	0.972	-0.53
32	0.8	0.2	0.84	-0.84	1.68	0.875	0.00
Mean	**0.84**	**0.10**			**2.54**	**0.923**	**0.12**
SD	**0.11**	**0.06**			**0.75**	**0.040**	**0.44**

Group 7: Middle (60-75). HIGH Memory Load - YOUNG faces – First 40 trials only

Participant	HR	FAR	Z-HR	Z-FAR	*d'*	*A'*	*c*
49	0.9	0.3	1.28	-0.52	1.8	0.881	-0.38
50	0.7	0.2	0.52	-0.84	1.36	0.835	0.16
51	0.5	0.1	0	-1.28	1.28	0.811	0.64
52	0.5	0.4	0	-1.25	0.26	0.592	0.63
53	0.8	0.5	0.84	0	0.84	0.744	-0.42
54	0.5	0.3	0	-0.52	0.52	0.671	0.26
55	0.9	0.1	1.28	-1.28	2.56	0.944	0.00
56	0.7	0.3	0.52	-0.52	1.05	0.786	0.00
57	0.99	0.3	2.33	-0.52	2.84	0.921	-0.91
58	0.7	0.3	0.52	-0.52	1.05	0.786	0.00
59	0.7	0.4	0.52	-0.25	0.78	0.732	-0.14
60	0.7	0.01	0.52	-2.33	2.84	0.921	0.91
61	0.99	0.3	2.33	-0.52	2.84	0.921	-0.91
62	0.8	0.1	0.84	-1.28	2.12	0.913	0.22
63	0.8	0.3	0.84	-0.52	1.36	0.835	-0.16
64	0.7	0.2	0.52	-0.84	1.36	0.835	0.16
Mean	**0.74**	**0.26**			**1.55**	**0.820**	**0.00**
SD	**0.16**	**0.13**			**0.85**	**0.100**	**0.50**

Group 8: Middle (60-75). HIGH Memory Load - OLD faces – First 40 trials only

Participant	HR	FAR	Z-HR	Z-FAR	*d'*	*A'*	*c*
49	0.99	0.01	2.33	-2.33	4.64	0.995	0.00
50	0.99	0.1	2.33	-1.28	3.6	0.972	-0.53
51	0.9	0.1	1.28	-1.28	2.56	0.944	0.00
52	0.9	0.2	1.28	-0.84	2.12	0.913	-0.22
53	0.9	0.5	1.28	0	1.28	0.811	-0.64
54	0.7	0.1	0.52	-1.28	1.8	0.881	0.38
55	0.9	0.2	1.28	-0.84	2.12	0.913	-0.22
56	0.99	0.2	2.33	-0.84	3.16	0.946	-0.75
57	0.99	0.2	2.33	-0.84	3.16	0.946	-0.75
58	0.9	0.2	1.28	-0.84	2.12	0.913	-0.22
59	0.9	0.1	1.28	-1.28	2.56	0.944	0.00
60	0.8	0.1	0.84	-1.28	2.12	0.913	0.22
61	0.7	0.1	0.52	-1.28	1.8	0.881	0.38
62	0.8	0.01	0.84	-2.33	3.6	0.946	0.75
63	0.9	0.2	1.28	-0.84	2.12	0.913	-0.22
64	0.8	0.2	0.84	-0.84	1.68	0.875	0.00
Mean	**0.88**	**0.16**			**2.53**	**0.919**	**-0.11**
SD	**0.09**	**0.11**			**0.88**	**0.044**	**0.42**

Group 11: Over 76 Elderly. HIGH Memory Load - YOUNG faces – First 40 trials only

Participant	HR	FAR	Z-HR	Z-FAR	*d'*	*A'*	*c*
81	0.9	0.3	1.28	-0.52	1.8	0.881	-0.38
82	0.5	0.2	0	-0.84	0.84	0.744	0.42
83	0.9	0.4	1.28	-0.25	1.54	0.847	-0.52
84	0.3	0.3	-0.52	-0.52	0	0.500	0.52
85	0.9	0.3	1.28	-0.52	1.8	0.881	-0.38
86	0.4	0.3	-0.25	-0.52	0.27	0.598	0.39
87	0.99	0.8	2.33	0.84	1.48	0.785	-1.59
88	0.6	0.3	0.25	-0.52	0.78	0.732	0.14
89	0.8	0.5	0.84	0	0.84	0.744	-0.42
90	0.5	0.5	0	0	0	0.500	0.00
91	0.8	0.4	0.84	-0.25	1.1	0.792	-0.30
92	0.99	0.3	2.33	-0.52	2.84	0.921	-0.91
93	0.8	0.7	0.84	0.52	0.32	0.615	-0.68
94	0.8	0.5	0.84	0	0.84	0.744	-0.42
95	0.99	0.5	2.33	0	2.32	0.869	-1.17
96	0.8	0.3	0.84	-0.52	1.36	0.835	-0.16
Mean	**0.75**	**0.41**			**1.13**	**0.749**	**-0.38**
SD	**0.22**	**0.16**			**0.81**	**0.133**	**0.57**

Group 12: Over 76 Elderly. HIGH Memory Load - OLD faces – First 40 trials only

Participant	HR	FAR	Z-HR	Z-FAR	*d'*	*A'*	*c*
81	0.9	0.2	1.28	-0.84	2.12	0.913	-0.22
82	0.6	0.01	0.25	-2.33	2.58	0.895	1.04
83	0.8	0.01	0.84	-2.33	3.16	0.946	0.75
84	0.5	0.3	0	-0.52	0.52	0.671	0.26
85	0.99	0.1	2.33	-1.28	3.6	0.972	-0.53
86	0.5	0.1	0	-1.28	1.28	0.811	0.64
87	0.99	0.1	2.33	-1.28	3.6	0.972	-0.53
88	0.9	0.1	1.28	-1.28	2.56	0.944	0.00
89	0.9	0.6	1.28	0.25	1.02	0.771	-0.77
90	0.8	0.1	0.84	-1.28	2.12	0.913	0.22
91	0.7	0.01	0.52	-2.33	2.84	0.921	0.91
92	0.99	0.1	2.33	-1.28	3.6	0.972	-0.53
93	0.99	0.4	2.33	-0.25	2.58	0.895	-1.04
94	0.99	0.5	2.33	0	2.32	0.869	-1.17
95	0.9	0.1	1.28	-1.28	2.56	0.944	0.00
96	0.8	0.4	0.84	-0.25	1.1	0.792	-0.30
Mean	**0.83**	**0.20**			**2.35**	**0.888**	**-0.08**
SD	**0.17**	**0.19**			**0.96**	**0.085**	**0.68**