# Age Differences in Recognition Memory: The Effects of Stimulus Presentation Mode, Stimulus Type, and Trial Difficulty

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## ABSTRACT

Forty young and 40 older adults completed a verbal and non-verbal recognition task to determine whether there were age differences in recognition memory for three factors. The between-group factors included the age of the participant (young vs. older) and the mode of stimulus presentation (one-alternative, forced choice vs. two-alternative, forced choice). The within-group factors were the type of stimulus (words vs. shapes) and the level of trial difficulty, as indicated by the degree of target-distractor similarity (similar vs. dissimilar). Signal detection analyses indicated that recognition accuracy declined with age. Older adults showed consistently poorer recognition than their younger counterparts. In contrast to the pictorial superiority effect, recognition accuracy was impaired across the lifespan for non-verbal as opposed to verbal stimuli. In accordance with previous studies, items that were high in target-distractor similarity were recognised at lower rates than items that were low in target-distractor similarity. When the two-alternative, forced choice data were transformed to d' and adjusted for comparison with the one-alternative, forced choice data, the effect of Presentation Mode disappeared. This result is in accordance with the predictions of signal detection theory. In addition to the main effects, a significant Stimulus Type x Trial Difficulty x Presentation Mode, and Presentation Mode x Age interaction emerged, which qualified the interpretation of the main effects.

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## PREFACE

The rationale for the present study was to add to and clarify the findings generated by the Parkinson's disease programme being conducted under the guidance of Dr John Podd at Massey University. Parkinson's disease is an extrapyramidal disorder which is caused by the degeneration of dopamine-containing axons in the brain (Kalat, 1992). The symptoms characteristic of this disease include resting tremors, rigidity and slow movements (Kaplan, Sadock, & Grebb, 1994). Usually manifesting itself in older adults, Parkinson's disease has been associated with a decline in cognitive functioning (Breen, 1993; Dewick, Hanley, Davies, Playfer, & Turnbull, 1991). At present, there are disparate views as to the precise extent and course of cognitive impairment. While some argue that substantial decrements are observed (e.g., Ogden, Growdon, & Corkin, 1990, cited in Owen *et al.*, 1993) others maintain that there are no differences in cognitive ability between people with Parkinson's disease and age- and sex-matched controls (e.g., Flowers, Pearce, & Pearce, 1984). It is often reported that recall memory is significantly impaired, while recognition memory remains largely intact (Breen, 1993; Gabrieli, Singh, Stebbins, & Goetz, 1996; Owen *et al.*, 1993). The focus of the research programme at Massey University is to determine both the quantitative and qualitative nature of recognition memory in people with Parkinson's disease.

As part of his doctoral dissertation on recognition memory in Parkinson's disease, Mr Craig Whittington is currently developing a verbal and non-verbal test of recognition memory. He has been comparing the recognition performance of people with Parkinson's disease with age- and sex-matched controls using a two-alternative, forced-choice (2AFC) procedure. The motivation for the present study was two-fold. The primary objective was to collect supplementary data on the recognition performance of older, normal adults compared to a more youthful sample using Whittington's recognition memory test. A second objective of the study was to determine whether the mode of stimulus presentation in the recognition memory task would affect performance. While Whittington's study has used a 2AFC presentation mode, the present study adopted both 1AFC and 2AFC presentation modes. Thus, the focus of the present study was more methodological than theoretical.

## INTRODUCTION

Human memory has been intensively investigated over the past few decades. A number of dichotomies have been proposed to account for the idiosyncrasies apparent in human memory research. One such dichotomy is the distinction between recall and recognition memory. The terms 'recall' and 'recognition' are commonly utilised when referring to both test genres and to memory processes themselves (Brown, 1976). Simply put, a recall test requires a participant to generate the target item(s) as specified in the study phase, usually in the absence of any cues. Conversely, a recognition test requires a participant to accept or reject a number of items that have been seen before ('old' items/targets) from those that have not been seen before ('new' items/distractors). Usually, one has to assign familiarity to a number of potential targets in a sequence (one-alternative, forced-choice, or 1AFC tests), or choose the most plausible stimulus from a range of items present (*m*-alternative, forced-choice tests). A one-alternative, forced-choice (1AFC) procedure is the most common form used in recognition testing.

It has been found that people who have been given items to remember perform better on a test of recognition (in terms of response accuracy) than on a test of recall (Postman, 1950, cited in Loftus & Loftus, 1976). Loftus and Loftus (1976) suggest that there are three main reasons why recognition is better than recall.

The primary reason is that on the (usual) two-alternative, forced-choice test, one has a 50% chance of guessing correctly. However, when faced with a recall test, one's performance may be zero when relying on guesswork. Secondly, it is believed that performance on tests of recognition and recall rest on different types of information. A participant requires 'complete' information concerning the item to be remembered in a test of recall. In contrast, a participant involved in a recognition test need only remember information sufficient to discriminate the target items from the distractor items. Finally, recognition performance is superior to recall performance partly because recall involves a more elaborate memory search. Some theorists (e.g., Kintsch, 1970) argue that while recall may involve two predominant sub-processes, recognition relies only on the second process. Because the focus of the present study is on recognition memory, recall memory is not discussed further.

Historically, some of the most pertinent theories of recognition memory to emerge were the discrete-state models, proposed by Bernbach (1967) and Kintsch (1967). Discrete-state models of recognition rest on the assumption that only a few discrete states of memory exist, and that each state has a continuous distribution of "apparent oldness" or "familiarity" (Vorberg & Schmidt, 1975). For example, according to Bernbach's model (1967, cited in Vorberg & Schmidt, 1975), any given item can be stored in one of three discrete states. All 'new' items are in state $D_1$, while old items are stored in either $D_1$, $D_2$ or $D_3$. An old item can only be stored in $D_1$ if it has returned from $D_2$ or $D_3$, that is, it has been forgotten. Each of these states has overlapping distributions of apparent oldness and newness attached to it, which assume various decision cutoffs that divide the distributions into intervals. A participant may very confidently respond that an item is 'old', only when the oldness or familiarity of the item presented falls within the interval labelled 'very confident old'. Although the discrete-state models of recognition memory suggested by Bernbach and Kintsch were held in high esteem at the time of their development, they have now largely fallen out of favour. Essentially, they fail to assume a distinct state for new items; both new and old items are stored in $D_1$ unless memory is perfect. Bernbach's model supposes that perfect recognition of new items as new only occurs in the absence of forgetting old items.

Another popular theory of recognition has been the lexical–marking theory, derived from the later work of Kintsch (1970) and Anderson and Bower (1972). This theory suggests that when a participant is given to-be-remembered items to study, their pre-existing lexical representations are stimulated and "marked" for later retrieval (Paul, 1979). During retrieval, it is assumed that each lexical representation is "checked" for occurrence information; if it is apparent, the item can be deemed 'old'. A similar process is proposed by scanning theories of recognition. Honed by Murdock (1974) and Murdock and Anderson (1975, cited in Gillund & Shiffrin, 1984), scanning models challenge several of the assumptions underlying lexical-marking models. Specifically, Paul (1979) argues that rather than marking lexical representations with occurrence information, a unique memory structure is produced. The newly created memory structure also has the capacity to store the temporal order of the presented items, allowing a recognition decision to be made by "scanning" the memory structure in reverse order. Thus, each presented item is compared to each stored item beginning from the most recently encoded item. Research findings support the more recent scanning model of recognition, rather than its lexical-marking counterpart (Paul, 1979).

Of all the models of recognition, it is perhaps the signal detection theory (SDT) model that has been the most widely supported. SDT was developed in the late 1950s and early 1960s (e.g., see Green & Swets, 1966) and resulted in one of the most useful and plausible models of recognition memory (Banks, 1970; Yonelinas, 1994).

The central thesis of recognition models based on SDT is that participants in a recognition test judge items on a scale of familiarity or memory strength. It is assumed that there are overlapping distributions for old and new items, anchored on an axis of familiarity. Recognition decisions are made by fixing a criterion level on the familiarity axis. Items above the criterion (that is, having a certain memory strength) are deemed 'old', and items below the criterion are judged 'new'. According to SDT, an 'old' response to an old item is called a hit, and an 'old' response to a new item is referred to as a false alarm. A 'new' response to an old stimulus is termed a miss, while a 'new' response to a new stimulus is labelled a correct rejection (Dennis, 1997). The main strength of SDT is that it is able to provide independent measures of "recognisability" (d') and response bias (the mere willingness to report an item as previously seen).

SDT has been applied to a variety of memory theories; however, its utility in explaining the recognition memory decision process has probably been its most valuable application. Consequently, a number of so-called process models of recognition memory have emerged. It is apparent that there is a great division of loyalty between the proponents of both single and dual process theories of recognition. Often referred to as global memory models, single process models of recognition assert that a target item is compared against information in memory by a passive, parallel process that produces an overall rating of the target item's familiarity or goodness of match (McKoon & Ratcliff, 1989). The goodness of match is reflective of the interaction between already encoded information in memory and the target itself. Typically, the higher the value of the goodness of match, the quicker and more accurate the response to the target.

One such model of recognition based on a single process is the Search of Associative Memory (SAM; Raaijmakers & Shiffrin, 1981). Originally proposed to account for a familiarity process used in recall, it has since been extended to help explain the recognition process (Gillund & Shiffrin, 1984). In a 1AFC test of recognition, it is suggested that a test probe set is compared to all of the items stored in memory. A test probe set is simply the test item itself and its associated context. This yields a global measure of familiarity: a value above a certain threshold will lead to an 'old' response, and a value below this threshold will lead to a 'new' response (Ratcliff, Van Zandt, & McKoon, 1995). In a 2AFC recognition test, the participant is assumed to calculate independent familiarity values for each of the two alternatives and choose the item with the highest value (Gillund & Shiffrin, 1984).

Compared to single process models, dual process models of recognition argue that any recognition decision is comprised of both an unconscious assessment of item familiarity and the outcome of a conscious process of recollection (Yonelinas, 1994). The first major dual process model was developed by Atkinson and Juola (1974, cited in Gillund & Shiffrin, 1984), and maintained that a judgement of recognition always prompts a familiarity process primarily, and that the recollection process would be instigated only if this familiarity process failed in some way (Cooper & Monk, 1976). Specifically, Ratcliff *et al.* (1995) argue that if the familiarity of an item is above a criterion value or below another criterion value, then a response is promptly made. Thus, the assessment of familiarity can be viewed as a signal detection process. The second recollection process occurs only if the value of familiarity falls between the two criteria. A later model constructed by Mandler (1980) argued that the recognition decision did not operate in such a sequential fashion. Rather, familiarity was a fast retrieval process that worked in parallel with the somewhat slower recollection process. Because the bulk of available data support the contention that the recollection process is relatively slow, and that people often make recognition judgements relatively quickly, Mandler reasoned that both processes are initiated upon item presentation (1980). More recent data refute aspects of both of the early models, supporting the explanation that recollection and familiarity processes operate independently and are always present (Jacoby, 1991; Ratcliff *et al.*, 1995; Richardson-Klavehn & Bjork, 1988). The dual process model of recognition memory has been extensively supported by the process dissociation procedure (Jacoby, 1991), a method by which both the familiarity and recollection processes can be empirically separated and evaluated (Ratcliff *et al.*, 1995).

In summary, although many models of recognition memory have been proposed, it appears that it is only those that are derived from SDT that are of any merit. While certain aspects of the discrete-state, lexical-marking, and scanning models are tantalising, they are not wholly supported by research data. In contrast, process models based on SDT emphasise the importance of a familiarity judgement, which seems to be an integral feature of the recognition decision. Irrespective of which theory best accounts for the data, ultimately, any theory of recognition memory will have to account for memory changes across the lifespan. Few theories of memory attempt to incorporate the effects of aging.

## Age Differences in Recognition Memory

It is well established that advancing age is accompanied by a decline in both memory and learning capacities (e.g., Baron & Surdy, 1990; McEntee & Crook, 1990; West & Crook, 1990). This progressive memory loss with age is common among people without dementia, and probably is characteristic of normal aging (McEntee & Crook, 1990). It is widely held that a memory loss associated with increasing age is integral to all mammalian species (Bartus & Dean, 1985, cited in McEntee & Crook, 1990). The term Age-Associated Memory Impairment (AAMI; Crook *et al.*, 1986) has been coined to describe this pattern of memory failure. According to McEntee and Crook (1990), AAMI is likely to affect the majority of people over the age of 50, at least to some degree. Although this change in cognitive functioning is well documented, there is little information regarding the importance, direction, extent, rate and course of cognitive aging (Giambra, Arenberg, Zonderman, Kawas, & Costa, 1995).

Although AAMI has been proposed to occur after the age of 50, there is little consensus as to what age a person is classed as an older person. The majority of studies investigating age differences in recognition memory have recruited people over the age of 60 to constitute an older adults' group. Other studies have defined older adults as anyone over the age of 54 (Foos, 1989). Studies comparing older adults' recognition accuracy with that of younger adults often recruit people between the ages of 18 and 30 to constitute the younger group. Most of the studies outlined below have adhered to these age ranges.

Older adults perform more poorly than young adults on a variety of tests of memory. Typically, large age-related memory decrements are observed in free recall, but these differences are reduced, sometimes eliminated, in recognition (Craik, Byrd, & Swanson, 1987). Schonfield and Robertson (1966) found that while participants' recall scores showed a statistically significant and systematic decline with advancing age, there were no differences between young and older people on a recognition task. Similarly, Arenberg (1985, cited in Craik & McDowd, 1987) demonstrated that while recall abilities decline systematically by decade from participants in their 20s to people in their 80s, recognition remains largely unaffected. Smith (1975) has suggested that the failure to find consistent age decrements in recognition memory may be accounted for in two ways. First, while recall involves two memory processes, recognition is dependent upon only the first process. Age-related declines in recall ability may be a function of an impaired second process, which leaves recognition ability intact. The second proposal is that the similarity of recognition performance between young and older adults is caused by a storage deficiency, which limits older adults to learning only partial information (McNulty & Caird, 1966).

In contrast, some research evidence suggests that there may be an age decrement in recognition. For example, a study by Gordon and Clark (1974) supports this notion. Older adults who were asked to respond to prose material achieved lower recognition memory scores than their younger counterparts. Erber (1974) found that while young participants obtained 80% correct on a 24-word list, the older participants achieved only 69% correct, highlighting a significant age-related decline. In summary, although the results of studies are mixed, on average, age decrements are somewhat smaller in recognition than in recall tests.

Older adults' recognition memory for words has been intensively investigated. Bowles and Poon (1982) investigated the effect of vocabulary level on recognition memory for words and found that young and older adults with a high vocabulary level performed similarly. Interestingly, an age difference was found between young and older low vocabulary level groups, indicating that verbal fluency and understanding may be an important factor in interpreting the results of verbal recognition tasks. In contrast to this finding, older adults in Rabinowitz's (1984) study achieved lower scores on a recognition test for words than younger adults. This result was particularly surprising because the older adults had a substantially higher vocabulary level than their younger counterparts. However, in general, the literature indicates that older adults are not as able as young adults to recognise verbal material (Smith, 1975).

Both younger and older adults recognise pictorial material better than verbal material. This phenomenon is often referred to as the 'pictorial superiority effect' and has been supported by a plethora of studies (e.g., Bloom, 1971, cited in Gehring, Toglia, & Kimble, 1976; Feenan & Snodgrass, 1990; Gehring *et al.*, 1976; Park & Puglisi, 1985). Park, Puglisi, and Sovacool (1983) found that when given either pictures or words to remember, older adults recognised more pictures than they did words. However, the pictorial superiority effect can be directly modified by the extent of contextual detail inherent to the pictorial material. A later study by Park, Puglisi, and Sovacool (1984) discovered that while increased contextual detail of pictures resulted in enhanced recognition memory for young adults, it had a detrimental effect on older adults' performance. Park and Puglisi (1985) investigated whether memory for picture and word colour declined with age. Participants in their study viewed lists of coloured pictures and words, and were subsequently instructed to choose from a larger list those items they had seen before. The results indicated that colour memory declined with age, and that the impairment was more pronounced for picture rather than word colour.

Not all studies support an age effect for pictorial recognition memory. For example, a series of studies conducted by Park, Puglisi, and Smith (1986) yielded few differences between young and old people for picture memory. Specifically, they manipulated the contextual detail of the pictorial material both between and within participants. All studies concluded that both young and older participants' memory improved as the pictures became more elaborate. In addition, the performance of the young and older participants was comparable over a variety of conditions and stimuli.

The above research on pictorial recognition memory has used mostly line drawings or photographs. Although few studies have used geometric designs and patterns, their effect on recognition memory is clear. Using the Benton Visual Retention Test, Arenberg (1978, cited in Winograd & Simon, 1980) determined that visual memory indeed declined with age. In particular it was found that the rate of decline increased markedly for men over the age of 70. These results are in accordance with those obtained by Lee and Pollack (1978, cited in Winograd & Simon, 1980). They concluded that performance on the Embedded Figures Test declined with age. Finally, Howell (1972) found that older adults perform more poorly in picture recognition for abstract patterns and everyday objects in comparison to their younger counterparts. Interestingly, the older participants did recognise images of generationally appropriate items at the same level as the younger adults.

The ability of older adults to recognise the spatial orientation of pictures is also noteworthy. A number of studies have concluded that there are adult age differences in remembering spatial information (Light & Zelinski, 1983; Pezdek, 1983). A common finding is that spatial memory is significantly better for pictures than for words (Park, 1980; Park & Mason, 1982). Park *et al.* (1983) compared spatial memory for both pictures and words using young and older adults. The results supported the above notion; both young and older adults were more adept at remembering the spatial location of pictorial material than matched words. In addition, an age-related decrement for spatial memory was reported.

Recognition memory for the spatial location of verbal and non-verbal material has also been investigated under both intentional and incidental learning conditions. Park, Puglisi, and Lutz (1982) found that while young participants remembered more spatial information about pictures under intentional learning conditions, older adults remembered somewhat less information under the same conditions. Similarly, Bartlett, Till, Gernsbacher, and Gorman (1983) noted an age-related memory decline for pictorial orientation under both intentional and incidental learning conditions.

It is possible that laboratory situations and stimuli fail to replicate those situations encountered in everyday life. Therefore, some studies have analysed older adults' memory for everyday objects. Although the majority of research has focused on older participants' recall abilities, an investigation by Foos (1989) compared young and older adults' recognition memory for the topside of a penny and for a pushbutton telephone dial. Each participant was given a stack of cards, each displaying a drawing of the potentially correct penny or pushbutton telephone dial. The results showed an age-related decline, indicating that older adults perform poorly in tests of at least some common, everyday objects as well as for abstract laboratory stimuli.

A considerable amount of research has been dedicated to the recognition of faces, and in particular, whether there is an age–related decline associated with facial recognition. It has been suggested that a decline in facial recognition memory performance is not linear; rather, it accelerates after the age of 70 (Crook & Larrabee, 1992). This finding stands in contrast to the performance on other aspects of everyday memory tasks, which display a linear performance decrement across the adult life span (Crook & West, 1990).

Although faces can be construed as contextually elaborate pictorial stimuli, pictures of faces may differ from other pictures in that faces all share the same configuration (Diamond & Carey, 1986). Owing to their high degree of inter-item similarity, it is reasonable to assume that discriminating old from new facial pictures might be reliant upon *stimulus* recognition rather than *face* recognition, a process that older adults may be impaired on (Bartlett, Leslie, Tubbs, & Fulton, 1989). Because face recognition may itself be a unique process, it should be considered independently of picture recognition.

Many studies have demonstrated the robust finding that young and older adults share similar hit rates for 'old' judgments, yet the false alarm rate is elevated for older adults (e.g., Bartlett & Leslie, 1986; Bartlett *et al.*, 1989; Ferris, Crook, Clark, McCarthy & Rae, 1980; Smith & Winograd, 1978). While older adults are just as able as younger adults to recognise a previously seen item, they are also prone to recognising new items as 'old' at a higher rate. This finding is not simply indicative of a change in response bias. Rather, it suggests that older adults may experience a change in recognisability, but only as a result of an increased false alarm rate.

The decrements observed in older adults' pictorial recognition memory is well-established. For example, an eyewitness identification study by Yarmey and Kent (1980) discovered that while young adults were more adept at identifying peripheral characters in a slide sequence, there were no differences between young and older adults at identifying the main proponents of the sequence. This indicates that older adults may selectively ignore conceptually trivial stimuli in a bid to focus their attention on the most integral factors (Yarmey & Kent, 1980).

Another study by Bartlett and Leslie (1986) manipulated the naturalism of facial images. They presented either single views of faces, or multiple views of faces to a group of young and older adults. They reasoned that multiple views of faces were more ecologically valid, and thus both groups would display a higher level of recognition performance than for the single view pictures. Indeed, their predictions were supported; there were significant age differences when the single view facial pictures were shown, but no age differences when the multiple view pictures were shown.

In a related investigation, Bartlett *et al.* (1989) presented a series of single view pictures to both young and old participants. During the recognition task, they were shown old and new faces, along with reversals, changed expressions and changed poses of the old items. The results indicated that while the older participants could correctly identify that the faces had changed, they were deficient in recognising *how* they had changed. Bartlett *et al.* (1989) concluded that there were significant age differences in matching pictorial information against information stored in memory.

An interesting study by Bäckman (1991) probed the effects of prior knowledge on recognition memory in young and older adults. Specifically, he presented both groups with a series of pictures of contemporary and dated famous faces. Young participants displayed a relatively high level of recognition for the contemporary faces and a reduced level of performance for the dated faces, while the reverse was true for older participants. In a subsequent experiment, it was determined that young adults were better able to recognise young than old unfamiliar faces, and better than older adults at recognising young unfamiliar faces. It is interesting to note that while the young adults were able to recognise both familiar and unfamiliar cohort-relevant faces, the older adults were only able to recognise those faces that were familiar.

In sum, it is apparent that older adults consistently perform worse than younger adults on a variety of recognition memory tests. The question arises as to the factors that may contribute to this performance difference. The potential causes of an age-related decline in memory performance can be conceptualised in terms of response biases, and cognitive and biological factors.

**Response Biases**

It has been noted that older adults are typically more cautious than younger adults when participating in tests of recognition memory. The observation that older adults take longer to make a recognition decision than young adults can at least be partially accounted for by their increased cautiousness (Van Gorp, Satz, & Mitrushina, 1990). Botwinick (1966) also suggests that older participants are less confident and have an especially elevated level of cautiousness when responding to laboratory stimuli. Later work by Botwinick (1970) indicated that older participants often rate their self-confidence level higher than do younger participants.

At present there is some debate as to how these sentiments are manifested. The argument is that older adults favour 'old' judgments, rather than taking a risk (e.g., Bartlett *et al.*, 1989; Foos, 1989). Snodgrass and Corwin (1988) found that this liberal bias in favour of 'old' decisions became stronger for participants with dementia. In contrast, it is contended that older adults must have a high level of certainty before they will indicate that an item is familiar (Botwinick, 1984; Poon & Fozard, 1980). This conservative bias suggests that older adults have a very strict criterion for judging items 'old', and favour making 'new' decisions. Still others maintain that there is only weak evidence to support the notion that older adults display any liberal or conservative response biases when participating in tests of recognition memory (e.g., Baron & Surdy, 1990; Le Breck & Baron, 1987).

Further research is needed to clarify whether response biases are characteristic of the recognition memory performance of older adults. Even if older adults are more prone to favouring either a liberal or conservative bias, this cannot be the sole source of variation in recognition memory. Explanations of age decrements in memory that rely on cognitive bases are also of some value.

## Cognitive Explanations

There are many cognitive explanations as to why older adults are not as able as young adults in memory recognition tests using laboratory materials. Most of these rest on the assumption that increasing age dictates a decline in encoding, storage and retrieval resources.

### *Encoding-Deficit Hypothesis*

Smith and Fullerton (1981, cited in Poon, 1985[1]) suggest three types of encoding deficits. First, they propose that older adults differ from younger adults in the degree to which they employ verbal elaboration – or the extent to which items are specifically encoded. This is often referred to as 'encoding specificity' (Matlin, 1989). Rabinowitz, Ackerman, Craik, and Hinchley (1982) believed that because attentional capacity decreases with age, older adults might be less adept at distinctly encoding new information with specific contextual cues. Instead, older adults may be more likely to encode information in the same manner that they always have. Rather than forming new internal representations for each new concept encountered, it is assumed that older adults simply reactivate similar existing representations. Although initial studies have lent credence to this viewpoint (e.g., Thomson & Tulving, 1970), more recent findings suggest that the hypothesis is flawed. Replications of the Thomson and Tulving study have failed to find age-related differences in the ability to encode specificity (e.g., Park, Puglisi, Smith, & Dudley, 1987).

Secondly, Smith and Fullerton (1981, cited in Poon, 1985) stated that older adults fail to make use of visual elaboration in a bid to remember information. The use of imagery, and in particular imagery mnemonics, have been found to enhance memory performance in older adults. Unfortunately, there seems to be an age-related decline in the ability to use this strategy spontaneously.

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[1] Much of the following section on the causes of memory impairment in older adults is based on the work of Poon, 1985 and Light, 1991.

Finally, they hypothesised that older adults are deficient in the degree to which they use organisational encoding. Hultsch (1969) provided young and older participants with no instructions, general instructions or specific instructions to organise a list of words. Participants in the no-instruction condition demonstrated the most substantial age-related decrements, while few differences were observed between age groups in the specific-instruction condition. This is in accordance with the assumptions of network models of memory (Collins & Loftus, 1975), which assume that there should be age-related differences in memory owing to older adults' inability to encode semantic information as richly or as deeply as younger adults.

Another reason why older adults exhibit impaired memory performance in comparison to younger adults could be because language comprehension declines with age. Because comprehension is a necessary component of encoding and memory retention, it is reasonable to assume that any language comprehension deficiency would result in memory decrements.

An age-related decline in the ability to activate relevant general knowledge does not seem to be responsible for the relationship between memory and aging. Older adults are as able as their younger counterparts to draw inferences during comprehension. Although difficulties in drawing inferences are not likely to cause poor semantic encoding and memory impairments, memory decrements probably contribute to comprehension errors.

***Storage-Deficit Hypothesis***

One of the earliest explanations regarding memory and aging was that older adults performed poorly on memory tasks because the already stored information was vulnerable to interference. Proactive interference (previous learning) and retroactive interference (subsequent learning) were believed to weaken memory traces and interfere with newly learned material. This explanation led to the hypothesis that older adults would be plagued by these types of cognitive inhibitions during the retrieval period. However, there is no evidence to suggest that there is an age-related susceptibility to interference (Craik, 1977).

### *Retrieval-Deficit Hypothesis*

Owing to the well-established phenomenon that older adults tend to show smaller deficits in recognition tasks than recall tasks in comparison to young adults, it has been assumed that older adults have difficulty in accessing already stored information. These observations indicate that although the information has been stored efficiently, it is the retrieval process that is hampered.

Although this hypothesis seems reasonable, a glaring deficiency is that it is virtually impossible to distinguish between memory decrements that are a consequence of impaired retrieval as opposed to impaired encoding. Because successful retrieval is dependent upon adequate encoding, it is unlikely that a retrieval deficit alone can be shown to account for age-related differences in human memory. Nonetheless, certain aspects of retrieval, such as deliberate recollection, metamemory, and available processing resources, undeniably contribute to recognition failure.

#### *Impairment of Deliberate Recollection*

It can be concluded that older adults have a marked inability to retrieve new information when intentional or conscious recollection is required. Strangely, when older adults' memory is tested *indirectly*, such as in a word fragment completion task, there seems to be little or no impairment present (e.g., Light, Singh, & Capps, 1986, cited in Light, 1991). Three accounts have been offered to explain this observation.

The first explanation is that while contextual processing is retarded, activation processes are spared. This is reminiscent of the review of older adults' memory for contextual detail mentioned earlier. Semantic activation processes remain intact throughout life; hence, this hypothesis seems valid. However, one point of contention is that older adults may remember less contextual information because they remember less target information. More research is needed to determine which is the more likely explanation.

Secondly, a number of investigators have argued that indirect tests of memory are more dependent upon the congruence between study items and test items than direct tests of memory. It has been suggested that these tests offer more cognitive support than tests of recognition and recall memory, which force participants to engage in more effortful processing. There is a great deal of support for this theory. Craik *et al.* (1987) found pronounced age differences when there was diminished support at both the encoding and retrieval stages. Bäckman (1991) made similar observations.

Thirdly, it has been assumed that the existence of multiple memory systems may have a role in the impairment of deliberate recollection. Tulving (1985) proposed a hierarchical multiple memory systems approach in which procedural memory contained semantic memory, which in turn contained episodic memory. Mitchell (1989) held that while procedural and semantic memory remain intact in old age, episodic memory is impaired. Research evidence indicates that this position is oversimplified, and a much more complex explanation is responsible for the disparity between intentional and incidental memory performance.

The observation that there is no difference in recognition performance between young and older adults on indirect tests of memory is encouraging. It lends credence to the idea that memory traces are not completely lost in older adults. Rather, there is simply a mechanism retarding retrieval. These retrieval deficits in older adults have also been explained by metamemory failure.

*Failures of Metamemory*

The term, metamemory, refers to one's knowledge and consciousness of one's own memory (Matlin, 1989). It has been suggested that older adults perform poorly on tests of recognition because they hold erroneous beliefs about memory, and thus fail to use encoding or retrieval strategies that are appropriate to the task at hand. This theory has been disputed by Hultsch, Hertzog, and Dixon (1987) who found that the beliefs held about the nature of memory and memory tasks are comparable for young and older adults.

Similarly, it has been proposed that older adults fail to use relevant encoding and retrieval mechanisms for two main reasons; 1) because they are removed from the educational system they have less opportunities to use these strategies (the disuse hypothesis); and 2) because they observe decrements in their own memory and consequently do not put as much effort into memory tasks. There is little evidence to support the first hypothesis, but some aspects of the second argument may be true. The Metamemory in Adulthood Scale (MIA; Dixon & Hultsch, 1983) and the Memory Functioning Questionnaire (MFQ; Gilewski, Zelinski, & Schaie, 1990, cited in Light, 1991) highlight older adults' sense of a loss of memory ability when performing memory tasks.

Finally, it has been claimed that age-related differences in memory may be due to the inability of older adults to monitor their own memory. Specifically, it is suggested that phenomena such as feelings of knowing and accordance between predicted and actual memory performance might be impaired. A number of studies attest to the inadequacy of this viewpoint, demonstrating that young and older adults are comparable in terms of most aspects of metamemory (e.g., Butterfield, Nelson & Peck, 1988; Lovelace & Marsh, 1985; Rabinowitz *et al.*, 1982).

*Reduced Processing Resources*

Perhaps one of the most popular theories of age-related memory decrements is that older adults experience fundamental changes to processing functions, such as attentional and cognitive capacity.

Research on the attentional capacity of both young and older adults has lead researchers to conclude that older people are subject to a reduced attentional capacity. Puglisi, Park, Smith, and Dudley (1988) and Park, Smith, Dudley, and La Fronza (1989) investigated the effects of divided attention during encoding and found reliable age differences. Hasher and Zacks (1979) asserted that memory for temporal, spatial and frequency information was automatic and thus unaffected by age. They maintained that it was only aspects of memory that were effortful that were impaired. However, a number of studies show that memory for temporal, spatial and frequency information does vary with age, dispelling the notion that memory for specific types of information is automatic (e.g., Park *et al.*, 1982; Park *et al.*, 1983).

One avenue of investigation into reduced cognitive capacity has been the belief that impaired working-memory resources may be responsible for observed age differences in recognition memory. Research has consistently demonstrated that the increasing complexity of a task has a reliable, deleterious effect on older adults' performance in comparison to younger adults (Salthouse, 1987). An alternative explanation for these effects has been suggested by Hasher and Zacks (1988, cited in Light, 1991). Labelled the 'reduced inhibition' theory, it argues that older adults do not suffer from a diminished working-memory capacity. Instead, a failure to inhibit inappropriate and irrelevant goal-directed thoughts results in the forgetting of integral target information. The entertaining of daydreams and mutually exclusive inferences in memory have also been shown to be true of older adults (e.g., Hamm & Hasher, 1990, cited in Light, 1991).

Finally, the slowing of cognitive processing in older adults is a valid reason why they perform more poorly than young adults on memory tasks that assess speed in particular. Allen (1991) found that older adults were significantly slower in correctly rejecting distractor items in a recognition memory task. The cognitive slowing hypothesis has important implications concerning recognition memory tasks that measure reaction time. Because many recognition tasks have a response interval of limited duration, any responses made after the interval are not recorded. As a consequence, accuracy levels are reduced.
Given that aging is accompanied by cognitive slowing, it seems likely that these changes have their correlates in underlying brain processes. A number of biological factors have been used to explain the age-related decrements observed in memory.

**Biological Factors**

Despite the emergence of a number of studies that outline the qualitative nature of memory impairment in older adults, there is still limited knowledge regarding the effect of biological mechanisms on memory. It has been noted that neurological, physical, and biological changes are a characteristic of increasing age. However, research has still to explain how these changes systematically effect memory. Most research has investigated pathological aspects of aging, such as Alzheimer's disease and dementia, rather than the causes of memory impairment observed in normal, healthy, older adults.

One reliable finding is that the prefrontal cortex is implicated in memory impairment. Kalat (1992) noted that aged monkeys and monkeys with prefrontal cortex damage performed similarly on memory tasks. There is little doubt that the hippocampus also plays a major role in memory. It has been estimated that for every decade of life after the mid-40s, there is a 5% reduction in the number of cells in the hippocampus (Ball, 1977, cited in Lezak, 1995). Studies of aged rats have confirmed a reduction of nerve cells, areas of degeneration, senile plaques, neurofibrillary tangles and pigment deposits inside the neurons of the hippocampus (Soumireu-Mourat, 1986). In addition, the hippocampi of aged rats have demonstrated retarded monosynaptic potentiation (Landfield & Lynch, 1977, cited in Soumireu-Mourat, 1986), spatial specificity, and alterations in firing pattern reliability during learning (Barnes, McNaughton, & O'Keefe, 1983, cited in Soumireu-Mourat, 1986). These findings, coupled with a general decrease in the weight of the whole brain, have been found to be characteristic of the older members of all animals (Soumireu-Mourat, 1986).

Further investigations with rats have discovered a similarity in deficits observed between aged rats and rats with hippocampal or prefrontal cortex damage on a number of memory tasks (Winocur & Moscovitch, 1990). Conversely, electrical stimulation of the hippocampus of young mice, rats and old rats has shown improved memory retention (e.g., Soumireu-Mourat, Destrade, & Cardo, 1975, cited in Soumireu-Mourat, 1986; Soumireu-Mourat, Martinez, Jensen, & McGaugh, 1980). Although much of the evidence supporting the significance of the hippocampus in memory impairment relies on animal models, it is assumed that this area is partially responsible for the cognitive decline characteristic of normal human aging, especially those involving memory.

The effect of neurotransmitter deficits on memory in older adults has also been intensively explored. Acetylcholine deficits have been associated with Alzheimer's disease and have thus been posited as a fundamental agent in memory impairment (G. D. Cohen, 1988). Cholinergic deficits in older adults have also been related to hippocampal change (Soumireu-Mourat, 1986). Deutch (1973) argued that the cholinergic neuronal system is responsible for memory activation, and memory performance is dependent upon neurotransmitter levels at the postsynaptic receptor sites. The importance of the cholinergic system's effect on memory performance has also been demonstrated by Drachman (1977). Young people who were given an acetylcholine antagonist (a receptor blocker) showed performance parallel to older adults on memory tasks. Kalat (1992) also echoes the sentiment that an age-related memory decline may be attributable to fluctuation in acetylcholine levels. Similarly, neurochemical deficits in the adrenergic, GABAergic, and dopaminergic neurotransmitter systems have shown cognitive declines (Kalat, 1992; Soumireu-Mourat, 1986). Of course, these neurotransmitter deficits merely correlate with memory deficits. At present it is not known whether these neurotransmitter deficits are the cause of memory impairments.

It has also been proposed that elevated levels of endorphins may contribute to an age-related memory decline. Endorphin levels in the hippocampal area of rats have been found to increase with age, and consequently have been found to correlate with memory impairment (Jiang, Owyang, Hong, & Gallagher, 1989, cited in Kalat, 1992). It has been suggested that endorphins somehow retard the formation of long-term potentiation, or modify the effects of the neurotransmitters mentioned above (Kalat, 1992).

Long-term potentiation may also be affected by higher than usual resting levels of calcium in postsynaptic neurons. Kalat (1992) noted that calcium channels have been found to become more diffuse as mammals age, increasing resting calcium levels within neurons. Consequently, calcium that enters during memory activation may result in a muted signal, owing to the already enhanced neuronal concentration of the chemical. In accordance with this theory, aged mammals that are injected with calcium antagonists have shown improved learning and memory (Deyo, Straube, & Disterhoft, 1989).

It is apparent that the neurochemical underpinnings of adult memory have yet to be specifically isolated. Woodruff-Pak (1990) suggests that multiple, interconnected neurotransmitter dysfunctions in association with impaired metabolic pathways may account for the cognitive decline observed in older adults. Furthermore, both Kinsbourne (1980) and Albert and Kaplan (1980) have devised models linking age-related memory impairment to neurological factors that are associated with compromising the ability to attend.

Kinsbourne's (1980) model maintains that the brain integrity of older adults might be affected in three ways. Based on the work of Lashley (1942, cited in Poon, 1985), Kinsbourne believed that certain memory functions are not localised in the brain. Rather, they are spread over wide cerebral areas. Kinsbourne's primary hypothesis was that the diffuse depletion of neurons might leave specific abilities unharmed, but render an individual generally slower and unable to attend. His second hypothesis suggested that this neuronal depletion could also be topographically skewed, as opposed to widespread. Because the bulk of the central nervous system operates as an opponent-process system, a neuronal depletion at one site and not another may cause an excess in some behaviour and a deficit in another behaviour. Thirdly, Kinsbourne held that intense focal damage might also contribute to older adults' reduced ability to attend. He argued that focal damage potentially could limit the range and modify the nature of a particular cognitive experience.

Kinsbourne's model is encouraging because there is still little known about the nature of neuronal depletion in older adults. Further research, in conjunction with more extensive, testable hypotheses should validate its utility as a working model (Poon, 1985).

Another neuropsychological model of aging, developed by Albert and Kaplan (1980), suggests that specific change occurs in the prefrontal cortex of older adults. Their hypothesis is based on observations of both normal older adults and brain damaged individuals, who both tend to exhibit poor attentional and visuospatial performance. Specifically, the steps taken by older adults on a battery of neuropsychological tests were comparable to those taken by individuals with prefrontal cortex damage.

In addition, there seems to be mounting evidence for the neuropsychological model of aging from electrophysiological measurements of the autonomic nervous system (Andreassi, 1995). Older adults tend to show impaired responsivity on galvanic skin response measurements, indicating underarousal. Various components of the Average Evoked Potential have also been found to decrease with age and have been correlated with cognitive decline.

The changes to attention and cognition that are observed in older adults are likely to be the result of corresponding changes in the central nervous system. Advancing technology will enable researchers to more accurately pinpoint biochemical changes and cortical deterioration, and consequently gauge their effects on memory. It is unlikely that there is any one cause of memory impairment in older adults. Presumably, a combination of the response biases, cognitive deficits, and a general age-related decline in brain function witnessed in older adults is responsible for their impaired performance on recognition memory tasks.

In sum, a great deal of research has been dedicated to recognition memory. The recognition/recall memory dichotomy is well-established, with many investigations suggesting that recognition memory relies on the second sub-process of recall. Nonetheless, most memory research has examined recall and recognition as separate factors.

Previous research examining the recognition abilities of older adults leads to the strong conclusion that an age-related decline exists. Older adults typically show better recognition for pictures as opposed to words. Furthermore, increasing the level of contextual detail of pictorial material has been shown to facilitate recognition. Older adults' ability to recognise faces has also been widely researched. A remarkable finding has emerged suggesting that older adults are able to correctly recognise faces at the same rate as young adults. However, older adults are more prone to erroneously conclude that they have seen a new face before.

While the fact that recognition memory declines with age remains undisputed, it is less clear as to the causes of this impairment. The notion that older adults may adopt either liberal or conservative biases still requires further research, although according to SDT, such response biases should not affect recognition memory *per se*. Certain cognitive explanations, especially those concerning encoding, storage, and retrieval deficits, offer plausible accounts of recognition memory failure. Ultimately, any explanation intended to account for memory changes with age must acknowledge the pathological effects of aging on the brain and its chemistry. It is likely that observed cognitive decrements are a direct result of this pathology.

Inspired by the issues raised by previous research, the present study investigated the effects of aging on recognition memory. In particular, it was designed to examine the effects of age on presentation mode (1AFC vs 2AFC), stimulus type (words vs shapes), and trial difficulty (similar vs dissimilar targets and distractors) on recognition performance. Although each of these factors has been researched at varying degrees, the present study is novel because it combines all factors in a bid to elucidate those that show age changes and those which may interact. In addition, the present study is unique in that it employed abstract geometric designs as opposed to the more usual pictorial material.

## THE PRESENT STUDY

Based on previous research and theoretical considerations, the present study aimed to test four main hypotheses using a planned comparison approach (Hays, 1973). Using this approach, the focus for the analysis was on the factors listed below.

### Planned Comparisons

#### *Age*

As the above review of aging and recognition memory demonstrates, there are a number of discrepant findings. It is by no means clear at this stage how different aspects of recognition memory deteriorate with age, if at all. While some researchers maintain that there is not a significant age-related decline of recognition memory (Craik *et al.*, 1987), others argue that a strong age-related decline exists (White & Cunningham, 1982).

The primary objective of the present study was to determine whether there would be a general age-related decline in recognition memory, using a task specifically designed to examine a number of factors that might interact with age. Although it is undeniable that older adults perform more poorly on certain tests of recognition than their younger counterparts, there is still little known about the specific aspects of recognition that are impaired. A number of experiments have outlined the particular recognition abilities of older adults. Many studies have investigated the effects of aging on recognition accuracy for pictures and have noted that older adults show enhanced recognition for pictorial rather than verbal material. Experiments that have increased the contextual detail of pictures presented to older adults have yielded increased recognition accuracy. In spite of these encouraging findings, older adults still fail to recognise items at the same rate as their younger counterparts. Based on this observation, it was predicted that the present study would find a main effect for age.

In the present study, presentation mode, stimulus type, and trial difficulty were all tested as a function of age. To date, it appears that no study has examined whether these factors combined have an age effect.

***Presentation Mode***

Recognition memory tasks often use a sequential or one-alternative, forced-choice presentation (1AFC), that is, both the targets and distractors are presented sequentially, one at a time. Some studies have utilised a simultaneous or *m*-alternative, forced- choice presentation, in which the target and its distractors are presented at the same time, as in a multiple-choice test (Shimamura & Jurica, 1994). Very few studies have directly compared the two modes of presentation. An early study by Kintsch (1968) analysed recognition memory for words, using a one, two, four and eight-alternative, forced-choice procedure. He determined that participants in the 1AFC condition demonstrated a strong bias for judging items 'new' and that performance accuracy decreased with the number of distractors presented.

The majority of other experiments comparing 1AFC and 2AFC presentations have used a 2AFC stimulus presentation in the *study phase* as opposed to the test phase (e.g., Frick, 1985; Marmurek, 1989; Tucker, Novelly, Isaac, & Spencer, 1986). Although the literature comparing memory performance for 1AFC and 2AFC tasks is sparse, it is clear that the latter enhances recognition. Marcer (1967, cited in Frick, 1985) suggests that having the target present as a comparison cue on each trial offers considerably more "cognitive support" than a 1AFC trial.

In response to the lack of knowledge in this area, the second objective of the present study sought to determine whether recognition memory performance on 2AFC trials is superior to performance on 1AFC trials. If the theory of signal detection (Macmillan & Creelman, 1991) holds true, it was expected that recognition performance on the 2AFC task would exceed that of the 1AFC task by a factor of $\sqrt{2}$. In other words, if 2AFC performance is adjusted by this factor to correct for the relative ease of this task, then there should be no difference between 1AFC and 2AFC *d'* performance.

An additional objective of the present study was to determine whether recognition accuracy would vary for each mode of presentation as a function of age. A number of studies have shown that there is little difference in hit rate between young and older adults, yet the false alarm rate is elevated in older adults (e.g., Bartlett, Strater, & Fulton, 1991; Crook & Larrabee, 1992). Based on this observation, it was predicted that there would be no difference in hit rate between young and older adults for either the 1AFC or 2AFC presentation mode. However, it was also predicted that the false alarm rate would be elevated for older adults for both the 1AFC and 2AFC tasks.

### *Stimulus Type*

Only a few experiments have directly compared recognition memory for verbal and non-verbal material. A consistent finding has emerged, however, indicating that accuracy for picture recognition far exceeds that for word recognition even at two week retention intervals (Bloom, 1971, cited in Gehring *et al.*, 1976). This finding has also been extended to spatial memory for pictures and words. The pictorial superiority effect has been well documented, and has been observed across the adult lifespan. Most investigations that have examined the pictorial superiority effect have failed to take into account the level of contextual detail provided by the image. Many have employed simple photographs or line drawings, and have subsequently manipulated the contextual detail of the stimuli to gauge memory effects (e.g., Park *et al.*, 1984; Pezdek, 1987; Pezdek & Chen, 1982). A number of studies by Park *et al.* (1986) concluded that increasing the contextual detail of pictorial material actually facilitates recognition performance in both young and older adults. Although the effect of contextual detail on recognition accuracy has been well researched, there does not appear to be any studies that have explicitly compared recognition memory for words and abstract geometric designs.

Thus, the third objective of the present study was to determine whether the pictorial superiority effect would remain solid for the recognition of words and abstract geometric shapes as a function of age. It was predicted that there would be an elevated d' value as a consequence of a higher hit rate for the verbal stimuli, as opposed to the non-verbal stimuli, for both young and older adults.

***Trial Difficulty***

The use of distractors has been a defining feature of recognition memory tasks, and it has been acknowledged that they are the most significant source of variation in recognition (Deese, 1963, cited in Wallace, 1980). Both the similarity between targets and distractors, and the presentation frequency of distractors affect recognition accuracy. Nonetheless, Wallace (1980) has disputed their employment. It has been highlighted that the use of distractors in a recognition test changes the nature of that test from a pure test of recognition to a test of recognition-discrimination.

Quite obviously, the more similar the distractors to the targets, the more difficult the recognition task (Loftus & Loftus, 1976). An unpublished study by McCoy (1974, cited in Loftus & Loftus, 1976) demonstrated how target-distractor similarity can distort recognition memory performance. In the study phase, participants viewed a series of pictures detailing a person shopping. In the test phase, participants who saw pictures of the same person shopping in a different context made 29% more errors than participants who were presented with unrelated pictures.

Much of the literature investigating target-distractor similarity involves visual searches (e.g., Pashler, 1987; Treisman, 1991; Wolfe & Friedman-Hill, 1992) or the recognition of faces (e.g., Davies, Shepherd, & Ellis, 1979). Most of these studies have noted increases in false alarms, but no differences in hits, for trials in which visually similar distractors were presented. As yet, little data have been collected on the relationship between target-distractor similarity for words and geometric patterns, and subsequent recognition memory performance.

The fourth objective of the present study was to investigate whether distractors that were highly similar to targets would decrease performance on both verbal and non-verbal recognition memory tasks as a function of age. On the basis of previous findings, it was predicted that increased target-distractor similarity would decrease recognition accuracy for both verbal and non-verbal tasks. Further, based on the findings of Davies *et al.* (1979) and Treisman (1991), it was predicted that there would be an increase in false alarms, but no change in hits, for trials in which a visually similar distractor was presented.

Although it appears that no studies have examined the effect of age on trial difficulty, it is assumed that theories of cognitive slowing and response biases would be relevant. Faced with a difficult trial, older adults may show a retarded motor response, and/or may be more likely to adopt a conservative bias. However, it is more likely that as people age, their ability to make fine discriminations may deteriorate. In light of these theories, it was also predicted that older adults would find the difficult trials significantly harder than young adults.

# METHOD

## Participants

### *Young Participants*

Forty people aged between 17 and 27 years ($M$ = 21.93, $SD$ = 2.25) volunteered to participate in the study. Of these 40 participants, 20 were male and 20 were female. The majority of young participants were either undergraduate students ($n$ = 19), or post-graduate students ($n$ = 9) mostly from the Department of Psychology at Massey University. The remainder occupied professional positions ($n$ = 11) or were unemployed ($n$ = 1). All young people were recruited by word-of-mouth.

### *Older Participants*

Twenty males and 20 females volunteered to complete the study. The 40 participants were aged between 60 and 88 years ($M$ = 72.08, $SD$ = 7.93). Most of the participants were retired ($n$ = 38); however, one was engaged in full-time employment and one was employed on a casual basis. Older participants were recruited from rest homes, retirement villages, a Kiwi Seniors aerobics group, and by word-of-mouth.

All materials and procedures used in the present study were approved by the Massey University Human Ethics Committee.

### *Group Assignment*

Participants were randomly assigned to one of four groups; 1) words presented first, 1AFC; 2) drawings presented first, 1AFC; 3) words presented first, 2AFC; and 4) drawings presented first, 2AFC. There were 10 young and 10 older participants in each of the conditions, with half of the young and older participants being female, and the other half male.

The criteria for inclusion in the study was the lifetime absence of all of the following: alcohol abuse, major depression, a neurological disorder, a hereditary disease, or any medical condition with known central nervous system complication. In addition, participants who had had a neurosurgical operation at any time during their lives were excluded. These factors were assessed using a structured interview and screening questionnaire developed by Whittington (1997; see Appendix A).

**Apparatus**

A Toshiba T2110CS/350 lap-top computer with a 10.5 inch colour monitor (non-active matrix) screen was used. Directly in front of the lap-top computer was a wooden response console (33 by 27 by 10 cm) with two metallic keys (8 by 14 cm) mounted to the top sloping surface. The keys were 10 cm apart and labelled "old" (left-hand) and "new" (right-hand) in the 1AFC condition. The keys were unlabelled for the 2AFC condition. An additional keyboard was attached to the lap-top computer, for use by the experimenter.

The software used was a programme called Experimental Run Time System (ERTS; Beringer, 1995). ERTS is a system for "developing and running non-adaptive, trial-oriented reaction time experiments and continuous tracking tasks" (Beringer, 1995, p. 1). It has had numerous applications within cognitive paradigms, and was ideally suited to developing the computer programmes required for the present study.

The lap-top computer was typically mounted on a dining-room-sized table or desk, so that the screen was approximately 50 cm away at eye-level when the participant was seated. The response keys were within easy reach, the distance being adjusted to suit each individual participant. Participants were tested in a distraction-free environment, and the computer screen was adjusted to give optimum viewing to the participants.

**Task and Stimuli**

The task was a recognition memory task using both words and shapes. There were two modes of presentation. While targets were presented sequentially for all participants in the study phase, participants completing the 1AFC recognition task also viewed either a target or a distractor sequentially during the recognition phase. Participants in the 2AFC recognition task viewed both a target and a distractor at the same time during the recognition phase. Each participant was required to make a judgement of recognition on each trial. Participants in the 1AFC condition indicated whether they had seen the stimulus before, while participants in the 2AFC condition indicated whether it was the stimulus on the left or right that they had seen before.

In the practice trials, eight three-digit numbers were used. Each number was 2 cm high, coloured yellow and presented on a blue background. The four target numbers consisted of a number repeated in triplicate, e.g., 111, 444, while the four distractor numbers consisted of three dissimilar numbers, e.g., 419, 623. In the 1AFC practice trials, each three-digit number was presented in the middle of the screen, the stimulus being presented in a random order. In the 2AFC recognition phase practice trials, pairs of three-digit numbers were presented side by side on the screen. Each target number was presented with a distractor number, and the side on which the target number appeared was randomised for each participant. The main purpose of the practice set was to ensure that participants were familiar with the sequencing and timing of the stimulus presentations. In addition, the practice set enabled participants to adjust to the length of the response interval.

The verbal stimuli used in the experimental trials were a mix of 80 nouns of 3-6 letters ($M$ = 4.35, $SD$ = 0.74) derived from a pool of words generated by Lesch and Pollatsek (1993) and Kucera and Francis (1982) (see Appendix B). All stimuli ranged in frequency from 1 times per million words to 201 times per million words (Kucera & Francis, 1982). Each of the 40 target nouns had either a visually similar or visually dissimilar distractor, which were equal in word length to their respective target. Visual similarity was determined using the "visual similarity rating system" developed by Lesch and Pollatsek (1993). This system estimates visual similarity between pairs of words based on the number of letters shared between the two words.

The non-verbal stimuli used in the experimental trials were abstract figures similar to those used in the Embedded Figures Test (Whitkin, Moore, Goodenough, & Cox, 1977). Like the verbal stimuli, each non-verbal target had either a visually similar or a visually dissimilar distractor. Visual similarity was based on certain parameters, such as the addition or subtraction of a line, or a partial colour change. Each word or drawing appeared on the screen against a blue background. All words were coloured yellow, while each coloured drawing was presented within a box with a white background.

In the 1AFC experimental trial, each stimulus was presented at screen centre, the order of presentation being randomised for each participant. In the 2AFC experimental trial, pairs of either words or shapes were presented side by side on the screen. Half of the target words were presented with visually similar distractors, while the other half were presented with visually dissimilar distractors. For example, the word 'beach' (target with visually similar distractor-'bench') might have been paired with the word 'chief' (distractor with visually dissimilar target-'guard'). In the next trial, the words 'guard' and 'bench' might have been presented. A more detailed description of verbal target-distractor pairings can be found in Appendix B. The same pairs of words were shown for each participant. However, the side on which the target appeared was randomised. For a full list of the targets and distractors used, see Appendix B.

Owing to the relative difficulty of the non-verbal task, the target drawings were always paired with a visually similar distractor. The side on which the target item appeared was randomised across trials for each participant. A complete pictorial example and detailed explanation of the non-verbal targets and distractors are provided in Appendix C.

## Design and Analysis

The design was a 2 x 2 x 2 x 2 mixed factorial design, in which age (young vs. older) and presentation mode (1AFC vs. 2AFC) were between-group factors and difficulty (hard vs. easy) and stimulus type (words vs. shapes) within-group factors. Participants were randomly assigned to both presentation mode and the type of stimulus they received first, and there were an equal number of males and females in each group. Table 1 provides a visual representation of the experimental design, with the between-group factors represented on the ordinate and abscissa and the within-group factors in each cell.

**Table 1**
*Visual representation of the mixed design, with Age and Presentation Mode as between-group factors and Trial Difficulty (hard vs. easy) and Stimulus Type (words vs. shapes) as within-group factors*

| PRESENTATION MODE | Old | Young |
|---|---|---|
| 1AFC | HARD / EASY — WORDS<br>HARD / EASY — SHAPES | HARD / EASY — WORDS<br>HARD / EASY — SHAPES |
| 2AFC | HARD / EASY — WORDS<br>HARD / EASY — SHAPES | HARD / EASY — WORDS<br>HARD / EASY — SHAPES |
| | AGE | |

The main analyses of variance (ANOVAs) were completed using the statistical package SAS (SAS Institute, 1987). Effect sizes (*ES*) and statistical power (*SP*) for both the *F* and *t* statistics were calculated in accordance with J. Cohen's

(1988) recommendations. In the present study, *ES* and *SP* are usually reported along with the results of statistical tests. The Type I error probability was set at the conventional level of 0.05.

**Procedure**

Participants were individually tested either in their own homes or in the home of the experimenter. In all conditions, an information sheet about the study was given to participants to read, and a consent form was given to sign (see Appendixes D and E). Following this, the experimenter administered a brief questionnaire to screen for any neurological impairments that might alter performance (Appendix A). A positive response to any of the questions meant the participant's data could not be used. However, such participants were still invited to complete the study, and remained unaware that their data could not be used. Biographical data were also obtained regarding each participant's age, marital status, level of education, eyesight, and current state of health.

All participants were seated at either a dining-room table or desk on which the lap-top computer, response console and additional keyboard were arranged. Because a number of the participants had little experience with computers, time was taken to introduce them to the apparatus and help them feel at ease.

Participants viewed a series of instructions that were presented on the computer screen (see Appendix F). At the bottom of each screen was an instruction to press either the left or right console button to view the next screen. This allowed participants to read the instructions at their own pace.

For the practice trials, all participants saw four three-digit numbers presented one at a time in the middle of the screen. On each trial, each number was presented for 3 s with a 1 s interstimulus interval. Immediately after the presentation phase had ended, additional instructions were given (see Appendix F). Participants in the 1AFC condition then saw eight randomly ordered three-digit numbers; four were the numbers that they had just seen, and four were completely new numbers. Their task was to decide for each three-digit number whether it was an old number or a new number. Participants were advised to press the left button (labelled "old") if they thought it was an old number (previously seen), or the right button (labelled "new") if they thought it was a new number.

The study phase for the 2AFC task was identical to that employed for the 1AFC task described above. Participants saw pairs of three-digit numbers presented side by side on the screen. One three-digit number was the target (number previously seen), while the other was the distractor. The side on which the target item appeared was randomised. The participants' task was to decide whether it was the three-digit number on the left or the right that they had previously seen. They were advised to press the corresponding (unlabelled) button on the response console. All participants had six seconds in which to make their response from the time each number appeared on the screen. A failure to enter a response within the required time resulted in no response being coded for that trial.

In addition, all participants were required to make a rating of confidence in their decision for each trial, choosing from either; 1) Very confident, 2) Confident; 3) Somewhat confident; or 4) Not at all confident. The four ratings of confidence appeared on the screen subsequent to participants making their response for each trial. Participants said aloud the appropriate response, which was entered into the computer by the experimenter using the additional keyboard. Because the experimenter's response triggered the commencement of the following trial, confidence ratings were entered approximately 3 s after participants had verbalised their rating. Because the data on confidence ratings were collected as part of another study involved in the Parkinson's disease research programme, the data were not analysed in the present study. Figure 1 shows the sequence of events in a 1AFC (upper level) and 2AFC (lower level) trial during the recognition phase of the experiment.

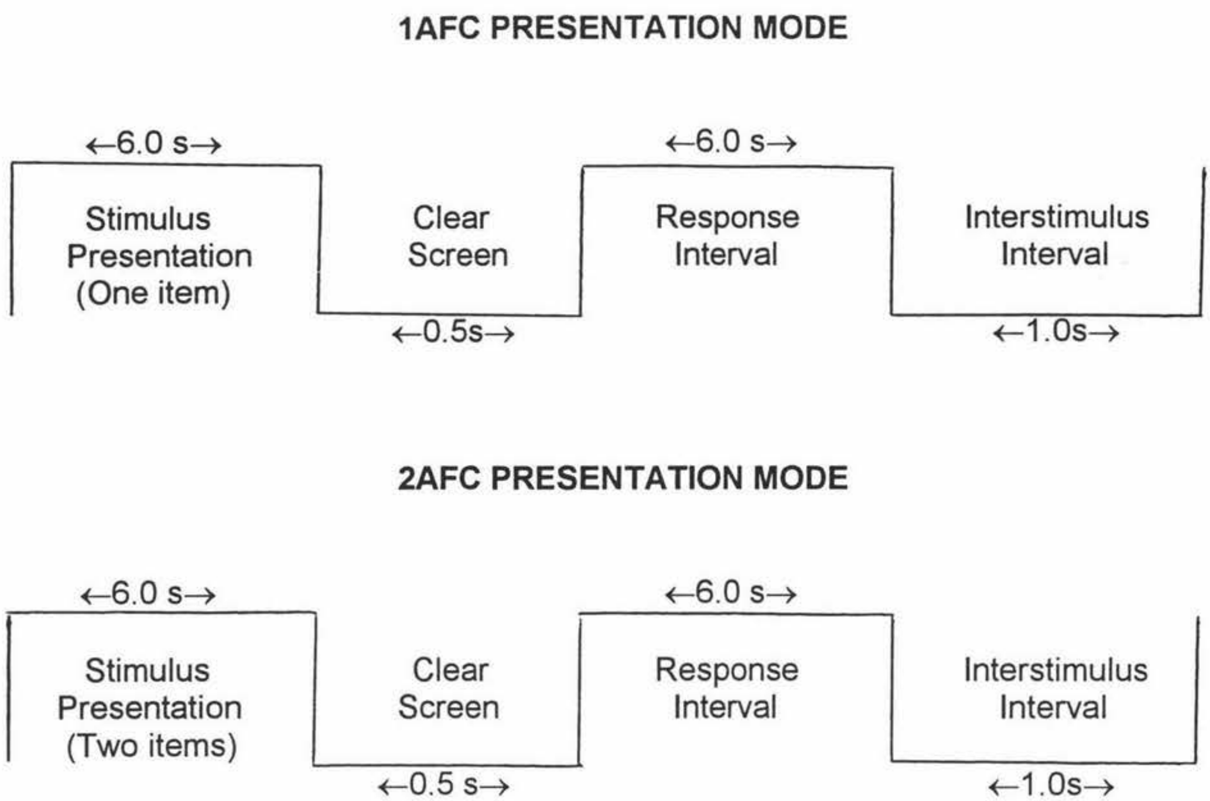



***Figure 1.*** Sequence of events in a 1AFC (upper level) and 2AFC (lower level) trial during the recognition phase of the experiment.

On completion of the practice trials, participants were given the opportunity for further practice if they were still unsure as to what was expected of them. Although the vast majority of participants continued without additional practice trials, a small number of older participants chose to complete a second series. Once participants were at ease with the task, they proceeded to the experimental trials.

Prior to commencing the experimental trials, further instructions were given to remind participants of their task (see Appendix F). Half of the participants completed the verbal recognition memory task first followed by the non-verbal recognition memory task, while the remaining participants completed the tasks in reverse order. Participants in the 1AFC condition then completed the study phase of either the verbal or non-verbal recognition task. There was a retention interval of approximately 1 min in which participants were given further reminding instructions. Following this interval, they were presented with 80 words or drawings also presented one at a time in the middle of the screen. Forty items were targets randomly interspersed with 40 distractor items. Judgements of recognition were made followed by a rating of confidence in the decision for each trial.

Participants in the 2AFC condition also viewed a series of either 40 words or drawings presented one at a time in the middle of the screen. Forty pairs of either words or drawings were then shown following a retention interval of approximately 1 min. Each target item was paired with a distractor item and appeared on either side of the screen at random. On each trial, a decision was made as to whether the previously seen ('old') stimulus appeared on the left or the right of the screen, followed by a rating of confidence.

Once the first recognition memory task (either the verbal or non-verbal task) had been completed, all participants were shown instructions virtually identical to those presented in the first practice and experimental phase. They then commenced the remaining verbal or non-verbal task (whichever had not yet been completed). Because a block of experimental trials had already been completed, it was not necessary for participants to engage in further practice trials following the second set of instructions. After participants had read the instructions, the second set of experimental trials began.

Once both tasks had been completed, participants were thanked and debriefed. They were also asked if they would like to view their results, which were qualified and interpreted in a positive light by the experimenter.

## RESULTS

Hit and false alarm rates were calculated for each participant (see Appendixes G and H). Hit rates are defined as "the conditional probability of responding yes to an old item", while false alarm rates are defined as "the conditional probability of responding yes to a new item" (Snodgrass & Corwin, 1988, p. 35). Recognisability measures were calculated for the 2AFC task (percentage correct; PC) and the 1AFC task (d'). The 2AFC PC tabulated data are included in Appendix I. Although these measures are not directly comparable, a d' value can be derived from the 2AFC PC scores (e.g., see McNicol, 1972). SDT predicts that the 2AFC d' will be a factor of $\sqrt{2}$ larger than the 1AFC d'. Macmillan and Creelman (1991) point out that the reason for this is that the 2AFC task is comparatively easier than the 1AFC task. In the 2AFC task, the participant, in essence, has two observations to base a recognition decision on, while in the 1AFC task only one observation is made.

A d' measure for the 2AFC task was derived from hits and false alarms for this task (Macmillan & Creelman, 1991). A hit in the 2AFC presentation mode was defined as judging the item on the left as 'old' when it was old. A false alarm in the 2AFC task was defined as judging the item on the left as 'old' when the item on the right was old. The resulting 2AFC d' was then multiplied by $\sqrt{2} / 2$ to scale it down for comparison with the 1AFC d'. The prediction is that, once this correction has been made, there should be no differences between 1AFC and 2AFC performance. Table 2 shows the similarity in d' measures between the 1AFC and 2AFC presentation mode for Age, Stimulus Type, and Trial Difficulty.

To check that the 2AFC d' equated to the 1AFC d', a 2 (Age) x 2 (Stimulus Type) x 2 (Trial Difficulty) ANOVA was conducted on both PC and corrected d' (transformed from PC) data for the 2AFC presentation mode only. According to SDT, both PC and the transformed d' data should yield identical main effects and interactions.

**Table 2**
*Means (M) and standard deviations (SD) for d' as a function of Presentation Mode, Age, Stimulus Type, and Trial Difficulty*

| | | | Presentation Mode | | | |
|---|---|---|---|---|---|---|
| | | | 1AFC | | 2AFC | |
| Age | Stimulus Type | Trial Difficulty | *M* | *SD* | *M* | *SD* |
| Young | Words | Hard | 1.54 | 0.98 | 1.72 | 0.82 |
| | | Easy | 2.14 | 0.75 | 2.14 | 0.62 |
| | Shapes | Hard | 0.84 | 0.50 | 0.81 | 0.65 |
| | | Easy | 0.93 | 0.52 | 1.34 | 0.70 |
| Old | Words | Hard | 1.07 | 0.63 | 1.01 | 0.77 |
| | | Easy | 1.85 | 1.07 | 1.38 | 0.76 |
| | Shapes | Hard | 0.46 | 0.40 | 0.48 | 0.49 |
| | | Easy | 0.47 | 0.38 | 0.67 | 0.43 |

An analysis of all main effect and interaction *F* values did in fact show identical results. Since the 2AFC d' values yielded the same results as the original PC values, from this point, 2AFC performance will usually be described in terms of d'.

Although recognition memory research commonly examines and interprets hits and false alarms separately (e.g., Podd, 1990), it must be noted that this practice should be viewed with caution. Hits and false alarm values are both required to derive the relatively bias-free measure of recognisability, d'. The problem with considering hits and false alarms independently is that the value of each can change as a result of a response bias (a change in the willingness to report a stimulus as previously seen) or as a result of a change in recognisability. In theory, the d' measure indicates memory performance independent of testing conditions and response biases (Kintsch, 1968). Because much of the previous research on recognition memory using the 1AFC mode of presentation has examined hits and false alarms independently, a similar analysis is undertaken below. However, caution is required when deciding whether these changes are due to a shift in bias or a change in recognisability.

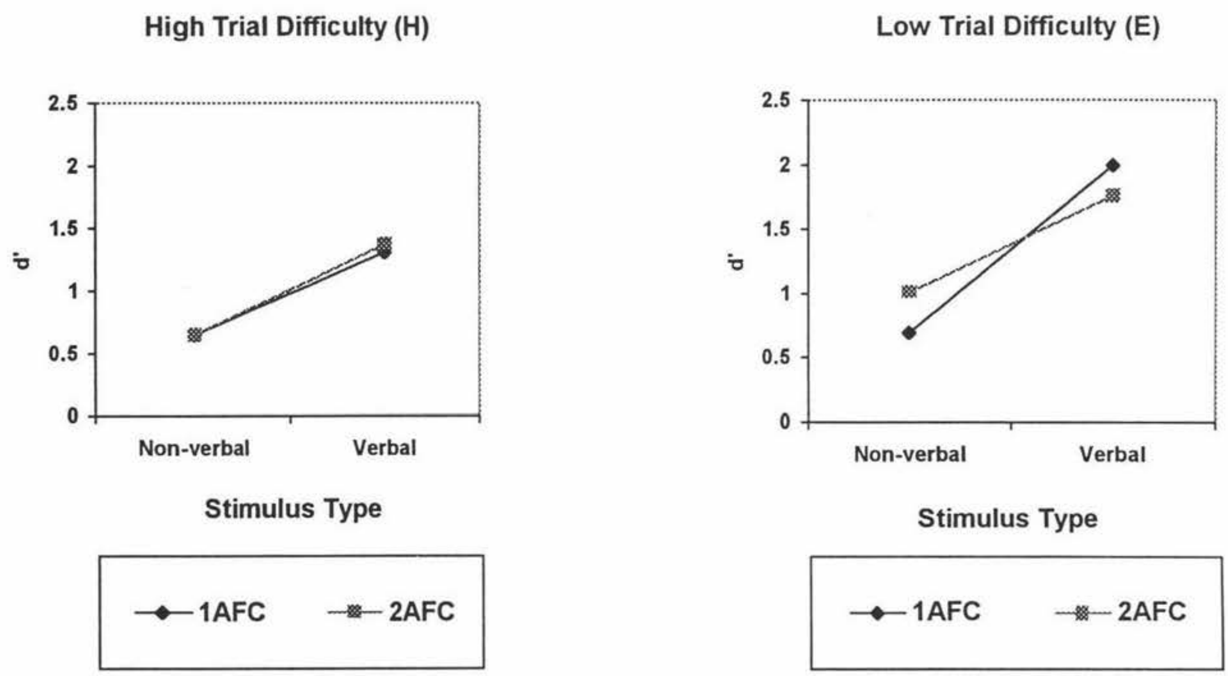
Although the present study intended to adopt a strict planned comparison approach, full-scale omnibus ANOVAs were conducted for hits and false alarms and d' for both presentation modes. These analyses were undertaken in order to check for any unexpected effects that might modify the interpretation of the planned comparisons.

Interestingly, an ANOVA on the d' data generated a statistically significant three-way interaction for Stimulus Type x Trial Difficulty x Presentation Mode, $F$ (1, 76) = 6.29, $p < .02$, $ES = 0.29$, $SP = 0.73$. Although the effect size was relatively small, it seemed prudent to include discussion of this interaction along with the planned comparisons.

Figure 2 shows the interactive effects of Trial Difficulty, Stimulus Type, and Presentation Mode on recognition performance. It can be seen that while non-verbal items were easier to recognise in the 2AFC compared to the 1AFC presentation mode, $t$ (76) = 3.44, $p < .025$, $ES = 0.22$, $SP = 0.49$, the reverse was true for verbal items, $t$ (76) = 2.67, $p < .025$, $ES = 0.19$, $SP \approx 0.39$. However, this effect only occurs for easy trials. There are no differences for presentation mode for the more difficult trials. The differences observed between the 1AFC and 2AFC modes of presentation for the easy trials were fairly small (d' $\approx$ 0.30), and accordingly, the effect size was relatively small too.

Presumably, this interaction is stable for both young and older adults, because Age does not feature in the interaction. Although this interaction will influence the interpretation of main effects and interactions found involving Stimulus Type, Trial Difficulty, or Presentation Mode, any main effects found for Age will be unaffected.

**Figure 2.**
Comparison of the interactive effects of Stimulus Type, Trial Difficulty, and Presentation Mode on recognition performance.




However, Age did in fact emerge as a factor in a post-hoc comparison. A significant Presentation Mode x Age interaction was observed for d', $F\ (1, 76) = 4.43$, $p < .04$, $ES = 0.25$, $SP = 0.60$, which will qualify any main effects found for Age. This interaction shows that the 2AFC presentation mode yielded better performance than the 1AFC presentation mode, but only for young participants, $t\ (76) = 0.78$, $p < .025$, $ES = 0.24$, $SP = 0.12$. Figure 3 shows that older participants performed similarly irrespective of mode of presentation, whereas the young participants did not. Again it can be noted that the d' difference was small, resulting in only a small effect size.

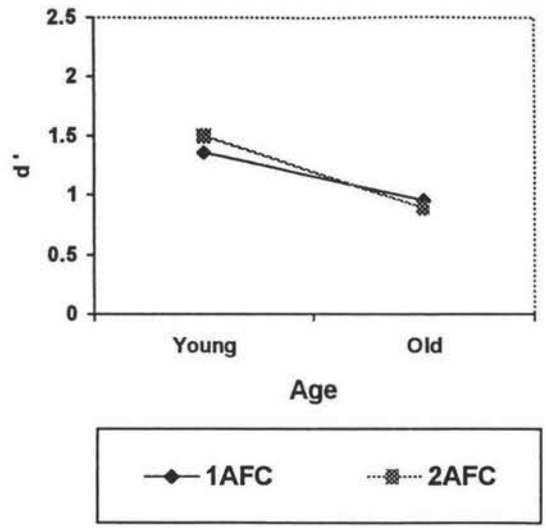



**Figure 3.**
Comparison of the interactive effects of Age and Presentation Mode on recognition performance.

## Planned Comparisons

### *Age*

There was a statistically significant main effect for Age for d', $F$ (1, 76) = 79.03, $p < .0001$, $ES$ = 1.02, $SP \approx 1.00$. Older adults were less able to discriminate old from new items ($M$ = 0.92, $SD$ = 0.50) than young adults ($M$ = 1.43, $SD$ = 0.55), which accounted for the effect of age. This main effect must be qualified in the light of the Presentation Mode x Age interaction. However, the large effect size and consistent mean age differences confirm that there is a strong effect for age irrespective of mode of presentation (see Table 2).

An analysis of hits for both the 1AFC and 2AFC tasks also produced a main effect for Age, $F$ (1, 76) = 32.52, $p < .0001$, $ES$ = 0.65, $SP \approx 1.00$. This main effect for Age indicated that older adults tended to have lower hit rates ($M$ = 0.68, $SD$ = 0.10) than younger adults ($M$ = 0.76, $SD$ = 0.10), showing that older adults failed to correctly recognise previously seen items as often as younger adults. Table 3 shows the marked difference in mean hit rates between young and older adults, the older adults having lower hit rates than young adults in every condition.

**Table 3**
*Means (M) and standard deviations (SD) for hit rates as a function of Presentation Mode, Age, Stimulus Type, and Trial Difficulty*

| | | | Presentation Mode | | | |
|---|---|---|---|---|---|---|
| | | | 1AFC | | 2AFC | |
| Age | Stimulus Type | Trial Difficulty | *M* | *SD* | *M* | *SD* |
| Young | Words | Hard | 0.76 | 0.15 | 0.84 | 0.16 |
| | | Easy | 0.76 | 0.14 | 0.90 | 0.08 |
| | Shapes | Hard | 0.67 | 0.12 | 0.72 | 0.16 |
| | | Easy | 0.58 | 0.15 | 0.83 | 0.14 |
| Old | Words | Hard | 0.71 | 0.12 | 0.73 | 0.18 |
| | | Easy | 0.73 | 0.12 | 0.82 | 0.12 |
| | Shapes | Hard | 0.60 | 0.14 | 0.61 | 0.14 |
| | | Easy | 0.51 | 0.11 | 0.70 | 0.20 |

A main effect for Age was also observed when false alarms were examined for both the 1AFC and 2AFC tasks, $F$ (1, 76) = 53.38, $p < .0001$, $ES$ = 0.92, $SP \approx$ 1.00. Older adults had an average 9% higher false alarm rate ($M$ = 0.32, $SD$ = 0.08) than younger adults ($M$ = 0.23, $SD$ = 0.10) confirming that the age-related decrease in accuracy was a function of both a decrease in hits and an increase in false alarms. Along with the lower d' values for the older adults, this suggests that the increased hit rates and decreased false alarm rates were due to poorer recognition memory rather than response bias differences. The difference in mean false alarm rates between young and older adults can be seen in Table 4. The false alarm rates for the older adults were consistently higher than those for young adults.

**Table 4**
*Means (M) and standard deviations (SD) for false alarm rates as a function of Presentation Mode, Age, Stimulus Type, and Trial Difficulty*

| | | | Presentation Mode | | | |
|---|---|---|---|---|---|---|
| | | | 1AFC | | 2AFC | |
| Age | Stimulus Type | Trial Difficulty | *M* | *SD* | *M* | *SD* |
| Young | Words | Hard | 0.27 | 0.15 | 0.15 | 0.12 |
| | | Easy | 0.12 | 0.09 | 0.08 | 0.09 |
| | Shapes | Hard | 0.36 | 0.14 | 0.33 | 0.14 |
| | | Easy | 0.25 | 0.10 | 0.25 | 0.18 |
| Old | Words | Hard | 0.35 | 0.16 | 0.27 | 0.18 |
| | | Easy | 0.18 | 0.19 | 0.23 | 0.16 |
| | Shapes | Hard | 0.42 | 0.10 | 0.37 | 0.15 |
| | | Easy | 0.33 | 0.34 | 0.38 | 0.15 |

***Presentation Mode***

An analysis of d' yielded no main effect for Presentation Mode, $F$ (1, 76) = 1.49, $p > .20$, $ES$ = 0.14, $SP$ = 0.24. Participants performed similarly regardless of whether they were completing 1AFC or 2AFC trials, once the 2AFC data had been transformed to the d' metric (see Table 2). The similarity in collapsed mean values for the 1AFC ($M$ = 1.16, $SD$ = 0.62) and 2AFC trials ($M$ = 1.19, $SD$ = 0.60) suggested that once the SDT transformation from PC to 2AFC d' was done, Presentation Mode by itself had virtually no effect.

However, although there was no main effect for Presentation Mode, it is clear from the Stimulus Type x Trial Difficulty x Presentation Mode interaction that mode of presentation had some effect on recognition performance. Participants in the 2AFC condition were more able than participants in the 1AFC condition to recognise non-verbal items on the easy trials. In contrast, participants in the 1AFC condition were more able than participants in the 2AFC condition to recognise verbal items on the easy trials. This three-way interaction necessarily qualifies the main effect for Presentation Mode, but it should be remembered that the effect size associated with this interaction was relatively small (0.29).

***Stimulus Type***

A statistically significant main effect was observed when d' was analysed for Stimulus Type, $F$ (1, 76) = 203.78, $p < .0001$, $ES$ = 1.64, $SP \approx 1.00$. This was a particularly strong result verifying that it was more difficult to discriminate old from new non-verbal stimuli ($M$ = 0.75, $SD$ = 0.30) than old from new verbal stimuli ($M$ = 1.61, $SD$ = 0.44). The differences in d' for Stimulus Type can be observed in Table 2.

However, once again the Stimulus Type x Trial Difficulty x Presentation Mode interaction suggests that caution is required in interpreting the main effect for Stimulus Type. This three-way interaction showed that verbal items were easier to recognise than non-verbal items for each level of the subsidiary factors.

However, non-verbal items were easier to recognise on easy trials in the 2AFC compared to the 1AFC condition, while the reverse was true for verbal items. Verbal items were easier to recognise on easy trials in the 1AFC as opposed to the 2AFC condition.

An analysis of hits for both the 1AFC and 2AFC conditions also indicated a main effect for Stimulus Type, $F$ (1, 76) = 82.16, $p < .0001$, $ES$ = 1.04, $SP \approx$ 1.00. This effect demonstrated that participants tended to have lower hit rates when presented with non-verbal ($M$ = 0.65, $SD$ = 0.10) as opposed to verbal stimuli ($M$ = 0.78, $SD$ = 0.07). In other words, recognising previously seen words was easier than recognising previously seen shapes. A comparison of mean hit rates for the verbal and non-verbal items is shown in Table 3.

Stimulus Type also emerged as a significant effect for false alarms, $F$ (1, 76) = 98.91, $p < .0001$, $ES$ = 1.15, $SP \approx$ 1.00, which indicated that participants tended to have higher false alarm rates for non-verbal ($M$ = 0.34, $SD$ = 0.06) as opposed to verbal trials. ($M$ = 0.21, $SD$ = 0.09). This effect was specifically manifested as mistakenly recognising new non-verbal items as old items, which verified that the observed decline in accuracy for the non-verbal trials was a function of both a low level of hits and a high level of false alarms. These changes, in accordance with those for d', suggest that older people have poorer recognition than young people, rather than there being a difference in response bias. Table 4 provides a comparison of mean false alarm rates for the verbal and non-verbal items.

***Trial Difficulty***

There were two levels of trial difficulty in the present study. Hard trials were those in which there was a high degree of target-distractor similarity, and easy trials were those in which there was a low degree of target-distractor similarity. An analysis of d' for trial difficulty produced a statistically significant main effect, $F$ (1, 76) = 37.98, $p < .0001$, $ES$ = 0.70, $SP \approx$ 1.00. This main effect demonstrated that participants were less able to discriminate old from new items when presented with a visually similar distractor (*M* = 0.99, *SD* = 0.45) than when presented with a visually dissimilar distractor (*M* = 1.37, *SD* = 0.64). Table 2 provides a visual representation of the discrepancies in d' for both levels of Trial Difficulty.

The Stimulus Type x Trial Difficulty x Presentation Mode interaction again raises a question mark regarding the interpretation of this main effect. While there was no effect for Presentation Mode for the hard trials, there was a significant effect for mode of presentation for the easy trials. Participants in the 2AFC compared to the 1AFC condition correctly recognised more non-verbal items, while the reverse was true for verbal items.

Surprisingly, there was no significant main effect for trial difficulty when an examination of hits was conducted, $F$ (1, 76) = 2.43, $p > .10$, *ES* = 0.18, *SP* = 0.36. The relatively small effect size (compared to the effect size for false alarms below) suggested that participants were correctly identifying target information regardless of whether they were completing a trial in which a similar (*M* = 0.71, *SD* = 0.08) or dissimilar distractor (*M* = 0.73, *SD* = 0.13) was presented. The similarity in mean hit rates for both levels of trial difficulty are shown in Table 3.

In contrast, a statistically significant effect was observed when analysing false alarms, $F$ (1, 76) = 48.11, $p < .0001$, *ES* = 0.80, *SP* $\approx$ 1.00, which indicated that false alarms increased as a function of trial difficulty. This shows that participants were more likely to incorrectly recognise new items as being old when they completed trials involving similar distractors (*M* = 0.32, *SD* = 0.08) as opposed to dissimilar distractors (*M* = 0.23, *SD* = 0.10). The main effect found for d' can thus be largely attributed to the increase in false alarms made on the trials in which the visually similar distractor was presented. Table 4 shows the contrasting mean false alarm rates for both levels of trial difficulty.

## Post-Hoc Comparisons

Although the present study intended to adopt a strict planned comparison approach, the emergence of a Stimulus Type x Trial Difficulty x Presentation Mode, and a Presentation Mode x Age interaction precluded this format. These interactions inevitably affected the interpretations of some of the main effects, thus their effects were better reported with the planned comparisons. In addition to these interactions, a statistically significant two-way interaction was found involving Stimulus Type x Trial Difficulty.

### *Stimulus Type x Trial Difficulty*

The d' data yielded a statistically significant interaction for Stimulus Type x Trial Difficulty, $F$ (1, 76) = 5.79, $p$ < .02, $ES$ = 0.27, $SP$ = 0.66. This interaction indicated that the level of trial difficulty affected participants' ability to discriminate old from new items, but only for the verbal trials, $t$ (76) = 18.00, $p$ <.025, $ES$ = 1.50, $SP \approx 1.00$. However, this two-way interaction is embedded in the Stimulus Type x Trial Difficulty x Presentation Mode interaction described earlier. Clearly, this three-way interaction makes the Stimulus Type x Trial Difficulty interaction uninterpretable since the effect of Presentation Mode must be taken into account.

## DISCUSSION

The primary objective of the present study was to determine whether there would be an age-related decline in recognition memory that was moderated to any extent by the mode of presentation, the type of stimulus, and the difficulty level of the task. As expected, older adults were generally less able to recognise the differences between old and new items and were more prone to falsely recognising new items as 'old' than younger adults. Unexpectedly, however, older adults were also less likely to correctly recognise old items than their younger counterparts. Thus, in the present study, the decline in recognisability with age was a function of both a decline in hit rate and an increase in false alarm rate.

The second objective of the current study was to investigate whether stimuli presented sequentially (1AFC) or simultaneously (2AFC) during the recognition phase would influence recognition. There were no significant differences between the 1AFC and 2AFC presentation modes once the 2AFC data were adjusted by a factor of $\sqrt{2}/2$ to compensate for the relatively easier 2AFC task.

The third objective was to assess whether performance on non-verbal trials would be superior to performance on verbal trials as a function of age. In stark contrast to the predicted outcome, it was found that the discrimination of old and new items was easier for verbal trials than for non-verbal trials.

The current research had a fourth objective, namely, to gauge memory performance on trials that had either visually similar or visually dissimilar distractors. As expected, it was significantly more difficult to discriminate old from new items on hard trials (visually similar distractors) than on easy trials (visually dissimilar distractors). Furthermore, while there was an increase in false alarms for trials in which a visually similar distractor was presented, there was no concomitant change in hits.

Although the present study adopted a planned comparison approach, the emergence of a three-way interaction involving type of stimulus, trial difficulty, and presentation mode, and a two-way interaction involving age and presentation mode meant that this approach had to be modified. In particular, some main effects have to be interpreted in the light of these interactions.

**Age**

There was a significant main effect for Age when analysing d', hits and false alarms. The lower d' value for older adults compared to that of young adults highlighted the general difficulty that this group had in discriminating old from new items. This decreased level of performance was a consequence of both a decrease in hits and an increase in false alarms. Older adults were more likely than young adults to fail to recognise old items, and to disproportionately recognise new items as being old.

The finding that older adults had lower d' scores than young adults lends credence to the findings of Gordon and Clark (1974). One of the few studies using a 1AFC procedure, and thus the d' measure, they also found that older adults produced lower recognition memory scores than the young adults who participated in the study. Because some studies investigating adult lifespan recognition memory have utilised a 2AFC procedure, the results have been expressed in terms of PC rather than d'. In accordance with the results of the present study (see Appendix I), Erber (1974) found that there was a significant age difference in PC scores between young and older adults for a test of word recognition. Additional studies that have used non-parametric indices of recognisability, such as A', have also concluded that older adults perform more poorly than young adults on tests of recognition for words (Baron & Surdy, 1990), word and number combinations (Le Breck & Baron, 1987), and words appearing on differing pictorial backgrounds (Denney, Miller, Dew, & Levav, 1991). The present results are generally consistent with those obtained in these studies.

However, not all studies have found this age effect. Several investigations have yielded few differences between the overall recognition memory performance of young and older adults (e.g., Arenberg, 1985, cited in Craik & McDowd, 1987; Schonfield & Robertson, 1966). Interestingly, these studies compared verbal recall and recognition ability, concluding that while there are substantial age-related differences on recall tasks, the effect is not significant for recognition tasks. Owing to the large number of studies attesting to an age-related recognition memory decline, it can be assumed that the results found by the above studies can be attributed to methodological effects, choice of stimuli, or chance results. Unfortunately, these studies did not report effect sizes for recognition and recall performances, making it difficult to know whether small (but non-significant) recognition effects were in fact obtained.

The explanations offered by Smith (1975) and McNulty and Caird (1966) for the failure to find age decrements in recognition memory need reformulating in the light of the present study, and those previous studies with similar results. Smith argued that because recall is thought to involve an extra search process that is not instigated in recognition, older adults might only be impaired on that first process. Consequently, age-related decrements should be observed for tests of recall but not for tests of recognition. The results of the present study demonstrate that there are significant age differences in recognition memory ability, at least for some types of task. This suggests that older adults are impaired on both aspects of the search process.

McNulty and Caird (1966) offered a different explanation. They argued that the failure to find age differences in recognition experiments is due to a storage deficit in older adults. This storage deficit enables older adults to learn only parts of the information to be remembered. The partial information is insufficient to produce recall, yet rich enough to prompt recognition. If older adults are only able to learn partial information, then the results of the present study suggest that what they are able to learn is still insufficient to produce recognition rates equal to those of their younger counterparts. In other words, recognition performance level is a function of age, the same as for recall.

The main effect for Age needs to be interpreted with caution in the light of the Presentation Mode x Age interaction. While older adults performed similarly irrespective of mode of presentation, young adults had greater recognition accuracy in the 2AFC presentation mode. There certainly seems to be a general decline in recognition memory with age; however, this effect may be moderated by different modes of stimulus presentation. This could account for the mixed results found by previous studies concerning age differences in recognition memory. Because the effect size for this interaction was moderate (0.25), further systematic research is required to investigate how much variation in recognition is determined by the way in which stimuli are presented and the age of the participants.

A comparison of hits and false alarms generated by the older adults produced some interesting findings. Previous recognition memory studies (e.g., Bartlett *et al.,* 1991; Crook & Larrabee, 1992) indicate that there are few differences in hits but significant differences in false alarms across the adult lifespan. The results of the present study suggest otherwise, as there were reliable differences in hit rates as well as false alarm rates between the two age groups. Interestingly, all of the studies finding no difference in hit rates between young and older adults have investigated the recognition of faces. It could be that the intrinsic *nature* of face recognition prompts a certain response bias. As images that are seen every day, faces may imbue more of a sense of familiarity than nouns or abstract shapes. This may induce respondents to report a face as previously seen when it was not, thus increasing the false alarm rate. Diamond and Carey (1986) note that human faces all share the same configuration and have extraordinarily high levels of interitem similarity. Consequently, participants in a face recognition study may adopt a laxer criterion for judging items to be old compared to other stimulus types. There is now a considerable body of evidence to suggest that the recognition of faces may involve distinct areas of the brain, and thus may not be an appropriate process to generalise to other spheres of recognition (Ellis, 1981).

The age differences in recognition may be partially accounted for in the present study by the nature of the sample. The study's external validity could have been compromised by the constitution of the young adult group. Like many previous studies, the majority of participants in the present group were university students, and a large number of these were post-graduate psychology students. In particular, it is worth noting that university students are currently in an educative environment that is partly based on recognition skills, for example, multi-choice tests. Consequently, part of the relationship between aging and recognition memory may be explained in terms of skill maintenance; the young adults may have performed more accurately than the older adults for the simple reason that they have more practice at completing recognition tasks.

The differences in recognition accuracy between young and older adults can also be explained by biological theories of aging. It is well known that structures in the brain believed to be involved in memory deteriorate with age (Pinel, 1997). Although the results of the present study do not provide direct evidence for brain pathology in older adults, it is assumed that neurological changes contributed to the age differences observed in recognition memory in the current study. However, our understanding of what structural changes in the brain are associated with memory in general is still elementary. Better theories of recognition and recall are required before any attempt can be made to link these specific aspects of memory to the aging brain.

**Presentation Mode**

As expected, there was no main effect for presentation mode when d' was examined. The failure to find a difference between performance on 1AFC and 2AFC trials indicates that once 2AFC performance is transformed in accordance with SDT requirements, presentation mode has no other effects. Although it is predicted by SDT that the 2AFC presentation mode is $\sqrt{2}$ easier than the 1AFC presentation mode, applying this factor to the 2AFC d' values removed most of the presentation mode differences. Without rescaling the 2AFC PC data for comparison with 1AFC PC data, the present study's results indicated that the 2AFC condition would have in fact been $\sqrt{2}$ easier than the 1AFC condition. The finding that participants performed similarly, regardless of whether they completed a 1AFC or 2AFC trial, provides support for SDT predictions.

The failure to find a main effect for Presentation Mode must be interpreted in the light of a small Presentation Mode x Age interaction that emerged for d'. Although Presentation Mode is partly involved in the Stimulus Type x Trial Difficulty x Presentation Mode interaction, it is crucial to acknowledge this particular two-way interaction because it involves Age as a factor. Inspection of this interaction verified that while there was no difference in the discriminability of older adults in either the 1AFC or 2AFC presentation mode, the latter condition actually facilitated discriminability in younger adults. One can only speculate as to why this occurred. The interaction effect was quite small, accounting for a little over 5% of the experimental variance. However, further research is required to verify this mode of presentation by age interaction. SDT predicts that 2AFC will be $\sqrt{2}$ times better than 1AFC irrespective of the age of the participants. Verifying that this prediction holds only for some age groups would be a most interesting and provocative finding.

Owing to the paucity of studies directly comparing 1AFC and 2AFC presentations in the test phase of a recognition task, the present study has important implications. The only other investigation with a similar methodology considered verbal recognition memory, comparing 1AFC, 2AFC, 4AFC and 8AFC conditions (Kintsch, 1968). Kintsch employed PC data as a measure of performance, concluding that recognition decreased as a function of the number of alternatives present. Surprisingly, he failed to analyse the difference between 1AFC and 2AFC conditions, merely comparing the 1AFC condition with the overall performance on all other conditions. An examination of his results does, however, indicate that the unscaled 2AFC condition PC data were roughly $\sqrt{2}$ times higher than the 1AFC condition PC data.

An important implication of the current study's results concerns the identification of mug shots. In accordance with SDT, the present study found that before the data had been adjusted, the 2AFC condition was $\sqrt{2}$ easier than the 1AFC condition. Based on these results, it is recommended that mug shots be shown as a photo spread rather than sequentially, as this format should promote more accurate recognition (Ellis, 1981).

**Stimulus Type**

There was a statistically significant main effect for Stimulus Type when examining d', hits and false alarms. Surprisingly, participants demonstrated superior performance on the verbal trials as opposed to the non-verbal trials. This effect was particularly robust, as indicated by the very large effect size, *ES* = 1.64. The lower d' values for the non-verbal trials were a function of both a decrease in hits and an increase in false alarms. When completing the non-verbal trials, participants were more likely to fail to recognise old items, and were also more likely to erroneously recognise new items as old than on the verbal trials. However, these results have to be interpreted in the light of the Stimulus Type x Trial Difficulty x Presentation Mode interaction that emerged. The effect size associated with this three-way interaction was only small (0.10). Hence, it can be suggested that it should not have too much bearing on the present (much larger) main effects. Although the main effect for Stimulus Type suggested that non-verbal items were harder to recognise than verbal items, the three-way interaction indicates that non-verbal items were easier to recognise for the easy trials in the 2AFC presentation mode only. Verbal items produced greater recognition accuracy for all other conditions.

The above findings help to clarify the relationship between verbal and non-verbal stimuli and recognition memory. Few other investigations have found that the recognition of non-verbal material is superior to that of verbal material (but see Gehring *et al.*, 1976; Park *et al.*, 1983). Recent results of Whittington's (1997)[2] using exactly the same stimuli as those used in the present study, show that performance on the verbal task far outweighs that on the non-verbal task for control participants. Table 5 compares the PC results obtained from the 2AFC condition of the present study with those from Whittington's (1997) study.

In general, the participants in Whittington's study had higher recognition rates than the participants in the present study. While the standard deviations were relatively similar, there were sometimes marked differences in mean PC scores.

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[2] Yet to be completed Doctoral dissertation examining Cognitive Deficits in Parkinson's Disease.

For example, participants in Whittington's study performed considerably better on the verbal easy trials than the participants in the present study [ $t$ (63) = 3.33, $p < .025$, $ES$ = 1.00, $SP$ = 0.92]. It is unlikely that this difference in performance could be attributed to age differences between the two groups. The mean age of participants in the present study was 72.08 years, while that for Whittington's study was 69.10 years. It is possible that a sampling bias can account for the higher PC scores in Whittington's study. While the present study attempted to use a sample representative of the older population, by recruiting participants from rest homes, retirement villages and the community alike, Whittington did not recruit older adults from rest homes. Much of his sample were friends of people with Parkinson's disease. Humphries and Podd (1995) found that these people with Parkinson's disease and their spouses tend to be professionals and thus better-educated than average. It is a reasonable assumption that older adults from public rest homes may lack both the cognitive stimulation and educational background experienced by others in the community. Consequently, they may be less likely than other older adults to accurately recognise items.

**Table 5**
*A comparison of means (M) and standard deviations (SD) for percentage correct data from the present study and Whittington's (1997) study*

| | | The Present Study | Whittington (1997) | Percent Difference |
|---|---|---|---|---|
| | | *M* *SD* | *M* *SD* | *M* |
| Verbal | Hard | 0.72 (0.15) | 0.78 (0.11) | 0.06 |
| | Easy | 0.80 (0.12) | 0.90 (0.09) | 0.10 |
| Non-Verbal | Hard | 0.62 (0.11) | 0.67 (0.10) | 0.05 |
| | Easy | 0.65 (0.09) | 0.74 (0.09) | 0.09 |

Another possible reason why the systematic differences between the studies occurred may concern the context of the task. Whittington (1997) administered a battery of tests, of which the recognition task was one of the last to be completed. In contrast, participants in the present study completed the recognition task on its own. It is possible that the participants in Whittington's study felt more at ease than the participants in the present study, owing to the fact that they had time to become accustomed to the experimental process before the commencement of the recognition task. This could account for the greater recognition accuracy demonstrated by Whittington's sample.

It is also important to consider experimenter/participant effects. It is a well-documented fact that male and female experimenters elicit different responses from their participants. A study by Rosenthal (1966) demonstrated that an experiment conducted by a female assistant produced higher mean anxiety scores in participants than the same experiment conducted by a male assistant. Similarly, research has shown that participants led by male experimenters display significantly better learning than those led by female experimenters (Sarason & Harmatz, 1965). In contrast, a study by Binder, McConnell, & Sjoholm (1957) found that female experimenters elicited better learning from their participants than male experimenters in. Other studies have reported no differences in performance as a function of experimenter gender (e.g., Ferguson & Buss, 1960). It is possible that the results obtained by Whittington (a male) (1997) and the present study were influenced by the interacting effects of experimenter and participant gender.

There are a number of explanations why non-verbal material should be recognised better than verbal material. Feenan and Snodgrass (1990) suggest that verbal material is more polysemous than non-verbal material; that is, pictures usually have only one semantic representation while words often have more than one representation. Consequently, one can infer that because non-verbal stimuli have only one semantic representation, they are less likely to be confused with similar representations than verbal stimuli.

Another explanation is offered by Gehring *et al.* (1976). They propose that recognition memory for words is often inferior to that for pictures owing to the relative *frequency* with which they are presented in the environment. Because words are encountered on a daily basis they become more familiar, and thus are more difficult to discriminate.

However, the current results, and the results of Whittington's study, do not support these explanations. Rather, they lend credence to the findings of Diesfeldt and Vink (1989), who also obtained no support for the pictorial superiority effect. The crucial difference between those studies that demonstrate pictorial superiority and those that indicate verbal superiority seems to be the choice of non-verbal stimuli. Typically, investigations that have shown enhanced performance for non-verbal tasks have employed simple line drawings or photographs, which lack elaborative detail. In contrast, those studies that have generated the reverse pattern of results have manipulated either pictures of faces, or as in the present study, abstract geometric designs. Pezdek (1987) agrees that images in their simple form are recognised much more readily and accurately than images in their complex form. While a number of studies attest that increasing the contextual detail of an image facilitates recognition memory performance (e.g., Anglin & Levie, 1985; Park *et al.*, 1984; Park *et al.*, 1986), this phenomenon must be limited by a certain threshold. Essentially, the results of the present study, and those of Diesfeldt and Vink, suggest that the pictorial superiority effect may simply be a function of the stimuli chosen for recognition. The more elaborate the pictorial stimuli to be recognised, the less likely the pictorial superiority effect will occur.

The results of the present study may have also been affected by the colour of the non-verbal stimuli. It has been established that colour memory for both words and shapes deteriorates with age (Park & Puglisi, 1985). Sometimes, the target-distractor similarity of the non-verbal items was manipulated by altering the colour of the stimuli. In other words, while the main features of the target item may have been red and yellow, these may have been switched to orange and blue for the distractor item. As a consequence, recognition accuracy for the non-verbal items may have been impaired for the older adults, owing to the target-distractor colour change. Although no interaction emerged to this effect, the area of recognition memory for colour across the lifespan is an interesting avenue for future research.

**Trial Difficulty**

It will be recalled that trial difficulty was manipulated by varying target-distractor similarity. Half of the targets had distractors that were visually similar, while the other half had distractors that were visually dissimilar. A main effect was observed for trial difficulty for d' and false alarms, but not for hits. The role of target-distractor similarity was thus a factor in the discrimination of old from new items. Participants were less able to distinguish old from new items when presented with distractors that were visually similar than visually dissimilar to the targets. Furthermore, it was apparent that participants tended to incorrectly identify visually similar distractors as 'old' more often than visually dissimilar distractors. In contrast, there was no main effect for trial difficulty when hits were examined. These findings suggest that increasing target-distractor similarity does not impair the ability to identify targets. Rather, it increases the likelihood of identifying new items as targets. Thus, the depressed d' level for trials in which target-distractor similarity was high was largely due to an increase in false alarms.

Because a significant Stimulus Type x Trial Difficulty x Presentation Mode interaction emerged for d', the main effect for Trial Difficulty must be interpreted cautiously. Although this main effect showed that recognition accuracy decreased for trials in which there was a high degree of target-distractor similarity, the three-way interaction suggested that this effect was task-dependent. While these more difficult trials remained unaffected by presentation mode, trials in which there was a low degree of target-distractor similarity produced some interesting effects. Non-verbal items were more accurately recognised in the 2AFC compared to the 1AFC condition, while the reverse was true for verbal items. One can only speculate as to why this interaction occurred, owing to the fact that no other studies have investigated these same factors. Presumably, it was easier to recognise non-verbal items in the 2AFC presentation mode because the non-verbal target items were always paired with their own distractor item. This is in contrast to the verbal 2AFC tasks, in which verbal target items were always paired with another target's distractor item. Because the verbal items were, for the most part, easier to recognise than the non-verbal items, this is a plausible explanation as to why non-verbal items were significantly easier to recognise in the 2AFC presentation mode. Why this effect only occurred for the easy trials raises another question. It is a reasonable assumption that the hard trials were so difficult that all items were poorly recognised, irrespective of Stimulus Type and Presentation Mode. Although this was not a strong interaction, its enigmatic nature dictates further investigation.

The current results indicating that target-distractor similarity affects recognition accuracy conform to those found by previous studies. The target-distractor similarity effect is well documented and dictates impaired performance on memory tasks in which there is a high level of similarity between targets and their respective distractors (Pashler, 1987; Treisman, 1991; Wallace, 1980; Wolfe & Friedman-Hill, 1992). In an investigation employing identical targets and distractors to the present study, Whittington (1997) also found that participants performed more poorly on trials in which they were presented with a visually similar distractor (see Table 5).

It is interesting to note that the results of the present study also support those of Davis *et al.* (1979) and Treisman (1991) in spite of the fact that they employed different types of stimuli and methodologies. While Davis *et al.* investigated the target-distractor similarity effect for photographs of faces, Treisman manipulated coloured bars on a computer screen. Both authors noted a sizeable increase in false alarms made on trials in which visually similar distractors were presented, yet no differences in hits were observed. Davies *et al.* suggested that one of two theories could account for this phenomenon. The cue selection hypothesis argues that although participants are able to recognise a subset of items that have the critical features for recognition, they are not able to discriminate the target from the distractor items within this subset. Another explanation for the results rests on the tenets of SDT. When faced with visually similar distractors, a participant's criterion level remains unaffected. However, the distributions for old and new stimuli become more overlapped, resulting in an increase in false alarms, yet no change in hits.

A number of face recognition studies have also yielded the same results (e.g., Podd, 1990; Rockel, 1991). A possible explanation has been offered by Podd (1990), to account for the observed pattern of hits and false alarms for trials on which similar target-distractors are presented. Based on the piecemeal, or feature selection, theory of face processing, it is assumed that items are remembered as a combination of features, rather than as a whole item. When presented with items for a judgement of recognition, participants "scan" their memory for the presented features. If the item's features matches those already stored in memory, a participant is likely to recognise the item as being 'old'. As a result, a participant may recognise a distractor item as having already been seen if it shares many of the same features as the target. For example, in a test of face recognition, a participant may remember a particular face as a single attribute, such as the eyes. Should a distractor face be presented that shares similar eyes to the target face already stored in memory, it may be falsely identified as having been seen before, resulting in a false alarm. When the target face is presented, the eyes should still be recognised as the critical feature. Consequently, the stimulus should be correctly identified as a previously seen item, thereby maintaining the hit rate (see Podd, 1990). While there is increasing confusion in distinguishing between targets and distractors as they become more similar, the ability to recognise targets is unaffected, thus accounting for the failure to find an effect for hits. That is, a high level of target-distractor similarity leads to over inclusiveness, in respect to reporting stimuli as targets, but the same process does not operate for hits. A number of target cues may be lost while still leaving the stimulus recognisable as a target. Although the theory was originally formulated to be applied to the recognition of faces only, it has potential application to other spheres of recognition. Further research is required to test how well this theory holds up for verbal stimuli, and pictorial stimuli, other than faces.

**Limitations of the Present Study and Suggested Further Research**

One major limitation of the present study was its choice of age groups. Simply assigning participants to either a 'young' or 'older' age bracket may have been too coarse. A valuable modification to the present study would have been to further delineate subsections within the older adult group in particular. The ages in this group ranged from 60 to 88-years old, and it seems likely that there would have been marked differences in ability between people in the upper and lower sections of this group. A comparison of collapsed d' and false alarm data between the five youngest and five oldest participants of the older adults' group yielded some interesting findings. Although there were no significant differences between the two groups for d' or for false alarms, the failure to detect any effects may have been due to the small sample size. However, an effect size of 1.13 for d' and 0.29 for false alarms for the two groups suggests that there may be significant within-group variation. In the light of these findings, it would be worthwhile extending the study by gaining more participants in order to compare different groups of young-old with old-old and very old-old. Bäckman (1991) suggests that it may not be suitable to compare data from only one group of young adults with only one group of older adults. In fact, a number of studies have highlighted the significant differences in recognition memory ability for people in different decades of later life (e.g., Bäckman & Karlsson, 1986, cited in Bäckman, 1991; Hultsch, 1971; West & Crook, 1990). As yet, there is no theory of recognition memory that has considered these age differences in detail. Future explanations of the recognition process must acknowledge and incorporate the finding that there are systematic age differences in recognition memory.

A related limitation of the present study is concerned with the assumptions made regarding older adults' recognition memory ability. A caveat to the cross-sectional design used has been highlighted by Willis (1985). It is assumed that the older adults had comparable recognition memory ability to the young adults in the study when they were young themselves. Baron and Surdy (1990) warn that in the absence of longitudinal data, results can only be tentatively interpreted.

The emergence of the Stimulus Type x Trial Difficulty x Presentation Mode interaction needs further investigation. The problem is that this three-way interaction is possibly task-dependent and a slight manipulation of the non-verbal target/distractor pairing could eliminate the interaction altogether. The present study could be improved by pairing each non-verbal target with another target's distractor, as in the verbal trials. This was not executed in the present study, as it was believed that doing so would render the non-verbal tasks too difficult. In hindsight, it would have been more appropriate to have reduced the target/distractor similarity of the non-verbal items, so that targets could have been paired with another target's distractor. In this format, the non-verbal task would not be as difficult to complete.

On a more fundamental level, the relative complexity of all of the non-verbal stimuli could be reduced so that the verbal and non-verbal stimuli could be justly compared. The results of the present study suggest that the more complex non-verbal stimuli were very difficult to discriminate. Alternatively, a between-subjects design comparing recognition memory for verbal, simple non-verbal, and complex non-verbal tasks may elucidate the effect that increasing the contextual detail of non-verbal stimuli has on recognition performance.

Additionally, the effect of trial difficulty could be further examined by manipulating the degree of target-distractor similarity. Ideally, introducing at least one additional level (e.g., moderately similar distractor) that was still distinct from the other levels of distractor similarity may elucidate the threshold for judging items as unfamiliar.

Although the present study compared both 1AFC and 2AFC modes of presentation, most previous studies have opted for one procedure or the other based on their relative advantages and disadvantages (see McNicol, 1972; Macmillan & Creelman, 1991). One benefit of the 2AFC presentation mode is that it minimises response bias. As a result, many studies adopt a 2AFC mode of presentation as response bias theoretically does not need to be measured. However, some studies require response bias changes and their measurement, and thus adopt a 1AFC presentation mode. Because few studies have investigated age differences in verbal and non-verbal recognition memory using differing alternative, forced-choice procedures, an extension of the present study could use the same conditions outlined by Kintsch (1968). This would bolster the literature concerning the direct comparison of different modes of presentation.

**Summary and Conclusions**

The present study produced a number of results that were both interesting and valuable. Contrary to some previous findings (Craik *et al.*, 1987), recognition memory can become impaired with age. The older adults in the present study showed a decrease in recognition accuracy which was due to both a decrease in hits and an increase in false alarms, an effect that was maintained for the verbal and non-verbal items, and the hard and easy trials. Future theories of recognition memory must be able to account for the decline in this type of memory as a person ages. In addition, it may be interesting to find out to what extent a lack of practice in laboratory-type recognition tests may have on the ability of older adults to recognise.

The present study is the first to directly compare recognition memory for verbal and non-verbal material using both 1AFC and 2AFC presentation modes. SDT was supported by the failure to find a main effect for Presentation Mode once the 2AFC PC data were converted to 1AFC d' values and rescaled. In addition, a comparison of PC and d' effects for the 2AFC mode yielded identical effects, providing further support for the validity of this data transformation. This shows that the findings concerning recognition memory are generally not sensitive to whether stimuli are presented sequentially as targets and distractors, or as a target/distractor pair on each trial. More research is required to find out if this is true for a wide range of both verbal and non-verbal stimuli and for a range of target-distractor similarity levels.

A substantial finding was the strong effect for stimulus type. In contrast to what was hypothesised, the present results demonstrate that recognition performance for verbal material can be far superior to that for non-verbal material. This finding is contrary to the pictorial superiority effect, which argues that non-verbal material is always recognised more accurately than verbal material. It is assumed that the results of the present study can be attributed to the relative difficulty of the non-verbal items. While highly elaborate pictorial items tend to facilitate recognition, there must be a level of contextual detail at which recognition is hampered. The results of the present study indicate that highly complex non-verbal items will always be harder to recognise than verbal items. Thus, the pictorial superiority effect may merely be a function of the non-verbal stimuli chosen for recognition. Future research should focus on the manipulation of the contextual detail and elaboration of the stimuli in a bid to elicit results comparable to those for verbal stimuli. The well-documented conclusion that recognition memory for pictorial material is invariably superior to that for verbal material is incorrect.

The present study also supports the finding that target-distractor similarity is inversely related to recognition memory. However, this overall decrease in recognisability is a function of an increase in false alarms, rather than a decrease in hits. Thus, it can be concluded that a high level of target/distractor similarity does not impair the ability to recognise targets *per* se. Rather it increases the likelihood of recognising new items as 'old'. A number of other studies have attested to the distractor similarity effect, and have observed the same pattern in hits and false alarms (e.g., Davies *et al.*, 1979; Treisman, 1991). What is missing in the literature is a detailed explanation for why this interesting effect should occur (but see Podd, 1990).

The Stimulus Type x Trial Difficulty x Presentation Mode interaction created some problems for interpreting the results. If this three-way interaction is real, it suggests that there is a complex interplay among the type of stimuli used, the level of target-distractor similarity, and mode of presentation. All of these factors may simultaneously conspire to affect recognition memory performance. However, it is also possible that this interaction is task-dependent in being able to be removed by small changes to the stimuli. While non-verbal items were easier to recognise in the 2AFC rather than the 1AFC presentation mode, the opposite was true for verbal items. Interestingly, this effect only occurred for easy trials, leaving hard trials unaffected. One plausible reason for why this interaction occurred concerns the choice of distractor items in the 2AFC presentation mode. Verbal targets were paired with another target's distractor, while the non-verbal targets were always paired with their own distractor. Having a point of comparison in the 2AFC non-verbal trials may have facilitated recognition. Nonetheless, the point to be made is that stimuli can always be chosen such that the pictorial superiority effect is overturned. The finding that this effect occurred only for easy trials highlights further implications. Presumably, the hard trials were so difficult that all items were poorly recognised, irrespective of stimulus type and presentation mode.

In conclusion, the present study has shown that recognition memory is undoubtedly affected by age for both verbal and non-verbal stimuli and for both difficult and not so difficult tasks. However, some of the interactions observed between variables suggest that recognition memory may be affected by a complex interplay between variables and may be task-dependent. Future research should aim to find out more about experimental variables that may jointly affect the recognition process. Additionally, the age of participants should be broken down sufficiently to allow the function that relates recognisability to age to be more accurately assessed than was the case here.

## REFERENCES

Albert, M. S., & Kaplan, E. (1980). Organic implications of neuropsychological deficits in the elderly. In L. W. Poon, J. L. Fozard, L. S. Cermak, D. Arenberg, & L. W. Thompson (Eds.), *New directions in memory and aging: Proceedings of the George A. Talland Memorial Conference* (pp. 403-432). New Jersey: Erlbaum.

Allen, P. A. (1991). On age differences in processing variability and scanning speed. *Journal of Gerontology: Psychological Sciences, 46*, P191-201.

Anderson, J. R., & Bower, G. H. (1972). Recognition and retrieval processes in free recall. *Psychological Review, 79*, 97-123.

Andreassi, J.L. (1995). *Psychophysiology: Human behaviour and physiological response* (3rd ed.). New Jersey: Erlbaum.

Anglin, G. J., & Levie, W. H. (1985). Role of visual richness in picture recognition memory. *Perceptual and Motor Skills, 61*, 1303-1306.

Banks, W. P. (1970). Signal detection theory and human memory. *Psychological Bulletin, 74*, 81-99.

Bäckman, L. (1991). Recognition memory across the adult life span: The role of prior knowledge. *Memory & Cognition, 19*, 63-71.

Baron A., & Surdy, T. M. (1990). Recognition memory in older adults: Adjustment to changing contingencies. *Journal of the Experimental Analysis of Behaviour, 54*, 201-212.

Bartlett, J. C., & Leslie, J. E. (1986). Aging and memory for faces versus single views of faces. *Memory & Cognition, 14*, 371-381.

Bartlett, J. C., Leslie, J. E., Tubbs, A., & Fulton, A. (1989). Aging and memory for pictures of faces. *Psychology and Aging, 4*, 276-283.

Bartlett, J. C., Strater, L., & Fulton, A. (1991). False recency and false fame of faces in young adulthood and old age. *Memory & Cognition, 19*, 177-188.

Bartlett, J. C., Till, R. E., Gernsbacher, M., & Gorman, W. (1983). Age-related differences in memory for lateral orientation. *Journal of Gerontology, 38*, 439-446.

Beringer, J. (1995). *Experimental Run Time System*, Version 3.04. Frankfurt: Author.

Bernbach, H. A. (1967). Decision processes in memory. *Psychological Review, 74*, 462-480.

Binder, A., McConnell, D., & Sjoholm, N. A. (1957). Verbal conditioning as a function of experimenter characteristics. *Journal of Abnormal and Social Psychology, 55*, 309-314.

Botwinick, J. (1966). Cautiousness in advanced age. *Journal of Gerontology, 21*, 347-353.

Botwinick, J. (1970). Age differences in self-ratings of confidence. *Psychological Reports, 27*, 865-866.

Botwinick, J. (1984). *Aging and behaviour* (3rd ed.). New York: Springer.

Bowles, N. L., & Poon, L. W. (1982). An analysis of the effect of aging on recognition memory. *Journal of Gerontology, 37*, 212-219.

Breen, E. K. (1993). Recall and recognition memory in Parkinson's disease. *Cortex, 29*, 91-102.

Brown, J. (1976). An analysis of recognition and recall and of problems in their comparison. In J. Brown (Ed.), *Recall and recognition* (pp. 1-36). London: Wiley.

Butterfield, E. C., Nelson, T. O., & Peck, V. (1988). Developmental aspects of the feeling of knowing. *Developmental Psychology, 24*, 654-663.

Cohen, G. D. (1988). *The brain in human aging*. New York: Springer.

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences* (2nd ed.). New Jersey: Erlbaum.

Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic memory. *Psychological Review, 82*, 407-48.

Cooper, A. J. R., & Monk, A. (1976). Learning for recall and learning for recognition. In J. Brown (Ed.), *Recall and Recognition* (pp.131-156). London: Wiley.

Craik, F. J. M. (1977). Age differences in human memory. In J. E. Birren, & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (pp. 384-420). New York: Van Nostrand Reinhold.

Craik, F. J. M., Byrd, M., & Swanson, J. M. (1987). Patterns of memory loss in three elderly samples. *Psychology and Aging, 2*, 79-86.

Craik, F. J. M., & McDowd, J. M. (1987). Age differences in recall and recognition. *Journal of Experimental Psychology: Learning, Memory and Cognition, 13*, 474-479.

Crook, T., Bartus, R. T., Ferris, S. H., Whitehouse, P., Cohen, G. D., & Gershon, S. (1986). Age-associated memory impairment: Proposed diagnostic criteria and measures of clinical change: Report of a National Institute of Mental Health work group. *Developmental Neuropsychology, 2*, 261-276.

Crook, T. H., & Larrabee, G. J. (1992). Changes in facial recognition memory across the adult life span. *Journal of Gerontology: Psychological Sciences, 47,* P138-141.

Crook, T. H., & West, R. L. (1990). Name recall performance across the adult life span. *British Journal of Psychology, 81*, 335-349.

Davies, G. M., Shepherd, J. W., & Ellis, H. D. (1979). Similarity effects in face recognition. *American Journal of Psychology, 92*, 507-523.

Denney, N. W., Miller, B. V., Dew, J. R., & Levav, A. L. (1991). An adult developmental study of contextual memory. *Journal of Gerontology: Psychological Sciences, 46*, P44-50.

Dennis, S. (1997). *A brief introduction to signal detection theory in recognition memory*. (On-line). Available: http://psy.uq.edu.au/CogPsych/ic320/SDT.html

Deutch, J. A. (Ed.). (1973). *The physiological basis of memory*. New York: Academic Press.

Dewick, H. C., Hanley, A. D., Davies, A. D. M., Playfer, J., & Turnbull, C. (1991). Perception and memory for faces in Parkinson's disease. *Neuropsychologia, 29*, 785-802.

Deyo, R., Straube, K. T., & Disterhoft, J. F. (1989). Nimodipine facilitates associative learning in aging rabbits. *Science, 243*, 809-811.

Diamond, R., & Carey, S. (1986). Why faces are not so special: An effect of expertise. *Journal of Experimental Psychology: General, 115*, 107-117.

Diesfeldt, H., & Vink, M. (1989). Recognition memory for words and faces in the very old. *British Journal of Clinical Psychology, 28*, 247-253.

Dixon, R. A., & Hultsch, D. F. (1983). Metamemory and memory for text relationships in adulthood: A cross validation study. *Journal of Gerontology, 38,* 689-694.

Drachman, D. A. (1977). Memory and cognitive function in man: Does the cholinergic system have a specific code? *Neurology, 27*, 783-790.

Ellis, H.D. (1981). Theoretical aspects of face recognition. In G. Davies, H. Ellis, & J. Shepherd, Perceiving and remembering faces (pp. 171-197). London: Academic Press.

Erber, J. T. (1974). Age differences in recognition memory. *Journal of Gerontology, 29*, 177-181.

Feenan, K., & Snodgrass, J. G. (1990). The effect of context on discrimination and bias in recognition memory for pictures and words. *Memory & Cognition, 18*, 515-527.

Ferguson, D. C., & Buss, A. H. (1960). Operant conditioning of hostile verbs in relation to experimenter and subject characteristics. *Journal of Consulting Psychology, 24*, 324-327.

Ferris, S. H., Crook, T., Clark, E., McCarthy, M., & Rae, M. (1980). Facial recognition memory deficits in normal aging and senile dementia. *Journal of Gerontology, 35*, 707-714.

Flowers, K. A., Pearce, I., & Pearce, J. M. S. (1984). Recognition memory in Parkinson's disease. *Journal of Neurology, Neurosurgery, and Psychiatry, 47*, 1174-1181.

Foos, P. (1989). Age differences in recognition memory for two common objects. *Journal of Gerontology: Psychological Sciences, 44*, P178-180.

Frick, R. W. (1985). Testing visual short-term memory: Simultaneous versus sequential presentations. *Memory & Cognition, 13*, 346-356.

Gabrieli, J. D. E., Singh, J., Stebbins, G. T., & Goetz, C. G. (1996). Reduced working memory span in Parkinson's disease: Evidence for the role of a frontostriatal system in working and strategic memory. *Neuropsychology, 10*, 322-332.

Gehring, R. E., Toglia, M. P., & Kimble, G. A. (1976). Recognition memory for words and pictures at short and long retention intervals. *Memory & Cognition*, *4*, 256-260.

Giambra, L. M., Arenberg, D., Zonderman, A. B., Kawas, C., & Costa, P. T. (1995). Adult life span changes in immediate visual memory and verbal intelligence. *Psychology and Aging, 10*, 123-139.

Gillund, G., & Shiffrin, R.M. (1984). A retrieval model for both recognition and recall. *Psychological Review, 91*, 1-67.

Gordon S. K., & Clark, W. C. (1974). Application of signal detection theory to prose recall and recognition in elderly and young adults. *Journal of Gerontology, 29*, 64-72.

Green, D. M., & Swets, J. A. (1966). *Signal detection theory and psychophysics.* New York: Wiley.

Hasher, L., & Zacks, R. T. (1979). Automatic and effortful processes in memory. *Journal of Experimental Psychology: General, 108*, 356-388.

Hays, W.L. (1973). *Statistics for the social sciences* (2nd ed.). New York: Holt, Rinehart, and Winston.

Howell, S. (1972). Familiarity and complexity in perceptual recognition. *Journal of Gerontology, 27*, 364-371.

Hultsch, D. (1969). Adult age differences in the organisation of free recall. *Developmental Psychology, 1*, 673-678.

Hultsch, D. F. (1971). Adult age differences in free classification and free recall. *Developmental Psychology, 4*, 338-342.

Hultsch, D. F., Hertzog, C., & Dixon, R. A. (1987). Age differences in metamemory: Resolving the inconsistencies. *Canadian Journal of Psychology, 41*, 193-208.

Humphries, S., & Podd, J. (1995, December). *Parkinson's disease and Parkinson's disease society membership.* Paper presented at the British Psychological Society's London Conference.

Jacoby, L. L. (1991). A process dissociation framework: Separating automatic from intentional uses of memory. *Journal of Memory and Language, 30*, 513-541.

Kalat, J. W. (1992). *Biological psychology* (4th ed.). California: Brooks/Cole Publishing Company.

Kaplan, H. I., Sadock, B. J., & Grebb, J. A. (1994). *Synopsis of psychiatry* (7th ed.). Maryland: Williams & Wilkins.

Kinsbourne, M. (1980). Attentional dysfunctions in the elderly: Theoretical models and research perspectives. In L. W. Poon, J. L. Fozard, L. S. Cermak, D. Arenberg, & L. W. Thompson (Eds.), *New directions in memory and aging: Proceedings of the George A. Talland Memorial Conference* (pp.113-129). New Jersey: Erlbaum.

Kintsch, W. (1967). Memory and decision aspects of recognition learning. *Psychological Review, 74*, 496-504.

Kintsch, W. (1968). An experimental analysis of single stimulus tests and multiple-choice tests of recognition memory. *Journal of Experimental Psychology, 76*, 1-6.

Kintsch, W. (1970). Models for free recall and recognition. In D. A. Norman (Ed.), *Models of human memory* (pp. 333-374). New York: Academic Press.

Kucera, H., & Francis, W. (1982). *Computational analysis of present-day American English*. Rhode Island: Brown University Press.

Le Breck, D. B., & Baron, A. (1987). Age and practice effects in continuous recognition memory. *Journal of Gerontology, 42*, 89-91.

Lesch, M. F., & Pollatsek, A. (1993). Automatic access of semantic information by phonological codes in visual word recognition. *Journal of Experimental Psychology: Learning, Memory & Cognition, 19*, 285-294.

Lezak, M. D. (1995). *Neuropsychological assessment* (3rd ed.). New York: Oxford University Press.

Light, L. L. (1991). Memory and aging: Four hypotheses in search of data. *Annual Review of Psychology, 42*, 333-376.

Light, L. L., & Zelinski E. M. (1983). Memory for spatial information in young and old adults. *Developmental Psychology, 19*, 901-906.

Loftus, G. F., & Loftus, E. F. (1976). *Human memory: The processing of information*. New Jersey: Erlbaum.

Lovelace, E. A., & Marsh, G. R. (1985). Prediction and evaluation of memory performance by young and older adults. *Journal of Gerontology, 40*, 192-197.

Mandler, G. (1980). Recognising: The judgment of previous occurrence. *Psychological Review, 87*, 252-271.

Macmillan, N. A., & Creelman, C. D. (1991). *Detection theory: A user's guide.* New York: Cambridge University Press.

Marmurek, H. H. (1989). Familiarity effects and word unitization in visual comparison tasks. *Memory & Cognition, 17*, 483-489.

Matlin, M. W. (1989). *Cognition* (2nd ed.). New York: Holt, Rinehart and Winston.

McEntee, W. J., & Crook, T. H. (1990). Age-associated memory impairment: A role for catecholamines. *Neurology, 40*, 526-530.

McKoon, G., & Ratcliff, R. (1989). Assessing the occurrence of elaborative inference with recognition: Compatibility checking vs compound cue theory. *Journal of Memory and Language, 28*, 547-563.

McNicol, D. (1972). *A primer of signal detection theory.* London: Allen & Unwin.

McNulty, J. A., & Caird, W. (1966). Memory loss with age: Retrieval or storage? *Psychological Reports, 19*, 229-230.

Mitchell, D. B. (1989). How many memory systems? Evidence from aging. *Journal of Experimental Psychology: Learning, Memory & Cognition, 15*, 31-49.

Murdock, B. B. (1974). *Human memory: Theory and data.* Maryland: Erlbaum.

Owen, A. M., Beksinska, M., James, M., Leigh, P. N., Summers, B. A., Marsden, C. D., Quinn, N. P., Sahakian, B. J., & Robbins, T. W. (1993). Visuospatial memory deficits at different stages of Parkinson's disease. *Neuropsychologia, 31*, 627-644.

Park, D. C. (1980). Item attribute storage of pictures and words in memory. *American Journal of Psychology, 93*, 603-615.

Park, D. C., & Mason, D. (1982). Is there evidence for automatic processing of spatial and colour attributes present in matched pictures and words? *Memory & Cognition, 10*, 76-82.

Park, D. C., & Puglisi, J. T. (1985). Older adults' memory for the colour of pictures and words. *Journal of Gerontology, 40*, 198-204.

Park, D. C., Puglisi, J. T., & Lutz, R. (1982). Spatial memory in older adults: Effects of intentionality. *Journal of Gerontology, 37*, 330-335.

Park, D. C., Puglisi, J. T., & Smith, A. D. (1986). Memory for pictures: Does an age-related decline exist? *Journal of Psychology and Aging, 1*, 11-17.

Park, D. C., Puglisi, J. T., Smith, A. D., & Dudley, W. N. (1987). Cue utilization and encoding specificity in picture recognition by older adults. *Journal of Gerontology, 38*, 582-588.

Park, D. C., Puglisi, J. T., & Sovacool, M. (1983). Memory for pictures, words and spatial location in older adults: Evidence for pictorial superiority. *Journal of Gerontology, 38*, 582-588.

Park, D. C., Puglisi, J. T., & Sovacool, M. (1984). Picture memory in older adults: Effects of contextual detail at encoding and retrieval. *Journal of Gerontology, 39*, 213-215.

Park, D. C., Smith, A. D., Dudley, W. N., & La Fronza, V. N. (1989). Effects of age and a divided attention task presented during encoding and retrieval on memory. *Journal of Experimental Psychology: Learning, Memory & Cognition, 15*, 1185-1191.

Pashler, H. (1987). Target-distractor discriminability in visual search. *Perception & Psychophysics, 41*, 285-292.

Paul, L. M. (1979) . Two models of recognition memory: A test. *Journal of Experimental Psychology: Human Learning and Memory, 5*, 45-51.

Pezdek, K. (1983). Memory for items and their spatial locations by young and elderly adults. *Developmental Psychology, 19*, 895-900.

Pezdek, K. (1987). Memory for pictures: A life-span study of the role of visual detail. *Child Development, 58*, 807-815.

Pezdek, K., & Chen, H. C. (1982). Developmental differences in the role of detail in picture recognition memory. *Journal of Experimental Child Psychology, 33*, 207-215.

Pinel, J. (1997). *Biopsychology* (3rd ed.). Boston: Allyn & Bacon.

Podd, J. (1990). The effects of memory load and delay on facial recognition. *Applied Cognitive Psychology, 4*, 47-60.

Poon, L. W. (1985). Differences in human memory with aging: Nature, causes, and clinical applications. In J. E. Birren & K. W. Schaie (Eds.), *The Handbook of the Psychology of Aging.* (2nd ed., pp. 427-462). New York: Van Nostrand Reinhold.

Poon, L. W., & Fozard, J. L. (1980). Age and word frequency effects in continuous recognition memory. *Journal of Gerontology, 35*, 77-86.

Puglisi, J. T., Park, D. C., Smith, A. D., & Dudley, W. N. (1988). Age differences in encoding specificity. *Journal of Gerontology: Psychological Sciences, 43*, P145-150.

Raaijmakers, J. G. W., & Shiffrin, R. M. (1981). Search of associative memory. *Psychological Review, 88*, 93-134.

Rabinowitz, J. C. (1984). Aging and recognition failure. *Journal of Gerontology, 39*, 65-71.

Rabinowitz, J. C., Ackerman, B. P., Craik, F. I. M., & Hinchley, J. L. (1982). Aging and metamemory: The roles of relatedness and imagery. *Journal of Gerontology, 37*, 688-695.

Ratcliff, R., Van Zandt, T., & McKoon, G. (1995). Process dissociation, single-process theories and recognition memory. *Journal of Experimental Psychology: General, 124*, 352-374.

Richardson-Klavehn, A., & Bjork, R. A. (1988). Primary versus secondary rehearsal in an imagined voice: Differential effects of recognition memory and perceptual identification. *Bulletin of the Psychonomic Society, 26*, 187-190.

Rockel, W. (1991). *The effect of retention interval and target-decoy similarity on facial recognition*. Unpublished master's thesis, Massey University, Palmerston North, New Zealand.

Rosenthal, R. (1966). *Experimenter effects in behavioural research.* New York: Appleton-Century-Crofts.

Salthouse, T. A. (1987). Adult age differences in integrative spatial ability. *Psychology and Aging, 2*, 254-260.

Sarason I. G., & Harmatz, M. G. (1965). Test anxiety and experimental conditions. *Journal of Personality and Social Psychology, 1*, 499-505.

SAS Institute. (1987). *SAS/STAT advanced statistics*, version 6.04. North Carolina: Author.

Schonfield, D., & Robertson, B. A. (1966). Memory storage and aging. *Canadian Journal of Psychology, 20*, 228-236.

Shimamura, A. P., & Jurica, P. J. (1994). Memory interference effects and aging: Findings from a test of frontal lobe function. *Neuropsychology, 8*, 408-412.

Smith, A. D. (1975). Partial learning and recognition memory in the aged. *International Journal of Aging and Human Development, 6*, 359-365.

Smith, A. D., & Winograd, E. (1978). Adult age differences in remembering faces. *Journal of Gerontology, 14*, 443-444.

Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: Applications to dementia and amnesia. *Journal of Experimental Psychology: General, 117*, 34-50.

Soumireu-Mourat, B. (1986). Experimental studies of aging: Behavioural and physiological correlates. *Gerontology, 32*, 24-29.

Soumireu-Mourat, B., Martinez, J. L., Jr., Jensen, R. A., & McGaugh, J. L. (1980). Facilitation of memory processes in aged rats by subseizure hippocampal stimulation. *Physiology and Behaviour, 25*, 263-265.

Thomson, D. M., & Tulving, E. (1970). Associative encoding and retrieval: Weak and strong cues. *Journal of Experimental Psychology, 86*, 255-262.

Treisman, A. (1991). Search, similarity, and integration of features between and within dimensions. *Journal of Experimental Psychology: Human Perception and Performance, 17*, 652-676.

Tucker, D. M., Novelly, R. A., Isaac, W., & Spencer, D. (1986). Effects of simultaneous vs. sequential stimulus presentation on memory performance following temporal lobe resection in humans. *Neuropsychologia, 24*, 277-281.

Tulving, E. (1985). How many memory systems are there? *American Psychologist, 40*, 385-398.

Van Gorp, W. G., Satz, P., & Mitrushina, M. (1990). Neuropsychological processes associated with normal aging. *Developmental Neuropsychology, 6*, 279-290.

Vorberg, D., & Schmidt, R. (1975). A testable property of some discrete-state models for recognition memory. *Psychological Review, 82*, 316-324.

Wallace, W. P. (1980). On the use of distractors for testing recognition memory. *Psychological Bulletin, 88*, 696-704.

West, R. L., & Crook, T. H. (1990). Age differences in everyday memory: Laboratory analogues of telephone number recall. *Psychology and Aging, 5*, 520-529.

White, N., & Cunningham, W. R. (1982). What is the evidence for retrieval problems in the elderly? *Experimental Aging Research, 8*, 169-171.

Whitken, H. A., Moore, C. A., Goodenough, D. R., & Cox, P. W. (1977). Field-Dependent and Field-Independent cognitive styles and their educational implications. *Review of Educational Research, 47*, 1-64.

Whittington, C. J. (1997). *Cognitive deficits in Parkinson's disease*. Unpublished doctoral dissertation data, Massey University, Palmerston North, New Zealand.

Willis, S. L. (1985). Towards an educational psychology of the older adult learner: Intellectual and cognitive bases. In J. E. Birren, & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (2nd ed., pp. 818-847). New York: Van Nostrand Reinhold Company.

Winocur, G., & Moscovitch, M. (1990). Hippocampal and prefrontal cortex contributions to learning and memory: Analysis of lesion and aging effects on maze learning in rats. *Behavioural Neuroscience, 104*, 544-551.

Winograd, E., & Simon, E. W. (1980). Visual memory and imagery in the aged. In L. W. Poon, J. L. Fozard, L. S. Cermack, D. Arenberg, & L. W. Thompson (Eds.), *New Directions in Memory and Aging: Proceedings of the George A. Talland Memorial Conference* (pp. 485-506). New Jersey: Erlbaum.

Wolfe, J. M., & Friedman-Hill, S. R. (1992). On the role of symmetry in visual search. *Psychological Science, 3*, 194-198.

Woodruff-Pak, D. S. (1990). Mammalian models of learning, memory and aging. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the Psychology of Aging* (3rd ed., pp. 235-258). California: Academic Press.

Yarmey, A. D., & Kent, J. (1980). Eyewitness identification by elderly and young adults. *Law and Human Behaviour, 4*, 359-371.

Yonelinas, A. P. (1994). Receiver-operating characteristics in recognition memory: Evidence for a dual-process model. *Journal of Experimental Psychology: Learning, Memory & Cognition, 20*, 1341-1354.

## Appendix A

Screening Questionnaire.

# STRUCTURED INTERVIEW AND SCREENING QUESTIONNAIRE

(To be completed by the experimenter).

Participant ID: Date of interview:

Session:

## Screening Questionnaire

Have you ever suffered from:

- Alcohol Abuse (Y/N)

- Major Depression (Y/N)

- Neurological disorder (E.g., Alzheimer's, stroke, head trauma with loss of consciousness greater than 1hr, brain tumour) (Y/N) If yes, describe:

___

___

___

- Hereditary Disease (E.g., Wilson's disease, Huntington's disease) (Y/N) If yes, describe:

___

___

___

- Medical Condition with Known Central Nervous System Complication: (Y/N) If yes, describe:

___

___

___

- Have you ever had a Neurosurgical Operation: (Y/N)

Date of Birth: Gender: (M/F)

Marital Status: ________________

Years of Education: Years of secondary school:

Years of tertiary education:

Handedness: (L/R)

Colour Blind: (Y/N) Glasses: (Y/N)

Occupation:

______________________________________________________

______________________________________________________

______________________________________________________

Any recent illnesses:

______________________________________________________

______________________________________________________

______________________________________________________

Current medication:

______________________________________________________

______________________________________________________

______________________________________________________

## Appendix B

Stimuli for the Verbal Recognition Memory Task.

**Target words - similar**

PICTURE TS01 T
beach

PICTURE TS02 T
breath

PICTURE TS03 T
candle

PICTURE TS04 T
crook

PICTURE TS05 T
dusk

PICTURE TS06 T
plain

PICTURE TS07 T
gloom

PICTURE TS08 T
lamp

PICTURE TS09 T
limp

PICTURE TS10 T
lion

PICTURE TS11 T
male

PICTURE TS12 T
maze

PICTURE TS13 T
minor

PICTURE TS14 T
mouth

PICTURE TS15 T
pane

PICTURE TS16 T
peace

PICTURE TS17 T
steak

PICTURE TS18 T
soul

PICTURE TS19 T
pail

PICTURE TS20 T
tune

**Visually similar distractors**

PICTURE DSO1 T
croak

PICTURE DSO2 T
handle

PICTURE DS03 T
wreath

PICTURE DS04 T
plane

PICTURE DSO5 T
lamb

PICTURE DSO6 T
bench

PICTURE DSO7 T
manor

PICTURE DSO8 T
tone

PICTURE DSO9 T
mail

PICTURE DS10 T
stake

PICTURE DS11 T
limb

PICTURE DS12 T
rent

PICTURE DS13 T
bloom

PICTURE DS14 T
piece

PICTURE DS15 T
soil

PICTURE DS16 T
month

PICTURE DS17 T
link

PICTURE DS18 T
pain

PICTURE DS19 T
haze

PICTURE DS20 T
dust

**<u>Target words – different</u>**

PICTURE TD01 T
broom

PICTURE TD02 T
bug

PICTURE TD03 T
cap

PICTURE TD04 T
creek

PICTURE TD05 T
fleet

PICTURE TD06 T
gate

PICTURE TD07 T
guard

PICTURE TD08 T
hall

PICTURE TD09 T
kite

PICTURE TD10 T
loot

PICTURE TD11 T
music

PICTURE TD12 T
poll

PICTURE TD13 T
rein

PICTURE TD14 T
rite

PICTURE TD15 T
roll

PICTURE TD16 T
ski

PICTURE TD17 T
son

PICTURE TD18 T
stair

PICTURE TD19 T
vein

PICTURE TD20 T
waist

**<u>Visually dissimilar distractors</u>**

PICTURE DD01 T
snake

PICTURE DD02 T
pit

PICTURE DD03 T
fig

PICTURE DDO4 T
toast

PICTURE DD05 T
goals

PICTURE DDO6 T
crow

PICTURE DD07 T
chief

PICTURE DD08 T
poet

PICTURE DD09 T
mast

PICTURE DD10 T
fear

PICTURE DD11 T
paper

PICTURE DD12 T
taxi

PICTURE DD13 T
cult

PICTURE DD14 T
bulb

PICTURE DD15 T
path

PICTURE DD16 T
hog

PICTURE DD17 T
leg

PICTURE DD18 T
lunch

PICTURE DD19 T
stop

PICTURE DD20 T
punch

## Appendix C

Description of the Target-Distractor Pairings
Used for the Verbal and Non-Verbal Trials.

The unique format of the target-distractor pairings in the 2AFC presentation mode warrants explanation. In the study phase of all conditions, targets were presented sequentially. For example, the following words were presented in a random sequence during the study phase of a verbal task:

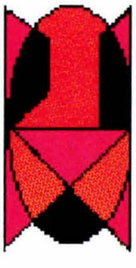
**1) beach**

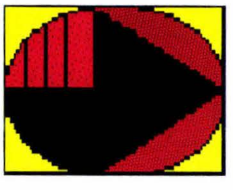
**2) guard**

During the recognition phase of a 2AFC verbal task, each target word was paired with another target's distractor. The visually similar distractor for the target word 'beach' was 'bench', and the visually dissimilar distractor for the target word 'guard' was 'chief'. It is important to note that each target was always paired with the same distractor, and the side on which the target appeared was randomised for each participant. The following pairs were presented during the recognition phase of a 2AFC verbal task.

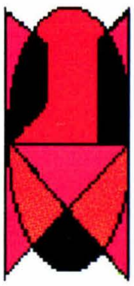
| | |
|---|---|
| **1) beach** (target) | **chief** (distractor for the word 'guard') |
| **2) guard** (target) | **bench** (distractor for the word 'bench') |

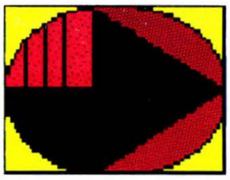
As in the verbal trials, each target non-verbal item was presented sequentially in the study phase. The following shapes are examples of items presented in the non-verbal trials.

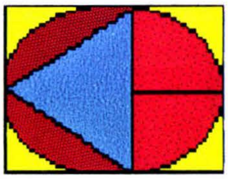




During the recognition phase, each non-verbal target was paired with *its own* distractor, as it was believed that presenting the target with another target's distractor would render the task too difficult. In accordance with the verbal trials, each target was always presented with the same distractor, and the side on which the target appeared was randomised for each participant. The following items appeared in the recognition phase of a 2AFC non-verbal task:







**Appendix D**

Information Sheet.

## RECOGNITION MEMORY STUDY

### Information for Participants

The principal researchers for this study are Dr John Podd and Tania Lithgow, both of the Department of Psychology at Massey University. Dr Podd can be contacted at work by phoning 350 4135. Tania Lithgow can be contacted by phoning 356 9099, extension 7678.

The Department of Psychology is conducting a series of investigations that are looking at memory deficits in people with Parkinson's disease. As part of this research, we need to collect information on normal people's memory too. This study looks at aspects of memory in both young and older people. We are also trying to find out if the way in which we present the things we want you to remember interferes with your memory.

You will be asked to watch a series of words and shapes that will be presented to you on a computer. After that presentation, you will be asked to respond to another set of words or shapes picking out those you think you saw earlier. We will also get you to state how confident you feel about each choice you make.

You could expect the whole session to be complete in about 1 hour. This time would include introducing you to the study, answering any questions you might have about the study, and providing you with any more information you might like at the end.

You may have an interest in the way human memory works. In return for your participation in the study, we will be very willing to tell you as much as we can about the different types of memory and why they interest us so much.

If you agree to take part in our study, you have to right to:

- Refuse to answer any particular question we might ask.
- Withdraw from the study at ANY time.
- Ask questions as they occur to you at any time during your participation.
- Provide information on the understanding that it is completely confidential to the researchers. All information is collected anonymously, and it will not be possible to identify you in any reports prepared from the study.
- Be given access to your own personal data, and a copy of it if you want it.
- Be given access to a summary of the findings from the study when it is concluded.

**Dr John Podd (Department of Psychology Extn 4135)**

**Tania Lithgow (Department of Psychology Extn 7678)**

## Appendix E

Consent Form.

## RECOGNITION MEMORY STUDY

Consent Form

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

I also understand that I have the right to withdraw from the study at any time, and to decline to answer any particular questions in the study. I agree to provide information to the researchers on the understanding that it is completely confidential.

I wish to participate in this study under the conditions set out in the information sheet.

Signed: ______________________________

Name: ______________________________

Address: ______________________________

Telephone: ______________________________

Date: ______________________________

Please tick here if you would like to receive:

☐ A copy of your individual results

☐ A copy of the overall results of the study

**Appendix F**

Instructions Given to Participants for the

Verbal and Non-Verbal, 1AFC and 2AFC Tasks.

# VERBAL 1AFC RECOGNITION MEMORY TASK

**PICTURE Title T**
Verbal Recognition Memory Task

**PICTURE intro T**
This task was developed by Harvey Jones and Craig Whittington,
for a project by Tania Lithgow
Department of Psychology, Massey University.
Instructions will follow.
Start by pressing the RIGHT button

**PICTURE Page1 T**
This task consists of two parts:

1) In the first part you will
see a list of words presented
one at a time in the middle
of the screen.

**PICTURE Page2 T**
2) In the second part you will see
a longer list of words. Half of
the words will be from the
study list (an old word),
the others will be new.
You will be asked to choose
which word is old.

**PICTURE Page3 T**
You will receive further instructions
before each of these two parts. You
will also get a chance to practice the
task. During practice, numbers will be
used instead of words.

**PICTURE Page4 T**
You will begin the practice session
shortly. Do you have any questions?

**PICTURE Page5 T**
Please watch the numbers carefully
and do your best to remember them.

* * *

**PICTURE Page6 T**
You have finished the first part of
the practice. In the next part you
will see a list of numbers presented
one at a time in the middle
of the screen.

**PICTURE Page7 T**
Half of the numbers will be old,
the others will be new. Your task
is to decide which numbers are old.

**PICTURE Page8 T**
If you think the number is old,
press the LEFT button. If you
think the number is new,
press the RIGHT button.

**PICTURE Page9 T**
From the time the number appears on
the screen, you will have 6 seconds
to make your response. Please
respond by pressing one of the buttons
as soon as you have made your decision.

**PICTURE Page10 T**
After making your response, you will be
asked to say how confident you are that
your decision is correct.

**PICTURE Page11 T**
To rate your confidence, you will be
given four choices:

Very confident
Confident
Somewhat confident
Not at all confident

**PICTURE Page12 T**
When you are asked about your
confidence, please say aloud the
appropriate response.

**PICTURE Page15 T**
You are about to begin, do you have
any questions?

* * *

**PICTURE Page16 T**
You have completed a practice or
first session. You will shortly
repeat the task but with a list
of 40 words.
Do you have any questions?

**PICTURE Page17 T**
Please watch the words carefully and
do your best to remember them.

* * *

**PICTURE Page18 T**
You have finished the first part.
In the next part you will see
a list of words presented one at
a time in the middle of the screen.

**PICTURE Page19 T**
Remember that if you think the
word is old, press the LEFT
button. If you think the word
is new, press the RIGHT button.

**PICTURE Page20 T**
Remember also that you will be
asked how confident you are in this
decision. Please say aloud the
appropriate response.

**PICTURE Page21 T**
You have 6 seconds to make your
response. Try to be as accurate
as you can. However, if you do
have to guess, try not to use
the same button every time.

**PICTURE Page22 T**
You are about to begin, do you have
any questions?

* * *

**PICTURE End T**
Congratulations, you have
completed the Verbal
Recognition Memory Task.

Thank You

# VERBAL 2AFC RECOGNITION MEMORY TASK

**PICTURE Title T**
Verbal Recognition Memory Task

**PICTURE intro T**
This task was developed by Harvey Jones and Craig Whittington,
for a project by Tania Lithgow
Department of Psychology, Massey University 1997.
Instructions will follow.

Start by pressing the RIGHT button

**PICTURE Page1 T**
This task consists of two parts:

1) In the first part you will see a list of words presented one at a time in the middle of the screen.

**PICTURE Page2 T**
2) In the second part you will see pairs of words. One word will be from the word list (an old word), the other will be new. You will be asked to choose which word is old.

**PICTURE Page3 T**
You will receive further instructions before each of these two parts. You will also get a chance to practice the task. During practice, numbers will be used instead of words.

**PICTURE Page4 T**
You will begin the practice session shortly. Do you have any questions?

**PICTURE Page5 T**
Please watch the numbers carefully and do your best to remember them.

* * *

**PICTURE Page6 T**
You have finished the first part of the practice. In the next part you will see a pair of numbers presented side by side on the screen.

**PICTURE Page7 T**
One number will be old, the other will be new. Your task is to decide which number is old.

**PICTURE Page8 T**
If you think the number on the left is old, press the LEFT button. If you think the number on the right is old, press the RIGHT button.

**PICTURE Page9 T**
From the time the pair of numbers appear on the screen, you will have 6 seconds to make your response. Please respond by pressing one of the buttons as soon as you have made your decision.

**PICTURE Page10 T**
After making your response, you will be asked to say how confident you are that your decision is correct.

**PICTURE Page11 T**
To rate your confidence, you will be given four choices:

Very confident
Confident
Somewhat confident
Not at all confident

**PICTURE Page12 T**
When you are asked about your confidence, please say aloud the appropriate response.

**PICTURE Page15 T**
You are about to begin, do you have any questions?

* * *

**PICTURE Page16 T**
You have completed the practice or
first session. You will shortly
repeat the task but with a list
of 40 words.
Do you have any questions?

**PICTURE Page17 T**
Please watch the words carefully and
do your best to remember them.

* * *

**PICTURE Page18 T**
You have finished the first part.
In the next part you will see
pairs of words presented side
by side on the screen.

**PICTURE Page19 T**
Remember that if you think the
word on the left is old, press
the LEFT button. If you
think the word on the right
is old, press the RIGHT button.

**PICTURE Page20 T**
Remember also that you will be
asked how confident you are in this
decision. Please say aloud the
appropriate response.

**PICTURE Page21 T**
You have 6 seconds to make your
response. Try to be as accurate
as you can. However, if you do
have to guess, try not to use
the same button every time.

**PICTURE Page22 T**
You are about to begin, do you have
any questions?

* * *

**PICTURE End T**
Congratulations, you have
completed the Verbal
Recognition Memory Task.

Thank You

# NON-VERBAL 1AFC RECOGNITION MEMORY TASK

**PICTURE Title T**
Nonverbal Recognition Memory Task

**PICTURE intro T**
This task was developed by Harvey Jones and Craig Whittington,
for a project of Tania Lithgow
Department of Psychology, Massey University (1997).
Instructions will follow
Start by pressing the RIGHT button

**PICTURE Page1 T**
This task consists of two parts:

1) In the first part you will
see abstract drawings
presented one at a time
in the middle of the screen.

**PICTURE Page2 T**
2) In the second part you will see
drawings from a bigger set. Half
of the drawings will be from the
study list (an old drawing),
the others will be new.
You will be asked to choose
which drawing is old.

**PICTURE Page3 T**
You will receive further instructions
before each of these two parts. You
will also get a chance to practice the
task. During practice, numbers will be
used instead of drawings.

**PICTURE Page4 T**
You will begin the practice session
shortly. Do you have any questions?

**PICTURE Page5 T**
Please watch the numbers carefully
and do your best to remember them.

* * *

**PICTURE Page6 T**
You have finished the first part of the practice. In the next part you will see a list of numbers presented one at a time in the middle of the screen.

**PICTURE Page7 T**
Half of the numbers will be old, the others will be new. Your task is to decide which numbers are old.

**PICTURE Page8 T**
If you think the number is old, press the LEFT button. If you think the number is new, press the RIGHT button.

**PICTURE Page9 T**
From the time the number appears on the screen, you will have 6 seconds to make your response. Please respond by pressing one of the buttons as soon as you have made your decision.

**PICTURE Page10 T**
After making your response, you will be asked to say how confident you are that your decision is correct.

**PICTURE Page11 T**
To rate your confidence, you will be given four choices:

Very confident
Confident
Somewhat confident
Not at all confident

**PICTURE Page12 T**
When you are asked about your confidence, please say aloud the appropriate response.

**PICTURE Page15 T**
You are about to begin, do you have any questions?

* * *

**PICTURE Page16 T**
You have completed a practice or first session. You will shortly repeat the task but with a list of 40 abstract drawings. Do you have any questions?

**PICTURE Page17 T**
Please watch the drawings carefully and do your best to remember them.

* * *

**PICTURE Page18 T**
You have finished the first part. In the next part you will see a drawing presented one at a time in the middle of the screen.

**PICTURE Page19 T**
Remember, if you think the drawing is old, press the LEFT button. If you think the drawing is new, press the RIGHT button.

**PICTURE Page20 T**
Remember also that you will be asked how confident you are in this decision. Please say aloud the appropriate response.

**PICTURE Page21 T**
You have 6 seconds to make your response. Try to be as accurate as you can, but guess if you have to.

**PICTURE Page22 T**
You are about to begin, do you have any questions?

* * *

**PICTURE End T**
Congratulations, you have completed the Nonverbal Recognition Memory Task.

Thank You

# NON-VERBAL 2AFC RECOGNITION MEMORY TASK

**PICTURE Title T**
Nonverbal Recognition Memory Task

**PICTURE intro T**
This task was developed by Harvey Jones and Craig Whittington,
for a project by Tania Lithgow
Department of Psychology, Massey University 1997.
Instructions will follow.
Start by pressing the RIGHT button

**PICTURE Page1 T**
This task consists of two parts:

1) In the first part you will
see abstract drawings
presented one at a time
in the middle of the screen.

**PICTURE Page2 T**
2) In the second part you will see
pairs of drawings. One drawing
will be from the first part (an
old drawing), the other will be
new. You will be asked to
choose which drawing is old.

**PICTURE Page3 T**
You will receive further instructions
before each of these two parts. You
will also get a chance to practice the
task. During practice, numbers will be
used instead of drawings.

**PICTURE Page4 T**
You will begin the practice session
shortly. Do you have any questions?

**PICTURE Page5 T**
Please watch the numbers carefully
and do your best to remember them.

* * *

**PICTURE Page6 T**
You have finished the first part of the practice. In the next part you will see a pair of numbers presented side by side on the screen

**PICTURE Page7 T**
One number will be old, the other will be new. Your task is to decide which number is old.

**PICTURE Page8 T**
If you think the number on the left is old, press the LEFT button. If you think the number on the right is old, press the RIGHT button.

**PICTURE Page9 T**
From the time the pair of words appear on the screen, you will have 6 seconds to make your response. Please respond by pressing one of the buttons as soon as you have made your decision.

**PICTURE Page10 T**
After making your response, you will be asked to say how confident you are that your decision is correct.

**PICTURE Page11 T**
To rate your confidence, you will be given four choices:

Very confident
Confident
Somewhat confident
Not at all confident

**PICTURE Page12 T**
When you are asked about your confidence, please say aloud the the appropriate response.

**PICTURE Page15 T**
You are about to begin, do you have any questions?

* * *

**PICTURE Page16 T**
You have completed the practice or first session. You will shortly repeat the task but with a list of 40 abstract drawings. Do you have any questions?

**PICTURE Page17 T**
Please watch the drawings carefully and do your best to remember them.

* * *

**PICTURE Page18 T**
You have finished the first part. In the next part you will see pairs of drawings presented side by side on the screen.

**PICTURE Page19 T**
Remember, if you think the drawing on the left is old, press the LEFT button. If you think the drawing on the right is old, press the RIGHT button.

**PICTURE Page20 T**
Remember also that you will be asked how confident you are in this decision. Please say aloud the appropriate response.

**PICTURE Page21 T**
You have 6 seconds to make your response. Try to be as accurate as you can, but guess if you have to.

**PICTURE Page22 T**
You are about to begin, do you have any questions?

* * *

**PICTURE End T**
Congratulations, you have completed the Nonverbal Recognition Memory Task.

Thank You

## Appendix G

Raw Data from the 1AFC Presentation Mode.

The following data are those obtained from participants in the 1AFC mode of presentation only. The key of the data set is as follows:

Line 1: Subject ID, Session Type, Rate Correct-Hard Trials, Rate Correct-Easy Trials
Line 2: Frequency-Hard Trials: Hits, False Alarms, Signal, No Signal, Correct Rejections, Misses
Line 3: Frequency-Easy trials: Hits, False Alarms, Signal, No Signal, Correct Rejections, Misses
Line 4: Rates-Hard Trials: Hits, False Alarms, Correct Rejections Misses, d'
Line 5: Rates-Easy Trials: Hits, False Alarms, Correct Rejections Misses, d'
Line 6: Frequency-Very Confident: Hard Correct, Hard IC, Easy Correct, Easy IC, Sum
Line 7: Frequency-Confident: Hard Correct, Hard IC, Easy Correct, Easy IC, Sum
Line 8: Frequency-Somewhat Confident: Hard Correct, Hard IC, Easy Correct, Easy IC, Sum
Line 9: Frequency-Not at all Confident: Hard Correct, Hard IC, Easy Correct, Easy IC, Sum

Session Type: V = Verbal / N = Non-Verbal
S = Single (1AFC) / D = Double (2AFC)
Y = Young / O = Old

(Hard IC = Hard Incorrect; Easy IC = Easy Incorrect)

---

002 VSO 0.66 0.79
12 6 19 19 13 7
16 4 20 19 15 4
0.63 0.32 0.68 0.37 0.80
0.80 0.21 0.79 0.20 1.64
8 2 7 0 17
4 4 8 2 18
6 5 7 4 22
7 2 9 2 20

002 NSO 0.50 0.58
9 9 20 20 11 11
10 7 20 20 13 10
0.45 0.45 0.55 0.55 0.00
0.50 0.35 0.65 0.50 0.38
1 3 2 4 10
6 7 11 4 28
9 6 8 3 26
4 2 6 16

003 NSO 0.73 0.67
12 4 16 14 10 4
9 3 18 18 15 9
0.75 0.29 0.71 0.25 1.23
0.50 0.17 0.83 0.50 0.95
0 0 0 0 0
15 6 16 7 44
7 2 7 5 21
0 0 1 0 1

003 VSO 0.78 0.88
11 0 20 20 20 9
15 0 20 20 20 5
0.55 0 1 0.45 2.01
0.75 0 1 0.25 2.56
4 0 6 0 10
27 9 26 5 67
0 0 3 0 3
0 0 0 0 0

004 NSO 0.53 0.63
11 11 18 20 9 7
10 5 20 20 15 10
0.61 0.55 0.45 0.39 0.15
0.50 0.25 0.75 0.50 0.68
0 0 0 0 0
9 9 10 2 30
7 7 7 6 27
4 2 8 7 21

004 VSO 0.54 0.73
13 11 20 19 8 7
11 2 20 20 18 9
0.65 0.58 0.42 0.35 0.18
0.55 0.10 0.90 0.45 1.41
0 0 0 0 0
5 3 5 1 14
7 9 15 4 35
9 6 9 6 30

005 NSY 0.80 0.63
15 3 20 20 17 5
9 4 20 20 16 11
0.75 0.15 0.85 0.25 1.72
0.45 0.20 0.80 0.55 0.71
9 2 8 5 24
7 3 12 3 25
15 2 3 2 22
1 1 2 5 9

006 NSY 0.65 0.56
14 8 20 20 12 6
7 5 19 20 15 12
0.70 0.40 0.60 0.30 0.78
0.37 0.25 0.75 0.63 0.34
6 7 5 3 21
7 4 12 5 28
8 2 2 8 20
5 1 3 1 10

009 NSY 0.73 0.78
15 6 20 20 14 5
16 5 20 20 15 4
0.75 0.30 0.70 0.25 1.20
0.80 0.25 0.75 0.20 1.52
1 0 0 0 1
9 1 13 2 25
15 6 10 3 34
4 4 8 4 20

013 VSY 0.68 0.88
16 9 20 20 11 4
18 3 20 20 17 2
0.80 0.45 0.55 0.20 0.97
0.90 0.15 0.85 0.10 2.32
15 6 24 0 45
6 6 4 2 18
5 1 7 2 15
1 0 0 1 2

016 NSO 0.55 0.54
10 8 19 19 11 9
8 8 16 19 11 8
0.53 0.42 0.58 0.47 0.28
0.50 0.42 0.58 0.50 0.20
6 2 5 5 18
9 10 6 6 31
5 5 7 5 22
1 0 1 0 2

005 VSY 0.70 0.81
9 1 20 20 19 11
12 1 18 19 18 6
0.45 0.05 0.95 0.55 1.51
0.67 0.05 0.95 0.33 2.08
13 4 16 0 33
6 4 9 2 21
7 4 4 5 20
2 0 1 0 3

006 VSY 0.85 0.78
17 3 20 20 17 3
13 2 20 20 18 7
0.85 0.15 0.85 0.15 2.08
0.65 0.10 0.90 0.35 1.66
24 1 18 0 43
5 3 11 4 23
5 2 2 5 14
0 0 0 0 0

009 VSY 0.64 0.73
10 4 20 19 15 10
13 4 20 20 16 7
0.50 0.21 0.79 0.50 0.80
0.65 0.20 0.80 0.35 1.22
8 0 5 0 13
7 3 7 2 19
8 7 8 5 28
2 4 9 4 19

013 NSY 0.72 0.75
14 5 20 19 14 6
14 4 20 20 16 6
0.70 0.26 0.74 0.30 1.16
0.70 0.20 0.80 0.30 1.36
22 5 21 5 53
2 3 8 3 16
4 3 1 2 10
0 0 0 0 0

016 VSO 0.66 0.49
14 8 19 19 11 5
12 13 18 19 6 6
0.74 0.42 0.58 0.26 0.84
0.67 0.68 0.32 0.33 –0.03
12 7 8 11 38
11 4 9 5 29
2 2 1 3 8
0 0 0 0 0

023 NSO 0.70 0.58
16 8 20 20 12 4
11 8 20 20 12 9
0.80 0.40 0.60 0.20 1.10
0.55 0.40 0.60 0.45 0.38
11 1 8 4 24
11 6 10 6 33
6 5 5 7 23
0 0 0 0 0

023 VSO 0.83 0.90
17 4 20 20 16 3
18 2 20 20 18 2
0.85 0.20 0.80 0.15 1.88
0.90 0.10 0.90 0.10 2.56
21 1 20 0 42
11 3 13 2 29
1 3 3 2 9
0 0 0 0 0

024 VSY 0.73 0.80
16 7 20 20 13 4
17 5 20 20 15 3
0.80 0.35 0.65 0.20 1.22
0.85 0.25 0.75 0.15 1.72
1 0 5 0 6
16 3 10 1 30
8 4 10 4 26
4 4 7 3 18

024 NSY 0.60 0.63
12 8 20 20 12 8
11 6 20 20 14 9
0.60 0.40 0.60 0.40 0.51
0.55 0.30 0.70 0.45 0.66
1 0 0 0 1
9 11 14 7 41
12 5 10 5 32
2 0 1 3 6

025 VSO 0.68 0.78
15 8 20 20 12 5
15 4 20 20 16 5
0.75 0.40 0.60 0.25 0.93
0.75 0.20 0.80 0.25 1.52
2 0 0 0 2
13 2 15 2 32
10 6 9 3 28
2 5 7 4 18

025 NSO 0.64 0.64
12 7 19 20 13 7
11 5 20 19 14 9
0.63 0.35 0.65 0.37 0.72
0.55 0.26 0.74 0.45 0.77
1 0 0 0 1
10 5 8 4 27
6 5 11 6 28
8 4 6 4 22

027 NSY 0.72 0.55
17 8 20 19 11 3
9 7 20 20 13 11
0.85 0.42 0.58 0.15 1.24
0.45 0.35 0.65 0.55 0.26
3 0 0 0 3
9 2 8 4 23
11 6 11 11 39
5 3 3 3 14

027 VSY 0.80 0.83
17 5 20 20 15 3
18 5 20 20 15 2
0.85 0.25 0.75 0.15 1.72
0.90 0.25 0.75 0.10 1.96
6 0 8 0 14
16 2 14 0 32
7 4 8 4 23
3 2 3 3 11

030 NSO 0.55 0.71
8 6 19 19 13 11
12 5 17 18 13 5
0.42 0.32 0.68 0.58 0.27
0.71 0.28 0.72 0.29 1.14
1 0 3 1 5
11 12 13 4 40
9 5 8 5 27
0 0 1 0 1

030 VSO 0.67 0.87
14 7 20 19 12 6
16 1 20 18 17 4
0.70 0.37 0.63 0.30 0.86
0.80 0.06 0.94 0.20 2.39
5 1 5 0 11
17 9 22 2 50
3 3 6 1 13
1 0 0 2 3

032 NSY 0.53 0.60
10 9 20 20 11 10
10 6 20 20 14 10
0.50 0.45 0.55 0.50 0.13
0.50 0.30 0.70 0.50 0.52
0 0 0 0 0
10 6 11 4 31
8 7 9 8 32
3 6 4 4 17

032 VSY 0.75 0.85
16 6 20 20 14 4
17 3 20 20 17 3
0.80 0.30 0.70 0.20 1.36
0.85 0.15 0.85 0.15 2.08
2 0 10 0 12
8 4 12 0 24
15 4 10 4 33
5 2 2 2 11

035 VSY 0.61 0.81
13 9 19 19 10 6
15 4 18 19 15 3
0.68 0.47 0.53 0.32 0.54
0.83 0.21 0.79 0.17 1.76
7 5 14 0 26
10 8 13 3 34
6 2 1 2 11
0 0 2 2 4

035 NSY 0.48 0.68
11 12 20 20 8 9
15 8 20 20 12 5
0.55 0.60 0.40 0.45 –0.12
0.75 0.40 0.60 0.25 0.93
4 3 8 4 19
10 11 12 4 37
5 5 6 5 21
0 2 1 0 3

039 NSY 0.58 0.60
8 5 20 20 15 12
7 3 20 20 17 13
0.40 0.25 0.75 0.60 0.42
0.35 0.15 0.85 0.65 0.66
0 0 0 0 0
7 8 9 7 31
16 9 15 9 49
0 0 0 0 0

039 VSY 0.83 0.80
14 1 20 20 19 6
13 1 20 20 19 7
0.70 0.05 0.95 0.30 2.16
0.65 0.05 0.95 0.35 2.02
9 0 8 1 18
20 5 21 4 50
4 2 3 3 12
0 0 0 0 0

041 NSO 0.57 0.67
11 8 16 14 6 5
8 6 12 18 12 4
0.69 0.57 0.43 0.31 0.32
0.67 0.33 0.67 0.33 0.88
0 0 0 0 0
11 9 11 4 35
6 4 9 6 25
0 0 0 0 0

041 VSO 0.57 0.54
12 11 16 19 8 4
12 10 18 17 7 6
0.75 0.58 0.42 0.25 0.48
0.67 0.59 0.41 0.33 0.21
0 0 0 0 0
6 4 4 6 20
11 9 13 8 41
3 2 2 2 9

047 VSO 0.76 0.82
16 5 20 18 13 4
15 2 20 18 16 5
0.80 0.28 0.72 0.20 1.42
0.75 0.11 0.89 0.25 1.90
5 0 3 0 8
11 0 11 1 23
11 9 16 6 42
2 0 1 0 3

047 NSO 0.48 0.56
12 13 20 20 7 8
10 7 20 19 12 10
0.60 0.65 0.35 0.40 –0.13
0.50 0.37 0.63 0.50 0.33
0 0 1 0 1
4 4 7 2 17
15 17 13 13 58
0 0 1 2 3

048 NSO 0.66 0.67
12 9 15 20 11 3
12 7 17 19 12 5
0.80 0.45 0.55 0.20 0.97
0.71 0.37 0.63 0.29 0.88
1 2 2 0 5
13 7 14 8 42
9 1 8 4 22
0 2 0 0 2

048 VSO 0.75 0.83
19 9 20 20 11 1
16 3 20 20 17 4
0.95 0.45 0.55 0.05 1.77
0.80 0.15 0.85 0.20 1.88
1 0 3 0 4
19 8 24 3 54
9 2 6 4 21
1 0 0 0 1

050 VSO 0.69 0.76
14 6 20 19 13 6
13 2 20 18 16 7
0.70 0.32 0.68 0.30 1.00
0.65 0.11 0.89 0.35 1.62
9 2 10 0 21
6 0 3 0 9
12 10 15 9 46
0 0 1 0 1

050 NSO 0.65 0.62
15 9 20 20 11 5
11 6 20 19 13 9
0.75 0.45 0.55 0.25 0.80
0.55 0.32 0.68 0.45 0.60
1 0 2 1 4
2 1 1 1 5
23 13 21 11 68
0 0 0 2 2

053 VSO 0.81 0.85
14 2 19 18 16 5
14 0 20 20 20 6
0.74 0.11 0.89 0.26 1.87
0.70 0 1 0.30 2.40
20 2 17 2 41
4 2 7 3 16
5 3 8 0 16
1 0 2 1 4

053 NSO 0.68 0.60
12 5 20 20 15 8
7 3 20 20 17 13
0.60 0.25 0.75 0.40 0.93
0.35 0.15 0.85 0.65 0.66
1 0 0 0 1
3 3 6 3 15
17 6 13 8 44
6 4 5 5 20

055 VSY 0.62 0.85
12 8 19 20 12 7
15 1 20 19 18 5
0.63 0.40 0.60 0.37 0.58
0.75 0.05 0.95 0.25 2.32
1 0 4 0 5
13 7 13 3 36
7 7 13 1 28
3 1 3 2 9

055 NSY 0.68 0.59
14 7 20 20 13 6
11 8 19 20 12 8
0.70 0.35 0.65 0.30 0.91
0.58 0.40 0.60 0.42 0.46
0 0 0 0 0
5 5 6 2 18
16 4 13 7 40
6 4 4 7 21

056 VSY 0.73 0.93
18 9 20 20 11 2
19 2 20 20 18 1
0.90 0.45 0.55 0.10 1.41
0.95 0.10 0.90 0.05 2.92
10 3 17 0 30
7 3 9 1 20
11 5 6 1 23
1 0 5 1 7

056 NSY 0.78 0.63
14 3 20 20 17 6
9 4 20 20 16 11
0.70 0.15 0.85 0.30 1.56
0.45 0.20 0.80 0.55 0.71
13 3 10 1 27
9 2 11 6 28
8 4 4 6 22
1 0 0 2 3

058 NSO 0.58 0.54
9 6 20 20 14 11
6 4 20 19 15 14
0.45 0.30 0.70 0.55 0.40
0.30 0.21 0.79 0.70 0.28
9 7 11 5 32
8 4 4 7 23
5 6 5 6 22
1 0 1 0 2

059 VSO 0.53 0.75
11 10 20 20 10 9
13 3 20 20 17 7
0.55 0.50 0.50 0.45 0.13
0.65 0.15 0.85 0.35 1.42
2 0 3 0 5
8 4 12 4 28
7 10 9 5 31
4 5 6 1 16

061 VSO 0.70 0.76
11 3 20 20 17 9
11 1 19 19 18 8
0.55 0.15 0.85 0.45 1.17
0.58 0.05 0.95 0.42 1.84
3 1 2 0 6
22 9 24 7 62
2 2 3 2 9
1 0 0 0 1

062 NSO 0.64 0.67
11 10 13 20 10 2
8 3 15 15 12 7
0.85 0.50 0.50 0.15 1.04
0.53 0.20 0.80 0.47 0.92
1 0 0 0 1
8 5 7 3 23
5 5 6 3 19
7 2 7 4 20

063 NSO 0.55 0.61
13 11 20 20 9 7
12 8 19 19 11 7
0.65 0.55 0.45 0.35 0.26
0.63 0.42 0.58 0.37 0.53
4 1 1 4 10
16 14 17 9 56
2 3 5 2 12
0 0 0 0 0

058 VSO 0.88 1
18 3 20 20 17 2
19 0 19 19 19 0
0.90 0.15 0.85 0.10 2.32
1 0 1 0 3.93
26 1 34 0 61
6 1 1 0 8
3 3 3 0 9
0 0 0 0 0

059 NSO 0.63 0.50
13 8 20 20 12 7
10 10 20 20 10 10
0.65 0.40 0.60 0.35 0.64
0.50 0.50 0.50 0.50 0.00
1 0 1 1 3
9 9 8 6 32
7 2 10 4 23
8 4 1 9 22

061 NSO 0.54 0.51
11 10 19 20 10 8
9 8 20 19 11 11
0.58 0.50 0.50 0.42 0.20
0.45 0.42 0.58 0.55 0.07
0 0 0 0 0
12 13 8 9 42
9 5 12 10 36
0 0 0 0 0

062 VSO 0.68 0.83
16 9 20 20 11 4
15 2 20 20 18 5
0.80 0.45 0.55 0.20 0.97
0.75 0.10 0.90 0.25 1.96
4 1 2 0 7
8 1 15 3 27
8 7 8 1 24
7 4 8 3 22

063 VSO 0.70 0.83
15 7 20 20 13 5
13 0 20 20 20 7
0.75 0.35 0.65 0.25 1.06
0.65 0 1 0.35 2.26
6 2 17 1 26
22 9 16 5 52
0 0 0 0 0
0 1 0 1 2

067 VSY 0.63 0.73
14 9 20 20 11 6
9 0 20 20 20 11
0.70 0.45 0.55 0.30 0.66
0.45 0 1 0.55 1.75
7 2 7 0 16
10 5 15 4 34
8 5 7 6 26
0 3 0 1 4

067 NSY 0.68 0.88
14 7 20 20 13 6
18 3 20 20 17 2
0.70 0.35 0.65 0.30 0.91
0.90 0.15 0.85 0.10 2.32
10 1 12 0 23
8 5 16 1 30
9 5 6 4 24
0 2 1 0 3

068 VSO 0.58 0.88
12 9 20 20 11 8
18 3 20 20 17 2
0.60 0.45 0.55 0.40 0.38
0.90 0.15 0.85 0.10 2.32
7 4 12 0 23
12 4 13 3 32
4 9 10 2 25
0 0 0 0 0

068 NSO 0.51 0.54
9 8 20 19 11 11
10 9 19 20 11 9
0.45 0.42 0.58 0.55 0.07
0.53 0.45 0.55 0.47 0.20
1 0 1 0 2
5 3 5 3 16
14 15 15 15 59
0 1 0 0 1

070 NSO 0.62 0.53
12 8 19 20 12 7
8 7 20 20 13 12
0.63 0.40 0.60 0.37 0.58
0.40 0.35 0.65 0.60 0.13
1 1 2 1 5
10 5 9 5 29
10 8 10 11 39
3 1 0 2 6

070 VSO 0.65 0.83
16 10 20 20 10 4
15 2 20 20 18 5
0.80 0.50 0.50 0.20 0.84
0.75 0.10 0.90 0.25 1.96
2 0 6 0 8
14 1 16 2 33
7 12 8 4 31
3 1 3 1 8

073 VSO 0.72 0.82
16 7 20 19 12 4
17 4 20 19 15 3
0.80 0.37 0.63 0.20 1.17
0.85 0.21 0.79 0.15 1.84
0 0 0 0 0
11 0 12 2 25
11 5 11 1 28
6 6 9 4 25

073 NSO 0.63 0.50
13 8 20 20 12 7
7 7 20 20 13 13
0.65 0.40 0.60 0.35 0.64
0.35 0.35 0.65 0.65 0.00
0 0 0 0 0
5 3 0 2 10
11 6 9 5 31
9 6 11 13 39

075 VSO 0.64 0.50
10 4 20 19 15 10
9 9 18 18 9 9
0.50 0.21 0.79 0.50 0.80
0.50 0.50 0.50 0.50 0.00
0 0 0 0 0
0 0 0 0 0
24 13 18 18 73
1 1 0 0 2

075 NSO 0.49 0.48
6 7 19 20 13 13
11 12 20 20 8 9
0.32 0.35 0.65 0.68 –0.08
0.55 0.60 0.40 0.45 –0.12
0 0 0 0 0
0 3 0 0 3
5 6 4 3 18
14 11 15 18 58

071 VSY 0.64 0.71
13 7 19 17 10 6
11 3 19 19 16 8
0.68 0.41 0.59 0.32 0.70
0.58 0.16 0.84 0.42 1.19
8 2 9 0 19
6 5 8 2 21
7 2 6 7 22
2 4 4 2 12

072 VSY 0.58 0.85
11 8 20 20 12 9
16 3 19 20 17 3
0.55 0.40 0.60 0.45 0.38
0.84 0.15 0.85 0.16 2.03
3 1 7 0 11
4 2 7 1 14
14 13 17 5 49
2 1 2 0 5

078 VSY 0.78 0.83
18 7 20 20 13 2
13 0 20 20 20 7
0.90 0.35 0.65 0.10 1.66
0.65 0 1 0.35 2.26
7 0 6 0 13
20 3 16 3 42
3 6 9 4 22
1 0 2 0 3

079 NSY 0.60 0.64
13 9 20 20 11 7
9 3 20 19 16 11
0.65 0.45 0.55 0.35 0.52
0.45 0.16 0.84 0.55 0.86
6 0 8 1 15
6 5 5 3 19
3 4 9 8 24
9 7 3 2 21

083 VSY 0.77 0.68
15 5 19 20 15 4
12 5 20 20 15 8
0.79 0.25 0.75 0.21 1.48
0.60 0.25 0.75 0.40 0.93
17 3 13 4 37
13 6 14 9 42
0 0 0 0 0
0 0 0 0 0

071 NSY 0.55 0.71
13 10 20 18 8 7
13 4 20 18 14 7
0.65 0.56 0.44 0.35 0.24
0.65 0.22 0.78 0.35 1.16
8 6 3 0 17
8 7 8 5 28
3 4 13 4 24
2 0 3 2 7

072 NSY 0.65 0.70
16 10 20 20 10 4
11 3 20 20 17 9
0.80 0.50 0.50 0.20 0.84
0.55 0.15 0.85 0.45 1.17
6 1 8 2 17
9 6 9 5 29
10 6 10 4 30
1 1 1 1 4

078 NSY 0.56 0.72
11 9 19 20 11 8
12 3 20 19 16 8
0.58 0.45 0.55 0.42 0.33
0.60 0.16 0.84 0.40 1.24
1 0 0 0 1
3 2 9 3 17
14 10 16 5 45
4 5 3 3 15

079 VSY 0.85 0.78
17 3 20 20 17 3
15 4 20 20 16 5
0.85 0.15 0.85 0.15 2.08
0.75 0.20 0.80 0.25 1.52
2 0 9 0 11
13 0 7 0 20
10 3 8 4 25
9 3 7 5 24

083 NSY 0.68 0.73
16 9 20 20 11 4
15 6 20 20 14 5
0.80 0.45 0.55 0.20 0.97
0.75 0.30 0.70 0.25 1.20
20 4 18 3 45
7 9 11 8 35
0 0 0 0 0
0 0 0 0 0

084 NSY 0.77 0.78
12 2 19 20 18 7
13 2 20 20 18 7
0.63 0.10 0.90 0.37 1.61
0.65 0.10 0.90 0.35 1.66
9 2 7 0 18
14 3 16 3 36
7 3 8 5 23
0 1 0 1 2

084 VSY 1 0.98
20 0 20 20 20 0
19 0 20 20 20 1
1 0 1 0 3.93
0.95 0 1 0.05 3.52
36 0 32 0 68
4 0 6 0 10
0 0 1 0 1
0 0 0 1 1

085 NSY 0.65 0.61
4 18 19 15 9
11 7 19 19 12 8
0.50 0.21 0.79 0.50 0.80
0.58 0.37 0.63 0.42 0.53
4 0 0 0 4
11 3 5 4 23
7 8 14 9 38
2 2 4 2 10

085 VSY 0.93 0.95
19 2 20 20 18 1
18 0 20 20 20 2
0.95 0.10 0.90 0.05 2.92
0.90 0 1 0.10 3.16
25 0 16 0 41
10 0 13 0 23
2 3 9 2 16
0 0 0 0 0

## Appendix H

Raw Data From the 2AFC Presentation Mode.

The following data are those obtained from participants in the 2AFC mode of presentation only. The key of the data set is as follows:

Line 1: Subject ID, Session Type, Rate Correct-Hard Trials, Rate Correct-Easy Trials
Line 2: Frequency-Hard Trials: Hits, False Alarms, Signal, No Signal, Correct Rejections, Misses
Line 3: Frequency-Easy trials: Hits, False Alarms, Signal, No Signal, Correct Rejections, Misses
Line 4: Rates-Hard Trials: Hits, False Alarms, Correct Rejections Misses, d'
Line 5: Rates-Easy Trials: Hits, False Alarms, Correct Rejections Misses, d'
Line 6: Frequency-Very Confident: Hard Correct, Hard IC, Easy Correct, Easy IC, Sum
Line 7: Frequency-Confident: Hard Correct, Hard IC, Easy Correct, Easy IC, Sum
Line 8: Frequency-Somewhat Confident: Hard Correct, Hard IC, Easy Correct, Easy IC, Sum
Line 9: Frequency-Not at all Confident: Hard Correct, Hard IC, Easy Correct, Easy IC, Sum

Session Type: V = Verbal / N = Non-Verbal
S = Single (1AFC) / D = Double (2AFC)
Y = Young / O = Old

(Hard IC = Hard Incorrect; Easy IC = Easy Incorrect)

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007 NDY 0.85 0.80
9 2 10 10 8 1
8 2 10 10 8 2
0.90 0.20 0.80 0.10 1.50
0.80 0.20 0.80 0.20 1.19
11 0 9 2 22
4 0 3 0 7
1 2 4 1 8
1 1 0 1 3

007 VDY 1 1
10 0 10 9 9 0
10 0 10 10 10 0
1 0 1 0 2.78
1 0 1 0 2.78
18 0 19 0 37
1 0 1 0 2
0 0 0 0 0
0 0 0 0 0

008 NDY 0.68 0.70
7 4 9 10 6 2
8 4 10 10 6 2
0.78 0.40 0.60 0.22 0.72
0.80 0.40 0.60 0.20 0.78
2 0 2 0 4
4 1 5 0 10
6 2 6 4 18
1 3 1 2 7

008 VDY 1 1
10 0 10 10 10 0
10 0 10 10 10 0
1 0 1 0 2.78
1 0 1 0 2.78
18 0 17 0 35
2 0 3 0 5
0 0 0 0 0
0 0 0 0 0

010 NDY 0.65 0.90
8 5 10 10 5 2
9 1 10 10 9 1
0.80 0.50 0.50 0.20 0.59
0.90 0.10 0.90 0.10 1.81
1 1 5 0 7
6 3 6 0 15
2 1 5 0 8
4 2 2 2 10

010 VDY 0.95 1
10 1 10 10 9 0
10 0 10 10 10 0
1 0.10 0.90 0 2.35
1 0 1 0 2.78
18 0 20 0 38
1 1 0 0 2
0 0 0 0 0
0 0 0 0 0

011 NDY 0.65 0.80
7 4 10 10 6 3
10 4 10 10 6 0
0.70 0.40 0.60 0.30 0.55
1 0.40 0.60 0 1.63
0 0 0 0 0
6 2 7 2 17
6 5 7 0 18
1 0 2 2 5

012 NDY 0.85 0.95
8 1 10 10 9 2
9 0 10 10 10 1
0.80 0.10 0.90 0.20 1.50
0.90 0 1 0.10 2.23
5 0 5 0 10
6 0 3 0 9
5 0 5 1 11
1 3 6 0 10

014 NDO 0.47 0.56
4 4 9 8 4 5
5 4 8 8 4 3
0.44 0.50 0.50 0.56 -0.11
0.63 0.50 0.50 0.38 0.23
0 0 0 0 0
0 0 0 0 0
5 7 8 4 24
3 2 1 3 9

015 VDY 1 1
10 0 10 10 10 0
10 0 10 10 10 0
1 0 1 0 2.78
1 0 1 0 2.78
4 0 5 0 9
7 0 3 0 10
6 0 10 0 16
3 0 2 0 5

017 NDO 0.56 0.67
4 2 9 7 5 5
5 1 10 8 7 5
0.44 0.29 0.71 0.56 0.28
0.50 0.13 0.88 0.50 0.80
0 0 0 0 0
6 1 2 0 9
1 4 7 5 17
2 2 3 1 8

011 VDY 0.75 0.90
8 3 10 10 7 2
8 0 10 10 10 2
0.80 0.30 0.70 0.20 0.96
0.80 0 1 0.20 1.92
10 1 10 0 21
4 1 7 1 13
1 3 1 1 6
0 0 0 0 0

012 VDY 0.95 1
10 1 10 10 9 0
10 0 10 10 10 0
1 0.10 0.90 0 2.35
1 0 1 0 2.78
18 0 19 0 37
1 0 1 0 2
0 0 0 0 0
0 1 0 0 1

014 VDO 0.75 0.75
9 4 10 10 6 1
10 5 10 10 5 0
0.90 0.40 0.60 0.10 1.09
1 0.50 0.50 0 1.45
0 0 0 0 0
0 0 0 0 0
15 5 15 5 40
0 0 0 0 0

015 NDY 0.80 0.80
8 2 10 10 8 2
9 3 10 10 7 1
0.80 0.20 0.80 0.20 1.19
0.90 0.30 0.70 0.10 1.27
0 0 0 0 0
3 0 4 0 7
10 1 5 3 19
3 3 7 1 14

017 VDO 0.67 0.89
5 1 10 8 7 5
9 1 10 9 8 1
0.50 0.13 0.88 0.50 0.80
0.90 0.11 0.89 0.10 1.77
1 0 0 0 1
8 1 11 0 20
2 4 4 1 11
1 1 2 1 5

018 NDO 0.56 0.75
5 4 8 8 4 3
6 2 8 8 6 2
0.63 0.50 0.50 0.38 0.23
0.75 0.25 0.75 0.25 0.95
0 0 0 0 0
0 0 0 0 0
5 0 2 0 7
4 7 10 4 25

019 NDO 0.56 0.65
5 4 9 9 5 4
8 5 10 10 5 2
0.56 0.44 0.56 0.44 0.21
0.80 0.50 0.50 0.20 0.59
0 0 0 0 0
1 4 1 2 8
9 3 10 5 27
0 1 2 0 3

020 NDO 0.53 0.53
5 4 9 8 4 4
3 3 7 8 5 4
0.56 0.50 0.50 0.44 0.11
0.43 0.38 0.63 0.57 0.08
1 0 0 0 1
7 8 7 7 29
1 0 1 0 2
0 0 0 0 0

026 NDY 0.80 0.85
9 3 10 10 7 1
10 3 10 10 7 0
0.90 0.30 0.70 0.10 1.27
1 0.30 0.70 0 1.82
5 0 5 0 10
1 0 4 0 5
7 4 6 0 17
3 0 2 3 8

028 VDY 0.75 0.85
9 4 10 10 6 1
9 2 10 10 8 1
0.90 0.40 0.60 0.10 1.09
0.90 0.20 0.80 0.10 1.50
6 3 10 0 19
8 1 6 2 17
1 1 1 1 4
0 0 0 0 0

018 VDO 0.65 0.79
7 4 10 10 6 3
9 3 10 9 6 1
0.70 0.40 0.60 0.30 0.55
0.90 0.33 0.67 0.10 1.22
0 0 0 0 0
3 0 5 0 8
10 7 10 3 30
0 0 0 1 1

019 VDO 0.90 0.80
9 1 10 10 9 1
7 1 10 10 9 3
0.90 0.10 0.90 0.10 1.81
0.70 0.10 0.90 0.30 1.27
0 0 0 0 0
8 0 9 0 17
10 2 7 4 23
0 0 0 0 0

020 VDO 0.44 0.56
4 6 8 10 4 4
6 5 9 9 4 3
0.50 0.60 0.40 0.50 -0.18
0.67 0.56 0.44 0.33 0.21
0 0 0 0 0
8 10 10 8 36
0 0 0 0 0
0 0 0 0 0

026 VDY 0.90 0.95
9 1 10 10 9 1
9 0 10 10 10 1
0.90 0.10 0.90 0.10 1.81
0.90 0 1 0.10 2.23
10 0 12 0 22
4 0 3 0 7
4 2 2 0 8
0 0 2 1 3

028 NDY 0.75 0.90
7 2 10 10 8 3
8 0 10 10 10 2
0.70 0.20 0.80 0.30 0.96
0.80 0 1 0.20 1.92
2 0 5 0 7
4 0 7 1 12
8 5 3 1 17
1 0 3 0 4

029 VDY 0.89 0.85
8 1 9 10 9 1
8 1 10 10 9 2
0.89 0.10 0.90 0.11 1.77
0.80 0.10 0.90 0.20 1.50
9 0 8 0 17
5 0 4 0 9
3 2 4 1 10
0 0 1 2 3

031 NDY 0.75 0.70
9 4 10 10 6 1
8 4 10 10 6 2
0.90 0.40 0.60 0.10 1.09
0.80 0.40 0.60 0.20 0.78
4 0 5 0 9
6 0 5 3 14
5 5 4 3 17
0 0 0 0 0

033 VDY 1 1
10 0 10 10 10 0
10 0 10 10 10 0
1 0 1 0 2.78
1 0 1 0 2.78
18 0 18 0 36
1 0 2 0 3
1 0 0 0 1
0 0 0 0 0

034 VDO 0.84 0.94
9 2 10 9 7 1
7 0 8 10 10 1
0.90 0.22 0.78 0.10 1.45
0.88 0 1 0.13 2.16
9 0 9 0 18
4 1 6 0 11
3 2 0 0 5
0 0 2 1 3

036 NDY 0.45 0.89
4 5 10 10 5 6
8 1 9 10 9 1
0.40 0.50 0.50 0.60 -0.18
0.89 0.10 0.90 0.11 1.77
0 0 0 0 0
1 0 3 0 4
8 6 10 2 26
0 5 4 0 9

029 NDY 0.65 0.63
7 4 10 10 6 3
5 2 10 9 7 5
0.70 0.40 0.60 0.30 0.55
0.50 0.22 0.78 0.50 0.54
3 0 2 0 5
8 2 4 2 16
2 2 5 3 12
0 3 1 2 6

031 VDY 0.80 1
7 1 10 10 9 3
10 0 10 10 10 0
0.70 0.10 0.90 0.30 1.27
1 0 1 0 2.78
14 0 17 0 31
1 1 1 0 3
1 2 2 0 5
0 1 0 0 1

033 NDY 0.65 0.89
8 5 10 10 5 2
9 2 9 10 8 0
0.80 0.50 0.50 0.20 0.59
1 0.20 0.80 0 2.04
8 0 5 0 13
3 1 5 1 10
2 4 6 1 13
0 2 1 0 3

034 NDO 0.55 0.70
5 4 10 10 6 5
9 5 10 10 5 1
0.50 0.40 0.60 0.50 0.18
0.90 0.50 0.50 0.10 0.90
3 0 8 1 12
8 3 4 1 16
0 5 2 3 10
0 1 0 1 2

036 VDY 0.75 0.90
6 1 10 10 9 4
8 0 10 10 10 2
0.60 0.10 0.90 0.40 1.09
0.80 0 1 0.20 1.92
3 0 4 0 7
4 2 1 1 8
7 3 9 1 20
1 0 4 0 5

037 VDY 0.65 0.80
5 2 10 10 8 5
9 3 10 10 7 1
0.50 0.20 0.80 0.50 0.59
0.90 0.30 0.70 0.10 1.27
3 1 5 0 9
7 1 7 1 16
3 3 4 2 12
0 2 0 1 3

037 NDY 0.50 0.85
3 3 10 10 7 7
9 2 10 10 8 1
0.30 0.30 0.70 0.70 0
0.90 0.20 0.80 0.10 1.50
0 0 0 0 0
4 3 5 1 13
4 5 8 1 18
2 2 4 1 9

038 NDY 0.70 0.45
7 3 10 10 7 3
5 6 10 10 4 5
0.70 0.30 0.70 0.30 0.74
0.50 0.60 0.40 0.50 -0.18
1 0 2 0 3
1 1 0 1 3
10 2 6 8 26
2 3 1 2 8

038 VDY 0.60 0.80
6 4 10 10 6 4
9 3 10 10 7 1
0.60 0.40 0.60 0.40 0.36
0.90 0.30 0.70 0.10 1.27
8 2 8 1 19
2 2 2 1 7
2 2 4 0 8
0 2 2 2 6

040 NDO 0.63 0.59
5 3 9 10 7 4
5 5 7 10 5 2
0.56 0.30 0.70 0.44 0.48
0.71 0.50 0.50 0.29 0.40
0 0 0 0 0
12 5 8 7 32
0 2 2 0 4
0 0 0 0 0

040 VDO 0.50 0.65
6 6 10 10 4 4
6 3 10 10 7 4
0.60 0.60 0.40 0.40 0
0.60 0.30 0.70 0.40 0.55
0 0 0 0 0
7 6 9 2 24
3 4 4 5 16
0 0 0 0 0

042 VDO 0.85 0.75
8 1 10 10 9 2
8 3 10 10 7 2
0.80 0.10 0.90 0.20 1.50
0.80 0.30 0.70 0.20 1.96
6 0 3 1 10
9 1 7 1 18
2 1 3 3 9
0 1 2 0 3

042 NDO 0.45 0.70
4 5 10 10 5 6
9 5 10 10 5 1
0.40 0.50 0.50 0.60 -0.18
0.90 0.50 0.50 0.10 0.90
2 0 1 0 3
3 4 8 2 17
3 6 5 3 17
1 1 0 1 3

043 VDY 0.89 0.95
9 2 9 10 8 0
9 0 10 10 10 1
1 0.20 0.80 0 2.04
0.90 0 1 0.10 2.23
8 0 10 0 18
3 0 2 0 5
5 1 6 0 12
1 1 1 1 4

043 NDY 0.75 0.58
8 3 10 10 7 2
7 5 10 9 4 3
0.80 0.30 0.70 0.20 0.96
0.70 0.56 0.44 0.30 0.27
2 0 1 0 3
4 0 2 0 6
4 2 4 5 15
5 3 4 3 15

045 VDO 0.84 0.68
10 3 10 9 6 0
8 4 10 9 5 2
1 0.33 0.67 0 1.76
0.80 0.44 0.56 0.20 0.70
3 0 1 0 4
4 2 2 2 10
8 1 7 3 19
1 0 3 1 5

045 NDO 0.65 0.63
6 3 10 10 7 4
7 4 10 9 5 3
0.60 0.30 0.70 0.40 0.55
0.70 0.44 0.56 0.30 0.48
0 0 0 0 0
3 0 4 0 7
8 6 6 4 24
2 1 2 3 8

046 NDO 0.70 0.60
8 4 10 10 6 2
8 6 10 10 4 2
0.80 0.40 0.60 0.20 0.78
0.80 0.60 0.40 0.20 0.41
3 1 4 1 9
10 1 5 4 20
0 4 1 2 7
1 0 2 1 4

046 VDO 0.74 0.85
5 1 9 10 9 4
7 0 10 10 10 3
0.56 0.10 0.90 0.44 1.01
0.70 0 1 0.30 1.70
7 1 10 0 18
6 1 5 0 12
1 0 0 0 1
0 3 2 3 8

049 VDO 0.65 0.84
5 2 10 10 8 5
9 2 10 9 7 1
0.50 0.20 0.80 0.50 0.59
0.90 0.22 0.78 0.10 1.45
1 0 4 0 5
4 1 6 0 11
6 3 2 0 11
2 3 4 3 12

049 NDO 0.65 0.65
8 5 10 10 5 2
8 5 10 10 5 2
0.80 0.50 0.50 0.20 0.59
0.80 0.50 0.50 0.20 0.59
0 0 0 0 0
5 0 2 0 7
4 4 9 4 21
4 3 2 3 1

052 VDO 0.95 1
9 0 10 10 10 1
10 0 10 10 10 0
0.90 0 1 0.10 2.23
1 0 1 0 2.78
19 0 20 0 39
0 0 0 0 0
0 0 0 0 0
0 1 0 0 1

052 NDO 0.83 0.83
6 0 9 9 9 3
7 1 9 9 8 2
0.67 0 1 0.33 1.64
0.78 0.11 0.89 0.22 1.41
3 0 3 0 6
5 2 6 0 13
7 1 6 3 17
0 0 0 0 0

054 NDY 0.55 0.80
6 5 10 10 5 4
8 2 10 10 8 2
0.60 0.50 0.50 0.40 0.18
0.80 0.20 0.80 0.20 1.19
6 1 7 0 14
2 5 3 4 14
1 1 4 0 6
2 2 2 0 6

054 VDY 0.85 0.85
8 1 10 10 9 2
8 1 10 10 9 2
0.80 0.10 0.90 0.20 1.50
0.80 0.10 0.90 0.20 1.50
11 0 10 1 22
2 3 1 0 6
2 0 2 1 5
2 0 4 1 7

057 VDY 0.75 0.85
7 2 10 10 8 3
8 1 10 10 9 2
0.70 0.20 0.80 0.30 0.96
0.80 0.10 0.90 0.20 1.50
10 0 12 0 22
2 1 1 2 6
2 2 3 0 7
1 2 1 1 5

057 NDY 0.80 0.95
7 1 10 10 9 3
9 0 10 10 10 1
0.70 0.10 0.90 0.30 1.27
0.90 0 1 0.10 2.23
10 0 8 1 19
1 0 3 0 4
3 0 4 0 7
2 4 4 0 10

060 VDO 0.50 0.70
6 6 10 10 4 4
7 3 10 10 7 3
0.60 0.60 0.40 0.40 0
0.70 0.30 0.70 0.30 0.74
0 0 0 0 0
8 5 9 4 26
2 5 5 2 14
0 0 0 0 0

060 NDO 0.45 0.58
5 6 10 10 4 5
7 5 10 9 4 3
0.50 0.60 0.40 0.50 -0.18
0.70 0.56 0.44 0.30 0.27
0 0 0 0 0
0 1 0 0 1
8 9 11 8 36
1 1 0 0 2

064 NDO 0.74 0.80
7 3 9 10 7 2
10 4 10 10 6 0
0.78 0.30 0.70 0.22 0.92
1 0.40 0.60 0 1.63
0 0 0 0 0
7 2 6 1 16
7 3 10 3 23
0 0 0 0 0

064 VDO 0.85 0.80
9 2 10 10 8 1
8 2 10 10 8 2
0.90 0.20 0.80 0.10 1.50
0.80 0.20 0.80 0.20 1.19
11 1 7 0 19
3 0 5 0 8
1 1 2 4 8
2 1 2 0 5

065 VDO 0.76 0.95
6 3 7 10 7 1
9 1 9 10 9 0
0.86 0.30 0.70 0.14 1.13
1 0.10 0.90 0 2.35
9 2 16 0 27
2 1 1 1 5
2 1 1 0 4
0 0 0 0 0

065 NDO 0.65 0.50
8 5 10 10 5 2
3 3 10 10 7 7
0.80 0.50 0.50 0.20 0.59
0.30 0.30 0.70 0.70 0
1 0 3 0 4
8 4 5 6 23
4 3 2 4 13
0 0 0 0 0

066 NDO 0.58 0.63
4 3 9 10 7 5
4 2 9 10 8 5
0.44 0.30 0.70 0.56 0.27
0.44 0.20 0.80 0.56 0.49
0 0 0 0 0
1 0 0 0 1
7 3 8 3 21
3 5 4 4 16

066 VDO 0.65 0.70
6 3 10 10 7 4
8 4 10 10 6 2
0.60 0.30 0.70 0.40 0.55
0.80 0.40 0.60 0.20 0.78
0 0 0 0 0
6 2 9 0 17
7 5 5 6 23
0 0 0 0 0

069 NDO 0.60 0.75
7 5 10 10 5 3
9 4 10 10 6 1
0.70 0.50 0.50 0.30 0.37
0.90 0.40 0.60 0.10 1.09
0 0 0 0 0
5 1 4 0 10
6 5 8 4 23
1 2 3 1 7

074 VDO 0.60 0.83
7 5 10 10 5 3
9 2 10 8 6 1
0.70 0.50 0.50 0.30 0.37
0.90 0.25 0.75 0.10 1.39
0 0 0 0 0
0 0 0 0 0
8 5 8 0 21
4 3 7 3 17

076 VDO 1 1
10 0 10 10 10 0
10 0 10 10 10 0
1 0 1 0 2.78
1 0 1 0 2.78
20 0 18 0 38
0 0 2 0 2
0 0 0 0 0
0 0 0 0 0

077 VDO 0.65 0.65
5 2 10 10 8 5
6 3 10 10 7 4
0.50 0.20 0.80 0.50 0.59
0.60 0.30 0.70 0.40 0.55
0 0 0 0 0
3 0 4 0 7
8 7 8 7 30
2 0 1 0 3

080 VDY 1 1
10 0 10 10 10 0
10 0 10 10 10 0
1 0 1 0 2.78
1 0 1 0 2.78
15 0 18 0 33
3 0 2 0 5
2 0 0 0 2
0 0 0 0 0

069 VDO 0.68 0.85
7 3 10 9 6 3
8 1 10 10 9 2
0.70 0.33 0.67 0.30 0.68
0.80 0.10 0.90 0.20 0.50
1 1 1 0 3
7 3 6 2 18
4 2 8 1 15
1 0 2 0 3

074 NDO 0.58 0.58
5 3 10 9 6 5
4 2 10 9 7 6
0.50 0.33 0.67 0.50 0.31
0.40 0.22 0.78 0.60 0.37
0 0 0 0 0
6 2 5 0 13
5 6 5 7 23
0 0 1 1 2

076 NDO 0.80 0.75
7 1 10 10 9 3
9 4 10 10 6 1
0.70 0.10 0.90 0.30 1.27
0.90 0.40 0.60 0.10 1.09
4 0 3 0 7
9 1 5 0 15
2 3 7 2 14
1 0 0 3 4

077 NDO 0.80 0.70
8 2 10 10 8 2
6 2 10 10 8 4
0.80 0.20 0.80 0.20 1.19
0.60 0.20 0.80 0.40 0.78
0 0 1 0 1
4 0 6 0 10
12 4 7 5 28
0 0 0 1 1

080 NDY 0.80 0.90
8 2 10 10 8 2
10 2 10 10 8 0
0.80 0.20 0.80 0.20 1.19
1 0.20 0.80 0 2.04
6 0 6 0 12
6 0 7 0 13
2 1 1 0 4
2 3 4 2 11

081 VDY 0.85 0.85
8 1 10 10 9 2
8 1 10 10 9 2
0.80 0.10 0.90 0.20 1.50
0.80 0.10 0.90 0.20 1.50
3 1 1 0 5
8 0 4 1 13
5 1 8 0 14
1 1 4 2 8

081 NDY 0.75 0.80
9 4 10 10 6 1
7 1 10 10 9 3
0.90 0.40 0.60 0.10 1.09
0.70 0.10 0.90 0.30 1.27
2 0 2 0 4
5 0 3 1 9
6 1 10 2 19
2 4 1 1 8

082 VDY 0.90 1
10 2 10 10 8 0
10 0 10 9 9 0
1 0.20 0.80 0 2.04
1 0 1 0 2.78 2.78
12 0 11 0 23
5 0 4 0 9
1 0 2 0 3
0 2 2 0 4

082 NDY 0.50 0.79
4 4 10 10 6 6
7 1 10 9 8 3
0.40 0.40 0.60 0.60 0
0.70 0.11 0.89 0.30 1.24
1 1 3 0 5
2 2 6 1 11
4 4 5 0 13
3 3 1 3 10

## Appendix I

Percentage Correct Data for the 2AFC Presentation Mode.

| Age | Stimulus Type | Trial Difficulty | *M* | *SD* |
| --- | --- | --- | --- | --- |
| Young | Words | Hard | 0.85 | 0.13 |
| | | Easy | 0.92 | 0.08 |
| | Shapes | Hard | 0.70 | 0.12 |
| | | Easy | 0.79 | 0.14 |
| Old | Words | Hard | 0.72 | 0.15 |
| | | Easy | 0.80 | 0.12 |
| | Shapes | Hard | 0.62 | 0.11 |
| | | Easy | 0.65 | 0.09 |