The Effects of Modulating Temporal Separation and Distractor Identity on Distractor Interference in an Older Population Sample

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The Effects of Modulating Temporal Separation and Distractor Identity on Distractor Interference in an Older Population Sample

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DECLARATION

I, Renee Carr, declare that the Doctor of Psychology (Clinical Neuropsychology) thesis entitled "The Effects of Modulating Temporal Separation and Distractor Identity on Distractor Interference in an Older Population Sample" is no more than 40,000 words in length, exclusive of tables, figures, appendices, references and footnotes. This thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma. Except where otherwise indicated, this thesis is my own work.

Signature: Date: 14.09.09.

ABSTRACT

The phenomenon of distractor interference indicates that information not relevant to the goal is processed and has an impact on goal-directed actions. Recent work in young, healthy participants indicates that distractors presented simultaneously and also 200ms prior to targets have a significant, though attenuated, impact on responses to targets (Kritikos, McNeill & Pavlis 2008; Watson & Humphreys 1998). Beyond this interval, interference starts to diminish (Kritikos et al., 2008; Watson & Humphreys 1998). Incongruent distractors presented 200 ms prior to targets are associated with greater interference than neutral and congruent distractors (Kritikos et al., 2008; Watson & Humphreys 1998). These findings imply that internal representations of irrelevant information are capable of affecting subsequent responses to goals. In the current study, older participants were compared with younger participants to investigate age effects on response times and accuracy to simultaneously presented as well as temporally separated distractors at intervals at/greater than 200ms. The impact of age on response times to manipulations of distractor congruence was also investigated. Simultaneous presentation of target and distrator, as well distractors preceded by the target by 200 ms or 1000 ms, was associated with increased distractor interference for both groups. The presence of incongruent distractors led to increased distractor interference for both groups. During all conditions in both experiments the older group had significantly longer reaction times compared to younger participants and was relatively more accurate in response selection. Overall, the older group's slower response style seemed to be more advantageous, allowing them enough time to think more carefully about their responses. These findings are discussed with reference to Salthouse's (1996) reduced speed of processing theory, which states that normal ageing is associated with generalized slowing of neural transmission. The finding that older participants were accurate in their responses and had no greater difficulty than younger participants in inhibiting incongruent distractors does not support Hasher and Zack's (1998) reduced inhibition theory. Despite overall slower reaction times, older participants demonstrated a preserved ability to inhibit unwanted stimuli in their responses.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

GENERAL INTRODUCTION

In every day life we are inundated with a multitude of sensory information from the environment. To interact effectively and efficiently we must be able to identify which information is relevant to our goal, and exclude information that is irrelevant or interferes with our goal-directed actions. The visual attention system plays a vital role in selecting information from the environment and processing it in the most efficient way possible (Watson & Humphreys, 1998). It is not, however, capable of selecting infinite amounts of extraneous stimuli (Eriksen & Eriksen, 1974). To limit the amount of information processed simultaneously, it is necessary for the organism to selectively attend to the relevant (target) information and ignore the irrelevant (distracting) information (Lavie, 2005). Nevertheless, irrelevant information is processed to at least some extent, and is associated with increased response times and reduced accuracy in goal-directed actions a phenomenon referred to as distractor interference (Eriksen & Eriksen, 1974).

Importantly, there is considerable evidence that the extent of distractor interference is modulated by a variety of different factors, including the distance of the distractors from the target (Muller & Hubner, 2002; Broadbent 1958); the size of the visual array (Eriksen & St. James, 1986; Eriksen & Yeh, 1985); the perceptual load of the task (Lavie 2001; Lavie 2005); and also the distractor-target "compatibility" (Eriksen & Eriksen, 1974; Eltiti et al., 2005). Relevant to this series of experiments, the temporal separation between distractor and targets also modulates interference (Kritikos, McNeill & Pavlis, 2008; Watson & Humphreys, 1998). Specifically, distractor interference has been identified in simultaneous as well as temporally separated (particularly 200 ms intervals) target and distractor conditions, with significant effects seen in both response times and accuracy of responses (Kritikos et al., 2008; Watson & Humphreys, 1998).

It has been suggested that distractor interference is also exaggerated in the healthy older population. Recent lines of investigation have postulated that this is probably attributable to reduced speed of processing with advancing age

(Salthouse, 1996); or to impaired ability to inhibit irrelevant information (Hasher & Zacks, 1988). Given the substantial increase in the ageing population, the recent literature within this area is starting to grow. It has been well documented that ageing seems to involve a decline in both focused and divided attention; however, the exact nature of this deficit remains unclear (Maylor and Lavie, 1998). Therefore, it is important to further explore the differences between younger and older adults' selective attentional processes in order to better understand the cognitive changes associated with normal ageing. This has significant implications for the effective use of rehabilitation strategies in the ageing population. The adequate identification of deficient mechanisms involved in selective processing would ensure appropriate intervention measures would be pursued and ultimately a better quality of life for the older patient.

By implementing a distractor-target temporal separation paradigm, this project aims to investigate whether distractor interference in older populations is due to reduced speed of processing or impaired inhibition of irrelevant information (Salthouse, 1996; Hasher & Zacks, 1988). In the following sections, various theories regarding the mechanisms underlying the processes of selective attention are discussed, with reference to the fate of irrelevant information (distractors) on response selection. A selective review of the distractor interference literature looking at both younger and older participants is provided with the aim of identifying why older adults in particular are subject to difficulties with selective processing. The underlying neuroanatomical systems involved in visual attention will also be discussed and the practical implications of age-related changes to visual attentional processes will be considered.

1.1 The Process of Selective Attention and the Impact of Distractor Interference on Response Selection

The processing of relevant stimuli by the visuo-motor system involves identification, selection and isolation of stimuli from an irrelevant background based on certain distinctive characteristics so that discriminative responses to the selected items can be made (Kahneman et al., 1983). This process is generally effective in reducing interference from irrelevant stimuli (Kahneman et al., 1983). There has been debate, however, regarding the mechanisms involved in appropriate selection of information for the performance of goal-directed, successful actions. It has been suggested that such processes are dependent on the depth to which information is identified; that is, the level of conscious awareness of the presence of potentially distracting information (Kahneman et al., 1983). Different theorists have suggested that selection of information for action occurs either early (Eriksen & Eriksen, 1974; Broadbent, 1958) or late (Deutsch & Deutsch, 1973; Treisman, 1964; 1969) during visual attentional processing. The development of both theories, as well as their distinguishing features, is discussed in more detail in the following sections.

1.1.1 Early Selection Models

Broadbent (1958) pioneered research into early selective attention. He proposed that all incoming sensory information is processed in parallel and held in a temporary, short-term buffer before further processing. Within this short-term buffer, information passes through a filter into a limited capacity channel whereby irrelevant information is discarded and only goal-relevant information is selected for further processing. With the use of a dichotic listening task, Broadbent demonstrated that participants could selectively discriminate gender differences in people's voices when asked to selectively attend to a message presented in one ear and to ignore the other message which was simultaneously presented in the other ear. However, when asked to later report aspects of the ignored message in the unattended ear, participants could not report anything at all. Broadbent concluded that this was because the initially sensed information was characterized by a certain physical feature (which ear to attend to) which was identified and selected to enter a short term buffer store. The ignored message, however, remained completely undetected, as it did not possess any identifying feature to help demarcate important aspects of the "heard" information.

Thus, a common physical feature may be required so that a selective filter can identify and select goal-relevant information. This selective filter then links the incoming environmental stimuli to long term information stores for later use (Lavie, 2001). The postulated filter allows entry of novel information into the sensory system for more efficient and accurate response selection. It is thought to prevent conditions in which interference would otherwise occur, causing slower, less accurate responses (Lavie, 2001). Despite Broadbent's findings, however, some researchers assert that filtering does not block out all of the unattended information; rather, some irrelevant features can break through and can trigger a wide variety of other less accurate long-term processes (Lavie, 2001).

To understand more clearly the limitations of selective attention and also the precise mechanisms involved in such a process, researchers have manipulated the nature of the information presented to participants. The flanker task developed by Eriksen and Eriksen (1974) extended Broadbent's (1958) theory to investigate this notion. During this task participants were exposed to a linear display of letters and were required to identify target letters out of the sets (H) and (K) or (S) and (C) appearing in the center of the display. The letters were displayed for approximately one second and participants responded with a left or right sided lever press according to the corresponding side the target was positioned. The flankers (distractors) were either congruent or incongruent to the target and positioned on either side of the target between the letters in the display were to be ignored. The results indicated that reaction times were faster when the letters in the display were spatially separated, ultimately having a facilitative effect and allowing for quicker response selection and execution. Furthermore, reaction times were slower when the distractors were incongruent rather than congruent to the target. Mixed distractors (belonging to neither incongruent nor congruent sets) were found to have an intermediate effect on reaction times. Eriksen and Eriksen also found that unattended distractors seemed to be processed at the initial point of identification, early in the visual attentional process. They postulated that active inhibition mechanisms were responsible for slowing reaction times in order to suppress the unwanted irrelevant information. This was more apparent in incongruent than congruent distractor conditions, ultimately resulting in greater interference and making it harder for the participants to inhibit their responses. Slower reaction times were also evident when the distractor was presented closer to the target in space, making it harder for the participants to discriminate the letter differences, also resulting in greater interference effects. In terms of the visuo-motor system, this "bottom-up" activation was postulated to involve more stimulus-driven attentional control based on physical differences between items in the visual field (Bekkering & Neggers, 2002).

The results of Eriksen and Eriksen (1974) have been consistently replicated (Maylor & Lavie, 1998; Lavie, 1995 & 2001; Paquet, 2001; Flowers & Wilcox, 1982; Eltiti et al., 2005); and recent theorists have also argued for early selection of information for action. For example, Lavie (2001) proposed that attentional selection is applied early in the stream of information processing based on physical identifying features, implying that goal-irrelevant information has minimal influence on subsequent goal-directed actions dependent on the nature and identity of distracting information. Nevertheless, some other researchers have proposed that attentional selection is applied later in the stream of information processing, suggesting that irrelevant information is processed at a deeper level and therefore has more of a profound impact upon subsequent goal-directed actions (Flowers & Wilcox 1982). Late attentional selection is discussed in more detail in the following section.

1.1.2 Late Selection Models

In contrast to the early selection models, considerable subsequent research suggested that visual information is processed simultaneously across the visual field and that attentional selection is based on a late-location stage involving higher order processes (Muller & Hubner, 2002). More specifically, late attentional selection studies highlight the importance of the semantic content or salience of information, as opposed to simple stimulus identification or discrimination (Deutsch & Deutsch, 1963). In late selection it is proposed that people who seek specific objects in the environment have to do so with the intention of engaging in actions with those objects (Deutsch & Deutsch, 1963; Bekkering & Neggers, 2002). Therefore, in visual search, action-relevant information is detected through higher order processes (Deutsch & Deutsch, 1963; Bekkering & Neggers, 2002). This action-intention is responsible for guiding selection so that only information that is relevant to the goal is initially sought, instead of the random selection of physical stimuli, which could ultimately be meaningless and distracting to the goal at hand.

This "late selection" theory of attention proposes that "a message will reach the same perceptual and discriminatory mechanisms whether attention is paid to it or not; and that such information is then grouped or segregated by these mechanisms" (Deutsch & Deutsch, 1963). Incoming information is compared and weighted for importance using some sort of comparative mechanism (Deutsch & Deutsch, 1963). However, any signal that needs to be compared with all other possible signals would make decision times very slow and/or impossible. Thus, this theory assumes that all sensory messages are initially perceptually analysed at the highest level of processing (Deutsch & Deutsch, 1963). This is thought to be automatic and unconscious, such that all information is processed into semantic memory so that its meaning can be accessed before it reaches conscious awareness (Deutsch & Deutsch, 1963). It is thought that once the sensory information reaches semantic systems, pertinence values are then assigned (Deutsch & Deutsch, 1963). These values then allow for easier selection of information from memory stores for more efficient response selection relevant to the dynamic development of each individual goal (Deutsch & Deutsch, 1963).

Treisman's work (1964 & 1969) provides some support for late selection. She asserted that if irrelevant information had an effect on responses, such information must be initially processed and then filtered out later in the system once meaning or importance is assigned to the stimuli. The Attenuation Model (Treisman, 1964 & 1969) of attention explains that a filter may be responsible for attenuating the strength of irrelevant stimuli, rather than entirely blocking it out. This means such information may enter the stream of information processing and still affect response selection and execution. Also known as the "Feature Integration Theory" of visual attention, this theory proposes that if one is attending to a stream of events in one channel, information can still breakthrough from the unattended message, especially in circumstances in which there is a meaningful relationship between the two sets of information. Rather than blocking out all irrelevant information, the filter attenuates or reduces the strength of the channels that do not require attention. Therefore, partial information that is consistent with current expectations or that is personally relevant could still eventually enter consciousness and long-term memory stores after full processing (Feintuch & Cohen, 2002).

An example of such attenuation can also be seen in a study by Watson and Humphreys (1998) who showed that new items can be prioritised for selection by the top-down attentional inhibition of old stimuli already in the field, using visual marking. They used a single-feature search task (blue H target among blue A distractors), and a conjunction task (blue H target among green H and blue A distractors) as baselines for their third condition which included a temporal interval between the distractors from each colour (gap condition). In the gap condition, the green distractors were presented alone for 1,000 ms, and then both the blue items were added. "Old" distractors presented at 1,000 ms were to be ignored. They found responses were just as efficient in the gap condition as when the targets were presented alone. This was called the gap effect. Watson and Humphreys (1998) concluded that participants marked and inhibited the initial old green distractors, allowing priority to be given to the new blue items added later. They theorized that this was due to visual marking or a top-down goal based inhibitory process (which is estimated to take approximately 400 ms to initiate). They proposed that the initial distractors led to the development of an inhibitory template that specified the location in which inhibition should be applied. This inhibition was thought to be applied to the location or intra-identifying details of the target, to decrease the priority of old stimuli in subsequent trials in competing for selection. Overall, Watson and Humphreys concluded that visual marking was responsible for attenuating the strength of the old irrelevant information so that more important novel information (which was relevant to the goal) could be selectively attended to.

Another way of manipulating interference effects is by maximising or minimising the capacity limitations of selective processing. The perceptual load theory of attention combines both early and late selection by asserting that early selection exists due to limited perceptual capacity and that late selection occurs by automatic perceptual processes, so long as there are available attentional resources (Lavie, 2005). This means that early or late selection depends on the perceptual load of the visual scene (Lavie, 2005). This hypothesis was developed based on the theory that perception has a limited capacity (as in early selection) but processes all stimuli in an automatic and mandatory fashion (as in late selection) until it runs out of capacity (Lavie, 2005).

To investigate this assumption, Lavie (1995) used a display with low perceptual load (a small number of items in the display) which allowed plenty of attentional resources to be allocated to the distractor. In such a display, participants found it hard to engage in focused attention as attentional resources were not exhausted, therefore there was more chance for interference to take place. She hypothesised a limited amount of attentional capacity limits were taken up by task-relevant information, therefore the remaining resources "spilled over" into task-irrelevant information, ultimately leading to an increased likelihood of distractor interference. Conversely, in a display with high perceptual load (increasing the number of items in the display). Lavie found there were minimal attentional resources and therefore minimal chances for attention to be allocated to a distractor and consequently less interference effects. This led to the notion that high perceptual load engages full attentional capacity so that there is limited space available for task-irrelevant stimuli. In other words, high-load evoked focused attention because attentional resources were exhausted.

Thus, selective attention can result in either selective perception (early selection) of relevant information or unselective perception of relevant and irrelevant information (late selection), dependent on the perceptual load involved in relevant processing (Lavie, 2005). This model has received support from a number of studies (Lavie & Cox, 1997 & 2000; Paquet, 2001; Kahneman et al., 1983; Eltiti et al., 2005) that manipulate both perceptual load and processing of target-irrelevant information by examining flanker (distractor) interference effects.

Overall, the debate between early vs. late selection is ongoing in the research literature and it seems that both theories hold some credence and are dependent upon the amounts, types and speed of information presented (Eriksen & Eriksen, 1974; Treisman, 1964 & 1969; Lavie, 1995; Watson & Humphreys, 1998). What is apparent is that attentional selection is not as simple as once proposed. Instead of the uncomplicated idea of selective attention being a singular filtering process, other factors also need to be considered. For example, the varying degrees of selective processing may vary according to differences in task demands and dynamic changes in stimulus presentation. Selective attention is now viewed as a more complex pool of processing resources, which may vary according to the nature of the environment (Posner, 2004). These constraints can ultimately affect accuracy and efficiency in the execution of response decisions and can lead to "distractor interference" which is discussed in more detail in the following section.

1.1.3 Distractor Interference

Distractor interference occurs when irrelevant information has an impact on processing of relevant information, and typically manifests as impaired response selection, either by increasing response times or by decreasing accuracy in performance to a given stimulus. Generally, distractor interference or "interference of task-irrelevant information" may occur in two different stages of selective processing. The first stage is when attention fails to filter out the distractors, impairing target perception; or when the distractors perceptually degrade the representation of the target, ultimately causing perceptual interference (Jiang & Chun, 2001). The last stage occurs when the response codes (anticipated response styles triggered by a given stimulus) of the target and distractors are incompatible, impairing response selection of the target (response interference) (Jiang & Chun, 2001). Imperfect filtering at both the perceptual identification and response selection stage may therefore increase processing of distractor items and enhance chances of response interference (Jiang & Chun, 2001). These two types of distractor interference may rely on different subsystems of attention; however, they may not be completely two separate entities (Jiang & Chun, 2001). In order to examine the varying types of interference and their effects on attentional processing, many studies have attempted to modulate the effects of environmental stimuli in controlled priming tasks. Some of these studies are discussed in more detail in the next section.

1.1.3.1 Modulation of Distractor Interference

Distractor interference is modified by a wide range of extraneous factors such as; the distance of the distractors from the target (Muller & Hubner, 2002; Broadbent 1958); the size of the visual array (Eriksen & St. James, 1986; Eriksen & Yeh, 1985); the perceptual load of the task (Lavie 2001; Lavie 2005); and also the distractor-target "compatibility" (Eriksen & Eriksen, 1974; Eltiti et al., 2005). For example, interference or negative priming is generally associated with a small distance between distractor and target items (Eriksen & Eriksen, 1974); a larger visual array of items (Eriksen & St. James, 1986; Eriksen & Yeh, 1985); low perceptual load (Lavie 2001; Lavie 2005); and distractors that are incongruent or incompatible with target items (Eriksen & Eriksen, 1974; Eltiti et al., 2005). In contrast, facilitation or positive priming occurs when there is a larger distance between distractor and target (Eriksen & Eriksen, 1974); a smaller visual array of items (Eriksen & St. James, 1986; Eriksen & Yeh, 1985); high perceptual load (Lavie 2001; Lavie 2005); and when distractors are congruent or compatible with target items (Eriksen & Eriksen, 1974; Eltiti et al., 2005).

Priming tasks in general involve the presentation of a stimulus (prime) followed by another second target stimulus (probe) to which the participant responds. Response to the probe is thought to be facilitated if the prime is either visually or semantically associated with it, resulting in "positive priming" (Driver & Tipper, 1989). If the first stimulus is not related, reaction times tend to increase and "negative priming" becomes apparent (Driver & Tipper, 1989; Kritikos et al., 2008). Increased interference effects due to negative priming is thought to occur as a result of the time it takes to inhibit the initial distractor and then to allow the selection and execution of a correct response to a target (Driver & Tipper, 1989). In terms of selection, the stimulus is either discriminated based on its physical characteristics in early processing models, or on an internal representation such as a past memory of the target in later processing models (Driver & Tipper, 1989).

Such studies that investigate the modulation of distractor interference have demonstrated positive or negative outcomes on selective attention, which are dependent on manipulations within a given environment, but do not explain what is happening within the given attentional construct/paradigm itself. Despite its complex and dynamic range of functions, the selective attention system may also be limited by certain processing constraints. Why is the process of selective attention subject to fallibility? In what circumstances does the selective filter allow entry of potentially distracting information, and why? These questions are examined more closely in the next two sections by firstly looking at the timing of distractor presentation and then the impact of distractor salience/identity on response selection.

1.1.4 Rapid Serial Visual Presentation Paradigms

Only some segments of a visual display can be processed at any given time, whilst the other segments must wait (Jiang & Chun, 2001). Rapid serial visual presentation (RSVP) tasks involve series of distractor items (digits, letters, words etc.) which are presented sequentially in time. The time that attentional focus remains fixated on a single stimulus can be measured according to the speed and/or accuracy of visual search (Duncan et al., 1994). If the time to detect a target increases with the number of non-targets presented in a visual display, then one would presume that attention moves rapidly and serially from one object to another until the target object is found (Duncan et al., 1994). With any longer response time to a given stimulus it is presumed that there is some form of limited-capacity parallel processing (Duncan et al., 1994). More specifically, attention can be divided between several objects at once. However, there is an increasing cost in terms of speed as the number of attended objects increases (Duncan et al., 1994). This cost, referred to as "attentional dwell" and is measured according to reaction time to a given stimulus (Duncan et al., 1994).

Furthermore, when two signals are presented in rapid succession, reaction times to presentation of the second stimulus depend on stimulus onset asynchrony (SOA), which refers to the timing of the presentation between the first and second stimulus (Gathercole & Broadbent 1987). Short SOAs result in slower reaction times when compared to longer SOAs (Gathercole & Broadbent 1987). So when an SOA is relatively small, there is a corresponding increase in reaction time (Gathercole & Broadbent 1987). This has also been coined the "bottle neck" whereby processing of the first stimulus must be completed before the second stimulus can be processed (Gathercole & Broadbent 1987). This means that once an initial target is identified, the magnitude of interference depends on temporal intervals for subsequent target items. Thus, the time it takes to process small amounts of information may impact on processing of subsequent information if presented in rapid succession. More specifically, Kritikos et al. (2008) identified a temporal interval (0 -200 ms) in which the processing of relevant information was susceptible to disruption from residual processes relating to the previously presented irrelevant distractor. As the interval between the distractor offset and target onset increased (500 - 600 ms), distractor interference effects were replaced by potential facilitation of the relevant target response.

Other studies using rapid RSVP have demonstrated that temporal selection for a single target is quite rapid (approximately 100ms); however, if two targets in a series must be identified, identification of the second target is impaired if it follows the first target within 100-500ms (Jiang & Chun, 2001). This phenomenon has been called the "attentional blink" (Raymond, Shapiro & Arnell, 1992). It has been suggested that it only occurs if the first target needs to be reported (Jiang & Chun, 2001). An attentional blink uses all attentional resources to process an initial stimulus so that there is not enough readily available to process a second stimulus immediately. Therefore, the second stimulus may be overlooked simply because the selective attentional system does not have enough capacity to take in both sets of information at once. An attentional blink is not considered to be due to "sensory" interference, because if the first target is asked to be ignored, no attentional blink is apparent (Jiang &

Chun, 2001). The second target performance can be improved once the interval between the two targets increases (Jiang & Chun, 2001).

Duncan, Ward and Shapiro (1994) used a visual search task to directly measure how long an identified object continues to occupy attentional capacity. They presented several display items at unpredictable locations within a single trial but separated by different time intervals. Subjects were asked to identify the first object. Then, the second object was presented after varying time intervals and the interference of the first object on the second object was measured as a function of temporal separation. Temporal separation intervals ranged between 0-900ms. At intervals of 100-300ms, the second object was identified with less accuracy than the objects presented simultaneously. This was thought to be due to even division of attention in simultaneous conditions, compared to the impact of focused attention on the first object when the presentation was asynchronous. Interference declined with separations greater than 300ms. Duncan and colleagues concluded that the time that an identified object continued to occupy attentional capacity was between 100-300ms. They asserted that attention to a relevant object is a sustained state during which the object is available to awareness for the control of the behaviour. If the behaviour is effectively controlled it results in positive priming, as it has no effect on speed of visual search or accuracy. Suppression of neuronal responses to ignore objects develops over several hundred milliseconds, as does the interference with subsequent inputs shown in behaviour responses. Such circumstances result in negative priming effects as the utilisation of active inhibition mechanisms interferes with speed of processing as well as accuracy of response selection.

Olivers and Watson's (2006) RSVP study also demonstrates positive and negative priming effects as a function of temporal separation as well as stimulus identification. They presented participants with target letters that differed in color from distractor letters for 100ms followed by a 33ms blank. This was then followed by a display containing a varying number of dots (between 0 and 5 or 0 and 3 dots) for 100ms followed by a 33ms blank screen. The color of the dots was the same as the target, the same as the distractor or completely different. The RSVP stream ended with a mask containing numerous white dots in a black background for 853ms. Participants were then asked to report the letter that was present and how many dots were apparent. Olivers and Watson reported that the task of identifying the target letter resulted in an attentional blink for the subsequent dot patterns. Interestingly, this effect was reduced when the dots were the same color as the target letter. In contrast, performance was hindered when the color of the dots was the same as the distractor letters or different to the target. Similarity between the targets also affected competition between the different sets of dots presented simultaneously within a single display. These results highlight not only the importance of the timing of the targets and distractors in the display sequence, but also the importance of identity of the distractor and its effects on response selection. More specifically, targets which were compatible with distractors (same color) seemed to have a more facilitative effect compared to those targets which were incompatible (different color) to the distractor.

In conclusion, the timing of sequentially presented information is imperative as it allows researchers to examine the changing influences of internal representations (of external information) on responses to targets over time. This timing factor can enable researchers isolate the effects of distracting information at different stages of information processing (Flowers & Wilcox 1982). That is, at the level of perception, encoding or response execution (Flowers & Wilcox 1982). Overall, the RSVP research tends to yield consistent findings such that smaller temporal intervals between distractor offset and target onset (0 - 200 ms) are associated with maximal interference effects when identifying and responding to subsequent target items, whilst larger temporal intervals (500 ms - 600 ms) are associated with a reduction in the degrees of interference (Kritikos et al., 2008). Interference effects tend to diminish once they reach a critical interval of about 1000 ms (Kritikos et al., 2008; Eltiti et al., 2005; Watson & Humphreys, 1998).

Despite methodological differences, most RSVP studies have shown that systematic manipulation of the timing of distractor presentation may isolate interactions occurring at different stages of target classification (Flowers &

Wilcox, 1982). This may prove to be an effective method of identifying specific deficits in populations suffering from difficulties in attentional processing. More specifically, it may help to identify whether a patient is experiencing troubles with encoding information vs. response selection or execution. Furthermore, as already addressed in Olivers and Watson's (2006) study, the identity/nature of the distracting information can also have differential effects on response selection or execution by also impacting on response times and accuracy of visual search. That is, the type of selective processing utilised within the visuo-motor system is also dependent on the identity of the distractor-target stimulus. This effect is discussed in more detail in the next section.

1.1.5 Distractor-Target Compatibility

The effect of modulating distractor-target compatibility was first systematically demonstrated in the flanker task developed by Eriksen and Eriksen (1974) whereby flankers were either congruent or incongruent with the target. As described in section 1.1.1, Eriksen and Eriksen reported differential effects of distractor compatibility, such that incongruent distractors caused more interference than congruent distractors, while neutral distractors had an intermediate effect. This means that an incongruent distractor is different to the target uncovered in the same response set (for example, target H with I, or target I with H). Compatible distractors are indistinguishable from the target item (for example, target H with H). Neutral distractors are visually well-defined and bear no relationship with both the distractor and target items (for example, target H with Z). These results have been consistently replicated (Flowers & Wilcox, 1982; Gathercole & Broadbent, 1987; Watson & Humphreys, 1998; Olivers & Watson, 2006).

A more recent study, however, by Kritikos, McNeill and Pavlis (2008) extended Eriksen and Eriksen's findings in their research design. The results of their study using sixteen participants found distractors incongruent to the target were associated with the highest response latencies, followed by neutral and congruent distractors, for both simultaneous and temporally separated distractor-target presentations. The incompatible distractor was thought to prime a response that was linked to, but in opposition with, the relevant target response, thus maximizing interference (response competition). The compatible distractor was thought to result in minimal interference due to the fact that there was less response competition produced by the item that was "identical" to the target. The neutral distractor brought about an intermediate amount of distractor interference, as it was unrelated to the target response set. Overall the results concluded that the amount of response competition therefore modulated the amount of filtering required to "block out" the potentially distracting information within the visuo-motor attentional system. That is, as response competition increased, so did the activation of inhibition mechanisms on response selection.

Gathercole and Broadbent (1987) also demonstrated this effect by varying the intervals with which distractors preceded the onset of targets. In their study, the distance between targets and distractors was either 0.6 or 1.9 degrees of visual angle. A target letter was flanked by a distractor on either side for each trial. The participants had to press one of two keys according to whether the target letter was A or B. Distractors were either congruent or incongruent. Four SOAs were compared. Distractors preceded the target by either 40 ms or 20 ms, or appeared 20 or 40 ms after the target. Congruent distractors presented prior to target presentations led to faster RTs irrespective of spatial location (near to or far from the targets). Thus, preceding congruent distractors had a facilitative or positive priming effect on subsequent responses. Incongruent distractors presented prior to target presentations led to slower RTs irrespective of spatial location (near to or far from the targets). Thus, preceding incongruent distractors had an obstructive or negative priming effect on subsequent responses. Distractors (both congruent and incongruent) did not influence target performance when presented after the target in both the near and far conditions. This study highlights that this negative priming effect is dependent on stimulus identification, that is, when spatial location is not taken into consideration, incongruent distractors elicit active inhibition mechanisms responsible for slowing down response times and decreasing accuracy of responses. In contrast, congruent distractors do not require active inhibition to take place, therefore do not affect speed or accuracy of responses, and instead, may increase accuracy and efficiency of responses resulting in positive facilitation.

Flowers and Wilcox (1982) also investigated the changing patterns of interference and facilitation caused by congruent, incongruent and neutral distractors as a function of temporal and spatial separation between target digits and distractors. Using a naming procedure, they found significantly greater reaction times (interference effect) for those distractors that were incongruent to the target, especially when presented 100 - 200ms prior to the target. Faster reaction times were noted when a congruent distractor preceded the target. This facilitative effect was thought to be due to the fact that the congruent distractors overcome the initial perceptual interference that occurs when identical visual features are presented simultaneously. Facilitative priming effects may, therefore, result from processes that differ from those that contribute to interference when incongruent distractors are present. This suggests that facilitation and interference effects may follow different time courses. In a narrower range of temporal and spacing levels, Flowers and Wilcox found that interference effects/negative priming was most marked at the smallest temporal interval and attenuated with longer delays. In contrast, facilitation effects incremented over the first 100ms and were maintained throughout the longer temporal levels. Interference also declined strikingly with increases in spatial separation, whilst facilitation affects were still apparent with wider separations. Once again, these data support the concept that facilitative priming and response-competition interference are not the manifestations of the same set of process interactions and in fact involve two separate mechanisms. That is, facilitative priming allows entry of novel information into the visuo-motor system so that active inhibition mechanisms are not utilised, whilst negative priming or increased response competition triggers active inhibition mechanisms so that potentially distracting information is filtered out.

As discussed in sections 1.1.4 and 1.1.5, selective processing and response execution is dependent on the timing and nature of the distracting stimulus. This type of paradigm may also be usefully applied to research with older adults in order to gain a better understanding of age related changes in cognitive functioning and identify the specific mechanisms involved in such changes. Age associated changes in cognitive functioning are discussed in more detail in the following section and are then linked to studies which try to elucidate which attentional constructs are responsible for such changes with advancing age.

1.2 Theories Of Attention/Cognition in the Ageing Population

The brain changes associated with normal ageing tend to affect particular areas of cognitive functioning, specifically fluid intellectual and cognitive abilities (Troller & Valenzuela, 2001). The Cattell-Horn theory of fluid and crystallised intelligence proposes that intelligence in general, involves a complex assortment of approximately 100 abilities that work together in many different ways to bring about a wide variety of multiple intelligence's (Horn & Cattell, 1966a). This theory divides cognitive abilities into two broad domains, which take on widely discrepant courses throughout one's development from childhood to adulthood (Horn & Cattell, 1966a). These include crystallised abilities (Gc) which are obtained via learning and acculturation and are reflected in tests of knowledge, general information, vocabulary and many other acquired skills (Horn & Cattell, 1966a). In contrast, fluid abilities (Gf) are those that drive one's ability to think and act quickly, solve novel problems, and encode short-term memories (Horn & Cattell, 1966a). That is, those abilities that involve cognitive faculties responsible for the attainment of new information (Horn & Cattell, 1966a). These include skills such as attention, memory, information processing, mental control and executive functioning (Horn & Cattell, 1966a). Fluid abilities rely on physiological efficiency and not heavy encoding of already acquired skills (Horn & Cattell, 1967). It is these fluid abilities that tend to be more readily affected by the ageing process. Both cross-sectional and longitudinal studies have found reductions in fluid abilities by the age of 50 with speed of information processing, working memory and complex attention particularly affected (Troller & Valenzuela, 2001). Older adult strengths tend to lie with strong acquisition of cultural, personal and historical information relatively unaffected by the ageing process (Troller & Valenzuela, 2001). These are crystallised abilities based on accumulated knowledge extrapolated from exposure to education, culture and information over time (Troller & Valenzuela, 2001).

It has been proposed that declines in attention may underlie the other changes seen in fluid cognition associated with normal ageing. Stankov (1988) used part correlation's to establish the relationship between attentional processes and fluid and crystallized intelligence. He found that a decrease in fluid intelligence with increasing age disappears when attentional factors are partialled out. He also found an increase in crystallized intelligence with increasing age when attentional processes were controlled. This implies that age-related declines in fluid functions might be predominantly due to a deficiency in attentional processes. Nevertheless, the multifaceted nature of attention as well as the complex experimental control required to study it has slowed investigations in this area of research involving the ageing population. A consensus view of changes underlying the mechanisms and processes of attention in the ageing brain has not yet emerged.

Furthermore, there are other physical systemic changes related to normal ageing which may affect visual attention, such as sensory deficiencies and slowed neural transmission, independent of primary changes to attention. For example, Kaneko, Kuba, Sakata, and Kuchinomachi (2004) showed that alterations in saccadic eye movements have been mistakenly associated with age related difficulties with visual selective attention in some studies. They proposed that with advancing age saccadic latencies increase, and saccadic accuracy and velocities decrease (Kaneko et al., 2004). It is this saccadic eye movement towards a location in the visual field which may be mistaken for a shift of spatial attention to the location (Kaneko et al., 2004).

It is also proposed that people with advancing age tend to have a restricted scope of visual attention. Kosslyn, Brown and Dror (1999) investigated whether cognitive deficits associated with ageing were related to a restricted scope of visual attention, by comparing older and younger cohorts on a visual search task. They measured adjustment of attention according to the speed and accuracy of responses. They reported that older adults found it easier to adjust their attention to the smaller display scope and had difficulties focusing on larger regions of space, suggesting that older adults might have a restricted visual attentional field. In contrast to these findings however, other studies have suggested that attention selectivity in specific perceptual/feature dimensions (e.g. color or spatial location) remains unaffected and is comparable to younger cohorts (Madden et al., 2002).

Overall, these sensory and perceptual difficulties can in turn impact upon higher level cognitive abilities such as speed of information processing, inhibition and mental flexibility. These cognitive functions are discussed in more detail in the following sections.

1.2.1 Speed of Information Processing and the Ageing Brain

An alternative explanation for the changes in visual attention seen in normal ageing adults proposes that a primary cognitive deficit may be reduced processing speed. The processing speed theory of adult age asserts that the speed with which many cognitive operations can be executed ultimately affects aspects of cognitive functioning including memory (Salthouse, 1996). It is thought that generalized slowing causes a decrement in the power and efficiency of working memory which impairs other higher order functions such as attention, memory, decision making and thinking (Salthouse, 1996). Even quite simple visual attentional tasks such as the identification of individual search items, and shifting attention to different visual display locations are usually associated with longer reaction times in the ageing population (Salthouse, 1996). Therefore, a general age-related slowing of information processing may underpin age-related declines in selective and divided attention, rather than there being a decline in actual attentional processes themselves (Salthouse, 1996).

The reduced speed of processing theory involves two theoretical assumptions. The first is that performance on cognitive tasks is limited by general processing constraints, including restrictions of knowledge (declarative, procedural, and strategic), and variations in the efficiency or effectiveness of specific processes associated with ageing (Salthouse, 1996). The second is that speed of processing is a critical processing constraint associated with increasing age and in particular may also be related to a decrement in fluid cognitive abilities in general (Salthouse, 1996).

Salthouse (1996) describes two distinct mechanisms, which are responsible for the relationship between speed and cognition with advancing age. The first is called the limited time mechanism, whereby relevant cognitive operations are executed too slowly to be successfully completed in time. The second is the simultaneity mechanism, whereby a reduction in processing speed limits the amount of simultaneous information available for higher level processing. That is, information is decayed or displaced before relevant processing can occur. Therefore, early processing may be lost by the time that later processing is completed. This means that higher order problem solving efficiency is ultimately impaired, as lower operations are too slow to integrate relevant information for further processing. Thus, processes such as abstraction, elaboration or integration may be affected, leading to increased errors or repetitions of critical processing operations which ultimately affect the time it takes to complete such tasks. Craik and Byrd (1982) also propose more complex, novel, stimulus response patterns are more difficult to implement with advancing age, as they require substantial processing resources as opposed to stereotyped, habitual, over-learned patterns of behaviour.

Tests of perceptual speed usually involve a series of repetitive operations and responses including "search, comparison, matching and substitution procedures" (Salthouse et al., 1998, pp. 445). All perceptual speeded tasks involve multiple switching or constant redirection of attention (Salthouse et al., 1998). Salthouse and colleagues (1998, pp. 445) propose that in simple comparison tasks, "individuals must focus on the first element and encode it; switch attention to the second element and encode it; make a decision; switch attention to make a response; and then switch attention to the next item and repeat the sequence of operations." Therefore, switching between operations may also be a critical factor in contributing to age related differences in processing speed as well as higher order cognitive abilities. A study by Salthouse et al. (1998) found individual differences in the ease and efficiency with which participants could shift from one task to another and actually perform individual tasks. They found measures of task switching were moderately correlated across different combinations of individual tasks and that such tasks could be distinguished from measures reflecting processing speed in general. They also found that measures of task switching were also correlated significantly to adult age (e.g. older adults had more difficulty switching) and measures of cognitive functioning (e.g. people who could switch faster had higher levels of cognitive performance). Nevertheless, once baseline reaction times were statistically controlled, switching was not statistically related to age or to measures of higher order cognition. Instead, processing speed was more closely related to age-cognition declines in functioning. Their results highlight that even though switching can be perceived as an individual construct, it also involves inter-relationships with other variables, which are not unique to switching solitarily.

Overall, Salthouse proposes that the major cause of age-associated changes in cognitive function is processing speed, which ultimately affects other higher order cognitive operations. Another factor which is also thought to impair higher order cognitive operations, particularly with advancing age, is the ability to inhibit unwanted stimuli or distracting information (Hasher & Zacks, 1988). This is discussed in more detail in the next section.

1.2.2 Inhibition Mechanisms and the Ageing Brain

In contrast to Salthouse's processing speed theory, Hasher and Zacks (1988) proposed that the major cognitive change associated with normal ageing is a decrease in the ability to inhibit unwanted stimuli and responses. This leads to the amplification of unwanted information in working memory, making it harder to ignore irrelevant information and exert conscious control over a wide range of mental processes. In addition to any excitation associated with the target, they proposed that the detection of a target stimulus involves a suppression or inhibition process that operates on response tendencies toward unselected stimuli. It is proposed that this lack of inhibition can be measured according to carryover effects or negative priming which ultimately impacts on target selection in subsequent trials. Hasher, Stolzfus, Zacks and Rypma (1991) examined this notion using a letter-naming task in which participants were asked to name one of two letters (based on colour) in each series of trials. This involved being able to name some of the letters (e.g. those that were red, green or yellow) and inhibit those letters that were a specified colour (e.g. blue). Hasher and colleagues hypothesised that irrelevant information would lead to smaller response times in older adult populations due to the fact that they would not have the resources to suppress it, and therefore it would not reach conscious awareness. They found this to be the case. The older adult group showed no evidence of negative priming, suggesting that they were not processing the distractor letter whilst selecting the target. Negative priming was evident in the younger group, reflective of intact inhibitory functioning.

Maylor and Lavie (1998) extended and added further support to this theory with their perceptual load hypothesis. In their study, sixteen older (age 65-79) and sixteen younger (19-30) adult participants made speeded choice responses in order to detect two target letters in the center of a visual display whilst ignoring the distractor item in the periphery. Perceptual load was manipulated by varying the central set size (set sizes of one to six non-target items). Maylor and Lavie found when the relevant set size was small (one to two non-targets), the interference from the incompatible distractor was greater for the older participants when compared to the younger participants, providing support for Hasher and Zacks' (1988) reduced inhibition theory of ageing. Thus, in conditions of little or no load, the older adults had more difficulty inhibiting distracting information. In addition, the distractor effect was decreased for older participants at low levels of perceptual load (e.g. four non-targets) than it was for younger participants (for whom it was reduced with a set size of six). Therefore, there was a more pronounced improvement in distractor suppression with the increase in load.

Maylor and Lavie concluded older adults have an impairment in the ability to focus on relevant stimuli in response to competing inputs, or a decline in the ability to sustain focused, selective attention. This selective attention difficulty was thought to be due to an inability to suppress irrelevant responses to perceived distractors, specifically, a decline in inhibitory control mechanisms. This was thought to result in greater effects of incompatible distractors on target selection, compared to younger adults. This adds support to the inhibitory control hypothesis, and may be associated with deterioration of the frontal lobes with ageing (Lavie et al., 2004). However, these results may also be interpreted to support Salthouse's (1996) limited processing resources theory that postulates older adults do not process the distractor items due to reduced perceptual capacity, which is ultimately exhausted, by relevant target processing. This was due to the fact that lower levels of perceptual load were needed to reduce distractor interference in older subjects. This results in more profound improvements in selectivity in older adults with smaller increases of perceptual load.

Overall, once sensory and perceptual changes are accounted for, there is a debate about whether speed of processing is the primary cognitive deficit in normal ageing, or whether there are additional deficiencies including a reduction in the efficacy of inhibitory processes. In order to elucidate which factors are more likely to account for age-related difficulties with selective attention, researchers have used a wide range of distractor interference tasks. The next section reviews the current literature looking at distractor interference effects in older adults.

1.2.3 Distractor Interference and Ageing

Considerable evidence suggests that a significant characteristic of the normally ageing cognitive system is a decline in selective attention (Simone & Baylis, 1997). Such deficits have been consistently demonstrated in divided attention tasks such as visual search, with responses of older adults more impaired by presentation of irrelevant stimuli than younger adults (Simone & Baylis, 1997). Such deficits have been consistently demonstrated in divided attention tasks such as visual search, where older adults seem to be more distracted by irrelevant stimuli (Simone & Baylis, 1997). As discussed above in section 1.2, some researchers propose this is due to a decline in older adults' ability to locate task relevant information in the visual field (Kosslyn et al., 1999; Kaneko et al., 2004). Others have postulated that it is due to older adults' increased susceptibility to interference when the task is more effortful or demanding due to generalized slowing mechanisms (Salthouse et al., 1998; Craik & Byrd, 1982). Some postulate these deficits are due to impaired inhibitory mechanisms (Simone & Baylis, 1997; Hasher & Zacks, 1988). In contrast, some studies which examine the effects of age on visual search tasks find no age related differences in performance at all (Gamboz, Russo & Fox, 2002; Verhaeghen & Meersman 1998).

It is still unknown whether normal ageing has a primary detrimental effect on selective visual attention, or whether the effects reported are mediated by another more fundamental deficit such as the age-related decline in processing speed. Researchers have utilised a variety of different paradigms to elucidate the specific constructs/mechanisms responsible for age differences in selective attention, including temporal sequencing and negative priming as well as the effects of perceptual load which are discussed in more detail in the following sections.

1.2.3.1 Rapid Serial Visual Presentations and Older Adults

As discussed in section 1.1.4, during RSVPs of between ten and twelve items per second, it is difficult for younger adults to detect a second target when it is presented between 200 ms and 600 ms (Kritikos et al., 2008; Eltiti et al., 2005; Watson & Humphreys, 1998; Duncan et al., 1994; Jiang & Chung, 2001; Broadbent & Broadbent, 1987). This impairment is called "attentional blink" and is a temporal measure of attention that is yet to be identified specifically in older populations (Maciokas & Crognale, 2003).

RSVP paradigms provide a means with which to potentially distinguish between theories of age-related deficits due to cognitive slowing or reduced attentional resources or impaired selective attentional mechanisms (Maciokas & Crognale, 2003). This is because they involve a timing factor that helps researchers isolate the effects of information at different stages of information processing (Flowers & Wilcox 1982). This is thought to help determine whether selective attention falters at stages of encoding or response execution in an attempt to identify whether ageing is generally associated with a deficiency in speed of information processing in general or cognitive/response inhibition. Maciokas and Crognale (2003) sought to do this using RSVP to measure attentional blink in younger (age from 18 to 27) and older (age from 64 to 79) participants. Their experiment involved identifying a target amongst a series of distractors, whereby participants ignored the first target, thereby directing attention to the second target only. They used a 20-framed RSVP with intermittent time intervals of 111 ms. Each trial consisted of 18 digits (distractors) and two letters (targets). They found that the older group's performance was relatively affected by reduced processing capabilities, as they were comparatively slower to respond when compared to the younger group. They found older participants were unable to ignore the first target during the trials. They proposed that this was because the distractors seemed to involuntarily capture attentional resources and impair subsequent target identification even thought they were asked to ignore the first target presentation. This finding adds further support for Hasher and Zacks (1988) notion that age is associated with reduced distractor suppression capabilities.

Palfai, Halperin and Hoyer (2003) also tested RSVP on 30 younger (mean age 19.1 years) and 33 older adults (mean age 69.2 years) using Chinese symbols (which held little semantic value for the participants). These symbols were presented for 500, 1000, 2000, 2500, 3000 and 6000 ms across six fixed sequences for each participant. They found recognition accuracy to be higher for the younger adults compared to the older adults, especially at shorter stimulus durations; however, performance accuracy differences between the groups were ameliorated with longer stimulus exposure times. Palfai and colleagues concluded that a limited time mechanism, such as that proposed by Salthouse (1996), could account for the age-related differences in memory for rapidly presented information, as the older adults performed similarly but were slower at encoding the information.

In a more comprehensive analysis, McDowd and Filion (1995) also used RSVP tasks to examine the effects of temporal separation on inhibitory function in older adults. They presented younger and older participants with an initial preparatory interval (PI) of either 3000 ms or 1,500 ms followed by a prime display (for 150 ms with either an x or o positioned in two of four locations); then a probe display (for over 350 ms until response is made, with either an x or o positioned in two of four locations); a negative prime (for 150 ms, with either an x or o positioned in two of four locations); and a repetition prime (until response is made, with either an x or o positioned in two of four locations and was a repetition in location of the stimulus between the prime and the probe).

During the shorter preparatory interval, responders showed more negative priming (distractor inhibition) suggesting they relied on more inhibitory processes to accomplish selection. Whilst during the slower prime trials responders showed more repetition priming demonstrating a reliance on more facilitation processes to accomplish selection. So the preparatory set allowed the participants more time to fully process the information and elicit the correct response. There was a statistically inverse relationship between negative priming and facilitation that may be due to the fact they relied on the same limited-capacity resource (when conditions are conducive to one type of resource then the output of the other is reduced). Furthermore, the response trials that were slower produced less negative priming in older than younger adults (PIs of 3000 ms). This was thought to be due to the fact that the older adults were less prepared to inhibit the distracting information in such conditions. The overall results indicated that the timing of stimulus presentation was important in age differences in inhibitory and facilitative functioning.

In conclusion, most RSVP studies support the contention that ageing is associated with deficits in speed of information processing (Maciokas & Crognale, 2003; Palfai et al., 2003; McDowd and Filion, 1995). Impaired inhibitory processes also seem contribute to the reduced performance seen in older adults (Maciokas & Crognale, 2003; McDowd & Filion, 1995). There has, however, been conflicting debate as to whether negative priming studies measure this specific selective processing construct solitarily or whether there are other unidentified sub-components involved (Simone et al., 2006). Therefore the next section is dedicated to examining this debate in an effort clear any current misconceptions and also in an aim to identify any flaws in current research designs which contribute to these misunderstandings.

1.2.3.2 Negative Priming and Older Adults

Research on negative priming has been plagued with inconsistent results in the ageing literature (Simone et al., 2006). The negative priming effect in selective attention tasks occurs when information about the previous occurrence of a stimulus is retrieved and assessed with the aim of either to "ignoring" or "responding," ultimately resulting in slowing down of reaction times (Simone et al., 2006). Some studies have used the response competition paradigm which has shown that adults experience greater interference from an incompatible distractor (as demonstrated by slower RTs) than younger adults and have attributed this to either a deficit in cognitive inhibition or episodic memory retrieval (Simone et al., 2006). In general, cognitive inhibition involves being able to inhibit the unwanted distracting information and select and elicit an efficient response (Simone et al., 2006). If one's ability to cognitively inhibit unwanted stimuli is degraded, it will take more time to process extra information and deliberate about response selection, ultimately affecting the time it taken to respond (Simone et al., 2006). Reaction times in selective attention tasks may also be affected by episodic memory retrieval. When a target stimulus appears, it cues the retrieval of past episodes from memory that involve a highly similar stimulus and the response elicited in such circumstances (Simone et al., 2006). So in what circumstances does cognitive inhibition or episodic retrieval cause negative priming or distractor interference effects in older vs. younger populations?

In their comprehensive analysis, Kane and colleagues (Kane, Hasher, Stoltzfus, Zacks, & Connelly, 1994; Kane, May, Hasher, Ranhal, & Stoltzfus, 1997) examined whether negative priming effects were due more to memory or inhibition difficulties. They found that by encouraging memory retrieval (difficult vs. easy useful information to retain) of the target (in attended repetition trials) they elicited a carryover effect on distractor processing which resulted in more negative priming in older adults. For older adults, Kane and colleagues found negative priming was largely determined by whether episodic retrieval was induced; that is, when it was induced, negative priming effects became more apparent. Younger adults also demonstrated negative priming under both retrieval and non-retrieval conditions. Overall, there was no significant difference between the two groups. They determined that the size of the negative priming effect was dependent on ease of stimulus detection in the display and the nature of the context of the experiment. This study highlights the importance of the context with which the construct is being examined. For example, studies using letter and word naming have generally produced smaller negative priming effects (Schooler, Neumann, Caplan, & Roberts, 1997) when compared to the use of pictures in younger adults. They proposed this might be due to less selective attentional competition due to reliance on more long-term memory stores and therefore less need for inhibition. Their findings appear to support the literature in which positive and negative priming effects seem to exist for both age groups (Gamboz et al., 2000; Kotary & Hoyer, 1995; Sullivan & Faust, 1993); and therefore refute Hasher and Zack's (1998) reduced inhibition theory with advancing age.

Furthermore, Schooler Neumann, Caplan, and Roberts (1997) examined negative priming by presenting targets and distractors (words) as centrally overlapping on the computer screen in an attempt to discourage episodic retrieval. They used semantic and conceptually identical targets and distractors in their design and found negative priming effects for both younger and older adults, with predominately larger effects in the older cohort. This was attributed to the possibility of inhibition based explanation as episodic retrieval was controlled for. They examined more episodic based theories in a second experiment by asking the participants to report the target after they reported the distractor. This was thought to require overt episodic retrieval of information for response selection. This was then compared to a task which required no retrieval of target information, that is, participants were asked to categorise the target immediately after it was presented rather than after categorizing the distractor. There were no significant age differences on such tasks. The researchers concluded that they could not rule out the possibility of episodic retrieval based theories of selective attention but asserted that in their research design distractor inhibition effects were less apparent in the older group, supportive of a reduced inhibition theory with advancing age (Hasher & Zacks, 1988).

McDowd and Oseas-Kreger (1991) also found the older group in their study could not actively inhibit the information effectively resulting in negative priming effects in younger adults and not the older adults. Hasher et al. (1991) also extended these findings in their letter-naming task. They found negative priming effects for younger participants were maintained when the response-to-stimulus onset interval was between 500 ms and 1200 ms. This effect was not seen in older participants. They could not reliably inhibit the "to be ignored" distractors, as reflected in increased reaction times. The younger adults could ignore the distractors more efficiently. Hasher et al. highlights there may be an underlying decrement in inhibitory processing due to episodic retrieval mechanisms in older adults when completing selective attention tasks as measured by the time it takes to inhibit the distracting information rather than looking solely at accuracy measures.

Overall some of the literature postulates that positive and negative priming effects exist for both age groups (Gamboz et al., 2000; Kotary & Hoyer, 1995; Sullivan & Faust, 1993; Kane et al., 1994; Kane et al., 1997); and therefore refute Hasher and Zack's (1998) reduced inhibition theory with advancing age. In contrast, other negative priming studies indicate that there does not seem to be a predominately negative priming effect for older adults, and suggest greater negative priming effects in younger adults (Schooler et al., 1997; McDowd & Oseas-Kreger, 1991; Hasher et al., 1991). That is, they propose the older adults do have reduced ability to inhibit distracting information, consistent with Hasher and Zack's (1988) reduced inhibition theory with advancing age. Nevertheless, what most of these studies have in common is the fact that a lack of negative priming effects in older adults is not due to deficient attentional processes but due instead episodic retrieval mechanisms. That is, older adults do not have trouble with selective inhibition per se, but instead rely on active memory stores to prevent distraction. This ultimately results in more profound negative priming effects, especially in terms of slowing down their speed of processing.

In conclusion there is a wide variety of cognitive measures looking at age-associated changes in selective attention including both RSVP and distractor identity measures. However, it is also important to understand what is happening within the ageing brain at a neuranatomical and neurobiological level, to ascertain whether the cognitive findings are associated with specific brain changes. New developments in the neurosciences have opened up the study of higher cognition to physiological analysis, and have revealed a system of anatomical areas that appear to be basic to the selection of information for focal (conscious) processing (Posner & Peterson, 1990). The neurobiological constructs responsible for selective attention are discussed in the following section and compared to age-related changes in integrity of brain anatomy in an attempt to clarify the wide variety of conflicting results already demonstrated in the cognitive literature.

1.3 The Ageing Brain and the Neurobiology of Selective Visual Attention

For decades, it has been clear to neurobiologists that the normally ageing brain undergoes a wide variety of biochemical, molecular, structural and functional changes (Troller & Valenzuela, 2001). Most people recognise that ageing results in a decrease in brain size due to neuronal death, perhaps affecting the efficiency of many different brain functions (Morrison & Hof, 1997). Reviews of computed tomography (CT) and magnetic resonance imageing (MRI) studies in normal individuals have reported an increase in lateral ventricular size (indicative of central atrophy) and an increase in sulcal volume (indicative of cortical atrophy) with increasing age (Troller & Valenzuela, 2001).

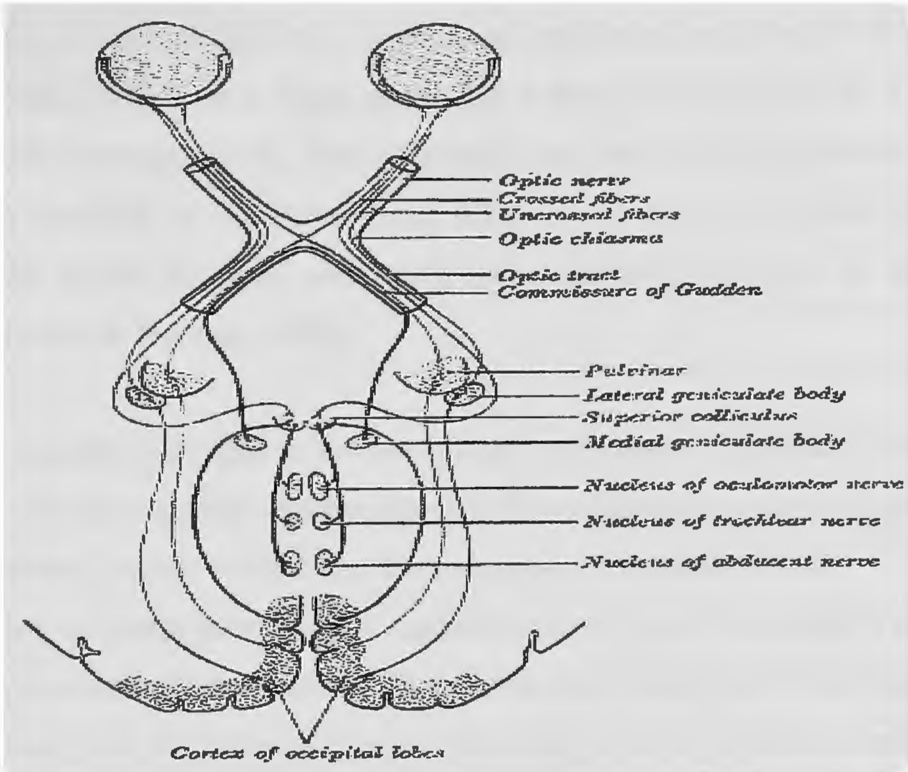

Figure 1. Flow of Visual Input to the Occipital Lobes

Given the widespread brain changes associated with normal ageing, and the distributed representation of the visuo-motor system within the brain, it is perhaps unsurprising that visual attention declines as adult's age. There are multiple cortical and subcortical structures that respond to visual input as illustrated in Figure 1 (Posner, 2004). These include the occipital, parietal and temporal cortices as well as the frontal eye fields, premotor cortex and prefrontal cortex; and the subcortical regions including the superior colliculus and multiple thalamic nuclei (Posner, 2004).

In addition, attention itself appears to be a complex process which is comprised of separate subsystems performing independent but inter-related functions interacting with other domain-specific systems (Posner & Peterson, 1990). In the following sections, the neuroanatomy of attention is outlined, and the effects of ageing on those parts of the brain involved in attention are also considered.

1.3.1 Neuroanatomy of Visual Attention

Attention is underpinned by a network of anatomical areas and is therefore neither the property of a single centre nor a function of the brain as a whole (Posner & Peterson, 1990). These networks carry out different functions which can be specified in cognitive terms such as; orienting to sensory events; detecting signals for focal processing; and maintaining vigilance or an alert state (Posner & Peterson, 1990).

Visual attention is thought to involve at least three stages of processing (Posner, 2004). The first stage of selective attention is the unconscious processing of visual stimuli, which is limited by the constraints of visual acuity and dependent on innate genetic visual capabilities; early visual experiences; and extensive practice (Posner, 2004). During this stage visual input is segregated perceptually into individual dimensions according to color, orientation and motion, which originate in the dorsal and ventral processing pathways found in the striate cortex (Madden et al., 2002). The dorsal pathway comprises the occipito-parietal cortical regions and is responsible for analyzing spatial relationships among objects; whilst the ventral pathway comprises the occipito-temporal cortical regions and is responsible for analyzing features of objects for object identification (Madden et al., 2002).

The second stage involves the conscious direction of attention initiated by setting a goal or a filter or a selection target with a specific reportable output or action (Posner, 2004). Visual dimensions are then involved in separate response-decision/selection processes according to specific features (Feintuch & Cohen, 2002). The parietal and prefrontal areas of the cortex are the most pivotal components of the attentional network in visual based tasks (Madden et al., 2002). The posterior parietal cortex helps orient and shift attentional focus across varying spatial locations (Madden et al., 2002); whilst focusing of attention is co-ordinated by the posterior thalamus (Hartley & Kieley, 1995). Overt orienting and the covert shift of attention is mediated by midbrain structures, including the superior colliculi (Hartley & Kieley, 1995). The basal ganglia and thalamus are activated in response to frontal- mediated top-down control (Madden et al., 2002). Both bottom-up (stimulus driven) and top-down attentional processes modulate the activation occipito-temporal networks (Madden et al., 2002).

The third is the cognitive abilities which allow a person to be able to perform multiple levels of processing in working memory (Posner, 2004). Visual pathways are constantly monitored by extensive networks that represent aspects of attentional functioning (Madden et al., 2002). Because multiple response decisions must be made, this system has a control mechanism (executive control) to ensure only one decision is executed (Feintuch & Cohen, 2002). Selection for action or the maintenance of attention on the location or identity of an object involves frontal brain structures such as the anterior cingulate and prefrontal cortex (Hartley & Kieley, 1995). More specifically, medial aspects of the prefrontal cortex are involved in motor actions responsible to maintain the attentional focus (e.g. eye movements) (Madden et al., 2002). Working memory and executive control components of visual attention are performed by the more lateral prefrontal regions (Madden et al., 2002); whilst the anterior cingulate is responsible for preparing for task performance or inhibiting irrelevant responses (Madden et al., 2002). This means that depending on the nature of the stimulus, response decisions are made and only some of these decisions reach executive functions (Feintuch & Cohen, 2002). Therefore, the role of attention is thought to act as pre/post perceptual gate of information to higher level processes that deal with response execution (Feintuch & Cohen, 2002).

In terms of physiological evidence for competition between stimuli, this process is thought to occur as a result of excitatory mechanisms that enhance or facilitate the processing of the target object in the visual areas of the occipital, parietal, temporal and frontal cortices (Posner, 2004). This excitatory process tends to be particularly more involved in second stage processing (Posner, 2004). It is also postulated that inhibitory mechanisms try to suppress responses to the distracting information in the prefrontal cortex which tends to be particularly more involved in third stage processing (Posner, 2004).

In conclusion, it seems the main areas responsible for selective visual attention involve the occipital, parietal and temporal cortices as well as the premotor and prefrontal cortices and the subcortical regions of the brain (Posner, 2004). As discussed in section 1.2, age associated changes to cognitive functioning particularly effect those abilities which tap into fluid cognitive skills such as attention, memory, information processing, executive functioning etc. (Troller & Valenzuela, 2001). The next section has a look at which specific areas of the brain involved in selective visual processing demonstrate distinct pathological changes associated with advancing age.

1.3.2 Neurobiological Changes in the Ageing Brain

Post mortem studies have been useful in identifying a wide variety of pathology associated with the normal ageing process, including a 5% reduction in brain weight and volume per decade after 40 years of age (Raz, 2000). Prefrontal atrophy is thought to be double that of the temporal or parietal neocortex (Andres et al., 2006). A more recent study by Head et al., 2009 used MRI-based volumetry and a wide variety of executive tasks including the Wisconsin Card Sorting Task to examine the effects of age related prefrontal atrophy on cognitive functioning. They found that older participants had more difficulty with processing speed, temporal processing and working memory. In particular their responses were significantly more perseverative and less inhibitive and were associated with reductions in prefrontal cortical volume. Troller and Valenzuela (2001), in their review article reported that up to 30% of normal older adults have demonstrated significant areas of white matter hyperintensities, often in the subcortical frontal regions of the brain and have been inversely related to performance in executive tasks as well as speed of information processing. Kennedy and Raz (2009) have also reported a predominance of shrinkage in the frontal lobes, particularly attributable to white matter loss.

Widespread reductions in hippocampal volume have also been associated with increasing age and are thought to be a contributing factor in declarative memory, new learning and spatial navigation difficulties (Cabeza et al., 2004). The amygdala has also been implicated in some ageing studies to date, with age-related amygdalar dysfunction resulting in memory deficits related to disrupted cortico-limbic functioning (Morrison & Hof, 1997). Moderate reductions in the caudate nucleus and putamen have also been studied with adverse effects on dopaminergic regulation of motor skills and stimulus salience (Machado, Devine & Wyatt, 2009). Moderate reductions in cerebellum volume have also been identified but alcohol usage may be an unidentified confounding factor in some studies (Troller & Valenzuela, 2001).

A recent comprehensive review by Raz (2000) also reported that the caudate nucleus, cerebellum, the hippocampus and the association cortices are vulnerable to age-related shrinkage with minimal changes in the entorhinal cortex and the primary visual cortex. Despite this, however there appears to be a high degree of individual differences in change, however, there are minimal sex differences in age trends except for a male predominance in caudate shrinkage. Raz (2000) also suggests no evidence of neuroprotective effects of larger brain size or educational attainment.

Age-related decline has also been identified in both structural (MRI and CT) and functional (functional MRI, PET and SPECT) brain measures (Raz, 2000). Despite this, however, ageing is also associated with a considerable amount of functional plasticity (Raz, 2000). An example of such plasticity or functional compensation was demonstrated by Grady et al., (1992) in a positron emission tomography study who found a declining functioning in the visual (striate) cortex was compensated for by higher order processes such as the prefrontal cortex, especially when completing spatial tasks. This may be due to age-related changes in hemispheric specialisation rather than functional compensation per se (Madden et. al., 2002). A fMRI study by Madden et al. (2002) compared older and younger cohorts on a visual search task that required participants to respond if an upright "L" (target) was present in an array of rotated "L" (distractors). All of the "Ls" varied between black and white shades. They found that increasing similarity of display items led to decreased target detectability, especially in the older adult group. As task demands increased (conjunction search task whereby half of all the "Ls" were white and the other half black), the older cohort showed reduced efficiency in the ventral processing (occipito-temporal) system required for object identification. The older adult group did, however, demonstrate higher cortical activation of the ventral pathway on easier tasks, probably to compensate for their decline in perceptual efficiency.

Using diffusion tensor imageing (DTI), Head et al. (2004) identified age-associated decline in executive functioning in general as well as cognitive control and attention. They found age related degradations associated with alterations of the anterior corpus callosum and frontal white matter of the brain, including volume reductions, demyelination and white matter degeneration observed as white matter hyperintensities. This was compared to a sample of patients with dementia that displayed more white matter changes in the posterior lobular and medial temporal regions, consistent with the known cognitive changes including memory impairment seen in this disease. Head and colleagues concluded that age-related cognitive decline is likely to undertake a pathologically distinct course to those older adults with underlying Alzheimer's disease (DAT). Relevant to the present series of studies, these pronounced changes in the ageing group might be evidence of the pathological underpinnings responsible for slowed information processing consistent with Salthouse's (1998) theory.

In another recent review of brain changes in normal ageing, Hedden (2007) also identified age-related changes particularly around the prefrontal, frontal-parietal and frontal-striatal cortices associate with white matter volume reductions, deficits in dopaminergic neurotransmission as well as functional activation. It is postulated that these pathological findings are the cause of many cognitive changes associated with advancing age including attentional control, working memory, task switching and inhibition.

Overall, normal ageing appears to cause changes in frontal brain regions involving both white and grey matter. These changes are likely to underpin the declines in fluid cognitive abilities such as executive functioning, working memory, attention and new-learning, and inhibition associated with normal ageing (Head et al., 2004; Hedden, 2007; Raz et al., 2005). Other sub-cortical and posterior brain regions have also been implicated, such as the caudate nucleus, cerebellum, hippocampus and the association cortices ultimately affecting functions such as encoding, declarative memory, new learning, motor skills and spatial navigation (Raz et al., 2005). However, in normal ageing these areas are affected far less than in dementing processes such as DAT.

1.4 Summary

The performance of many cognitive tasks requires allocation of attention to several sources of information (Maylor & Lavie, 1998). One may focus attention on one source of information by selectively processing goal-relevant information (target) and avoiding intrusions from irrelevant information that may be potentially distracting (Maylor & Lavie, 1998). The ability to divide attention between different sources or tasks is limited by attentional capacity (Maylor & Lavie, 1998). If the amount of information in the task exceeds capacity then a cost in the performance can be observed (Maylor & Lavie, 1998). The rate at which the information is presented also impacts on the ability to attend to relevant information; (Broadbent, 1987; Duncan et al., 1994; Jiang & Chun, 2001; Kritikos et al., 2008; Eltiti et al., 2005; Watson & Humphreys, 1998) as does the type of information presented. All of these factors may facilitate or inhibit appropriate response selection (Flowers & Wilcox, 1982; Kritikos et al., 2008; Driver & Tipper, 1989).

The phenomenon of distractor interference, usually studied with visual reaction time paradigms, indicates that information not relevant to the goal or target is processed by the visuo-motor system and has an impact on goal-directed actions (Flowers & Wilcox, 1982; Kritikos et al., 2008; Driver & Tipper, 1989). This leads to increased response times to the target (goal) and decreased accuracy in the presence of irrelevant information (Eriksen & Eriksen, 1974; Lavie & Tsal, 1994; Stroop, 1935). Typically, this phenomenon has been studied with button-pressing tasks, in which relevant and irrelevant information is presented on a computer screen (Eriksen & Eriksen, 1974; Lavie & Tsal, 1994; Stroop, 1935). In visual distractor interference paradigms buttons are pressed in response to targets appearing on a computer screen, and in the past these distractors and targets have usually been presented simultaneously

(Flowers & Wilcox, 1982, Broadbent, 1987; Duncan et al., 1994; Kritikos et al., 2008; Eltiti et al., 2005; Watson & Humphreys, 1998). Recent work in young, healthy participants, however, indicates that distractors presented 200ms prior to targets also have a significant, though attenuated, impact on responses to the target. (Flowers & Wilcox, 1982; Broadbent, 1987; Duncan et al., 1994; Kritikos et al., 2008; Eltiti et al., 2005; Watson & Humphreys, 1998). Beyond this interval, the effect of interference is not evident (Flowers & Wilcox, 1982; Broadbent, 1987; Duncan et al., 1994; Kritikos et al., 2008; Eltiti et al., 2005; Watson & Humphreys, 1998).

Ageing has been associated with declines in both focused and divided attention (Maylor & Lavie, 1998). However, the exact nature of attentional difficulties in older populations remains unknown (Maylor & Lavie, 1998). Some researchers have reported that simple divided attention remains intact with age (Salthouse et al., 1998; Maylor & Lavie, 1998). However, when a divided attention task increases in complexity and demands more processing resources, the older adults find it harder to perform accurately (McDowd & Oseas-Kregar, 1991; Madden et al., 2002; Craik & Byrd 1982). Numerous studies have concluded that there is an age-related impairment in the ability to attend or selectively focus on a single input when presented with other competing inputs (Salthouse et al., 1998; Maciokas & Crognale, 2003; Palfai et al., 2003). Some have concluded that this is due to poor inhibitory processes that prevent the blockage of irrelevant stimuli entering working memory ultimately affecting speed and accuracy of responses (Hasher et al., 1991; Simon et al., 2006). On the other hand some other studies have documented limited or reduced negative priming effects in responses to targets that appear as distractors on previous trials ultimately having no effect or even a facilitative effect on speed or accuracy (Sullivan and Faust, 1993; Kramer et al., 1994; Maylor & Lavie, 1998).

There is also a possibility of a more general explanation, such as age-related slowing (Maylor & Lavie, 1998; Salthouse, 1996). This is reflected in slowed response times and occasionally reduced accuracy of responses due to limited attentional capacity (Salthouse, 2004). Salthouse (2004) proposes that a reduction in information processing resources affects higher order aspects of cognitive functioning including working memory and executive functioning, which is thought to impair one's ability to encode, filter and therefore be able to hold potentially relevant information in mind. This is proposed to also have an effect on response times and accuracy of responses, especially for the older population.

Regardless of which cognitive process is primarily affected, the cognitive declines seen in normal ageing appear to be underpinned by corresponding changes in the brain, particularly in those frontal structures and white matter tracts known to mediate executive functioning and speed of processing. It is important for researchers to develop a more thorough understanding of age-associated attentional difficulties as it has significant implications both for the sequence and speed of presentation of information to the ageing population and for the development of effective rehabilitation strategies in elder populations suffering from neurological disorders. So far, there are no clear-cut explanations of the discrepancies that currently exist in visual search tasks in the ageing population. The aim of this present study was to try to provide additional information to aid in the understanding of which specific cognitive processes are primarily affected in normal ageing.

1.4.1 Overview of the Present Study

The overall aim in the present study was to extend the findings of Kritikos and colleagues (2008), to investigate whether older adults are as sensitive to manipulations of the interval between distractor and target as younger adults, or whether the reduced speed of processing seen in older adults would result in greater interference at longer intervals compared to younger adults. A second aim was to investigate differences in inhibitory processing between older and younger adults on experimental visual attention tasks, in order to establish whether normally ageing older adults experience cognitive deficits in addition to slowed speed of processing.

As well as the seminal findings of Eriksen and Eriksen (1974), the findings of Watson and Humphreys (1998) are relevant to the present study because they demonstrate the importance of target-distractor compatibility as well as temporal separation in the identification and selection of relevant information for further processing. They demonstrated that distractors presented prior to targets may have a significant, though attenuated impact on responses to the target. What is not really clear, however, is the critical interval in which interference may occur.

Kritikos and colleagues (2008) also explored the effects of temporal separation on distractor interference in young adults, and identified a critical interval at which distractor interference in maximal (200ms). However, their experiments were completed with young participants only, meaning that the critical interval for distractor interference identified may not be applicable for older adults. Therefore, the first experiment in the present study aimed to extend these findings and examine whether such interference effects also exist for the ageing population. The second experiment aimed to extend the findings of both Eriksen and Eriksen (1974) and Kritikos et al., (2008) by investigating further whether interference is also affected by distractor identity (congruent to target, incongruent to target or neutral to target), therefore providing a means by which to test the different hypotheses of Hasher and Zacks (1988; inhibition deficits) and Salthouse (1996; speed of processing deficits) regarding the underlying cognitive deficits in normally-ageing older adults.

1.4.2 Hypotheses

It was hypothesised that, consistent with Watson and Humphreys (1998) and the pilot study of Kritikos et al., 2008, the duration of the interval between distractor and target would modulate responses to the target. It was postulated that distractor interference (measured as longer reaction times and reductions in accuracy) would be maximal when targets were presented simultaneously with distractors. Short target-distractor separation intervals of 200ms were also hypothesised to be associated with greater distractor interference. It was postulated that longer intervals of 400ms up to 1000ms would be associated with decreased distractor interference. This was expected for all participants.

For both experiments, it was further hypothesised that while older adults would show the same general pattern of results as younger adults, older adult's reaction times over all, during all conditions, would be longer due to impaired speed of processing operations, consistent with Salthouse's (1996) reduced processing speed theory. Furthermore, consistent with Hasher & Zacks (1988) it was postulated that the older group would also demonstrate larger reductions in performance due to impairments in inhibitory processes with advancing age. In particular, it was proposed there would be an interaction of age and congruence; that is the older participants would demonstrate greater interference with incongruent distractors when compared to the younger participants. It was anticipated that the older adults would need a longer period of time to process and inhibit the distractor items as reflected in longer reaction times as well as reduced accuracy.

In the first experiment it was hypothesised that the longer processing intervals (distractor presented 600 - 1000 ms before target) would lead to reductions in distractor interference effects by giving the older adult enough time to fully process all of the information. It was also hypothesised that when the processing interval was smaller (distractor preceding target by 200 ms or simultaneously presented) that the older adults would make more errors and experience reductions in information processing speed as reflected in longer response times.

During the second experiment it was hypothesised that, consistent with Eriksen and Eriksen (1974) and the pilot study of Kritikos et al., 2008, when target and distractor appeared simultaneously, distractor interference (as measured by increased reaction times and reduced accuracy) would be minimal when the distractor was congruent with the target; moderate when the distractor was neutral; and maximal when the distractor was incongruent. Based on the results of Experiment 1, it was anticipated that this pattern of interference would be evident, though attenuated, when the distractor preceded the target. That is, response times would be slower and accuracy reduced when an incongruent distractor preceded the target, compared with a congruent or neutral distractor. This was expected for all participants.

EXPERIMENT 1

The main objective of the first experiment was to ascertain whether the critical interval between irrelevant and relevant information required to produce distractor interference is longer in older adults (age > 60 years) compared with younger adults (age < 50 years). It was anticipated that, compared to younger adults, people in late adulthood would need a longer period of time to process the target and distractor items (Salthouse, 1996).

2.1 Method

2.1.1 Participants

Seventeen older adults participated in Experiment 1. They were members from Probus and University of the Third Age (organisations providing activity and educational-based programs for people who have retired) who responded to fliers sent to the president of each organization. They each received $10 for their participation in one experiment and light refreshments and morning tea were provided.

Two people from the older adult group were excluded from analysis as they did not meet response reliability criteria (more than 10 percent errors, or response time greater that one standard deviation above or below the mean), leaving a total of fifteen older adults whose data were retained for analysis (10 females, 5 males; age range 64 to 80 years, M = 71.29, SD =5.66).

Seventeen younger adults (13 females, 4 males; age range 24 to 49 years, M =29, SD =9.66) also participated. They were undergraduate students from Victoria University who participated voluntarily and no incentives were provided.

All participants were right handed with self-reported normal or corrected to normal vision. Potential participants were screened over the phone for any history of illnesses that could affect the integrity of brain function including diabetes, stroke, any heart conditions, epilepsy, and dementia. Those who experienced any aforementioned health difficulties were not invited to participate in the study. There were no specific screening tools utilised in this experiment as it was anticipated that those participants with any type of cognitive deficit would not meet response reliability criteria (more than 10 percent errors), and would therefore be excluded from the final analysis.

2.1.2 Apparatus and Stimuli

An IBM PC compatible computer attached to a VGA color monitor (set to 1024 x 768 pixels) presented the stimuli and recorded the latency (in milliseconds; ms) and accuracy of responses. The experimental paradigm was displayed using DmDX (version 3) experimental software (Forster & Forster, 2003).

Figure 2 shows the timing of events in Experiment 1. There was an initial single fixation point followed by a single target (Target Alone condition), the target and distractor presented simultaneously (Simultaneous condition) or a distractor presented for 200ms, 400ms, 600ms, or 1000ms before target onset (Preceding conditions).

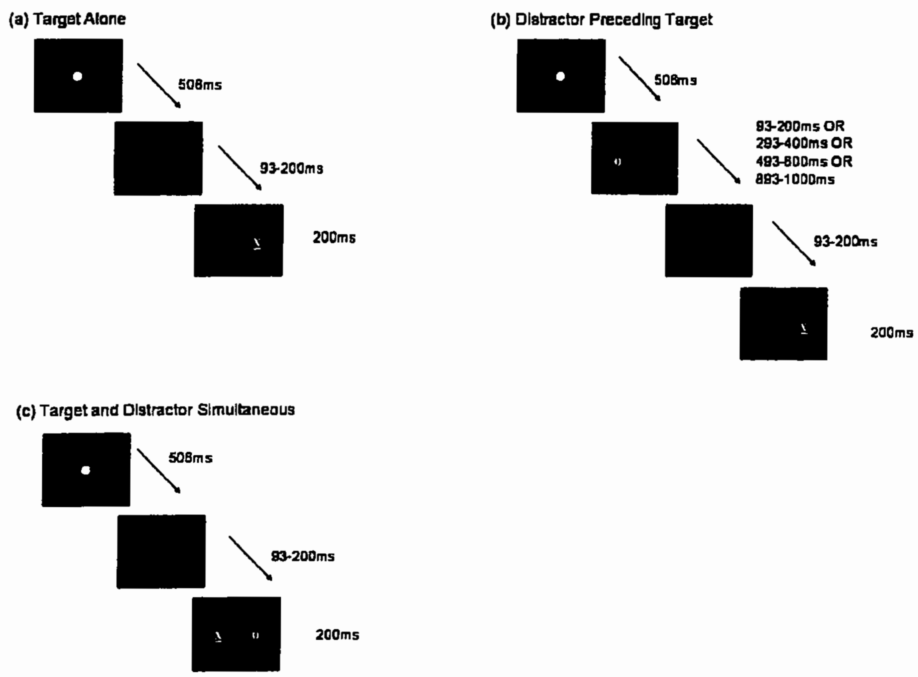

Figure 2. Demonstration of temporal sequence of events for Target Alone (panel a), Preceding conditions (panel b) and Simultaneous conditions (panel c)

The target was designated by an underscore (either an x̲ or o̲). The distractor (either an x or o) was always incompatible with the target (x with o̲, or o with x̲). Both the target and distractor were presented in lower case. (No. 10 Courier New font) in a grey colour on a black background (see Figure 2), and appeared randomly and equiprobably at one of two locations, either to the left or right of the central fixation point. All letters subtended a visual angle of 1° (from the centre of the screen on the x-axes on both sides) and participants sat at a viewing distance of 57cm to the computer.

2.1.3 Procedure

Data were collected in a sound attenuated and darkened laboratory. Participants were read a plain language statement and instructions and signed the consent form (see Appendices A, B, C and D).

Participants sat facing the computer screen with their head placed in an adjustable chin rest that was 57 cm away from the computer and the body midline was aligned with the centre of the computer screen. Participants were instructed to respond to the target letter as quickly as possible without compromising accuracy, and were also asked to ignore the distractor letter. They were instructed to press the left or right shift keys in response to the target with their left and right hands respectively. For half the experimental blocks participants used their left hand to respond to the target x̲, and their right hand to respond to the target o̲. Hand-to-letter correspondence was counterbalanced for the remaining half of the experimental blocks.

This experiment consisted of six conditions. For all conditions each trial commenced with a central fixation point that appeared for 506 ms. In the Target Alone condition, following the fixation point offset, a blank screen appeared and remained on for a randomly varied interval (93 – 200 ms); the peripheral target subsequently appeared alone for 200ms. In the Simultaneous condition, following the fixation point offset, a blank screen appeared and remained on for a randomly varied interval (93 – 200 ms); the distractor appeared simultaneously with the target for 200ms. The randomly varied interval of 93-200ms was used to reduce the predictability of events.

There were four Preceding conditions. In these conditions the distractor appeared immediately after the fixation point offset for a period of randomly varied intervals; 93 – 200 ms (Preceding-200), 293 – 400 ms (Preceding-400), 493 – 600 ms (Preceding-600) or 893 - 1000 ms (Preceding-1000). These times of distractor presentation within each interval range were also randomly varied to reduce the predictability of events. Following this, a blank screen appeared and remained on the screen for a randomly varied interval of 93-200 ms (also in an attempt to reduce predictability). Following this, the target letter was presented solitarily for 200ms.

For all conditions the order of trials according to distractor-target spatial positions were randomised within each block. Conditions were blocked into; Target Alone, Simultaneous-200, Preceding-200, Preceding-400, Preceding-600 and Preceding 1000 conditions.

After reading final instructions on the screen indicating hand-to-target correspondence, participants pressed the spacebar to begin. For each of the six trial types, participants initially completed a representative randomised sample of twenty practice trials, followed by a block of experimental trials. The blocks were interspersed with rest periods of five minutes. The order of block presentation was counterbalanced across participants. Within each block, there were 24 trials for each of the two positions (left or right of the fixation point) for the Target Alone, Simultaneous and Preceding conditions, a total of 358 trials.

The end of each trial was taken as either the time of response or 2,000 ms after the target offset (if the response was made beyond this time period). The following responses were considered errors: trials on which no response was made (defined as a response not made by a temporal interval of 2,000 ms), and responses using the incorrect hand.

2.1.4 Design and Data Analysis

The reaction time and error data were analysed using paired sample t-tests to demonstrate distractor interference by comparing Target Alone with the five distractor conditions. Henceforth Target Alone was excluded from the data analysis. The participants who did not meet response reliability criteria were treated as outliers and were also excluded from the final analysis. This included those with more than 10 percent errors (as outlined in section 2.1.1).

A two-way mixed repeated measures ANOVA with the within subjects factor of distractor order (Simultaneous and the three Preceding conditions) and one between subjects factor (Age) was used to compare the reaction times and accuracy of older and younger participants. ANOVAs are reported with Huynh-Feldt correction, a more conservative measure of significance; effects sizes are reported using partial eta-squared (ηp^2). Pairwise comparisons with Bonferroni correction ($p = .01$) were used to investigate any further significant effects. Independent samples t-tests with Bonferroni correction ($p = .01$) were used to compare reaction times and errors between older and younger participants for all conditions. All analyses were completed using the Statistical Program for the Social Sciences (SPSS version 14).

2.2 Results

2.2.1 Reaction Times

Mean RT performance for both older and younger participants across the six conditions is shown in Figure 3.

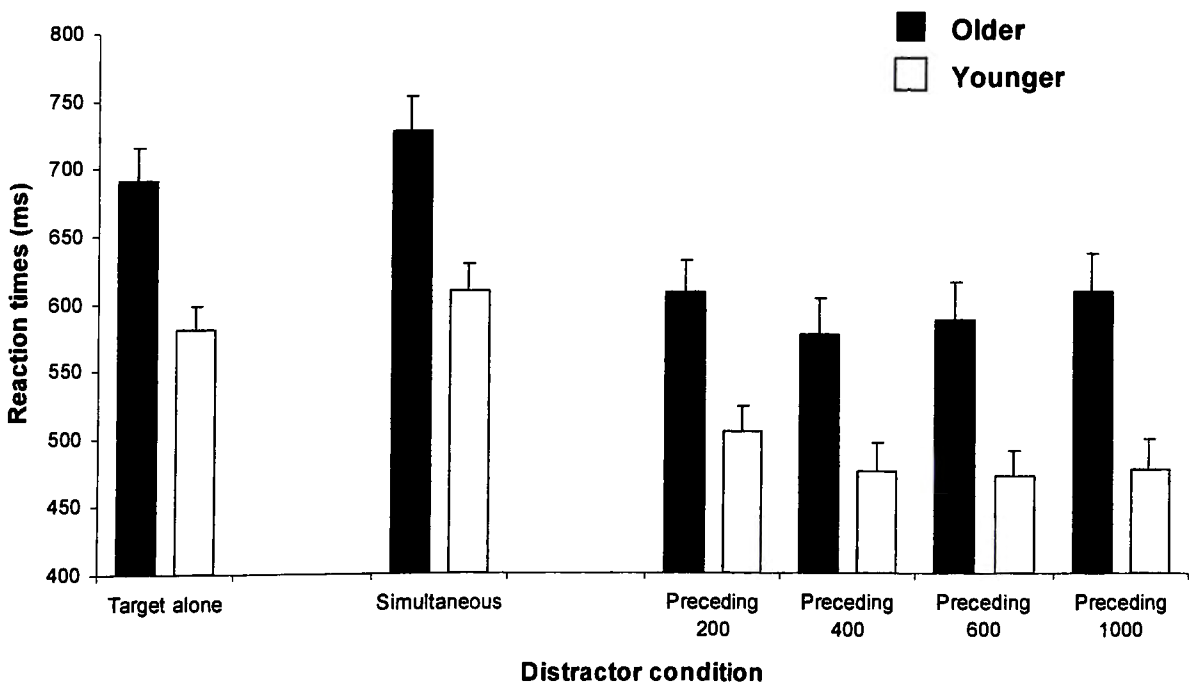

Figure 3. Mean reaction times (standard error bars) for distractor order

Pairwise comparisons of the Target Alone condition with the Preceding and Simultaneous conditions for all participants showed that RTs for Target Alone were significantly slower than all preceding conditions and significantly faster than the simultaneous condition (for all comparisons $p < .05$; see Table 1).

Table 1. Target Alone comparisons with all other conditions for all participants

Condition	**Mean Reaction Time (ms)**	**Standard Error**	***t***	***p***
Target Alone	632.10	29.61	-	-
Simultaneous	664.16	32.61	-4.34	.000
Preceding-200	552.64	29.95	10.67	.000
Preceding-400	522.23	33.32	11.69	.000
Preceding-600	525.20	33.55	9.75	.000
Preceding-1000	537.51	36.07	7.84	.000

Two-way repeated measures ANOVA showed that there was a significant main effect of age, $F(1, 30) = 12.962$, $p = .001$, with a small effect size, $\eta p^2 = 0.302$. Independent samples t-tests showed that younger participants' reaction times were significantly faster than older participants in all conditions (for all comparisons $p < .05$; see Table 2).

Table 2. Independent t-test age comparisons for each condition

	Mean Reaction Time (ms) (Standard Error)			
Condition	**Older Group**	**Younger Group**	***t***	***p***
Target Alone	690.48 (24.71)	580.59 (17.29)	3.71	.001
Simultaneous	727.36 (25.43)	608.40 (20.86)	3.65	.001
Preceding-200	607.24 (24.04)	504.46 (18.51)	3.43	.002
Preceding-400	575.56 (26.85)	475.18 (20.46)	3.01	.005
Preceding-600	586.57 (28.09)	471.05 (19.50)	3.44	.002
Preceding-1000	607.12 (28.33)	476.08 (22.89)	3.63	.001

There was also a significant main effect of distractor order $F(4,120) = 111.07$, $p < .0001$, with a small effect size $\eta p^2 = .0787$, showing that RTs differed significantly between the Simultaneous, Preceding -200, -400, -600 and -1000 conditions. Further pairwise t-test comparisons for each of the five conditions revealed that RT latencies in the Simultaneous condition were significantly slower compared with RT latencies for the Preceding -200, -400, -600 and -1000 conditions. ($t(32) = 13.160$, $t(32) = 14.687$, $(32) = 12.706$, $t(32) = 9.998$, all significant at $p = .00011$, respectively).

Post-hoc pairwise t-tests for the Preceding conditions, showed that RT latencies in the Preceding -200 condition were significantly slower than the Preceding -400, -600, and -1000 conditions, ($t(32) = 7.324$, $p < .0001$; $t(31) = 4.768$, $p < .0001$; $t(31) = 2.136$, $p < .05$, respectively). RT latencies were significantly faster in the Preceding -1000 condition when compared to the Preceding -400 and Preceding -600 condition ($t(31) = 2.276$, $p < .05$ and $t(31) = 2.492$, $p < .05$ respectively). There were no significant differences in RT latencies between the Preceding -400 and Preceding -600 conditions ($p > .05$).

The interaction between age and distractor order was not significant ($F(4,120) = 1.293$, $p = .298$, $\eta p^2 = .040$), indicating the effects of distractor order on reaction times did not differ depending upon the age of the participants.

Overall, these results demonstrate that the presence of a simultaneous distractor interfered with both younger and older participants' ability to respond efficiently, thus increasing their response times when compared to the target appearing alone or preceded by a distractor. Compared to a simultaneous distractor, the appearance of a distractor preceding target onset resulted in attenuated distractor interference and faster reaction times. In the preceding conditions, distractor interference was at its maximum (shown by longer reaction times) when distractors preceded target onset by 200ms and 1000ms. There was relatively less distractor interference when distractors preceded targets by 400 to 600 ms. There was also a main effect of age, indicating that older participants' reaction times were significantly slower than younger participants' reaction times in all conditions.

2.2.2 Response Accuracy (Mean Number of Errors)

Mean response errors for both older and younger participants across the six conditions are shown in Figure 4. Overall errors due to anticipatory responses (response latencies of less than 150ms), or no response (2,000 ms elapsed) were less than one percent and were excluded from subsequent analyses. Those participants with more than a 10% error rate were excluded from further analyses.

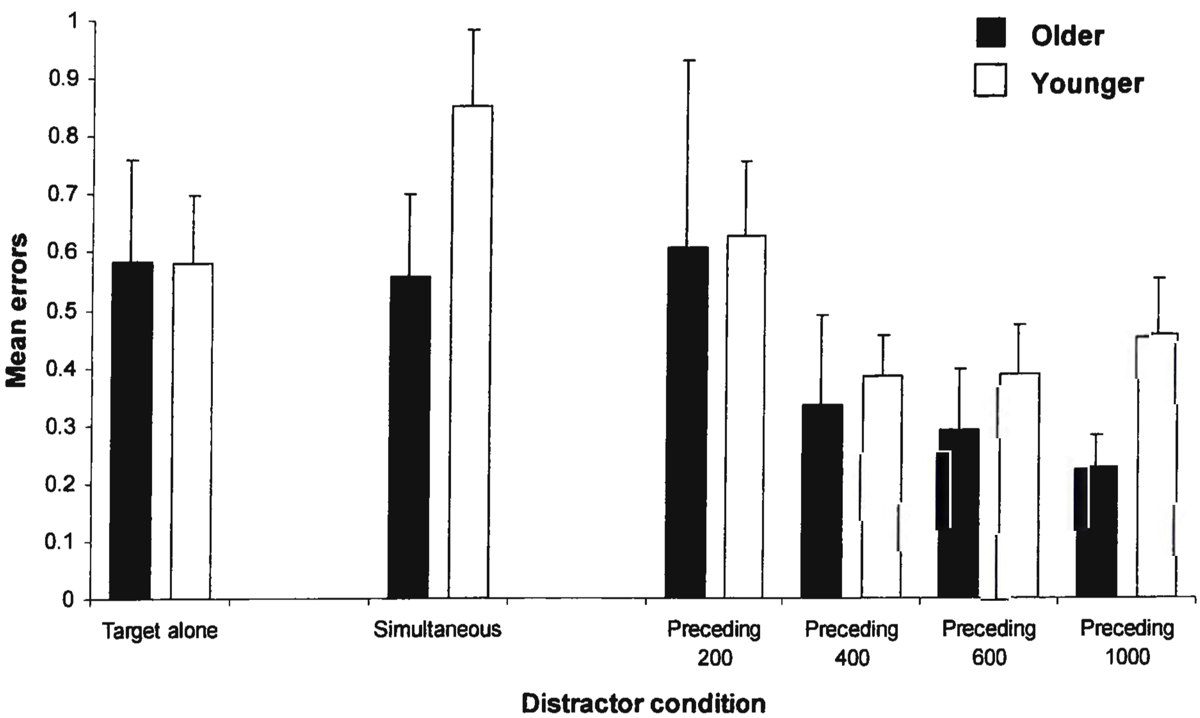

Figure 4. Mean errors (standard error bars) for distractor order

Pairwise comparisons of the Target Alone condition with the Preceding and Simultaneous conditions for all participants showed that number of errors for each condition did not differ significantly (for all comparisons $p > .05$; see Table 3).

Table 3. Target Alone comparisons with all other conditions for all participants

Condition	Mean Errors	Standard Error	*t*	*p*
Target Alone	0.58	0.15	-	-
Simultaneous	-0.13	0.09	-1.53	.135
Preceding-200	-.036	0.19	-0.19	.848
Preceding-400	0.22	0.12	1.85	.075
Preceding-600	0.24	0.10	2.51	.017
Preceding-1000	0.24	0.10	2.48	.019

There was no significant main effect of age on errors made ($p = >.05$, $\eta p^2 = .124$); however, an independent samples t-test revealed a trend towards greater accuracy for the elderly participants in the Preceding -1000 ($p = .057$; for all other comparisons $p < .1$; see Table 4).

Table 4. Independent t-test age comparisons for each condition

	Mean No. Errors (Standard Error)			
Condition	**Older Group**	**Younger Group**	***t***	***p***
Target Alone	0.58 (0.18)	0.58 (0.12)	.012	.991
Simultaneous	0.56 (0.14)	0.85 (0.13)	1.503	.143
Preceding-200	0.61 (0.32)	0.63 (0.13)	-.054	.958
Preceding-400	0.33 (0.15)	0.38 (0.07)	-.309	.759
Preceding-600	0.29 (0.10)	0.39 (0.08)	-.732	.470
Preceding-1000	0.23 (0.05)	0.45 (0.10)	1.981	.057

There was a significant main effect of distractor order, $F(4, 120) = 5.076$, $p = .001$, with a small effect size $\eta p^2 = 0.145$, showing that number of errors differed significantly between the Simultaneous, Preceding -200, -400, -600 and -1000 conditions. Pairwise comparisons further revealed there were significantly more errors made in the Simultaneous condition compared with the Preceding -400, -600 and -1000 conditions ($t(32) = 3.424$, $p = .002$, $t(32) = 4.388$, $p = .00011$ $t(32) = 4.533$, $p = .00011$ respectively). The mean number of errors within the Simultaneous condition did not differ significantly from the number made in the Preceding -200 condition ($p > .05$).

Pairwise t-test comparisons of the Preceding conditions revealed the mean number of errors made in the Preceding -200 condition was significantly greater than errors seen in the Preceding -400, and -600 conditions ($t(32) = 2.526$, $p = .017$, $t(32) = 2.089$, $p = .045$, respectively). The mean number of errors within the Preceding 200 condition did not differ from those made in the Preceding -1000 condition ($p > .05$).

There was no significant interaction for distractor order and age ($F(4, 120) = .582$, $p = >.05$, $\eta p^2 = .019$), indicating the effects of distractor order on reaction times did not differ depending upon the age of the participants.

Overall, these results indicate that Simultaneous distractors caused more errors than distractors preceding targets. The Preceding-200 condition was associated with a greater number of errors than the Preceding-400 and -600ms conditions, but did not differ from the 1000 ms condition. These effects were not modulated by age.

2.3 Discussion

The main objective of the first experiment was to extend the findings of Watson and Humphreys (1998) and Kritikos et al., (2008) in order to discover the critical interval in which distractor presentation was likely to affect target responses in an older population sample when compared to a younger population sample. The latency and accuracy of responses were examined at temporal separation intervals of 200, 400, 600 and 1000ms and also during the simultaneous presentation of stimuli (Watson & Humphreys, 1998; Kritikos et al., 2008). It was hypothesised that the older group would be slower to respond (Salthouse, 1996); and also that they would be less able to inhibit potentially distracting information (Hasher & Zacks, 1988), during all temporal separation conditions.

Consistent with previous findings, the results showed that for both groups, reaction times were impaired when the distractor was presented simultaneously with the target (Kritikos et al., 2008; Watson & Humphreys, 1998). Interestingly, responses times to the target were reduced when the distractor preceded target onset in general when compared to the Simultaneous condition. It seems the presentation of a distractor cued or facilitated distractor processing, interfering less with target processing and allowing enough time for both groups to be able to process and inhibit the information. Based on previous research, it was expected that distractor interference would be maximal at 93-400ms, resulting in longer response times (Kritikos et al., 2008; Watson & Humphreys, 1998). It was postulated that this interval would not be long enough for both groups to process the information and respond more efficiently. Distractor interference was evident with relatively increased response times compared to the other Preceding conditions but was still marginally less than the Simultaneous condition. Unexpectedly, there was a large distractor interference effect at 893-1000ms, which was comparable to the Preceding-200 condition. It was originally postulated that this interval would have been long enough for both groups to process the information and respond more efficiently. Instead, some interference was evident with relatively increased response times compared to the other Preceding conditions.

With respect to accuracy, participants' performance was less accurate in the presence of a simultaneous distractor and a distractor preceding target onset by 93-200ms and more accurate when distractors preceded the target onset by 293-400, 493-600, and 893-1000 ms. That is greater distractor interference effects were apparent at Preceding-200ms intervals when compared to the other Preceding conditions; and smaller distractor interference effects are apparent in Preceding-200ms intervals when compared to the Simultaneous condition. These findings are consistent with the literature whereby maximal interference generally occurs at 0-200ms intervals (Kritikos et al., 2008, Watson & Humphreys, 1998).

As expected, the distractor interference effect was also modulated by age. Overall, the data demonstrated an increase in reaction time in the older group in all conditions when compared to the younger group. The older adults generally were slower in their response selection. Nevertheless, despite an overall difference in speed between the two groups, the pattern of performance was similar in nature for both groups. That is, the current findings indicate that the older group mainly have difficulties with slowness of information processing and that the older groups' accuracy remained comparatively unaffected. Their ability to inhibit the distracting stimuli remained relatively intact, as there were no significant differences between the two groups on accuracy measures or pattern of results. Instead, analysis of the data suggested a trend towards greater accuracy for the older group. This difference may have been more statistically sound had there been more participants in the research design. This result is consistent with previous research showing that distractor interference as measured by negative priming effects may not vary as a function of age (Kotary & Hoyer, 1995; Kane et al., 1994; Kane et al., 1997).

In summary, the presence of a distractor in general led to high levels of distractor interference (increase in response times and a decrease in accuracy), particularly when the distractor was presented within a small interval before target onset. Distractor interference was maximal in the presence of a simultaneous distractor and also when the distractor preceded target onset by 93-200ms. This means that the distractor continued to be processed when temporal intervals were minimal, as active inhibition mechanisms were not efficiently utilised. When the duration of the temporal interval increased, both groups were able to effectively inhibit distracting responses with the distractor interference effects being replaced by a potential facilitation of target responses. A reduction in response times and also a reduction in number of errors made reflected this finding. This facilitative effect diminished, however, once temporal intervals reached 893-1000ms. It was proposed that the longer display presentation might have reflected temporal uncertainty and loss of preparation for the trial. Overall, there were significant age differences in response times with the older group being slower to respond in general, with no age-related differences in accuracy. These findings suggest that on this simple visual distractor task the older group demonstrated intact inhibitory mechanisms despite being slower to process the information.

This basic pattern of results seen in this first experiment was consistent previous research involving younger adults (Watson & Humphreys, 1998; Kritikos et al., 2008). That is, greater distractor interference effects are apparent when distractors precede targets by intervals of 200ms intervals (compared to the other preceding conditions); and smaller distractor interference effects are apparent in preceding 200ms intervals when compared to the simultaneous condition (Kritikos et al., 2008). Extending previous research findings, during the first experiment this effect was also maintained in the older adult group. Overall the older adult group were slower than the younger group but were no less accurate in their responses. Therefore, the aim of the second experiment was to provide a more challenging task, which would be better able to test Hasher and Zacks' (1988) reduced inhibition theory with advancing age. This was done by varying the identity of the distractor and including incongruent, neutral and congruent distractors.

EXPERIMENT 2

The aim of the second experiment was to investigate whether target-related information had an effect on response selection in older adults (over 60). Unlike the first experiment, where only incongruent distractors were used, experiment 2 utilised incongruent, neutral and congruent distractors. This modification ensured that participants were not able to suppress the distractor-related response in advance, because they did not know if the target would be congruent or incongruent to the distractor. A further aim was to ascertain which mechanisms were responsible for such interference effects in older adults, by specifically testing the inhibition theory of Hasher and Zacks (1988) and the processing-speed theory of Salthouse (1996). Consistent with Hasher and Zack's theory, it was expected that if the older group had impaired inhibitory mechanisms they would demonstrate significantly more interference for the incongruent distractor compared to younger participants, because they have impaired ability to suppress that distractor. This will be evidenced statistically by an interaction of age and congruence. If the findings are consistent with Salthouse and slowed information processing is the primary cognitive deficit associated with normal ageing, then older adults will show a similar pattern of results in response to changes in distractor congruence (i.e. intact inhibitory processing) and overall slowing of reaction times, as in Experiment 1.

It was hypothesised that distractor interference would be minimal when the distractor was congruent with the target; moderate when the distractor was neutral; and maximal when the distractor was incongruent. Based on the results of Experiment 1, it was expected that this pattern of interference would be evident, in the simultaneous condition though attenuated, when the distractor preceded the target. That is, response times would be slower and accuracy reduced upon presentation of an incongruent distractor compared with a congruent or neutral distractor when presented simultaneously or when preceding the target. This was expected for all participants.

Consistent with Salthouse, (1996) it was further hypothesised that while older adults would show the same general pattern of results as younger adults, older adults' reaction times overall, would be longer due to impaired speed of processing operations. Furthermore, consistent with Hasher and Zacks (1988) it was proposed there would be an interaction of age and congruence that is, the older participants would demonstrate greater interference (longer reaction times and greater errors) with incongruent distractors when compared to the younger participants. It was also hypothesised that similar to the younger participants the neutral distractor would have a moderate effect (by not impacting on response speed or accuracy) and the congruent distractor would have more of a facilitative effect (decreasing response speed and increasing accuracy) in the older group. It was anticipated in such circumstances that the older group would perform better, with a similar pattern to the younger group, when the distractors were neutral or congruent to the target, due to the reduced demand on active inhibitory processes.

3.1 Method

3.1.1 Participants

Sixteen older adults participated in experiment 2, fifteen of whom had also completed experiment 1. Two older adults were excluded because they did not meet the response reliability criteria (less than 10% errors, or reaction times greater than one standard deviation above or below the mean), leaving fourteen older participants (9 females, 5 males; age range 64 to 80 years, M = 62.75, SD =5.66) whose data was retained for analysis.

Of the seventeen younger participants who participated in experiment 1, two failed to participate in the second experiment. There were a total of fifteen participants in the younger adult group (11 females, 4 males; age range 24 to 49 years, M =30.2, SD =9.86). Recruitment methods, health status screening, exclusion criteria and payment were the same as in experiment 1.

3.1.2 Apparatus, Stimuli and Procedure

The apparatus, stimuli and procedure were identical to Experiment 1 with the some alterations, as described below. This study consisted of seven conditions in total. The first was Target Alone; this condition was identical to that in Experiment 1. There were three Simultaneous and three Preceding conditions, with differing levels of distractor congruence.

In the Simultaneous Congruent condition, the target and congruent distractor appeared simultaneously 93 – 200 ms after the fixation point offset. The target and distractor were the same letter, that is, the response associated with the distractor was congruent with that associated with the target (for example, x with x̲ or o with o̲). In Simultaneous Incongruent, the target and incongruent distractor appeared simultaneously 93 – 200 ms after the fixation point offset. The response associated with the distractor was opposite to that associated with the target, that is, the response associated with the distractor was incongruent with that associated with the target (for example, x with o̲).

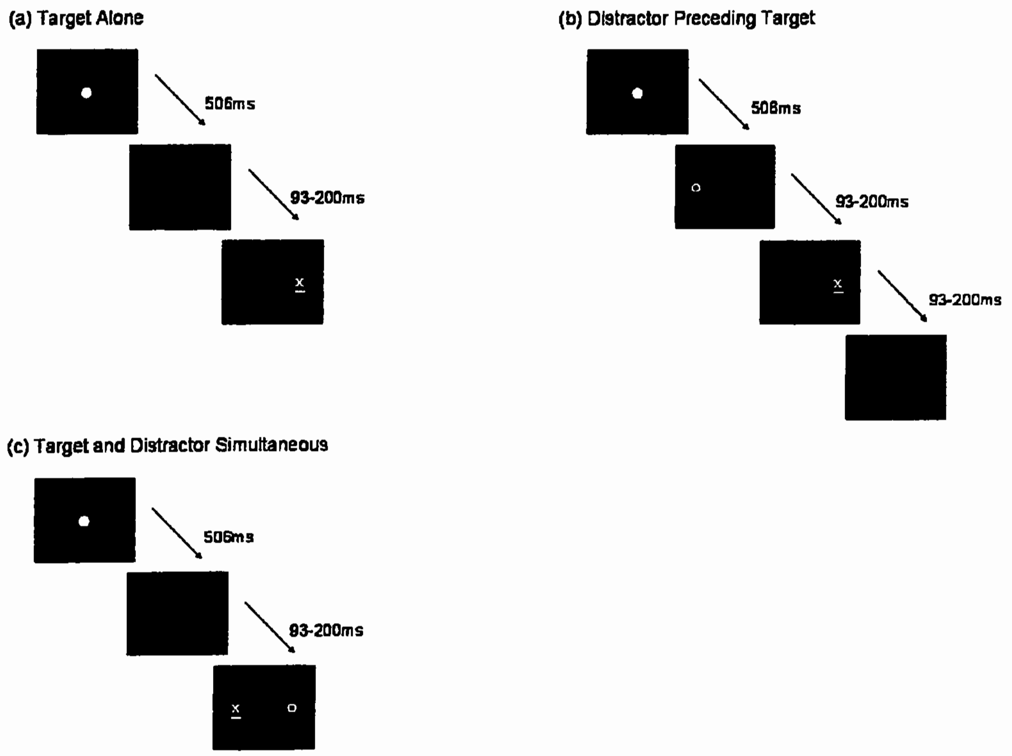

Figure 5. Demonstration of temporal sequence of events for Target Alone (panel a), Preceding conditions (panel b) and Simultaneous conditions (panel c)

In Simultaneous Neutral, the target and neutral distractor appeared simultaneously 93 – 200 ms after the fixation point offset and the distractor was not associated with any goal-directed response; specifically, a z appeared with either x or o (an example of Congruent, Incongruent and Neutral distractors is presented in Figure 5.). In Preceding Congruent, the target appeared 93-200 ms after distractor offset. In Preceding Incongruent, the target appeared 93-200 ms after distractor offset. In Preceding Neutral, the target appeared 93 – 200 ms after distractor offset.

The Target Alone trials were presented as one block. Trials comprising the Simultaneous Incongruent, Simultaneous Congruent and Simultaneous Neutral conditions were presented within another block in random order. Similarly, trials comprising the Preceding Incongruent, Preceding Congruent and Preceding Neutral conditions were presented within a third block in random order. Participants completed 21 practice trials prior to each experimental block. For all conditions, the order of trials according to distractor/target spatial positions and temporal intervals was randomised within each experimental block. The three types of blocks (Target Alone, Simultaneous and Preceding) were counterbalanced across participants. Thus, each participant completed 24 trials each for each position in four blocks for the three Preceding and Simultaneous conditions; and four blocks for the Target Alone condition, a total of 418 trials (an example of each condition with neutral distractors shown in Figure 5.).

3.1.3 Design and Data Analysis

The reaction time and error data were both analyzed with a three way mixed repeated measures ANOVA with Huynh-Feldt correction, with partial eta-squared reported as an effect size. Distractor Order (Preceding, Simultaneous) was the first within-subjects factor and Congruence (Congruent, Incongruent, and Neutral) was the second within-subjects factor. Participants' age was the between subjects factor. Pairwise comparisons with Bonferroni correction (p = .01) were used to further investigate any significant effects. Independent samples t-tests (with Bonferroni correction) were used to compare reaction times and errors between older and younger participants for all conditions. The

Target Alone condition was excluded from ANOVA analyses but pair-wise comparisons were still made to assess the distractor interference effect of the Target Alone condition with other conditions. All analyses were completed using the Statistical Program for the Social Sciences (SPSS version 14).

3.2 Results

3.2.1 Reaction Times

Mean reaction time (RT) performance for both older and younger participants across the seven conditions is shown in Figure 6. Pairwise t-test comparisons were conducted comparing the Target Alone condition with the Simultaneous and Preceding conditions to assess whether the presence of a distractor had an impact on participants' RT latencies collapsed across old and young.

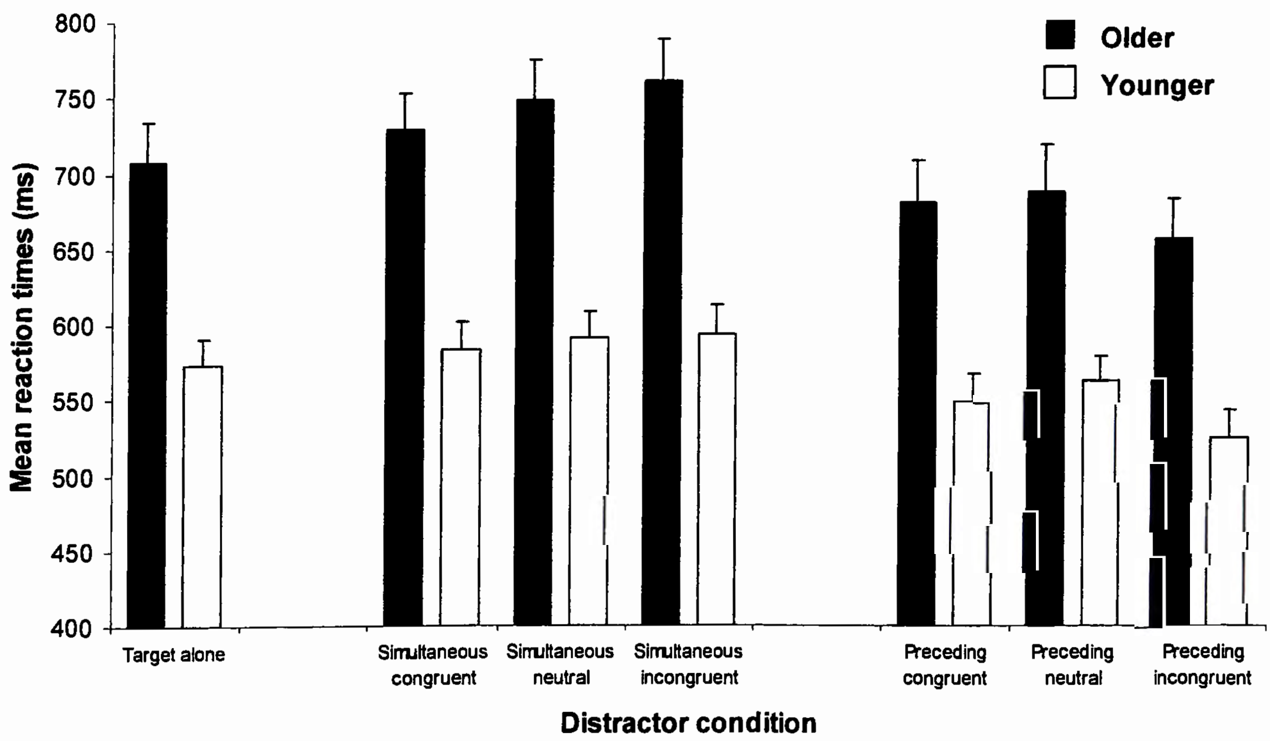

Figure 6. Mean reaction times (standard error bars) for distractor order

RT latencies in the Target Alone condition were significantly faster compared with the Simultaneous conditions and significantly slower compared with the Preceding Congruent and Incongruent conditions (for all comparisons $p < .05$; see Table 5). There was no significant difference between the Target Alone and Preceding Neutral condition ($p > .05$).

Table 5. Target Alone comparisons with all other conditions for all participants

Condition	Mean Reaction Time (ms)	Standard Error	*t*	*p*
Target Alone	640.77	30.93	-	-
Simultaneous Congruent	656.73	30.55	-3.86	.001
Simultaneous Neutral	670.35	32.18	-5.59	.000
Simultaneous Incongruent	678.27	33.27	-5.77	.000
Preceding Congruent	614.99	32.95	3.54	.001
Preceding Neutral	625.45	34.52	1.9	.062
Preceding Incongruent	590.83	32.03	7.87	.000

Three-way mixed repeated measures ANOVA showed that there was a significant main effect of age, $F(1, 26) = 20.724, p < .0001$, with a large effect size, $\eta p^2 = 0.992$. Independent samples t-tests showed that younger participants' reaction times were significantly faster than older participants in all conditions (for all comparisons $p < .05$; see Table 6).

Table 6. Independent t-test age comparisons for each condition

	Mean Reaction Time (ms) (Standard Error)			
Condition	**Older Group**	**Younger Group**	***t***	***p***
Target Alone	707.9949 (95.7859)	573.5429 (64.9759)	4.35	.000
Simultaneous Congruent	729.2707 (93.3442)	584.1820 (65.9496)	4.75	.000
Simultaneous Neutral	749.3329 (99.0839)	591.3600 (68.4376)	4.91	.000
Simultaneous Incongruent	762.0096 (102.5570)	594.5236 (70.5512)	5.03	.000
Preceding Congruent	680.5769 (103.0260)	549.4073 (67.7058)	3.98	.000
Preceding Neutral	688.1537 (114.1405)	562.7446 (60.4183)	3.63	.001
Preceding Incongruent	656.5012 (99.7931)	525.1661 (66.3721)	4.00	.000

There was a significant main effect of distractor order $F(4,120) = 114.890, p < .0001$, with a large effect size $\eta p^2 = .815$, showing that RTs differed significantly between the Simultaneous and Preceding conditions. Further pairwise t-test comparisons revealed that RT latencies in the Simultaneous conditions were significantly slower compared with RT latencies for the Preceding conditions (all significant at $p < .0001$; Congruent $t(27) = 6.176$, Neutral $t(27) = 5.867$, Incongruent $t(27) = 6.787$, respectively). The interaction between age and distractor order was also significant, with a small effect size ($F(4,120) = 6.473, p = .05$, $\eta p^2 = .199$), indicating the effects of distractor order on reaction times differed depending upon the age of the participants.

There was also a significant main effect of distractor congruence $F(2,52) = 5.316, p = .008$, with a small effect size $\eta p^2 = .0170$, showing that RTs differed significantly between the Congruent, Neutral and Incongruent conditions. Further pairwise t-test comparisons revealed that RT latencies in the Simultaneous Congruent conditions were significantly faster than those for the Simultaneous Neutral and Incongruent conditions ($t(27) = -2.937, p = .007$, $t(27) = -4.247, p < .0001$, respectively). There was no significant difference between the Simultaneous Neutral and Simultaneous Incongruent conditions ($p > .05$). The Preceding Incongruent condition was significantly faster than the Preceding Neutral and Preceding Congruent conditions ($t(27) = 6.736, p = .< .0001$, $t(27) = 3.565, p = .001$, respectively). There was no significant difference between the Preceding Neutral and Preceding Congruent conditions ($p > .05$).

There was no interaction between age and distractor congruence ($F(2,52) = .817$, $p = .448$, $\eta p^2 = .170$), indicating the effects of distractor congruence on reaction times did not differ depending upon the age of the participants. The three way interaction of age, order and congruence was also insignificant ($F(2,52) = 1.261$, $p = .292$, $\eta p^2 = .046$).

There was, however, a significant interaction between distractor order and distractor congruence, independent of age ($F(2,52) = 23.063$, $p > .0001$, medium effect size $\eta p^2 = .470$), indicating the effects of distractor congruence on reaction times was dependent on the order of distractor presentation. Subsequent analysis of this effect using pairwise t-test comparisons revealed participants' RT latencies were significantly longer in the Simultaneous Conditions when compared to the Preceding conditions (Congruent, $t(27) = 6.176$, $p > .0001$; Neutral, $t(27) = 5.867$, $p > .0001$; and Incongruent, $t(27) = 11.428$, $p > .0001$).

Further 2x3 repeated measures ANOVAs were used to explore the significant differences in reaction times within age groups. Analysis in the older group revealed there was a significant main effect of distractor order, $F(1, 26) = 60.709$, $p = .00011$, with a large effect size $\eta p^2 = .824$, showing that RTs differed significantly between Simultaneous and Preceding conditions. Pairwise t-test comparisons revealed significantly slower RT latencies in all Simultaneous conditions compared to the Preceding conditions (Congruent $t(14) = 4.479$, $p = .001$, Neutral $t(14) = 5.146$, $p > .0001$, and Incongruent $t(14) = 9.351$, $p > .0001$, respectively).

There was no significant main effect of distractor congruence, $F(1, 26) = 1.776$, $p = .189$, $\eta p^2 = .120$. However, there was a significant interaction of distractor order and congruence, $F(2, 26) = 13.496$, $p = .00011$, with a medium effect size $\eta p^2 = .509$, indicating that the effects of distractor congruence on reaction times differed depending upon the order of the distractor presentation. Subsequent analysis of this effect using pairwise t-test comparisons revealed the RT latencies in the Simultaneous conditions were significantly slower than the Preceding conditions (Congruent $t(13) = 4.479, p = .001$, Neutral $t(13) = 5.146$, $p > .0001$, and Incongruent $t(13) = 9.351, p = .00011$).

In the younger group, 2x3 repeated measures ANOVA revealed a significant main effect of distractor order, $F(1, 26) = 60.608, p < .0001$, with a large effect size $\eta p^2 = .823$, showing that RTs differed significantly between Simultaneous and Preceding conditions. Subsequent analysis using pairwise t-test comparisons revealed significantly slower RT latencies in the Simultaneous conditions compared to the Preceding conditions (Congruent $t(14) = 4.346, p = .001$, Neutral $t(14) = 3.660, p = .003$, and Incongruent $t(14) = 8.565, p = .00011$, respectively).

There was also a significant main effect of distractor congruence for younger participants, $F(1, 26) = 9.789, p = .003$, with a large effect size $\eta p^2 = .620$, showing that RTs differed significantly between the Congruent, Neutral and Incongruent conditions. Further analysis using pairwise t-test comparisons revealed that RT latencies in the Simultaneous Congruent conditions were significantly faster compared with RT latencies for the Simultaneous Incongruent condition ($t(14) = -2.188, p = .048$). There was no significant difference between RTs for the Simultaneous Neutral and Simultaneous Incongruent conditions, nor between the Simultaneous Neutral and Simultaneous Congruent conditions (both $p > .05$). RTs for the Preceding Incongruent condition were significantly faster than the Preceding Neutral and Preceding Congruent conditions ($t(14) = 5.002, p = .< .0001$, $t(14) = 2.562, p = .024$, respectively). There was no significant difference between the Preceding Neutral and Preceding Congruent conditions ($p > .05$).

The distractor congruence main effect was dependent upon distractor order as there was a significant interaction of distractor congruence and distractor order, $F(2, 26) = 10.283, p = .001$, with a medium effect size $\eta p^2 = .442$. The effects of distractor congruence on reaction times differed depending upon the order of the distractor presentation; pairwise comparisons revealed RT latencies were significantly slower in the Simultaneous condition when compared to the Preceding condition (Congruent $t(13) = 4.346, p = .001$, Neutral $t(13) = 53.660$, $p = .003$, and Incongruent $t(13) = 8.565, p > .0001$).

Overall, in terms of temporal sequence of distractor presentation, there was significantly more distractor interference in the simultaneous condition when compared to the preceding condition for both groups. There was also significantly more interference when the distractor was incongruent to the target compared to when the distractor was congruent or neutral to the target for both groups. There were significant age differences between the two groups according to distractor order but not distractor type. That is, there was a significant interaction between distractor order and age with the older adult group demonstrating significantly longer reaction times when compared to the younger group for both the simultaneous and preceding conditions. There was, however, no interaction of age and congruence suggestive that the older adults were just as capable of inhibiting the distracting information as the younger adults. That is, the older group demonstrated a similar pattern of responses in each condition that the younger group did, except they were slower, overall in their response execution.

3.2.2 Response Accuracy (Mean Number of Errors)

Mean number of errors for both older and younger participants across the six conditions is shown in Figure 7. Overall errors due to anticipatory responses (reaction times of less than 150ms), or no response (2,000 ms elapsed) were less than one percent and were excluded from subsequent analyses.

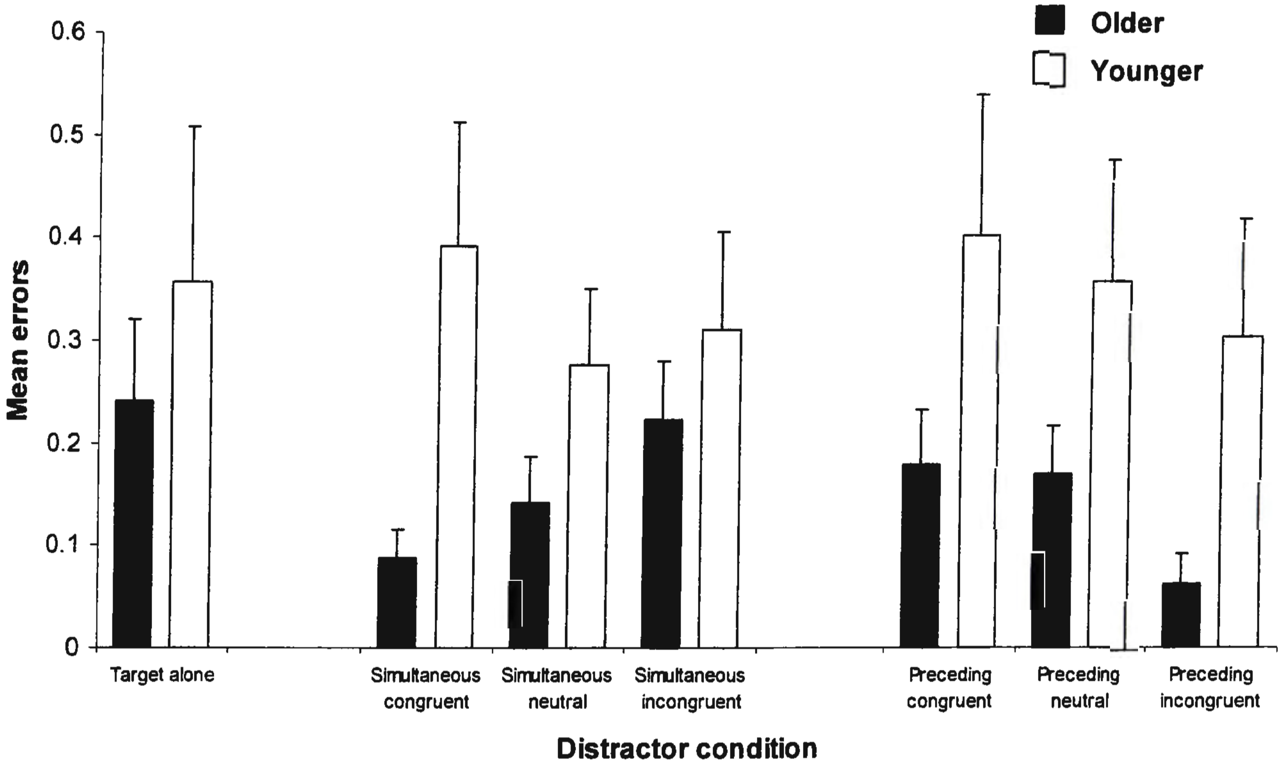

Figure 7. Mean no. errors (standard error bars) for each condition.

Pairwise t-test comparisons were conducted comparing the Target Alone condition with the Simultaneous and Preceding conditions to assess whether the presence of a distractor had an impact on error rate for both older and younger participants. There was no significant differences between any of the conditions (for all comparisons $p > .05$; see Table 7).

A 2x3x2 mixed repeated measures ANOVA revealed no significant main effect of age, $F(1, 26)$ 3.682, $p = .066$, $\eta p^2 = .124$; however, there appeared to be a trend towards greater accuracy for older participants, as shown in Figure 7. There was also no significant main effect of distractor order $F(1, 26) = .042$, $p > .05$, $\eta p^2 = .002$, or distractor congruence $F(2, 52) = .748$, $p > .05$, $\eta p^2 = .028$. There were no significant interactions of age and distractor order $F(1, 26) = .511$, $p > .05$, $\eta p^2 = .019$, age and congruence $F(1, 26) = 1.464$, $p > .05$, $\eta p^2 = .053$, or distractor order and congruence $F(1, 26) = .2.418$, $p > .05$, $\eta p^2 = .085$, The three-way age, order and congruence interaction was not significant $F(1, 26) = .1.327$, $p > .05$, $\eta p^2 = .049$.

Table 7. Target Alone comparisons with all other conditions for all participants

Condition	Mean Number of Errors	Standard Error	*t*	*p*
Target Alone	0.30	0.17	-	-
Simultaneous Congruent	0.24	0.12	0.97	.340
Simultaneous Neutral	0.21	0.09	1.61	.120
Simultaneous Incongruent	0.27	0.11	0.56	.578
Preceding Congruent	0.29	0.15	0.19	.853
Preceding Neutral	0.26	0.13	0.78	.443
Preceding Incongruent	0.18	0.12	1.86	.073

These results demonstrate that although response accuracy was not significantly affected by age of participant or by distractor order or congruence, there appears to be a trend towards greater accuracy (i.e. fewer errors) for older participants across all conditions, even those requiring greater inhibition.

3.3 Discussion

The aim of experiment 2 was to extend to findings of Eriksen and Eriksen (1974), Watson and Humphreys (1998) and Kritikos et al. (2008) by manipulating the compatibility or congruence of distractors and targets under various temporal separation conditions (Simultaneous and Preceding-200ms); and to also examine the impact of these manipulations on RT latency and response accuracy in different age groups. It was hypothesised that for both older and younger adults, incongruent distractors would result in increased levels of interference when compared to the neutral and congruent distractors, which would be more facilitative or have no effect at all. The modification of distractor identity ensured variety so participants were not able to predict distractor identity and therefore suppress the distractor-related responses in advance. This enabled the investigation of Hasher and Zack's (1988) proposal that older adults would experience even more distractor interference than the younger group due to reduced inhibition mechanisms, especially when the distractor-target presentation was incongruent. Salthouse's (1996) slowed information processing theory was also examined and it was anticipated that the older adults would show a similar pattern of results in response to changes in distractor congruence (i.e. intact inhibitory processing) with an overall slowing of reaction times when compared to the younger group.

Overall, the results indicated that RTs increased in the presence of a distractor, compared with a target presented alone, regardless of whether the distractor appeared with, or preceded the target. The compatibility between the distractor and target modulated the magnitude of distractor interference, especially in the presence of a simultaneous distractor. More specifically, incongruent distractors caused greater levels of interference for all participants, as measured by increased reaction times, particularly when they were presented simultaneously with targets. Consistent with the findings of Kritikos et al. (2008) response times were slower when the distractor was incongruent with the target and increased as a function of neutral and congruent distractors, respectively. These results are also consistent with Eriksen and Eriksen (1974) and Watson and Humphreys (1998) who found reaction times were slowest when the distractors were incongruent to the target, with neutral distractors having an intermediate effect and congruent distractors resulting in faster reaction times indicative of facilitatory effects.

Consistent with the results of Experiment 1, the distractor interference effect, as measured by reaction times, was marginally smaller for both groups when the distractor preceded target onset by 200ms when compared to the Simultaneous condition. Even though this time frame was used because it was when distractor interference was maximal (0-200ms) in Experiment 1, it seems that there were still some facilitatory mechanisms assisting response selection for both groups, even within this small time frame. When the duration of the temporal interval between distractor and target increased, both groups were able to effectively inhibit distracting responses with the distractor interference effects being replaced by a facilitation of target responses. This finding was reflected by a reduction in response times and also a reduction in number of errors made for both groups in the Preceding condition.

There were significant age differences between the two groups in reaction times according to distractor order. The older group was significantly slower in responding than the younger participants, particularly in the Simultaneous when compared to the Preceding conditions. Despite some significant methodological differences in research design, the current findings are consistent with many other studies that have also found significant age related declines in speed of information processing (Maciokas & Crognale, 2003; Palfai et al., 2003; Madden & Langley, 2003; Madden et al., 2002; Salthouse, 1996; McDowd & Filion, 1995). In contrast, the identity of the distractor (congruent, neutral or incongruent) did not seem to have a differential effect on reaction times as a function of age. That is, distractor interference as measured by response speed was no more apparent in the incongruent condition (presumably requiring greater inhibitory processing) in the older group when compared to the younger group as was hypothesised. In terms of accuracy (errors rates) there were no significant differences between any of the conditions or participants. However there was a trend towards greater accuracy for older participants. Therefore the presence of an incongruent distractor did not lead to significantly more errors for the older participants as originally predicted.

In summary, regardless of whether a distractor appeared simultaneously with, or preceded by a target, the identity and thus the relationship between distractor and target did modulate the magnitude of distractor interference for both groups with incongruent distractors being more distracting in general. Overall, there were significant age differences in response times with the older group being slower to respond. The results also show that on this simple visual distractor task the older group had intact inhibitory mechanisms despite being slower to process the information. They were no different in their response to incongruent distractors than the younger group and older adults were no less accurate than the younger group; in fact they did not vary in terms of performance accuracy.

GENERAL DISCUSSION

During both experiments the aim was to investigate whether the reported performance decrements of older compared with younger participants in attentional tasks is due to impairments in information processing speed or inhibitory operations as postulated by Salthouse (1996) and Hasher and Zack's (1988), respectively. This was addressed by replicating distractor interference paradigms used originally by Eriksen and Eriksen (1974); Watson and Humphreys (1988) and more recently by Kritikos et al. (2008). These paradigms typically require inhibition of response to a distractor, while responding as fast as possible to targets. In Experiment 1 the temporal interval between the appearance of a distractor and target was manipulated. In Experiment 2 the response compatibility between distractors and targets was manipulated. Distractor interference was measured using latency and accuracy of reaction time responses. The performance of an older group was compared with that of a younger group.

In Experiment 1 the pattern of performance was similar for the older and younger participants: distractor interference was significantly greater for both groups when the distractor appeared simultaneously with the target and also when the distractor offset preceded target onset by 93-200ms. The extent of distractor interference on target responses changed as the duration of the temporal separation between distractor offset and target onset increased. That is, distractor interference was significantly reduced after this interval, a finding that was consistent with the literature (Kritikos et al., 2008; Jiang & Chun, 2001; Flowers & Wilcox, 1982; Duncan et al., 1994). Interestingly, unlike previous studies, there was some restitution of distractor interference effects at 893-1000ms, an interval anticipated to be more facilitative (Kritikos et al., 2008; Jiang & Chun, 2001; Flowers & Wilcox, 1982; Duncan et al., 1994).

The crucial finding of Experiment 1, however, was that despite the similarity in distractor interference modulation across conditions for both groups, the only significant difference between the age groups was that the older group was slower to respond in all conditions compared with the younger group.

The results of Experiment 2 demonstrated that target-distractor congruence modulated distractor interference. That is, incongruent distractors caused greater interference than neutral and congruent distractors (consistent with Eriksen & Eriksen, 1974; Watson & Humphreys, 1998; Kritikos et al., 2008). This effect was apparent in both Simultaneous and Preceding conditions and was similar in nature for both age groups. That is, target-distractor compatibility did not have a differential effect on reaction times or accuracy as a function of age.

The same two older participants who were left out of the analysis for the first experiment continued with the second experiment at the time as it was uncertain whether they made the error criterion or not at that stage. However, an important issue to consider is the generalisability of the findings of the current experiments, especially given that two of the older participants were excluded from analysis due to greater than 10 percent errors. It is difficult to know whether this was an overrepresentation due to sampling issues, or whether it reflects a significant minority of normally ageing older adults who will perform poorly on such tasks. In future more robust screening of potential participants to ensure a more homogeneous sample in terms of illness and educational background would help to clarify this issue.

Overall, the older group were significantly slower in responding when compared with the younger group. However, they displayed similar patterns of performance across distractor conditions, and their accuracy was comparable to that of the younger group. These aforementioned results for both Experiments 1 and 2 will now be discussed in terms of inhibition of responses to distractors as well as speed of responses to targets with advancing age.

4.1 Distractor Inhibition and Ageing

As previously explained in section 1.2.3.2 the process of selective attention may be understood in terms of a dual process model. That is, first focused selective attention on relevant information is necessary for selection of relevant information. Secondly, but equally importantly, active inhibition of irrelevant information is also required (McDowd & Oseas-Kreger, 1991). This is consistent with Triesman's (1969) attenuating filter model of selective attention and is also supported by neurophysiological studies indicating activation of neural pathways to relevant information and inhibition of neural pathways to irrelevant information (McDowd & Oseas-Kreger, 1991). In terms of this current thesis, the responses of the older group during both experiments were overall slower than that of the younger group. It is feasible this was due to an impaired ability to inhibit irrelevant information, ultimately impacting on efficiency of response times. Essentially, two attentional processes may be causing this pattern of performance. First, distractor inhibition can facilitate response selection of a target (for example, Jiang & Chung, 2001). Second, attention may in fact fail to filter out the distractors at the stage of perceptual identification and analysis (Jiang & Chung, 2001). This means that the correct response may be elicited despite an increased latency to identify which stimulus needs to be inhibited. This type of performance could be one possible explanation of lengthy reaction times within the older group: that is, why the older group were slower at inhibiting the distractor than the younger group.

The findings of this thesis, however, do not support theories that with increased age there is a reduction of inhibition to irrelevant information reflected in increased errors and / or increased response latencies to targets. Instead, the findings of this research suggest that older participants may in fact be <u>more accurate</u> in their response selection their younger counterparts. Overall, there was no differential modulation of response latencies for target-distractor compatibility (congruent, neutral or incongruent) according to age. Therefore, it appears that the older adults' visual attentional mechanisms in these tasks were, with the exception of general slowing, at least equal to those of the younger participants. Furthermore these findings are in contrast to other studies which have used the response competition paradigm and have shown that older adults experience greater interference from an incompatible distractor (as demonstrated by slower RTs) than younger adults (Simone et al., 2006; Maylor & Lavie, 1998). Therefore, in terms of inhibition of responses to distractors, these results do not support Hasher and Zack's (1988) theory that ageing is associated with a reduction in the ability to inhibit unwanted information. This is evidenced by the older group demonstrating the same pattern of interference in both experiments as the younger group did. Furthermore, these findings are consistent with literature in which positive and negative priming effects seem to exist for both age groups (Gamboz et al., 2000; Kotary & Hoyer, 1995; Sullivan & Faust, 1993; Kane et al., 1994; Kane et al., 1997).

Overall, the results of this current thesis demonstrate that older participants can make an accurate response selection, although it is delayed. The results of Experiment 2 indicated that the older group could perform similarly to their younger counterparts and therefore were no different in inhibiting the distracting incongruent information, a finding which contradicts Hasher and Zack's (1988) theory of reduced inhibition with advancing age. Therefore, based on the findings of the current research, the next section of this thesis is dedicated to discussing the mechanisms responsible for the slowed speed of responses within the older group in an attempt to examine whether Salthouse's (1996) reduced processing speed theory can be confirmed or denied.

4.2 Speed Of Information Processing and Ageing

Overall, for both groups, distractor information impacted on goal-directed actions, especially when the target was presented simultaneously with or immediately following distractor presentation and also when the distractor was incongruent to the target. The only significant difference between the age groups was that the older group was slower in responding compared with the younger group for all conditions in both experiments. Overall the older adult group were slower than the younger group but were no less accurate in their responses. These findings are congruent with Salthouse's (1996) processing speed theory, in which he postulates that weaknesses in cognitive performance may be attributed to a general age-related slowing of information processing, rather than primary deficiencies in selective attention mechanisms. There are many other RSVP studies that provide support for the theory that age-related cognitive declines in normally ageing older adults are attributable to a primary deficit in speed of information processing (Maciokas & Crognale, 2003; Palfai, Halperin & Hoyer, 2003; McDowd & Filion, 1995; Kotary & Hoyer; 1995; Madden & Langley 2003).

The results also indicated that for both groups, the processing of the distractor continued to have an impact on responses after target onset, consistent with Treisman's (1964 & 1969) Attenuation Model of selective attention. There was, however, a critical time interval (293-400ms) during which the relevant target onset was no longer vulnerable to disruption from processes relating to the preceding distractor. It was speculated that distractor processing was completed at this point. Consistent with previous studies, at this interval postulated, negative priming caused facilitation in responses, ultimately leading to priming of more efficient response selection (Kritikos et al., 2008; Driver & Tipper, 1989; Flowers & Wilcox, 1982). Thus, the stimulus trace of the irrelevant information dissipated within this time frame, resulting in the utilisation of efficient information processing mechanisms and reducing the need for distractor inhibition.

This pattern is consistent with Salthouse's (1996) postulation of a limited time mechanism, whereby relevant cognitive operations were executed too slowly to be successfully completed within a small time frame (93-200ms) but could be performed effectively once the processing time increased (293-400ms). This is also consistent with Duncan and colleagues (1994) who used a visual search task with temporal separation intervals ranging between 0-900ms. They found the time that an identified object continued to occupy attentional capacity was only between 100-300ms. They asserted that the suppression of neuronal responses required to ignore objects develops over several hundred milliseconds resulting in negative priming effects as the utilisation of active inhibition mechanisms interferes with speed of processing as well as accuracy of response selection.

Unexpectedly, however, in the current study this facilitative effect at 293-400ms was replaced by re-emerging distractor interference at the 893-1000ms. It was initially anticipated that this lengthier time frame would be beneficial for an ageing group of participants, allowing them plenty of time to fully process all required information. It is postulated, however, that the 893-1000ms intervals may have led to an increase in interference of irrelevant information due to the fact that the participants might have initially drained capacity of attentional resources by focusing on information at an early stage of selection. Consistent with Eriksen and Eriksen (1974) the active inhibition mechanisms required to inhibit such information for a lengthy period of time, may be responsible for slowing reaction times.

Nevertheless, the findings of this current study are also inconsistent with the "attentional blink" hypothesis which asserts second target performances can be improved once the interval between the two targets increases (Jiang & Chun, 2001). Therefore, another possible explanation could be that after a lengthy time delay, both groups still had a multitude of attentional resources available which resulted in an increased likelihood for distractor interference to take place. Lavie (1995), who also used a display with low perceptual load (a small number of items in the display), showed (young) participants were susceptible to distractors when attentional resources to targets were not exhausted, therefore there was more chance for interference to occur. She hypothesised a limited amount of attentional capacity can be taken up by task-relevant information; therefore the remaining resources may "spill over" into task-irrelevant information, ultimately leading to an increased likelihood of distractor interference. It is possible that in the paradigms implemented here, the low perceptual load of the task along with the less restrictive time constraints may have placed less demand on attentional resources and therefore increased susceptibility to interference of extraneous information for both age groups.

Overall, there was no dissociation between the two age groups in terms of performance, suggesting that attentional processing was still intact in the older group, despite their overall slower reaction times. These findings are consistent with Salthouse's (1996) reduced processing speed hypothesis with advancing age, as within the longest time frame (893-1000ms), the older group was still relatively slower to respond to the distracting information when compared to the younger group. Palfai and colleagues also found the older adult participants (mean age 69.2 years) in their study performed similarly but were slower at encoding the information than younger participants (mean age 19.1 years), manifesting in increased RTs. In line with the current study, Palfai and colleagues concluded that a limited time mechanism, such as that proposed by Salthouse (1996), could account for the age-related differences in memory for rapidly presented information. This was because the older adults performed similarly to the younger adults but were slower at encoding the information. Both groups had difficulty retaining the target-distractor information, however, with increased intervals between distractor and target. They presented Chinese symbols between 500-6000 ms exposures across six fixed sequences for each participant. They found recognition accuracy to be lower for the older compared with the younger adults, especially at shorter stimulus durations. Performance accuracy differences between the groups improved, however, with longer stimulus exposure times. Thus, similar to the present study, processing was completed, or the distracting trace dissipated with time, resulting in no interference. This finding has implications for ideal rates of presentation of information to older people, especially when they need to make speeded responses. Furthermore, this study highlights the target-distractor interval of 893-1000ms might have been too long in order to effectively examine response-competition effects in both older and especially in younger cohorts.

In conclusion, the results of this current thesis support Salthouse's (1996) reduced processing speed theory with advancing age. Nevertheless, the cognitive findings discussed do not determine what is happening at a neurophysiological or neurobiological level within the ageing brain. The next sections will consider the reasons older adults seem to be slower at encoding and processing this relatively simple visual information.

4.3 The Ageing Brain and the Neurobiology of Information Processing

The results of this thesis, showing overall slowing of processing speed in older adults, with little evidence for deficits in inhibition, support the numerous previous findings that declines in processing speed are associated with advancing age. One probable cause of such cognitive difficulties may be related to the neurobiological changes associated with ageing. The ageing literature suggests that brain changes associated with normal ageing tend to affect information processing speed and may consequently also affect fluid intellectual and cognitive abilities (Troller & Valenzuela, 2001). Ageing is generally associated with a 5% reduction in brain weight and volume per decade after 40 years of age (Troller & Valenzuela, 2001). A predominance of this shrinkage has been identified in the frontal lobes, and is particularly attributable to gray matter loss (Troller & Valenzuela, 2001). Prefrontal atrophy is thought to be double that of the temporal or parietal neocortex (Troller & Valenzuela, 2001). Changes in the volume, structure and function (in terms of neurotransmitters) of the prefrontal cortex are thought to affect fronto-striatal and fronto-parietal circuits (Hedden, 2007). For example, in his 2007 review, Hedden identified age-related changes due to white matter volume reductions, deficits in dopaminergic neurotransmission as well as functional activation. These are thought to be associated with many cognitive changes related to advancing age including attentional control, working memory, task switching and inhibition. Furthermore, white matter tracts in the frontal lobes tend to exhibit an age-related loss of integrity thought to affect memory circuits involving the frontal cortices (Hedden, 2007). Head et al. (2004) have also identified age-associated declines in executive functioning and cognitive control and attention due to degradations associated with alterations of the anterior corpus callosum and frontal white matter of the brain, including volume reductions, demyelination and white matter degeneration observed as white matter hyperintensities.

In addition, studies have indicated that normal older adults have significant areas of white matter hyperintensities, often in the subcortical frontal regions of the brain which have been inversely related to performance in executive tasks as well as speed of information processing (Troller & Valenzuela, 2001). Troller and Valenzuela (2001) propose that by around the age of 50 years the degree and number of microvessel deformities increase, including thickening in the capillaries as well as thickening in the intima of the major cerebral arteries. The middle cerebral artery territories tend to be more affected. Such changes ultimately compromise neurocognitive functioning by increasing vascular resistance and decreasing perfusion pressure (ultimately impairing glucose and oxygen transportation and diffusion). This is thought to be the main reason for white matter hyperintensities. Such ischaemic changes along with cholinergic and dopaminergic alterations to neurotransmission are thought to cause neuronal degeneration around the surrounding areas of the affected arteries. This is thought to be associated with generalised slowing of information processing with documented changes in reaction times and motor speed and is thought to also contribute to executive dysfunction.

Furthermore, Hedden (2007) proposes that this age-related cognitive decline is likely to undertake a pathologically distinct course to those older adults with underlying Alzheimer's disease (DAT) in which pathological age-related changes tend to be more prominent in the medial temporal lobes. This distinct course is thought to begin with volume losses in the entorhinal cortex ultimately affecting networks between the hippocampus and association cortices. The effects of these neurobiological changes associated with DAT are discussed in more detail in the following section in an attempt to identify which specific constructs are likely to be affected, that is, information processing speed or attentional inhibition.

4.4 Slowed Processing and Inhibitory Mechanisms in Clinical Populations

It is well documented that people with DAT exhibit deficits in memory and learning (Simone & Baylis, 1997). Episodic amnesia is usually the first cognitive indication of DAT (Amieva et al., 2004). Attentional and executive (non-memory) deficits are also thought to occur early in the disease process (Amieva et al., 2004). Deficits in divided attention, selective attention and executive dysfunction have also been well documented in the literature (Amieva et al., 2004). It is thought that an inability to attend to relevant stimuli and ignore relevant stimuli may be responsible for the more complex memory and executive functioning deficits (Simone & Baylis, 1997). There has been a strong body of research to support normal ageing is generally associated with intact inhibition, whilst progressively dementing illnesses associated with ageing such as DAT have been more implicated in poor selective inhibition (Sullivan et al. 1995; Simone & Baylis, 1997; Langley et al., 1998; Ko et al., 2005; Amieva et al., 2004). For example, a study by Simone and Baylis (1997) examined the ability of young adults, older adults and older adults with DAT to perform a simple visually presented selective reaching task. Latencies in reaction times as well as latencies between the release of the home key to the reach of the next home key were recorded. They found increased response latencies for the older participants to move from the home key to the target key, attributable to slower processing of feedback information. They also found increased decision making times in the older and DAT participants when asked to depict when the display had been illuminated, possibly reflecting ageing-related effects on divided attention. In addition, the DAT group tended to respond more frequently to distractors presented closer in proximity to their hands and was generally unable to inhibit responses to distractors. This may implicate deficient inhibitory mechanisms in the DAT patient. The DAT patients were unable to inhibit their distractor responses and therefore made more distractor errors, despite knowing their responses were incorrect.

Sullivan et al. (1995) presented participants with a variety of line drawings, some with solid and others with dotted lines. The ones with dotted lines were the "to be ignored" pictures. They found significant negative priming effects in younger and older adults but less consistent results with the participants with DAT suggesting that DAT patients were unable to inhibit irrelevant information efficiently. In contrast, Langley et al. (1998) also examined negative priming effects in DAT patients using a letter-naming task. They found young adults; older adults and patients with DAT all exhibited negative priming effects, with particularly larger negatively priming effects in the Alzheimer's patients. However, their task was comparatively simpler in nature (using letters as opposed to words and pictures) and subjects were given longer preparatory intervals to respond. Perhaps the used of more semantic information (information which is known to be more difficult for people with Alzheimer's disease to understand) was problematic in the Sullivan et al. (1995) study.

Amieva et al. (2004) reviewed current literature on inhibitory functioning in DAT in a multitude of cognitive domains, such as working memory, selective attention and shifting abilities, slowed processing and the inhibition of verbal and motor responses. These abilities were measured according to tasks such as Stroop, negative priming, go/no-go task, antisaccades, inhibition of return, directed forgetting and retrieval-induced forgetting. They found evidence to suggest that some inhibitory measures were well preserved in the disease whilst most others were affected. They concluded that DAT was not associated with a general inhibitory breakdown. They felt more controlled inhibition processes which tapped in to executive functions were less preserved in the dementing brain whilst tasks which tapped into more primitive, reflexive inhibition were less affected.

Overall, the DAT literature suggests that patients demonstrate impaired inhibitory mechanisms associated with the disease, which seem to be more profound than that of normal, healthy older adults. Despite evidence of this however, it seems that results are inconsistent at times and may depend on the types of experimental tasks utilised and the consequential attentional mechanisms they are likely to tap into.

4.5 Future Directions

Whilst in the current study the effects of distractor congruency on inhibitory processing were examined, the research design was a relatively simple stimulus-response task. However, the literature reports a wide variety of other studies that attempt to explore other aspects of inhibitory processing that have not yet been adequately explored within older age groups. More challenging cognitive tasks that look at more complex inhibitory processing, such as modifications of the Stroop colour-word task or go/no-go tasks, may provide methods by which to further examine the impact of ageing on inhibitory mechanisms. For example, Sylvester et al., (2003; as reported in Nee & Jonides, 2004) compared brain activation in subjects (college students aged 18-25 years) who performed a flanker task, a go/no-go task, and a stimulus-response compatibility task that required utilisation of different types of distractor inhibition mechanisms. In a single experiment, a group of participants completed all of these tasks while they underwent scanning using functional MRI. In each case, they compared a version of the task that demanded a good deal of inhibition with one that required less. For example, the flanker task required comparing the effects of incongruent versus congruent flankers; the go/no-go task involved examining trials in which a response had to be withheld after a series of trials in which a response was executed; the stimulus-response task required comparing trials in which there was an incompatible mapping between stimuli and responses versus a compatible mapping. They found brain activations in all tasks seemed to overlap with the insula cortex, dorsolateral prefrontal cortex, and parietal cortex. In addition, there was common activation in anterior prefrontal and premotor cortices. They also discovered brain activations that were unique to each interference task. They proposed this was because of the differences in the stage of processing to which the inhibition mechanisms were applied, that is, at the time of encoding material vs. storing material vs. responding to material in working memory, in line with Hasher and Zacks (1988) distractor inhibition theory. But evidence arguing for or against such a theory has previously come from very different tasks in different contexts.

Using an older population sample, Fozard et al., (1994) analyzed auditory reaction time (RT) data from 1,265 participants (833 males and 432 females) who ranged in age from 17 to 96. They recorded data using simple stimulus response times and go/no-go reaction times across an eight-year time span. They found once the participants turned 20 years, their stimulus response times increased approximately 0.5 ms per year and their go/no-go reaction times, 1.6 ms per year. Accuracy also declined in an attempt to acquire more speed. This study also discovered age related slowing to be more prominent in women than men. Overall, the findings were consistent with the hypotheses that cognitive slowing continues to occur over the adult life span and is dependent on task complexity (and associated regions of the brain responsible for higher order cognitive functions.) This study highlights the importance of modifying inhibition tasks such as the go/no-go tasks by changing the response conditions in order to make them harder in order to tap into more complex measures of inhibition, by comparison to the simple manipulation of congruence used in the current study._ The tasks presented in the current study were perhaps too simple, and increased complexity or task demand such as with go/no-go tasks may uncover inhibitory deficits in the older adults.

Such an attempt was made by a more recent study performed by Potter and Grealy (2008). Using a stimulus response task similar to that utilised by Fozard et al., (1994), as well as a go/no-go task, Potter and Grealy (2008) investigated in 134 older (aged 60-88) and 133 younger adults (aged 20-59) the ability to inhibit a prepotent motor response during an ongoing action. They found the older adults (>60 years) produced more inhibition failures, as expected. In addition, difficulties controlling ongoing movements emerged from people as young as 40. They concluded that such results may not have been detected in traditional cognitive tasks and that future researchers need to tap into other more complex inhibitory processes reliant on executive functions, which could possibly be affected with advancing age. Future researchers may therefore wish to consider using go/no-go tasks or a Stroop-like task, which tap into different inhibitory capabilities. This may be performed by adding another dimension to the research design and increasing the load of the task. For example, the RSVP design may be used in conjunction with a higher order command, which would allow participants to respond to the target within the realms of certain designated criteria e.g. if a third stimulus is of a certain colour, shape, or both. This would allow the researcher to increase task demands sequentially in order to increase inhibitory demands and perhaps uncover the point at which older adults' inhibitory processes are likely to break down.

These types of tasks which involve more complex levels of processing within the realms of a relatively simple experimental paradigm may also prove beneficial in regards to therapeutic measures. That is, future researchers may wish to examine pre- and post-intervention measures to see if they could identify improvements in selective attentional measures which may help abate age associated decrements in cognitive performance.

Futhermore, it may also be beneficial for studies to be done with ecologically valid stimuli rather than just simple letters, as things that are more representative of "real life" experience may result in different, more relevant findings.

4.6 Conclusion

In conclusion, with regards to normal age related differences in performance, this study had four major findings. Normal ageing did not affect the performance of the selective attention task, because the pattern of performance was similar for younger and older adults. Second, the inhibition of distractors and resulting negative priming effect were also unaffected by normal ageing. Third, normal ageing had an adverse effect on information processing speed. Fourth, cognitive and attentional mechanisms remained relatively intact for the older group and almost superseded the younger group in performance accuracy. Overall, there was no evidence of an age-related decline in attentional processing, as cognitive systems for both younger and older adults were vulnerable to interference at the same temporal intervals and under similar distractor identity conditions. Normal ageing had more of a profound impact on information processing speed providing support for Salthouse's (1996) reduced information processing theory. Inhibition of distractors and the resulting negative priming were unaffected by normal ageing and do not support Hasher and Zack's (1998) theory of age associated reduced inhibition.

The pronounced brain changes in healthy advanced age, particularly affecting frontal circuitry of the brain might be the pathological underpinnings for the slowed information processing in advancing age, proposed by Salthouse (1996). Such frontal circuitry appears to play a central role in many age related cognitive changes, particularly fluid functions responsible for attainment of new information and executive functioning associated with advancing age (Salthouse, 1996). Decline in cognitive abilities has been shown to lead to an increased risk of difficulty in performing activities of daily living and can ultimately affect the quality of life for the older patient.

The older adult segment of populations in the western world is growing rapidly, reaching much older ages than previous generations, and in doing so, redefining what constitutes "normal" cognitive ageing. Contemporary elderly are healthier and more active; they drive and work well into their later years. It is therefore clinically relevant to study a "normal" ageing population in order to better understand how it can be differentiated from "abnormal" signs of ageing. The notion of "normal" ageing needs to be better characterized so that there is a representative body of information about contemporary older people, which can be compared to the ever-growing literature about dementia.

Given the substantial increase in the ageing population, adequate identification of deficient mechanisms involved in selective processing associated with normal ageing can therefore ensure appropriate intervention measures can be pursued. Findings such as the ones presented in this thesis have significant implications both for the sequence and speed of presentation of information to the ageing population and for the development of effective rehabilitation strategies in the ageing population. Older people's cognitive performance may therefore benefit from environmental support or cognitive training measures which improve information processing and attentional mechanisms, which can also be generalised to other similar activities, engaged in everyday life.

REFERENCES

Andres, P., Parmentier, F.B.R., Escera, C. (2006). The effect of age on involuntary capture of attention by irrelevant sounds: A test of the frontal hypothesis of aging. *Neuropsychologica, 44,* 2564-2568.

Amieva, H., Phillips, L.H., Sergio, D.S. & Henry, J.D. (2004). Inhibitory functioning in Alzheimer's disease. *Brain, 127,* 949.

Babcock, R., Laguna, K.D. & Roesch, S.C. (1997). A comparison of the factor structure of processing speed for younger and older adults: Testing the assumption of measurement equivalence across age groups. *Psychology and Aging, 12(2),* 268-276.

Bashore, T.R., Ridderinkhof, K.R. & Van der Molen, M.W. (1997). The decline of cognitive processing speed in old age. *Current Directions in Psychological Science, 6(6),* 163-169.

Bekkering, H. & Neggers, S.F.W. (2002). Visual search is modulated by action intentions. *Psychological Science, 13(4),* 370-374.

Broadbent, D.E. (1952). Listening to one of two synchronous messages. *Journal of Experimental Psychology, 44,* 51-55.

Broadbent, D.E. (1954). The role of auditory localisation in attention and memory span. *Journal of Experimental Psychology, 47,* 191-196.

Broadbent, D. E. (1958). *Perception & Communication.* London: Pergamon.

Cabeza, R., Dalsalaar, S.M., Dolcos, F., Prince, S.E., Budde, M., Nyberg, L. (2004). Task-independant and task-specific age effects on brain activity during working memory, visual attention and episodic retrieval. *Cerebral Cortex, 14(4):* 364-375.

Connelly, S.L. & Hasher, L. (1993). Aging and inhibition of spatial location. *Journal of Experimental Psychology: Human Perception and Performance, 19,* 1238-1250.

Deutsch, J.A. & Deutsch, D. (1963). Attention, some theoretical considerations. *Psychological Review, 70,* 80-90.

Driver, J. & Tipper, S.P. (1989). On the nonselectivity of "selective" seeing: Contrasts between interference and priming in selective attention. *Journal of Experimental Psychology: Human Perception and Performance, 15(2).*

Duncan, J., Ward, R. & Shapiro, K. (1994). Direct measurement of attentional dwell time in human vision. *Nature, 369,* 313-315.

Dywan, J., & Murphy, W.E. (1996). Aging and inhibitory control in test comprehension. *Psychology and Aging, 11,* 199-206.

Eltiti, S., Wallace, D. & Fox, E. (2005). Selective target processing: perceptual load or distractor salience? *Perception and Psychophysics, 67(5),* 876-885.

Eriksen, B.A. & Eriksen, C.W. (1974). Effects of noise letters upon identification of a target letter in a non-search task. *Perception and Psychophysics, 16(1),* 143-149.

Eriksen, C.W. & Yeh, Y. (1985). Allocation of attention in the visual field. *Journal of Experimental Psychology: Human Perception and Performance, 11,* 583-597.

Eriksen, C.W., & St. James, J.D. (1986). Visual attention within and around the field of focal attention: A zoom-lens model. *Perception & Psychophysics, 40,* 220-240.

Feintuch, U. & Cohen, A. (2002). Visual attention and coactivation of response decisions for features from different dimensions. *Psychological Science, 13(4),* 361-374.

Ferrer, E., Salthouse, T.A., Stewart, W.F., & Schwartz, B.S. (2004). Modeling age and retest processes in longitudinal studies of cognitive abilities. *Psychology and Aging, 19(2),* 243-259.

Flowers, J.H. & Wilcox, N. (1982). The effect of flanking context on visual classification: The joint contribution of interactions at different processing levels. *Perception and Psychophysics, 32(6),* 581-591.

Forster, K. I. & Forster, J. C. (2003). DMDX: A Windows display program with millisecond accuracy. *Behavior Research Methods, Instruments, & Computers, 35,* 116-124.

Fozard, J.L., Vercryssen, M., Reynolds, S.L., Hancock, P.A. & Quilter, R.E. (1994) Age differences and changes in reaction time: the Baltimore Longitudinal Study of Aging. *The Journal of Gerontology, 49(4),* 179-189.

Gathercole, S.E. (1987). Spatial factors in visual attention: Some compensatory effects of localisation and time arrival of non-targets. *Perception, 16,* 433-443.

Gamboz, N., Russo, R. & Fox (2002). Age differences and the identity negative priming effect: An updated meta-analysis. *Psychology & Aging, 17(3),* 525-531.

Gamboz, N., Russo, R. & Fox (2000). Target selection difficulty, negative priming and aging. *Psychology & Aging, 15(3).*

Gordon, C. (2001). The influence of age and gender on information processing rate and accuracy. *Dissertation Abstracts International: Section B: The Sciences and Engineering, 61(8-B),* 4405.

Grady, C.L., Haxby, J.V., Horwitz, B., Schapiro, M.B., Rapoport, S.I. & Ungerleider, L.G. (1992). Dissociation of object and spatial vision in human extrastriate cortex: Age-related changes in activation of regional cerebral blood flow measured with water and positron emission tomography. *Journal of Cognitive Neuroscience, (4),* 23–34.

Hartley, A.A. & Kieley, J.M. (1995). Adult age differences in the inhibition of return of visual attention. *Psychology & Aging, 10(4).*

Hasher, L., Stolzfus, E.R., Zacks, R.T. & Rypma, B. (1991). Age and inhibition. *Journal of Experimental Psychology: Learning, Memory & Cognition, 17(1),* 163-169

Hasher, L., & Zacks, R.T. (1988). Working memory, comprehension and aging: A review and a new view. In G.H. Bower (Ed.), *The Psychology of Learning and Motivation* (Vol. 22, pp. 193-225). San Diego CA: Academic Press.

Head, D., Buckner, R.L., Shimony, J.S., Williams, L.E., Akbudak, E., Conturo, T.E., McAvoy, M., Morris, J.C. & Snyder, A.Z. (2004). Differential vulnerability of anterior white matter in non-demented aging with minimal acceleration in dementia of the Alzheimer type: Evidence from diffusion tensor imaging. *Cerebral Cortex, 14,* 410-423.

Head, D., Kennedy, K.M., Rodrigue, K.M. and Raz, N. (2009). *Neuropsychologica, 47,* 1200-1203.

Hedden, T. (2007). Imaging cognition in the aging human brain. In D.R. Riddle (Ed.) *Brain aging: Models, methods, and mechanisms.* (pp. 251- 276). Boca Raton, FL, US: CRC Press.

Horn, J. L., & Cattell, R.B. (1966a). Refinement and test of the theory of fluid and crystallised general intelligences. *Journal of Educational Psychology, 57,* 253-270.

Horn, J. L., & Cattell, R.B. (1967). Age differences in fluid and crystallised intelligence. *Acta Psychologica, 26,* 107-129.

Jiang, Y. & Chun, M.M. (2001). The influence of temporal selection on spatial selection and distractor interference: An attentional blink study. *Journal of Experimental Psychology: Human Perception and Performance, 27(3).*

Jonides, J. & Nee, D.E. (2004). Resolving conflict in mind and brain. *Psychological Science Agenda, 18(5).* Retrieved March 23, 2008 from http://www.apa.org/science/psa/sb-jonides.html

Kahnneman, D., Treisman, A, and Jacquelyn, B. (1983). The cost of visual filtering. *Journal of Experimental Psychology, Human Perception and Performance, 9(4),* 510-522.

Kane, M.J., Hasher, L., Stolttzfus, E.R., Zacks, R.T. & Connelly, S.L. (1994). Inhibitory attentional mechanisms and aging. *Psychology & Aging, 15,* 542-550.

Kane, M.J., May, C.P., Hasher, L., Ranhal, T., & Stoltzfus, E.R. (1997). Dual mechanisms of negative priming. *Journal of Experimental Psychology: Human Perception and Performance, 23,* 632-650.

Kaneko, R., Kuba, Y., Sakata, Y. & Kuchinomachi, Y. (2004). Aging and shifts of visual attention in saccadic eye movements. *Experimental Aging Research, 30,* 149-162.

Kennedy, K.M. & Raz, N. (2009) Aging white matter and cognition: Differential effects of regional variations in diffusion properties on memory, executive functions and speed. *Neuropsychologia, 47,* 916-927.

Ko, P.C., Higgins, J.A., Kilduff, P.T., Milberg, W. & McGlinchey, R. (2005). Evidence for intact selective attention in Alzheimer's disease patients using a location priming task. *Neuropsychology, 19(3),* 381-389

Kosslyn, S.M., Brown, H.D. & Dror, I.T. (1999). Aging and the scope of visual attention. *Gerontology, 45:* 102-109.

Kotary, L. & Hover, W.J. (1995). Age and the ability to inhibit distractor information in visual selective attention. *Experimental Aging Research, 21(2),* 159-171.

Kramer, A.F., Humphrey, D.G., Larish, J.F., Logan, G.D. & Strayer, D.L. (1994). Aging and inhibition: Beyond a unitary view of inhibitory processing in attention. *Psychology and Aging, 9,* 491-512.

Kramer, A.F. & Strayer, D.L. (2001). Influence of stimulus repetition on negative priming. *Psychology & Aging, 4,* 580-587.

Kritikos, A., McNeill, J. & Pavlis, A. (2007). Temporal dissociation between distractors and targets: The impact of residual distractor processing on target responses. *Journal of Motor Behavior, 40 (1)*, 29-42.

Langley, L.K., Overmier, J.B., Knopman, D.S. & Prod'homme, M.M. (1998). Inhibition and habituation: Preserved mechanisms of attentional selection in aging and Alzheimer's disease. *Neuropsychology, 12,* 353-366.

Lavie, N. (2005). Distracted and confused? Selective attention under load. *Trends in Cognitive Sciences, 9(2),* 75-82.

Lavie, N. (2001). Capacity limits in selective attention: Behavioural evidence and implications for neural activity. In Braun, J. & Koch, C. (Eds.), *Visual attention and cortical circuits.* Cambridge, Massachusetts: MIT Press.

Lavie, N. (1995). Perceptual load as a necessary condition for selective attention: Response competition from unattended distractor features. *Perception & Psychophysics, 59,* 543-556.

Lavie, N. & Cox, S. (1997). On the efficiency of visual selective attention: Efficient visual search leads to inefficient distractor rejection. *Psychological Science, 8(5),* 395-398.

Lavie, N. & Fox, E. (2000). The role of perceptual load on negative priming. *Journal of Experimental Psychology, 26(3).*

Lavie, N., Hirst, A., Fockert, J.W. & Viding, E. (2004). Load theory of selective attention and cognitive control. *Journal of Experimental Psychology, 133(3).*

Levitt, T. J., & Saskatchewan, U. (2000). The role of processing speed and attentional capacity in age-related episodic and working memory change. *Dissertation Abstracts International: Section B: The Sciences and Engineering, 60(12-B),* 6391.

Machado, L., Devine, A. & Wyatt, N. (2009). Distractibility with advancing age and Parkinson disease. *Neuropsychologica, in press.*

Maciokas, J.B. & Crognale, M.A. (2003). Cognitive and attentional changes with age: Evidence from attentional blink deficits. *Experimental Aging Research, 29,* 137-153.

Madden, D.J. & Langley, L.K. (2003). Age-related changes in selective attention and perceptual load during visual search. *Psychology & Aging, 18(1),* 54-67.

Madden, D.J., Turkington, T.G., Provenzale, J.M., Denny, L.L., Langley, L.K., Hawk, T.C. & Coleman, R.E. (2002). Aging and attentional guidance during visual search: Functional neuroanatomy by positron emission tomography. *Psychology & Aging, 17(1),* 24-43.

Madden, D.J. (1992). Selective attention & visual search: Revision of an allocation model and application to age differences. *Journal of Experimental Psychology: Human Perception & Performance, 18(3),* 821-826.

Maylor, E.A. & Lavie, N. (1998). The influence of perceptual load on age differences in selective attention. *Psychology and Aging, 13(4),* 563-573.

McDowd, J.M. & Filion, D.L. (1995). Aging and negative priming in a location suppression task: The long and short of it. *Psychology and Aging, 10(1),* 34-47.

McDowd, J.M. & Oseas-Kreger, D.M. (1991). Aging, inhibitory processes, and negative priming. *Journal of Gerontology: Psychological Sciences, 46(6),* 340-345.

Muller, M.M. & Hubner, R. (2002). Can the spotlight of attention be shaped like a doughnut? Evidence from steady-state visual evoked potentials. *Psychological Science, 13(2),* 119-124.

Olivers, C.N. & Watson, D.G. (2006). Input control processes in rapid serial visual presentations: Target selection and distractor inhibition. *Journal of Experimental Psychology, Human Perception and Performance, 32(5),* 1083-1092.

Palfai, T., Halperin, S. & Hoyer, W. (2003). Age inequalities in recognition memory: Effects of stimulus presentation time and list repetitions. *Aging, Neuropsychology and Cognition, 10(2),* 134-140.

Paquet, L. (2001). Eliminating flanker effects and negative priming in flanker task: Evidence for early selection. *Psychonomic Bulletin & Review, 8(2),* 301-306.

Posner, M.I. (2004). *Cognitive Neuroscience of Attention.* Guilford Press: New York/London.

Posner, M.I. & Petersen, S.E. (1990). The attention system of the human brain. *Annual Review of Neuroscience, 13,* 25-42.

Potter, L.M. & Grealy, M.A. (2008) Aging and inhibition of a prepotent motor response during an ongoing action. *Aging, Neuropsychology & Cognition, 1515(2),* 232 – 255.

Raymond, J.E., Shapiro, K.L. & Arnell, K.M. (1992). Temporary suppression of visual processing in an RSVP task: An attentional blink? *Journal of Experimental Psychology: Human Perception and Performance, 18,* 849-860.

Raz, N., Lindenberger, U., Rodrigue, K.M., Kennedy, K.M., Head, D., Williamson, A., Dahle, C, Gerstorf, D. & James, D. (2005). Regional brain differences in aging healthy adults: General trends, individual differences and modifiers. *Cerebral Cortex, 15(11).*

Raz, N. (2000). Aging of the brain and its impact on cognitive performance: Integration of structural and functional findings. In F. I. M. Craik & T. A. Salthouse (Eds.) *Handbook of aging and cognition* (2nd ed., pp. 1-90). Mawhah, NJ: Erlbaum.

Salthouse, T.A. (1996). The processing-speed theory of adult aging differences in cognition. *Psychological Review, 103(3),* 403-428.

Salthouse, T.A., Fristoe, N., McGuthry, K.E. & Hambrick, D.Z. (1998). Relation of task switching to speed, age, and fluid intelligence. *Psychology & Aging, 13(3),* 445-461.

Schooler, C., Neumann, E., Caplan, L.J. & Roberts, B.R. (1997). Continued inhibitory capacity throughout adulthood: Conceptual negative priming in younger and older adults. *Psychology and Aging, 12(4),* 667-674.

Simone, P.M., Ahrens, K., Foerde, K.E.G., & Spinetta, M. (2006). Influence of attended repetition trials on negative priming in younger and older adults. *Memory and Cognition, 34(1),* 187-195.

Simone, P.M. & Baylis, G.C. (1997). Selective attention in a reaching task: Effect of normal aging and Alzheimer's disease. *Journal of Experimental Psychology: Human Perception and Performance, 23(3),* 595-608.

Sliwinski, M., Kennedy, R.F. & Buschke, H. (1999). Cross-sectional and longitudinal relationships among age, cognition, and processing speed. *Psychology and Aging, 14(1),*18-33.

Stankov, L. (1988). Aging, attention and intelligence. *Psychology and Aging, 3(1),* 59-74.

Sullivan, M.P. & Faust, M.E. (1993). Evidence for identity inhibition during Selective attention in old adults. *Psychology & Aging, 8(4).*

Sullivan, M.P., Faust, M.E & Balota, D.A. (1995). Identity negative priming in older adults and individuals with dementia of the Alzheimer's type. *Neuropsychology, 9,* 537-555.

Sylvester, C.C., Wager, T.D., Jonides, J., Lacey, S.C., Cheshin., A., & Nichols, T.E. (2003). Processes of interference resolution as revealed by functional magnetic resonance imaging. 2003 Meeting of Cognitive Neuroscience Society.

Tianyong, C. & Deming, L. (2006). The contributions of inhibition and processing speed to normal age-related differences in fluid intelligence. *Acta Psychologica Sinica, 38(5),* 734-742.

Treisman, A.M. (1964). Monitoring and storage of irrelevant messages in selective attention. *Journal of Verbal Learning and Verbal Behaviour, 3,* 449-459.

Treisman, A.M. (1969). Strategies and models of selective attention. *Psychological Review, 76,* 282-299.

Troller, J.N. & Valenzuela, M.J. (2001). Brain aging in the new millennium. *Australian and New Zealand Journal of Psychiatry, (35),* 788-805.

Verhaegen, P., & De Meersman, L. (1998). Aging and the negative priming effect: A meta-analysis. *Psychology & Aging, 13,* 435-444.

Watson, D.G. & Humphreys, G.W. (1998). Visual marking of moving objects: a role for top-down feature-based inhibition in selection. *Journal of Experimental Psychology, Human Perception and Performance, 24(3),* 946-962.

Yordanova, J., Kolev, V., Hohnsbein, J. & Falkenstein, M. (2004). Sensorimotor slowing with aging is mediated by a functional dysregulation of motor-generation processes: Evidence from high-resolution event-related potentials. *Journal of Neurology (BRAIN), 127(2),* 351-62.

Zimprich, D. (2002). Cross-sectionally and longitudinally balanced effects of processing speed on intellectual abilities. *Experimental Aging Research, 28(3),* 231-251.

APPENDICES

Appendix A: Participant information for older participants

You are invited to participate in a research study that aims to evaluate the impact of internal representations of visual stimuli (distractors) on subsequent action (response time) in young and elderly cohorts.

Participant Information Form

Does Temporal Separation between Distractors and Targets lead to Distractor Interference in the Elderly Population?

Principal Researcher: Dr. Ada Kritikos

Associate Researcher: Renee Carr

Please read this document carefully. Feel free to ask questions about any information in the document. You may also wish to discuss the project with a relative or friend. We cannot guarantee or promise that you will receive any benefits from this project. You will be paid $10 for your participation in this project.

Once you understand what the project is about and if you agree to take part in it, you will be asked to sign the Consent Form. By signing the Consent Form, you indicate that you understand the information and that you give your consent to participate in the research project. You may withdraw from the project at any time without any prejudice.

You will be given a copy of the Participant Information and Consent Form to keep as a record.

This project will be carried out according to *The University of Victoria Human Research Ethics Committee.* This statement has been developed to protect the interests of people who agree to participate in human research studies.

The ethical aspects of this research project have been approved by the Human Research Ethics Committee of The University of Victoria, St Albans Campus.

Purpose of the study.

This project will evaluate the impact of internal representations of visual stimuli (distractors) on subsequent action (response time) in young and elderly cohorts. In this study two computer simulated tasks will be used to assess response times in accordance to visually presented "distractor" and "target" icons. These tasks will be used to elucidate how visually presented distractors may impact on goal-directed actions. You will not be asked to give any information of a personal nature.

What will this project involve?

Participants who participate in this study will be assessed using a brief computer simulated task (taking about 60 minutes). It will involve sitting in front of a computer and pressing buttons in response to letters appearing on the screen. These short assessments will take place at The University of Victoria, St Albans Campus. A payment of $10 will be made upon completion of the sessions. Afternoon tea and refreshments, and frequent rest breaks will also be provided.

Are there likely to be any side-effects or risks?

There are no anticipated physical or psychological risks associated with the proposed study, but you will be encouraged to take short rests between blocks of the task.

Benefits.

Your participation will help in improving our understanding of visual attention and information processing in elderly populations. This may help improve standards for rehabilitation techniques used in this cohort. Ultimately, this will help us develop methods to ensure a better quality of life for the elderly client.

Costs.

There is no cost for being in this study.

What will happen to my results?

At the end of the study you will receive a report of your results and these will be explained to you by the researchers. The results of the study will be published, but your identity will never be revealed, nor will your results be shared with anyone else for any other purpose. The records dealing with this study will be kept in secure storage at the Victoria University for 7 years, then shredded.

Confidentiality.

Your confidentiality will be respected at all times. You are free to decline or withdraw from participation in this study at any time and this will not affect your present or future relationship with this hospital or doctor. If at any time you or your doctor feel it is in your best interest to discontinue, you will be withdrawn from the study. At all stages of the study, you will be encouraged to ask questions.

Contacts and Support.

For the duration of the study you will be under the supervision of Renee Carr and Dr. Ada Kritikos. If you have any questions concerning the nature of research or your rights as a participant, please contact:

Renee Carr 0413 233 937 (Day and Evening)

Dr. Ada Kritikos (03) 9919 2559 (W)

If you wish to contact someone, independent of the study, about any complaints, ethical issues or your rights, you may contact the Secretary, Human Research Ethics Committee, Office for Research, ph. 9688-4710; fax 9687-2089.

Appendix B: Participant information for younger participants

You are invited to participate in a research study that aims to evaluate the impact of internal representations of visual stimuli (distractors) on subsequent action (response time) in young and elderly cohorts.

Participant Information Form

Does Temporal Separation between Distractors and Targets lead to Distractor Interference in the Elderly Population?

Principal Researcher: Dr. Ada Kritikos

Associate Researcher: Renee Carr

Please read this document carefully. Feel free to ask questions about any information in the document. You may also wish to discuss the project with a relative or friend. We cannot guarantee or promise that you will receive any benefits from this project.

Once you understand what the project is about and if you agree to take part in it, you will be asked to sign the Consent Form. By signing the Consent Form, you indicate that you understand the information and that you give your consent to participate in the research project. You may withdraw from the project at any time without any prejudice.

You will be given a copy of the Participant Information and Consent Form to keep as a record.

This project will be carried out according to *The University of Victoria Human Research Ethics Committee*. This statement has been developed to protect the interests of people who agree to participate in human research studies.

The ethical aspects of this research project have been approved by the Human Research Ethics Committee of The University of Victoria, St Albans Campus.

Purpose of the study.

This project will evaluate the impact of internal representations of visual stimuli (distractors) on subsequent action (response time) in young and elderly cohorts. In this study two computer simulated tasks will be used to assess response times in accordance to visually presented "distractor" and "target" icons. These tasks will be used to elucidate how visually presented distractors may impact on goal-directed actions. You will not be asked to give any information of a personal nature.

What will this project involve?

Participants who participate in this study will be assessed using a brief computer simulated task (taking about 60 minutes). It will involve sitting in front of a computer and pressing buttons in response to letters appearing on the screen. These short assessments will take place at The University of Victoria, St Albans Campus. Afternoon tea and refreshments, and frequent rest breaks will also be provided

Are there likely to be any side-effects or risks?

There are no anticipated physical or psychological risks associated with the proposed study.

Benefits.

Your participation will help in improving our understanding of visual attention and information processing in elderly populations. This may help improve standards for rehabilitation techniques used in this cohort. Ultimately, this will help us develop methods to ensure a better quality of life for the elderly client.

Costs.

There is no cost for being in this study.

What will happen to my results?

At the end of the study you will receive a report of your results and these will be explained to you by the researchers. The results of the study will be published, but your identity will never be revealed, nor will your results be shared with anyone else for any other purpose. The records dealing with this study will be kept in secure storage at the Victoria University for 7 years, then shredded.

Confidentiality.

Your confidentiality will be respected at all times. You are free to decline or withdraw from participation in this study at any time and this will not affect your present or future relationship with this hospital or doctor. If at any time you or your doctor feel it is in your best interest to discontinue, you will be withdrawn from the study. At all stages of the study, you will be encouraged to ask questions.

Contacts and Support.

For the duration of the study you will be under the supervision of Renee Carr and Dr. Ada Kritikos. If you have any questions concerning the nature of research or your rights as a participant, please contact:

Renee Carr 0413 233 937 (Day and Evening)

Dr. Ada Kritikos (03) 9919 2559 (W)

If you wish to contact someone, independent of the study, about any complaints, ethical issues or your rights, you may contact the Secretary, Human Research Ethics Committee, Office for Research, ph. 9688-4710; fax 9687-2089.

Appendix C: Consent form for older adults to participate in research

Consent Form to Participate in Research

Does Temporal Separation between Distractors and Targets lead to Distractor Interference in the Elderly Population?

I, ... have been invited to participate in the above study which is being conducted under the direction of Renee Carr (Co-investigator, currently completing Doctorate of Clinical Neuropsychology at The University of Victoria, Australia) and Dr. Ada Kritikos (Supervisor/Senior Investigator).

- My consent is based on the understanding that the study involves one session which will take place at The university of Victoria, St Albans campus.

- Initially I will be required to formally consent, in writing to participate in the study.

- During the sessions I will be asked to complete a computer simulated task. Each session will take approximately 60 minutes to complete.

- The study may involve the following risks, inconvenience and discomforts, which have been explained to me:

  The main inconvenience is the time commitment involved.

- I have received and read the attached "Participant Information Sheet" and understand the general purposes, methods and demands of the study. All of my questions have been answered to my satisfaction.

- I understand that the project may not be of direct benefit to me. I understand that a payment of $10 will be given to me upon attendance at each of the sessions.

- I can withdraw or be withdrawn by the Principal Investigator from this study at any time, without prejudicing my further management.
- I consent to the publishing of results from this study provided my identity is not revealed.
- I hereby voluntarily consent and offer to take place in this study.

Signature (Participant) ______________________ Date: __________ Time: ______

Witness to signature ______________________ Date: __________ Time: ______

Signature (Investigator) ______________________ Date: __________ Time: ______

One copy to be given to participant,

One copy to be filed in participant's medical record

Appendix D: Consent form for younger adults to participate in research

Consent Form to Participate in Research

Does Temporal Separation between Distractors and Targets lead to Distractor Interference in the Elderly Population?

I, ... have been invited to participate in the above study which is being conducted under the direction of Renee Carr (Co-investigator, currently completing Doctorate of Clinical Neuropsychology at The University of Victoria, Australia) and Dr. Ada Kritikos (Supervisor/Senior Investigator).

- My consent is based on the understanding that the study involves one session which will take place at The university of Victoria, St Albans campus.
- Initially I will be required to formally consent, in writing to participate in the study.
- During the sessions I will be asked to complete a computer simulated task. Each session will take approximately 60 minutes to complete.
- The study may involve the following risks, inconvenience and discomforts, which have been explained to me:

  The main inconvenience is the time commitment involved.

- I have received and read the attached "Participant Information Sheet" and understand the general purposes, methods and demands of the study. All of my questions have been answered to my satisfaction.
- I can withdraw or be withdrawn by the Principal Investigator from this study at any time, without prejudicing my further management.

- I consent to the publishing of results from this study provided my identity is not revealed.

- I hereby voluntarily consent and offer to take place in this study.

Signature (Participant) ______________________ Date: ______________ Time: ______

Witness to signature ______________________ Date: ______________ Time: ______

Signature (Investigator) ______________________ Date: ______________ Time: ______

One copy to be given to participant,

One copy to be filed in participant's medical record

Appendix E: Experiment 1 ANOVA and t-tests

Reaction Times

ANOVA

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
order	Sphericity Assumed	449118.631	4	112279.658	111.070	.000	.787
	Greenhouse-Geisser	449118.631	1.703	263695.301	111.070	.000	.787
	Huynh-Feldt	449118.631	1.855	242062.153	111.070	.000	.787
	Lower-bound	449118.631	1.000	449118.631	111.070	.000	.787
order * Group	Sphericity Assumed	5008.545	4	1252.136	1.239	.298	.040
	Greenhouse-Geisser	5008.545	1.703	2940.715	1.239	.294	.040
	Huynh-Feldt	5008.545	1.855	2699.463	1.239	.296	.040
	Lower-bound	5008.545	1.000	5008.545	1.239	.275	.040
Error(order)	Sphericity Assumed	121307.362	120	1010.895			
	Greenhouse-Geisser	121307.362	51.095	2374.145			
	Huynh-Feldt	121307.362	55.662	2179.374			
	Lower-bound	121307.362	30.000	4043.579			

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	50679214.1	1	50679214.08	1274.472	.000	.977
Group	515413.355	1	515413.355	12.962	.001	.302
Error	1192945.982	30	39764.866			

Older versus younger independent samples t-tests

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
TA	Equal variances assumed	1.208	.280	3.711	30	.001	109.89320	29.60950	49.42253	170.36388
	Equal variances not assumed			3.643	25.683	.001	109.89320	30.16192	47.85727	171.92914
SIM	Equal variances assumed	.844	.365	3.648	30	.001	118.95823	32.60505	52.36984	185.54662
	Equal variances not assumed			3.617	28.063	.001	118.95823	32.88978	51.59344	186.32303
PRE200	Equal variances assumed	2.011	.166	3.431	30	.002	102.78415	29.95998	41.59770	163.97060
	Equal variances not assumed			3.387	27.164	.002	102.78415	30.34256	40.54392	165.02439
PRE400	Equal variances assumed	2.076	.160	3.013	30	.005	100.37442	33.31576	32.33456	168.41428
	Equal variances not assumed			2.973	27.010	.006	100.37442	33.76272	31.10022	169.64862
PRE600	Equal variances assumed	3.491	.072	3.443	30	.002	115.51790	33.55378	46.99194	184.04386
	Equal variances not assumed			3.378	25.548	.002	115.51790	34.19692	45.16458	185.87122
PRE1000	Equal variances assumed	.833	.369	3.633	30	.001	131.04501	36.07000	57.38024	204.70977
	Equal variances not assumed			3.598	27.860	.001	131.04501	36.41961	56.42597	205.66405

All Participants: Target Alone versus other conditions Paired Samples t-test

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	TA - SIM	-32.06605	41.76869	7.38373	-47.12527	-17.00683	-4.343	31	.000
Pair 2	TA - PRE200	79.45794	42.14123	7.44959	64.26441	94.65148	10.666	31	.000
Pair 3	TA - PRE400	109.86471	53.16597	9.39850	90.69634	129.03309	11.690	31	.000
Pair 4	TA - PRE600	106.89797	62.01426	10.96268	84.53945	129.25650	9.751	31	.000
Pair 5	TA - PRE1000	94.59120	68.29543	12.07304	69.96807	119.21432	7.835	31	.000

Older Participants: Target Alone versus other conditions Paired Samples t-test

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	TA - SIM	-36.88185	53.65450	13.85353	-66.59472	-7.16898	-2.662	14	.019
Pair 2	TA - PRE200	83.23462	37.32476	9.63721	62.56486	103.90439	8.637	14	.000
Pair 3	TA - PRE400	114.92157	52.99176	13.68241	85.57571	144.26743	8.399	14	.000
Pair 4	TA - PRE600	103.90985	61.61472	15.90885	69.78876	138.03095	6.532	14	.000
Pair 5	TA - PRE1000	83.35430	55.23666	14.26204	52.76526	113.94334	5.844	14	.000

Younger Participants: Target Alone versus other conditions Paired Samples t-test

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	TA - SIM	-27.81682	28.64134	6.94655	-42.54284	-13.09080	-4.004	16	.001
Pair 2	TA - PRE200	76.12557	46.86799	11.36716	52.02828	100.22287	6.697	16	.000
Pair 3	TA - PRE400	105.40278	54.53750	13.22729	77.36219	133.44338	7.969	16	.000
Pair 4	TA - PRE600	109.53455	64.13729	15.55558	76.55820	142.51090	7.041	16	.000
Pair 5	TA - PRE1000	104.50610	78.38678	19.01159	64.20334	144.80886	5.497	16	.000

All Participants: Simultaneous versus Preceding conditions Paired Samples t-test

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	SIM - PRE200	111.52399	47.93703	8.47415	94.24085	128.80713	13.160	31	.000
Pair 2	SIM - PRE400	141.93077	54.66459	9.66342	122.22208	161.63945	14.687	31	.000
Pair 3	SIM - PRE600	138.96403	61.86883	10.93697	116.65793	161.27012	12.706	31	.000
Pair 4	SIM - PRE1000	126.65725	71.66293	12.66834	100.82001	152.49449	9.998	31	.000
Pair 5	PRE200 - PRE400	30.40677	23.48558	4.15170	21.93932	38.87423	7.324	31	.000
Pair 6	PRE200 - PRE600	27.44003	32.55799	5.75549	15.70162	39.17844	4.768	31	.000
Pair 7	PRE200 - PRE1000	15.13325	40.08649	7.08636	.68053	29.58597	2.136	31	.041
Pair 8	PRE400 - PRE600	-2.96674	26.15255	4.62316	-12.39574	6.46226	-.642	31	.526
Pair 9	PRE400 - PRE1000	-15.27352	37.95964	6.71038	-28.95943	-1.58761	-2.276	31	.030
Pair 10	PRE600 - PRE1000	-12.30678	27.93955	4.93906	-22.38006	-2.23349	-2.492	31	.018

Errors

ANOVA

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
order	Sphericity Assumed	3.937	4	.984	5.076	.001	.145
	Greenhouse-Geisser	3.937	1.967	2.001	5.076	.010	.145
	Huynh-Feldt	3.937	2.174	1.811	5.076	.007	.145
	Lower-bound	3.937	1.000	3.937	5.076	.032	.145
order * Group	Sphericity Assumed	.451	4	.113	.582	.676	.019
	Greenhouse-Geisser	.451	1.967	.229	.582	.559	.019
	Huynh-Feldt	.451	2.174	.208	.582	.576	.019
	Lower-bound	.451	1.000	.451	.582	.452	.019
Error(order)	Sphericity Assumed	23.269	120	.194			
	Greenhouse-Geisser	23.269	59.012	.394			
	Huynh-Feldt	23.269	65.222	.357			
	Lower-bound	23.269	30.000	.776			

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	35.539	1	35.539	40.534	.000	.575
Group	.756	1	.756	.863	.360	.028
Error	26.303	30	.877			

All Participants: Simultaneous versus Preceding conditions Paired Samples t-test

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
Pair 1	SIM - PRE200	.09702	.92127	.16286	-.23514	.42917	.596	31	.556
Pair 2	SIM - PRE400	.35456	.58572	.10354	.14339	.56574	3.424	31	.002
Pair 3	SIM - PRE600	.37194	.47952	.08477	.19905	.54482	4.388	31	.000
Pair 4	SIM - PRE1000	.36808	.45938	.08121	.20246	.53371	4.533	31	.000
Pair 5	PRE200 - PRE400	.25755	.57667	.10194	.04963	.46546	2.526	31	.017
Pair 6	PRE200 - PRE600	.27492	.74455	.13162	.00648	.54336	2.089	31	.045
Pair 7	PRE200 - PRE1000	.27107	.87413	.15453	-.04409	.58623	1.754	31	.089
Pair 8	PRE400 - PRE600	.01737	.41472	.07331	-.13215	.16690	.237	31	.814
Pair 9	PRE400 - PRE1000	.01352	.49576	.08764	-.16522	.19226	.154	31	.878
Pair 10	PRE600 - PRE1000	-.00385	.35247	.06231	-.13093	.12323	-.062	31	.951

Appendix F: Experiment 2 ANOVA and t-tests

Reaction Times

ANOVA

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
order	Sphericity Assumed	141392.405	1	141392.405	114.890	.000	.815
	Greenhouse-Geisser	141392.405	1.000	141392.405	114.890	.000	.815
	Huynh-Feldt	141392.405	1.000	141392.405	114.890	.000	.815
	Lower-bound	141392.405	1.000	141392.405	114.890	.000	.815
order * Group	Sphericity Assumed	7966.475	1	7966.475	6.473	.017	.199
	Greenhouse-Geisser	7966.475	1.000	7966.475	6.473	.017	.199
	Huynh-Feldt	7966.475	1.000	7966.475	6.473	.017	.199
	Lower-bound	7966.475	1.000	7966.475	6.473	.017	.199
Error(order)	Sphericity Assumed	31997.577	26	1230.676			
	Greenhouse-Geisser	31997.577	26.000	1230.676			
	Huynh-Feldt	31997.577	26.000	1230.676			
	Lower-bound	31997.577	26.000	1230.676			
congru	Sphericity Assumed	6062.919	2	3031.460	5.316	.008	.170
	Greenhouse-Geisser	6062.919	1.931	3139.057	5.316	.009	.170
	Huynh-Feldt	6062.919	2.000	3031.460	5.316	.008	.170
	Lower-bound	6062.919	1.000	6062.919	5.316	.029	.170
congru * Group	Sphericity Assumed	931.197	2	465.598	.817	.448	.030
	Greenhouse-Geisser	931.197	1.931	482.124	.817	.444	.030
	Huynh-Feldt	931.197	2.000	465.598	.817	.448	.030
	Lower-bound	931.197	1.000	931.197	.817	.374	.030
Error(congru)	Sphericity Assumed	29651.309	52	570.217			
	Greenhouse-Geisser	29651.309	50.218	590.457			
	Huynh-Feldt	29651.309	52.000	570.217			
	Lower-bound	29651.309	26.000	1140.435			
order * congru	Sphericity Assumed	18235.651	2	9117.826	23.063	.000	.470
	Greenhouse-Geisser	18235.651	1.942	9389.561	23.063	.000	.470
	Huynh-Feldt	18235.651	2.000	9117.826	23.063	.000	.470
	Lower-bound	18235.651	1.000	18235.651	23.063	.000	.470
order * congru * Group	Sphericity Assumed	997.219	2	498.610	1.261	.292	.046
	Greenhouse-Geisser	997.219	1.942	513.470	1.261	.291	.046
	Huynh-Feldt	997.219	2.000	498.610	1.261	.292	.046
	Lower-bound	997.219	1.000	997.219	1.261	.272	.046
Error(order*congru)	Sphericity Assumed	20558.349	52	395.353			
	Greenhouse-Geisser	20558.349	50.495	407.135			
	Huynh-Feldt	20558.349	52.000	395.353			
	Lower-bound	20558.349	26.000	790.706			

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	11448586.0	1	11448586.01	1655.689	.000	.985
Group	143296.890	1	143296.890	20.724	.000	.444
Error	179782.056	26	6914.694			

All Participants: Simultaneous versus Preceding Paired Samples t-test

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	simultaneous congr mean - distr prec congr mean	41.73425	35.75475	6.75701	27.87001	55.59850	6.176	27	.000
Pair 2	simultaneous neu mean - dist prec neu mean	44.89721	40.49345	7.65254	29.19549	60.59893	5.867	27	.000
Pair 3	simultaneous incongr mean - dist prec incongr mean	87.43281	40.48317	7.65060	71.73507	103.13055	11.428	27	.000

All Participants: Congruence Paired Samples t-test

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	simultaneous congr mean - simultaneous neu mean	-13.62005	24.54064	4.63775	-23.13592	-4.10418	-2.937	27	.007
Pair 2	simultaneous congr mean - simultaneous incongr mean	-21.54025	26.83538	5.07141	-31.94592	-11.13458	-4.247	27	.000
Pair 3	simultaneous neu mean - simultaneous incongr mean	-7.92020	31.82227	6.01384	-20.25959	4.41919	-1.317	27	.199
Pair 4	distr prec congr mean - dist prec neu mean	-10.45709	37.85140	7.15324	-25.13434	4.22015	-1.462	27	.155
Pair 5	distr prec congr mean - dist prec incongr mean	24.15831	35.86061	6.77702	10.25302	38.06360	3.565	27	.001
Pair 6	dist prec neu mean - dist prec incongr mean	34.61540	27.19136	5.13868	24.07169	45.15911	6.736	27	.000

Older versus younger Independent Samples t-tests

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
simultaneous congr mean	Equal variances assumed	2.731	.110	4.750	26	.000	145.08871	30.54562	82.30129	207.87614
	Equal variances not assumed			4.750	23.390	.000	145.08871	30.54562	81.95847	208.21895
simultaneous neu mean	Equal variances assumed	3.191	.086	4.908	26	.000	157.97291	32.18398	91.81779	224.12803
	Equal variances not assumed			4.908	23.104	.000	157.97291	32.18398	91.41188	224.53394
simultaneous incongr mean	Equal variances assumed	2.486	.127	5.034	26	.000	167.48601	33.26883	99.10095	235.87106
	Equal variances not assumed			5.034	23.053	.000	167.48601	33.26883	98.67291	236.29910
distr prec congr mean	Equal variances assumed	2.943	.098	3.981	26	.000	131.16958	32.94848	63.44301	198.89614
	Equal variances not assumed			3.981	22.464	.001	131.16958	32.94848	62.92029	199.41886
dist prec neu mean	Equal variances assumed	10.074	.004	3.633	26	.001	125.40911	34.51543	54.46161	196.35660
	Equal variances not assumed			3.633	19.755	.002	125.40911	34.51543	53.35382	197.46439
dist prec incongr mean	Equal variances assumed	2.866	.102	4.100	26	.000	131.33477	32.03113	65.49385	197.17570
	Equal variances not assumed			4.100	22.619	.000	131.33477	32.03113	65.01152	197.65802

Older Participants Paired Samples t-tests

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	simultaneous congr mean - distr prec congr mean	48.69382	40.67389	10.87055	25.20942	72.17823	4.479	13	.001
Pair 2	simultaneous neu mean - dist prec neu mean	61.17912	44.48548	11.88925	35.49396	86.86427	5.146	13	.000
Pair 3	simultaneous incongr mean - dist prec incongr mean	105.50843	42.21531	11.28252	81.13404	129.88282	9.351	13	.000

Younger Participants Paired Samples t-tests

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	simultaneous congr mean - distr prec congr mean	34.77469	29.94085	8.00203	17.48735	52.06202	4.346	13	.001
Pair 2	simultaneous neu mean - dist prec neu mean	28.61531	29.25111	7.81769	11.72622	45.50440	3.660	13	.003
Pair 3	simultaneous incongr mean - dist prec incongr mean	69.35719	30.29834	8.09757	51.86346	86.85093	8.565	13	.000

Errors

ANVOA

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
order	Sphericity Assumed	.001	1	.001	.042	.840	.002
	Greenhouse-Geisser	.001	1.000	.001	.042	.840	.002
	Huynh-Feldt	.001	1.000	.001	.042	.840	.002
	Lower-bound	.001	1.000	.001	.042	.840	.002
order * Group	Sphericity Assumed	.018	1	.018	.511	.481	.019
	Greenhouse-Geisser	.018	1.000	.018	.511	.481	.019
	Huynh-Feldt	.018	1.000	.018	.511	.481	.019
	Lower-bound	.018	1.000	.018	.511	.481	.019
Error(order)	Sphericity Assumed	.928	26	.036			
	Greenhouse-Geisser	.928	26.000	.036			
	Huynh-Feldt	.928	26.000	.036			
	Lower-bound	.928	26.000	.036			
congruence	Sphericity Assumed	.048	2	.024	.748	.478	.028
	Greenhouse-Geisser	.048	1.650	.029	.748	.455	.028
	Huynh-Feldt	.048	1.815	.027	.748	.467	.028
	Lower-bound	.048	1.000	.048	.748	.395	.028
congruence * Group	Sphericity Assumed	.094	2	.047	1.464	.241	.053
	Greenhouse-Geisser	.094	1.650	.057	1.464	.242	.053
	Huynh-Feldt	.094	1.815	.052	1.464	.242	.053
	Lower-bound	.094	1.000	.094	1.464	.237	.053
Error(congruence)	Sphericity Assumed	1.675	52	.032			
	Greenhouse-Geisser	1.675	42.906	.039			
	Huynh-Feldt	1.675	47.202	.035			
	Lower-bound	1.675	26.000	.064			
order * congruence	Sphericity Assumed	.173	2	.087	2.418	.099	.085
	Greenhouse-Geisser	.173	1.661	.104	2.418	.110	.085
	Huynh-Feldt	.173	1.829	.095	2.418	.104	.085
	Lower-bound	.173	1.000	.173	2.418	.132	.085
order * congruence * Group	Sphericity Assumed	.095	2	.048	1.327	.274	.049
	Greenhouse-Geisser	.095	1.661	.057	1.327	.272	.049
	Huynh-Feldt	.095	1.829	.052	1.327	.273	.049
	Lower-bound	.095	1.000	.095	1.327	.260	.049
Error(order*congruence)	Sphericity Assumed	1.862	52	.036			
	Greenhouse-Geisser	1.862	43.197	.043			
	Huynh-Feldt	1.862	47.559	.039			
	Lower-bound	1.862	26.000	.072			

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	9.884	1	9.884	22.458	.000	.463
Group	1.621	1	1.621	3.682	.066	.124
Error	11.443	26	.440			

All Participants: Target Alone versus other conditions Paired Samples t-test

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Target alone mean - simultaneous congr mean	.05804	.31638	.05979	-.06464	.18071	.971	27	.340
Pair 2	Target alone mean - simultaneous neu mean	.08929	.29435	.05563	-.02485	.20342	1.605	27	.120
Pair 3	Target alone mean - simultaneous incongr mean	.03125	.29389	.05554	-.08271	.14521	.563	27	.578
Pair 4	Target alone mean - distr prec congr mean	.00893	.25214	.04765	-.08884	.10670	.187	27	.853
Pair 5	Target alone mean - dist prec neu mean	.03571	.24262	.04585	-.05836	.12979	.779	27	.443

Older Participants: Target Alone versus other conditions Paired Samples t-test

Paired Samples Test[a]

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Target alone mean - simultaneous congr mean	.15179	.32588	.08710	-.03637	.33994	1.743	13	.105
Pair 2	Target alone mean - simultaneous neu mean	.09821	.24108	.06443	-.04098	.23741	1.524	13	.151
Pair 3	Target alone mean - simultaneous incongr mean	.01786	.26338	.07039	-.13421	.16993	.254	13	.804
Pair 4	Target alone mean - distr prec congr mean	.06250	.26289	.07026	-.08929	.21429	.890	13	.390
Pair 5	Target alone mean - dist prec neu mean	.07143	.27172	.07262	-.08546	.22832	.984	13	.343

a. Group = elderly

Younger Participants: Target Alone versus other conditions Paired Samples t-test

Paired Samples Test[a]

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Target alone mean - simultaneous congr mean	-.03571	.28768	.07689	-.20182	.13039	-.465	13	.650
Pair 2	Target alone mean - simultaneous neu mean	.08036	.34879	.09322	-.12103	.28174	.862	13	.404
Pair 3	Target alone mean - simultaneous incongr mean	.04464	.33111	.08849	-.14653	.23582	.504	13	.622
Pair 4	Target alone mean - distr prec congr mean	-.04464	.23822	.06367	-.18219	.09290	-.701	13	.496
Pair 5	Target alone mean - dist prec neu mean	.00000	.21371	.05712	-.12339	.12339	.000	13	1.000

a. Group = young

Younger Participants: Congruence Paired Samples t-test

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	simultaneous congr mean - simultaneous neu mean	-7.17795	18.75863	5.01345	-18.00886	3.65296	-1.432	13	.176
Pair 2	simultaneous congr mean - simultaneous incongr mean	-10.34160	17.68330	4.72606	-20.55164	-.13157	-2.188	13	.048
Pair 3	simultaneous neu mean - simultaneous incongr mean	-3.16365	26.44194	7.06690	-18.43077	12.10347	-.448	13	.662
Pair 4	distr prec congr mean - dist prec neu mean	-13.33733	26.05785	6.96425	-28.38268	1.70802	-1.915	13	.078
Pair 5	distr prec congr mean - dist prec incongr mean	24.24091	35.40412	9.46215	3.79917	44.68264	2.562	13	.024
Pair 6	dist prec neu mean - dist prec incongr mean	37.57823	28.11008	7.51274	21.34795	53.80851	5.002	13	.000

Older Participants: Simultaneous versus Preceding Paired Samples t-test

Paired Samples Test[a]

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	simultaneous congr mean - distr prec congr mean	48.69382	40.67389	10.87055	25.20942	72.17823	4.479	13	.001
Pair 2	simultaneous neu mean - dist prec neu mean	61.17912	44.48548	11.88925	35.49396	86.86427	5.146	13	.000
Pair 3	simultaneous incongr mean - dist prec incongr mean	105.50843	42.21531	11.28252	81.13404	129.88282	9.351	13	.000

a. Group = Elderly

Younger Participants: Simultaneous versus Preceding Paired Samples t-test

Paired Samples Test[a]

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	simultaneous congr mean - distr prec congr mean	34.77469	29.94085	8.00203	17.48735	52.06202	4.346	13	.001
Pair 2	simultaneous neu mean - dist prec neu mean	28.61531	29.25111	7.81769	11.72622	45.50440	3.660	13	.003
Pair 3	simultaneous incongr mean - dist prec incongr mean	69.35719	30.29834	8.09757	51.86346	86.85093	8.565	13	.000

a. Group = Young

Participants: Target Alone versus other conditions Paired Samples t-test

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Target alone mean - simultaneous congr mean	.05804	.31638	.05979	-.06464	.18071	.971	27	.340
Pair 2	Target alone mean - simultaneous neu mean	.08929	.29435	.05563	-.02485	.20342	1.605	27	.120
Pair 3	Target alone mean - simultaneous incongr mean	.03125	.29389	.05554	-.08271	.14521	.563	27	.578
Pair 4	Target alone mean - distr prec congr mean	.00893	.25214	.04765	-.08884	.10670	.187	27	.853
Pair 5	Target alone mean - dist prec neu mean	.03571	.24262	.04585	-.05836	.12979	.779	27	.443
Pair 6	Target alone mean - dist prec incongr mean	.11607	.32972	.06231	-.01178	.24392	1.863	27	.073