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Inhibitory Mechanisms, Interference, and the Attentional Blink in Younger and Older Adults

by

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ABSTRACT

The inhibitory deficit hypothesis (Hasher & Zacks, 1988) of age-related cognitive decline was investigated. Thirty younger and 25 older adults were tested on two measures of suppression (negative priming (NP) and Stroop tasks) as well as on classic Stroop interference. The attentional blink (AB; Raymond, Shapiro, & Arnell, 1992), which is a phenomenon observed in a dual-task rapid serial visual presentation (RSVP) was also investigated. Younger and older adults produced equivalent suppression effects on both the Stroop and NP tasks, while older adults exhibited increased Stroop interference and an increased AB magnitude, relative to the younger adults. It is suggested that the results support the inhibitory deficit hypothesis that older adults have a deficit in inhibitory mechanisms. It is also suggested that the AB paradigm may be a very useful tool for further investigations of cognitive decline with age.

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INTRODUCTION

We live in a world which presents an abundance of information to our information processing system at all times. In order to make sense of this information one must be able to decide which information is important at any given moment, focus our attention on relevant stimuli, and ignore the rest. For this reason it seems necessary to have some mechanism or group of mechanisms which aid in selecting the important information from all of the irrelevant information. In recent years the process of inhibition has been implicated as one such mechanism. It is the process whereby, during attentional selection, unselected elements are actively suppressed. This concept applies to many aspects of our lives; including visual perception, audition, and cognition. The process of inhibition has more recently been implicated in a number of age-related cognitive deficits (Hasher & Zacks, 1988). Hasher and Zacks (1988) propose that a deficit in inhibitory functioning with age may explain a number of other age-related cognitive changes, including the observed age-related deficit in working memory (WM; e.g., Wingfield, Stine, Lahar, & Aberdeen, 1988). They propose that this deficit in inhibitory mechanisms leads to an increase in irrelevant information entering WM, thereby disrupting one's ability to focus on what is relevant at any given moment and decreasing the available WM capacity for relevant information. The present study was aimed at investigating the inhibitory deficit hypothesis in the hopes of obtaining a clearer understanding of the nature of the deficit.

There have been a number of different lines of research which support the inhibitory model of WM decline with age. Indirectly, the area of discourse comprehension provides some supportive evidence (Hasher & Zacks, 1988).

Discourse comprehension is thought to rely heavily on WM, and since there have been age-related deficits observed on such tasks, Hasher and Zacks' theory is well supported in this area (e.g., Connelly, Hasher and Zacks,1991; Gerard, Zacks, Hasher, & Radvansky, 1991). More direct evidence of an attentional inhibitory deficit comes from selective attention paradigms which are thought to tap inhibitory processes. Many of these tasks involve attending to certain items while ignoring others. For example, in a negative priming (NP; Tipper, 1985) task McDowd and Oseas-Kreger (1991) have reported that inhibitory abilities do decline with age. Many of these tasks, such as NP, have shown that older individuals have more difficulty selecting target stimuli, suggesting greater interference, which, arguably, is associated with decreased inhibitory abilities (Cohn, Dustman & Bradford, 1984).

The goal of this research is to investigate the inhibitory deficit hypothesis (Hasher & Zacks, 1988) by examining attentional inhibitory efficiency with age. However, following a more detailed description of Hasher and Zacks' proposal, a brief outline of the existing support from the language based literature will be beneficial. This will be followed by a discussion of the role of inhibition in selective attention. Then a review of the relevant literature on each of the inhibitory measures used in the present study will assist in introducing the present study. The NP paradigm (Tipper, 1985) has been widely used as an index of inhibitory mechanisms, and has been used to demonstrate a deficit in inhibitory mechanisms in the elderly. The Stroop (1935) paradigm, which has been widely used in investigations of attentional mechanisms and is suggested to elicit measures of interference as well as inhibition. Lastly, a relatively new phenomenon which has been demonstrated in a dual-task rapid serial visual presentation (RSVP) procedure, and has been termed the attentional blink (AB; Raymond, Shapiro & Arnell, 1992) will be investigated. Although there has been a fair amount of research in the area of inhibition, and the proposed deficit in the elderly population, none has clearly linked different measures of inhibition, and working memory. Furthermore, in recent years more and more research has demonstrated inconsistent results from commonly used paradigms to measure attentional inhibiton. Thus, the present research will investigate the inhibitory deficit hypothesis by employing a new task along with previously investigated tasks.

The Inhibitory Model of Age-related Cognitive Decline

The main goal of Hasher and Zacks' work was to explain the findings of a decreased WM span with age. WM can be defined as the process of both storing and processing information simultaneously (Wingfield et al., 1988). Hasher and Zacks (1988) propose that inhibitory mechanisms operate in two different manners in order to aid in the efficiency of WM. The first is to hinder the access of goal-irrelevant information into WM. This goal-irrelevant information may have initially been activated in parallel with the goal-relevant information, and may be internally or externally derived. For example, the irrelevant information could be irrelevant environmental information, personal memories or concerns, or off-goal path interpretations. The second function of inhibitory mechanisms is to suppress irrelevant information that does gain access into WM, as well as remove (or suppress) information which may have initially been relevant, but no longer is. In addition, it has been suggested that inhibitory mechanisms prevent attention from returning to previously rejected information (based on relevancy, e.g., Zacks & Hasher, 1994).

Although a fair amount of research has shown that older individuals perform more poorly than younger adults on measures of WM (e.g., Wingfield et al., 1988), some studies have not found such a deficit (e.g., Hartley, 1986). Zacks and Hasher (1994) suggest that such inconsistencies may be explained by their model. More specifically, they suggest that in cases where a WM deficit is observed the task was such that irrelevant information (whether it be of an external or internal nature) could have entered WM and therefore lead to what appears to be a WM deficit. On the other hand, in cases where no WM deficit is found, they suggest that the nature of the task was such that irrelevant information was precluded from entering WM. This explanation of the inconsistencies in the WM literature is questionable, however, as it seems unlikely that one can have an objective measure as to which tasks allow for irrelevant information to enter WM and which do not. Furthermore, the tasks used to measure WM capacity by both Hartley and Wingfield et al. were virtually identical.

Much of the support for the inhibitory model of cognitive decline proposed by Hasher and Zacks (1988) has come from the discourse processing literature. In addition, studies of selective attention have been used to demonstrate a deficit in inhibitory mechanisms in selective attention tasks, lending support to the general theory. These two lines of research will now be reviewed.

Discourse Processing

If one can explain age-related differences in WM performance, an understanding of age-related differences in discourse comprehension will likely follow for the following reasons. First, WM has been defined as the simultaneous storage and processing of information, and discourse processing requires the storage of previously processed information, while simultaneously continuing to process incoming information. This relationship between discourse processing and WM has been investigated by a number of researchers, who have demonstrated that a lower WM span is related to problems with discourse comprehension (e.g., Hartley, 1993; Just, & Carpenter, 1992; Kemper, 1992). Further, it has been demonstrated that WM declines with age (e.g., Wingfield et al., 1988) and that older individuals demonstrate some WM-related difficulties in both reading (Stine & Hindman, 1994) and discourse comprehension (e.g., Kemper, 1992).

The inhibitory deficit hypothesis (Hasher & Zacks, 1988) has led to a surge in new research. The claim is that it is not a decrease in WM capacity per se which is the problem, but a decrease in the available resources for processing relevant information. The reason there is a decline in available resources is that irrelevant information is using potentially available resources. Thus, it is proposed that there is an age-related deficiency in the ability to inhibit internal thoughts and irrelevant external stimuli, thus creating a situation in which it appears that there is a decreased WM capacity. In fact, there is no decline in total available resources, but rather a decline in the available resources for processing relevant information. Inhibitory mechanisms are essential for discourse processing as they are required to prevent irrelevant thoughts from gaining access into WM. Likewise, inhibition will serve to weaken ideas that are in WM that may have once been relevant but no longer are.

Much of the support for the inhibitory deficit hypothesis has come from studies investigating discourse processing in younger and older adults. The goal of many of these studies has been to demonstrate that older individuals have difficulty ignoring irrelevant information. For example, the effects of distracting text on reading time and the comprehension of relevant material was investigated by Connelly et al. (1991). Younger and older participants read target text (presented in italics) and ignored interspersed, distracting text (presented in standard print). It was found that, while the presence of distracting text slowed reading times for both young and old adults, the effect for the older adults was significantly larger. That is, the distracting text appeared to hamper their reading time to a greater extent than for the younger adults. Furthermore, if the distracting information was meaningfully related to the target material, older adults were slowed even further in their reading time, while the younger adults were not. This finding was interpreted as an indication that the older adults were processing the irrelevant information to a greater degree than the younger adults, which could suggest a deficit in inhibitory mechanisms (Connelly et al., 1991).

Further support for the inhibitory deficit hypothesis comes from a study of the fan effect in younger and older adults (Gerard et al., 1991). The fan effect is the finding that the more facts learned about a particular concept, the longer it will take to retrieve any one of those facts, and the more errors in retrieval will be made. This finding is thought to be due to interference, upon retrieval, between competing items (Gerard et al., 1991). Gerard et al. (1991) point out that because discourse processing requires speeded retrieval of target information, usually with a high degree of possible interference, the study of age differences in the fan effect is of relevance.

The task requires participants to learn facts, such as "The judge cut the apple pie into six pieces". Along with this fact there would also be a number of other facts about "judges" and "apple pies". Participants are later given a recognition test in which original facts, along with foils are presented. The fan effect is thought to occur because associated concepts are activated and there is competition (interference) at the time of retrieval (Gerard et al., 1991). They predicted that older adults would demonstrate an increased fan effect because, given the example sentence above, other "judge" and "apple pie" facts and associations which would become activated would be harder to suppress, and therefore cause increased interference.

Both the reaction time and error data did in fact show that older adults had increased difficulty with this task. That is, they demonstrated a greater fan effect than the younger adults. Gerard et al. suggest retrieval problems for older adults could be a source of problems in everyday discourse processing, where errors or slowing in retrieval might lead to a deficiency in forming critical linkages during discourse comprehension.

The directed forgetting paradigm has recently been used to investigate the inhibitory mechanisms of younger and older adults (Zacks, Radvansky, & Hasher,1996). The task consists of the presentation of study items followed by instructions as to which items they are to remember and which they are to forget. The most important aspect of the task is that they are not told which items they must remember until after they have studied the list. In this situation, therefore, it is beneficial to be able to forget information which is no longer relevant. In the directed forgetting task, participants must stop rehearsal of the 'to be forgotten' (TBF) items, as well as inhibit the TBF items at the time of retrieval (Zacks et al., 1996). According to the inhibitory deficiency model, Zacks et al. (1996) predicted that older adults would have increased difficulties with this task.

The results were in accordance with their predictions. Zacks et al. found that older adults produced more TBF intrusions in an immediate recall test, took longer, relative to a baseline, to reject TBF items on a recognition test, and demonstrated improved recall and recognition of TBF items upon delayed testing relative to the younger participants. Furthermore, in agreement with the results from Connelly et al. (1991), when the TBF items were associatively related to the relevant information there was an increased tendency for the older adults to report the TBF information at inappropriate times. The younger adults, however, performed the same regardless of whether the irrelevant material was related or unrelated to the relevant information. Zacks et al. (1996) concluded that the older adults were less able to suppress the TBF items compared to the younger adults. They also considered the implications of these results for discourse processing. Thus, they expect that older adults will be more likely to make errors in processing, and fail to make appropriate inferences due to competition in WM between relevant and irrelevant information. Furthermore, older adults will find it more difficult to change topics, frames of reference, or mental models.

Hamm and Hasher (1992) also report supportive evidence for the inhibitory deficit model. They demonstrate the importance of the ability to draw inferences during discourse processing, as they suggest that the comprehension of a passage requires the integration of explicit content, along with prior knowledge. Prior knowledge is what allows you to make inferences as you are processing the information.

To study the inferences of younger and older adults, Hamm and Hasher (1992) had participants read passages and in the middle, and towards the end of every passage, they were given a speeded decision task in which they were to decide whether a presented word was compatible with their present interpretation or not. There were two types of passages presented. One was an expected version, in which the target (final, correct) interpretation was strongly supported by the text. The other type of text was an unexpected version in which participants initially received misleading information which would lead to an incorrect inference, which was only later shown to be false.

The results showed no significant age differences in the likelihood to accept the target information, in either type of passage, or at the middle or end of the passage. However, there was a significant age effect in accepting the competing inference. That is, the older adults were more likely to accept a competing inference at the middle and end of a passage. Hamm and Hasher interpreted these results as an indication that older adults entertain a broader range of possible interpretations and fail to quickly narrow that range down. They suggest that these findings contradict what a simple decline in WM resources would predict. More specifically, if older adults possessed decreased WM resources one might expect that they could not hold as much information in WM, and therefore would not be likely to hold both interpretations. Instead they support the inhibitory model, most persuasively through the finding that the older adults held onto the incorrect interpretation right to the end of the passage, after the information which would suggest they were wrong was presented. This finding suggests a deficit in inhibiting inferences that are drawn and which are later shown to be incorrect.

Kwong See and Bouchard Ryan (1995) used regression analyses to look at how well performance in discourse processing could be predicted from a number of other tasks. A regression analysis was conducted in order to determine the relative importance of speed of processing, WM capacity, and inhibitory abilities, on language performance. Language performance was determined through administration of a language battery which included indices of discourse comprehension. The Stroop (1935) paradigm was used to get both a speed of processing measure and an inhibition measure. The Stroop task requires participants to respond to the print color of incongruent color-words (inhibition measure) or to a row of OOOs or IIIs (speed measure). A number of hierarchical regression analyses were conducted in attempts to untangle the importance of each of these mechanisms in language functioning. There were a number of important findings resulting from these analyses. They found that both a processing WM and storage WM measure separately predicted language performance. As well, the Stroop inhibition measure and the baseline condition each predicted language performance separately. However, further analyses showed that WM could not adequately predict language performance after speed of processing and inhibitory mechanisms had been accounted for, while inhibitory performance was still able to significantly predict performance after speed and WM performance had been accounted for. They concluded that both inhibitory efficiency and speed of processing contribute to the observed age-related differences in discourse processing.

In summary, it is evident that the discourse processing literature provides a fair amount of support for the inhibitory deficit hypothesis proposed by Hasher and Zacks (1988). The research suggests that older adults have difficulties staying focused on what is relevant and keeping irrelevant information, whether it be environmentally stimulated or internally stimulated, out of focus.

Selective Attention

The other main area of support for the inhibitory deficit hypothesis comes from investigations of selective attention. Selective attention has previously been regarded as the process of selectively attending to specific information (Neumann & DeSchepper, 1992). It was believed that there was a limited capacity for information to be attended to, and all other information not selected is passively ignored because there are no resources available for processing it. The investigation of what happens to the information that is not selected is relatively new. It has been said that "One of the largest gaps in the modern study of human information processing [is] the issue of inhibitory processes" (Neumann & DeSchepper, 1991, p. 1136). It is now widely believed that besides the active attending to selected information, selective attention also requires the inhibition of irrelevant information. This has been termed the dual-process model of selective attention, involving both the selection of relevant information and the inhibition of irrelevant information (McDowd & Filion, 1992). Efficient selection, therefore, is thought to require not only the enhancement of selected information, but also the suppression of irrelevant (or non-selected) information (e.g., Gernsbacher & Faust, 1991; Stoltzfus, Hasher, Zacks, Ulivi & Goldstein, 1993).

Since early investigations of selective attention one of the most widely debated areas has been as to the locus of selection. It was proposed (Broadbent, 1958) that it is an early selection process, where perception is a limited capacity process which requires selective attention (Lavie & Tsal, 1994). A rudimentary analysis of the physical features of stimuli precedes attentional selection, hence, the term, precategorical selection (Tipper, 1985). The main assumption of this model is that unattended stimuli are not fully perceived (Lavie & Tsal, 1994).

While early selection models gained initial support, this support later shifted to late selection (Deutsch & Deutsch, 1963) accounts (Lavie & Tsal, 1994). In this case, perception is unlimited and can automatically be performed in parallel without selection. Selection only occurs after complete perception of all stimuli, in order that an appropriate response can be made. Therefore, in contrast to the early selection model, the late selection model allows for the complete processing of all stimuli (relevant and irrelevant) (Lavie & Tsal, 1994). Selection is therefore said to be postcategorical (Tipper, 1985). Under the late selection model there are two different ideas about what happens to the irrelevant information following initial activation. According to the passive decay model (Neumann & DeSchepper, 1992) irrelevant information simply decays passively, while the relevant information remains activated through active processes (e.g., processing of the information). In the activation suppression model (e.g., Keele & Neill, 1987), however, following automatic activation, the irrelevant information is actively inhibited (Neumann & DeSchepper, 1992). This is the view that is becoming widely accepted based on a number of different experiments (e.g., McDowd & Oseas-Kreger, 1991; Tipper, Weaver, Cameron, Brehaut & Bastedo, 1991) which attempt to investigate cognitive inhibition.

Kahneman and Treisman (1984) suggested that this shift from early to late selection models was due to a change in the paradigms used to measure attentional influences. They suggested that the differences between the two paradigms which ruled the day may require different attentional mechanisms. While the filtering paradigm includes tasks such as shadowing of speech and partial-report of visually presented arrays, the selective set paradigm includes such tasks as spatial and semantic priming and visual search. Results from the first paradigm tend to support an early selection account, while results from the second a late selection account.

Lavie and Tsal (1994) suggest that the perceptual load of a given task is a major distinguishing factor between these two sets of paradigms. They suggest that there is a limited capacity system in which priority is given to relevant information. Depending on the task, therefore, irrelevant information may also be processed. If the task is relatively easy, and requires few resources, then the remaining resources will be used to analyze the irrelevant information. The entire reserve of resources is assumed to always be at capacity, therefore irrelevant information will automatically be processed if there are resources available.

McDowd and Filion (1992) investigated the inhibitory deficit hypothesis by using a psychophysiological measure of inhibitory mechanisms in younger and older adults. They looked specifically at the skin conductance orienting response (SCOR). This is one of the features of an orienting response which is elicited by novel, unexpected, interesting, or significant stimuli. It is believed to occur, along with other responses (e.g., increase in cephalic blood flow and pupil dilation) to facilitate and enhance the processing of sensory information (McDowd & Filion, 1992). The SCOR is believed to reflect the allocation of attention, and the size of the response is in accordance with the amount of attentional allocation. Habituation occurs with repeated presentation of a stimulus and is reflected in a decrease in the

SCOR size, and therefore is thought to reflect a decrease in attentional allocation.

McDowd and Filion (1992) investigated the attentional allocation of younger and older adults through auditory means, where participants heard a radio play along with tones. They were either to attend to the tones (count them), or to ignore them. McDowd and Filion's key interest was to look at the habituation of SCOR between attended and ignored stimuli. They reasoned that individuals should habituate much faster to the ignored stimuli. Based on the SCOR measures, McDowd and Filion concluded that the young adults appeared to quickly develop an efficient system of the allocation of attention as they continued to orient to the task-relevant information while reduce orienting to the task-irrelevant information. The older adults, however, continued to orient to both task-relevant and task-irrelevant information equally. They conclude that older adults are indeed less efficient at allocating attentional resources (McDowd & Filion, 1992).

Negative Priming

Since the introduction of inhibitory mechanisms in models of selective attention, a number of tasks have been developed which attempt to understand the process more clearly. Probably the most noted paradigm for testing cognitive inhibition is that of NP (Tipper, 1985). In the most simple of NP experiments letter pairs are presented overlapping one another. One letter is designated as the target and the other is the distractor. Participants are to identify the target letters and ignore the distractor letters. Targets and distractors are typically distinguished on the basis of color. When the target on one trial is the same letter as the distractor from the previous trial participants take longer to respond compared to when the pairs of sequential trials are not related (i.e., there is an increase in reaction time). A similar finding has been observed in Stroop experiments, where saying the hue is more difficult when it is the same as the preceding color word (Neill & Westberry, 1987). A similar result has also been observed using semantic associates (e.g., a green cat followed by a red dog; Tipper, 1985), and across symbolic domains (e.g., a picture of a dog and then the word dog; Tipper & Driver, 1988). It is believed that these effects could be due to a temporary modification of the internal state of activation of the concepts of interest (Tipper, 1985). When a distractor becomes a target on the subsequent trial it takes longer to respond because it was recently inhibited. Given these descriptions of the task and the existing interpretations, it can be seen how the inhibitory deficit hypothesis might be tested by such tasks. After a more in depth discussion of relevant NP literature, I will turn to a discussion of age-related NP research.

General characteristics of negative priming.

The strength of inhibitory mechanisms in selective attention tasks was investigated by Neumann and DeSchepper (1991). They were interested in the relationship between excitation and inhibition in selective attention tasks. They conducted positive priming and NP tasks simultaneously, using (overlapping) letters, with color cueing relevance. Positive priming occurs when reaction times are decreased in the identification of a target following an earlier presentation. The task consisted of a prime pair, followed by a probe pair, with a distractor and a target in each pair. Through differential pairings of primes and probes, Neumann and DeSchepper were able to infer the relative strengths of inhibitory and excitatory processes. For example, in some cases the distractor of the prime became the target of the probe (NP; a measure of inhibition), while in other cases the target of the prime was the same as the target of the probe (positive priming; a measure of excitation). It was found that, in the NP case, there was an increase in reaction time for the probe pair, while in the case of positive priming, there was a decrease in reaction time for the probe pair, both relative to the prime pair. These results indicated inhibitory and facilitory effects, respectively. Neumann and DeSchepper (1991) concluded that excitation and inhibition play mutual roles in selective attention. They further suggested that inhibition is just as powerful as excitation in the process of selective attention since the amount of facilitation (measured from positive priming) was not significantly different from the amount of inhibition obtained through NP.

In another examination of NP Tipper (1985) found that identification of a "red cat" was more difficult when it was preceded by a "green dog" than being preceded by a "green pot". Tipper's conclusions were that there is a spreading inhibition mechanism analogous to that of spreading activation (e.g., Collins & Loftus, 1975; Anderson, 1983, cited in Tipper et al., 1991), where, for example, a prime of "dog" would produce positive priming (facilitory) effects for the probe "cat". Hence, it appears that inhibition of a given distractor spreads to it's semantic neighbors.

One characteristic of spreading activation is that it is a limited capacity mechanism (Anderson, 1983, cited in Tipper et al., 1991). Neumann and DeSchepper (1992) investigated whether this characteristic is also true of inhibitory mechanisms. One consequence of a limited capacity system is that if there are more items to be inhibited, any single item will not be as strongly inhibited as when only one item is to be inhibited. Such an effect would be exhibited by a systematic reduction in magnitude of NP as the number of distractors in the immediate vicinity of the target increased. This was indeed the finding by Neumann and DeSchepper, and they therefore concluded that there is an analogous system to spreading activation that is subject to fan effects. They also report an inverse relationship between NP effects and overall reaction time. There appeared to be a tendency for people with faster reaction times in general to demonstrate greater NP effects. Neumann and DeSchepper concluded that this relationship was due to the fact that the degree of NP indicates strength of inhibitory abilities. Thus, the better one is at inhibiting irrelevant information, the faster one should be at detecting and identifying target material.

In a second experiment, Neumann and DeSchepper (1992) investigated the proposal that initially all items are automatically processed. They reasoned that if you could tap the information before inhibition set in then you should see reduced NP effects and possibly see facilitory effects instead. They attempted to test this by stressing the importance of speed over accuracy to participants, and having participants control the speed at which stimuli were presented. With this manipulation it was thought that participants would name the target items before the distractors were inhibited. The results indicated that, overall, reaction times significantly decreased compared to the first experiment. Furthermore, it was found that in the control condition, where accuracy was stressed, the typical NP effects were observed, however, for the speeded condition there was slight facilitation on the distractor repetition trials. From this finding, Neumann and DeSchepper concluded that if distracting information is to be suppressed, its internal representation must first be activated. This is understandable because if the representation had not been activated, one would not have expected to see facilitory effects.

To summarize, the NP paradigm has been useful in uncovering some of the characteristics of inhibitory mechanisms. For example, it has been shown that inhibitory mechanisms are subject to some of the similar effects as excitatory mechanisms are, such as fan effects and spreading activation. It should be noted that all of the above discussion of inhibition was of only identity information. Investigations of spatial location inhibition will not be discussed as it is not relevant to the present research (see Tipper, 1991). However, one point of interest is that some researchers suggest that there may be two separate systems (e.g., Connelly & Hasher, 1993). That is, one system for spatial location and one for identity.

Negative priming and older adults.

As noted earlier, Hasher and Zacks (1988) have proposed that reduced inhibitory abilities in the elderly may be able to explain a number of age-related cognitive deficits. Since this proposal a number of investigations have been conducted examining older individuals inhibitory abilities on selective attention tasks, with NP tasks appearing as a major means of inferring inhibitory efficiency.

Based on a recent description of selective attention (e.g., Keele & Neill, 1978) and the underlying mechanisms of NP tasks, McDowd and Oseas-Kreger (1991) investigated older adults performance on an NP task. They predicted that if NP is a measure of inhibition and if older adults do have a deficiency in inhibitory mechanisms, then older individuals should demonstrate little or no NP. They used the same stimuli as Tipper and

Cranston (1985), in which participants were to respond to a target letter, with a partially superimposed distractor letter presented in a different color.

McDowd and Oseas-Kreger (1991) compared reaction times from three different types of trials. One block of trials consisted of the presentation of single letters to which participants responded to the identity of the letter. The second type of trial consisted of the overlapping letters (presented in different colors) in which the distractor letters had no relationship to the target letters. The last type of trial was considered to be an NP trial, in which the target for every trial was the same as the previous trial's distractor letter. They found that, consistent with their prediction, the younger adults demonstrated a NP effect while the older adults did not. Furthermore, the older adults appeared to be less able to ignore distracting letters than the younger participants, even when the distractor was a constant letter throughout (based on the difference in reaction times between the no-distractor trials and the trials in which a distractor letter was present, but not an NP trial).

Stoltzfus et al. (1993) postulated that older adults may exhibit a different time course of inhibitory processing compared to younger adults. They based their investigation on the time-course of inhibition in older adults on Neill and Westberry's (1987) work investigating the time-course of inhibitory effects in younger adults. Neill and Westberry (1987) found a buildup of inhibition between 20ms and 520ms, followed by a decline to about 2020ms, in younger adults. Stoltzfus et al. suggested that because it has been shown that older adults are generally slower than younger adults on a number of cognitive tasks (Salthouse, 1985), their inhibitory mechanism may act on a different time frame than younger adults'. Thus, they suggested two possibilities. The first was that suppression may be present in older adults, but may not appear until some time after it does for younger adults, and possibly beyond the timing of the previous investigations of NP in older adults. The second proposal was that suppression may develop at the same rate as it does for younger adults but may diminish at a faster rate. If this were the situation, then previous investigations may have investigated the inhibitory mechanism only after it had dissipated for older adults.

In order to investigate these two possibilities Stoltzfus et al. (1993) manipulated the time course between the naming response for one trial and the stimulus presentation of the next trial (i.e., response-stimulus interval; RSI). In their first experiment they used a time course of 1700ms in order to test the hypothesis that older adults need more time for inhibition to build up. Like McDowd and Oseas-Kreger (1991), Stoltzfus et al. used letter pairs for stimuli, with an alteration that pairs were presented side by side rather than slightly superimposed. Their results complimented the earlier findings, that the young adults demonstrated a NP effect, while the older adults failed to show such an effect. This finding suggests that inhibitory mechanisms do not occur at a later time in older adults than in younger adults (Stoltzfus et al., 1993).

Therefore, in a second experiment Stoltzfus et al. used an RSI of 300ms to investigate whether inhibition dissipates more quickly for older adults. Once again the younger adults demonstrated a NP effect and the older adults did not. Thus, they found no support for the possibility that older adults' inhibitory mechanism may diminish at a faster rate than for younger adults. Furthermore, it appears that the inhibitory effect is relatively stable for younger adults from 300 to 1700ms after a response is made to a target stimulus (Stoltzfus et al., 1993).

Kane, Hasher, Stoltzfus, Zacks and Connelly (1994) suggest that manipulations of exposure duration (i.e., how long the stimulus is presented) may result in different age-related findings. They suggest that the exposure durations in previous studies may have been too brief for older adults to sufficiently process the distractors. They remind us that in order to inhibit something it must first be activated. Kane et al. (1994) increased the exposure time of the stimuli to 500ms. They also included trials which have been shown to demonstrate facilitory effects (i.e., a decrease in reaction times) in younger participants. If older participants also demonstrated facilitory effects on such trials then this would suggest that the distractors are processed by older individuals and therefore a lack of NP is indeed indicative of a deficit in inhibitory mechanisms. The results indicated that the older adults did not demonstrate a NP effect even at a longer exposure duration, but they did demonstrate facilitory effects not significantly different from the younger participants. This finding suggests that although the older adults appear to be processing the distractors enough to produce facilitory effects, they do not demonstrate inhibitory effects, suggestive of a deficit in inhibitory mechanisms.

One other manipulation was made by Kane et al. (1994) in order to investigate the possibility that the NP task may not be sensitive enough to elicit a NP effect for older adults. Kane et al. point to the fact that most of the NP effects which have been demonstrated by younger adults are statistically reliable but very small (about 10ms). With such a small effect it is suggested that older adults may have a weaker suppression effect which does not emerge because it is such a small effect to begin with (Kane et al., 1994). In order to investigate this possibility Kane et al. used familiar words for stimuli, rather than the often used letters. These stimuli were successful in producing a greater NP effect for the younger adults (18ms), but still the older adults still did not demonstrate a suppression effect. Kane et al. conclude that the findings which have been reported, which indicate a lack of inhibition in older adults demonstrated through a lack NP effect do not appear to be due to methodological issues, but represent a true deficit in inhibitory mechanisms.

The above studies have converged to support the finding that older adults do not show the typical slowing in reaction time on NP trials, where the target is the distractor from the previous trial. It has been shown that this lack of NP effect in older adults is not due to timing effects, and has been taken as evidence that older adults have an inhibitory deficit. However, more recently, investigations have suggested some interesting reanalysis of the NP task.

Kramer, Humphrey, Larish, Logan and Strayer (1994) investigated the inhibitory deficit hypothesis and incorporated a number of different measures of inhibitory efficiency. Although they did find age differences on some of their tasks (e.g., the stopping paradigm), there were no age differences on the NP task. That is, the older adults demonstrated equivalent amounts of NP compared to the younger adults. Sullivan and Faust (1993) also report equivalent amounts of suppression in an investigation of identity inhibition in younger and older adults.

Stroop

In addition to the NP paradigm, a well known selective attention paradigm has also been cited in support of the inhibitory deficit hypothesis. One of the most widely used and diverse paradigms in the history of psychology is the Stroop (1935) paradigm. It has been used in clinical settings (e.g., Bryson, 1983), developmental research (e.g., Cohn et al., 1984), and normal perceptual/attentional investigations. The Stroop phenomenon occurs when individuals must respond to the color of ink that words are printed in, and show slowing (i.e., reaction times increase) when the word presented is a color word that is incongruent with the color of ink, compared to control conditions. For example, the word red , printed in blue ink, must be responded to "blue", and it will take longer to do so compared to the word red printed in red ink and responded to "red". This finding has been called the Stroop interference effect (Dulaney & Rogers, 1994). This increase in reaction time has been demonstrated to be a very robust effect, withstanding a number of different control stimuli manipulations (e.g., a color patch, congruent word/color, rows of XXXs) and has even been found when the two dimensions are not integrated, but presented spatially, or temporally separated (MacLeod, 1991).

Explanations.

Since it has been shown that older individual's demonstrate an increased Stroop interference (Cohn et al., 1984), an understanding of why this effect occurs may help us explain why it is increased in older adults. MacLeod (1991) presents five lines of explanations which have been proposed in the literature to explain the findings of the Stroop paradigm. The most prominent goal of these explanations is to explain the asymmetry in interference. That is, naming the color of the stimulus demonstrates greater interference effects than naming the word (MacLeod, 1991). It is assumed, therefore, that the word interferes significantly more with naming the color, than the color of the stimulus interferes with naming the word.

According to MacLeod (1991), one explanation of the Stroop assymmetry is a "relative speed of processing" account. The main premise of this account is that words are processed faster than colors, which leads to the asymmetry in interference. The interference occurs at the response level, whereby there is competition between two incompatible responses. The asymmetry in interference arises because words are read faster than colors are named, thereby reaching the response channel first. The main distinguishing aspects of this account, therefore, are that relative speed of processing is important, and the interference is at the stage of response output.

The second account of the Stroop asymmetry effect which MacLeod (1991) discusses and which has been very popular is the "automaticity" account (e.g., Hunt & Lansman, 1986). Here the asymmetry results from the processing of one dimension requiring much more attention than the processing of the other (e.g., naming the color requires more attention than reading the word). According to this account, naming the ink color is obligatory and naming the color is not, due to our history of reading. This, then, is what leads to the asymmetry. Therefore, the more automatic process interferes with the less automatic one.

MacLeod (1991) briefly describes a third account of the Stroop effect termed "perceptual encoding". Opposite to the above two descriptions, this model is an early selection model, as opposed to a late selection model. The main distinction is that interference occurs early in the system, at the encoding level, rather than later, at the response stage. In this case, perceptual encoding of the ink color is slowed due to the incompatible color word, which is recognized first. MacLeod (1991) briefly points out that this account has been criticized on a number of different grounds and has not been very prominent in the literature.

MacLeod (1991) also presents a discussion of parallel models (e.g., Logan, 1980). He notes that while the previous models were sequential models, a new breed of models in which parallel processing was incorporated began. In parallel models, the information is gathered separately from different dimensions (e.g., color, word). Two weights determine a dimension's contribution to the decision. One is a stable, automatic weight, and the other is a flexible and strategic, attentional weight. All of the evidence from each dimension is summed together and a response is made when threshold is achieved.

Parallel models account for facilitation by allowing evidence from other dimensions to influence the required threshold. Facilitation occurs, therefore, when the evidence from other dimensions is consistent with the desired dimension (i.e., the dimension which you must respond to), thus lowering the threshold. Interference occurs when there is incompatible evidence from other dimensions, with the required dimension. The amount of interference is determined by the weights of the other dimensions, with larger weights leading to more interference. The interference leads to a slowing in response speed. The interference occurs at the stage of gathering evidence.

The last type of model which MacLeod discusses is the parallel distributed processing models (Cohen, Dunbar & McClelland, 1990). MacLeod suggests that these models are the most promising to date. In a parallel distributed processing model, processing takes place through activation moving along pathways of different strengths. What is important, therefore, is the relative strength of the pathways, and not the speed. There is also an automatic gradient involved, whereby degree of automaticity is a function of the strength of the pathway. The stronger a pathway is, the more automatic it will be. MacLeod (1991) concludes that parallel distributed processing accounts can nicely explain the Stroop, as this model captures the good aspects of the previous explanations while eliminating their flaws.

Lavie and Tsal (1994) explain the Stroop assymetry by suggesting that the task (i.e., identifying the color of the ink) requires such low perceptual load that the processing of irrelevant information (i.e., the words) occurs involuntarily. They suggest that there is a limited capacity system which must be used to it's full extent. Therefore, in tasks which require a high degree of perceptual "space", there will be no spare space to analyze the irrelevant information. On the other hand, while performing tasks that are low in perceptual load irrelevant information will automatically be processed in order to maximally use the system. In the Stroop task, therefore, the spare attentional capacity, following identification of the color, is automatically filled by processing irrelevant information (i.e., the word), thus interfering with responding to the color because it is an incompatible response. In fact, Lavie and Tsal suggest that this model explains effects seen in many other selective attention tasks, such as NP.

After this brief review of some of the different explanations of the Stroop phenomenon, it can be seen that the theoretical development is an ongoing process and will most likely continue to develop as long as the paradigm is used. It appears that models will continue to evolve along with the ever evolving research findings.

Negative priming and the Stroop paradigm.

More recently, sequential effects of Stroop stimuli have been of research interest. Neill and Westberry (1987) make reference to a proposal by Keele and Neill (1978). They suggested that, following activation in memory by stimuli, there must be a narrowing down of activations, retaining only the most appropriate for current task demands. They suggested that this narrowing down is accomplished through direct, selective inhibition of irrelevant or distracting information. From this, it follows that if the distracting information becomes relevant, processing may be hampered due to the inhibition. Neill and Westberry (1987) also point out that the suppression effect takes time to develop, and therefore, if a response for a previously irrelevant stimulus is selected before it has been fully inhibited, it may still be at a highly activated level, and therefore, facilitory effects will occur.

Neill and Westberry (1987) investigated a number of different sequential effects using Stroop stimuli. The one of most interest was an investigation of a NP-type effect, which they call the "distractor suppression effect". It is the relative slowing of Stroop color naming when the current response is the same as the previous distractor, or color word (e.g., having to respond to the color green when the previous stimulus was the word green presented in red). The main goal of the study was to investigate the time course of distractor suppression. They also investigated the effect of different instructions (speed versus accuracy) on distractor suppression.

The first experiment investigated whether there might be a difference in the distractor suppression effect under different instructional circumstances. They gave some participants instructions which emphasized the importance of speed in their responses while other participants received instructions which emphasized the importance of accuracy. Of most significant interest, it was found that when participants had to make a response that was the same color as the preceding distractor (i.e., the word) their reaction time was slowed. Thus, the distractor suppression effect was found. This increase in reaction time was not only for cases where participants were to respond to the color of a word, but also in control conditions in which participants responded to the color of a row of 000s that appeared in the same color as the previous word (e.g., green 000s following the word green in red ink). However, this distractor suppression effect was only found when participants were given the accuracy instructions. Neill and Westberry note that under the speed instructions there was a non-significant trend in the opposite direction.

The main purpose of the second experiment was to investigate how long it takes for the distractor inhibition effect to dissipate. This was investigated by varying the response-stimulus interval (RSI). After participants responded to the stimulus the next stimulus appeared either 20, 520, 1020, or 2020ms later. All participants were given the strict accuracy instructions based on the results of the first experiment. Here, the greatest distractor suppression effect occurred at an RSI of 520ms, at which point it began to dissipate.

Age effects in Stroop.

It has been demonstrated that elderly individuals have difficulty with selective attention tasks (e.g., Plude & Doussard-Roosevelt, 1989), and this does not exclude the Stroop paradigm. Cohn et al. (1984) investigated how older individuals would perform on the classic Stroop task. They point out that the Stroop paradigm has been used to distinguish between normal and cerebrally impaired individuals (Golden, 1976), and that it has also been shown that elderly individuals demonstrate decrements on a number of neurological examinations. They reported that their older participants demonstrated significantly more interference than the younger participants on the Stroop color naming task.

Besides the important finding of increased Stroop interference in the elderly, Cohn et al. (1984) report several other important results. They suggest that the difference between the young and old groups cannot be explained solely by differences in response speed per se because they found that there was no significant difference between the groups on simple reading tasks. They also suggest that the increase in interference reflects a cognitive, rather than a purely sensory process. They make this claim after an investigation of the possibility that due to the yellowing of the lens older individuals may have increased difficulty discerning the different colors. They investigated the errors according to the different color patterns and found no difference for the young or old adults. Lastly, they ruled out the possibility that the effect was due to an increased cautiousness of the older individuals. They examined the speed/accuracy trade-off through a look at the number of errors made and found that only one of the four groups (the second oldest group; 61-70 years) had significantly less errors than the rest.

After ruling out the above explanations for the differences between the younger and older participants, Cohn et al. (1984) discuss their results with regards to inhibitory mechanisms. They note that there has been some evidence to suggest that older individuals demonstrate an inhibitory deficit and the Stroop task may be another behavioral measure of such a mechanism. They suggest that the increased interference effect may be due to a deficit in the ability to inhibit one stimulus (i.e., the words) while attending to another (i.e., the color).

A modification of the Stroop task was used to investigate automatic processes and practice effects in younger and older adults by Rogers and Fisk (1991). They used an arithmetic Stroop procedure to investigate the stability of well-learned (automatic) processes through adulthood, as well as whether there might be a deficit in the ability to modify these automatic processes with age. They assumed that reading is an automatic process, and that this automaticity of reading is the reason for the Stroop interference effect. They were interested in whether the same type of findings might be observed with simple arithmetic stimuli.

Especially considering the increased technology in today's society, individuals may be very familiar with arithmetic stimuli and therefore such stimuli may be processed automatically. Rogers and Fisk (1991) reasoned that $3 + 3 = 9$ and $3 \text{ X } 3 = 6$, in a verification task, would cause associative interference, and therefore, participants would have a tendency to report "yes" in both cases (Rogers & Fisk, 1991). These type of equations, where the equation would be correct if the addition operation were changed to a multiplication operation or vice versa, do lead to a slowing in reaction time compared to equations not subject to associative interference.

Consistent with the regular color Stroop task, as well as Cohn et al.'s (1984) results, Rogers and Fisk (1991) found that the older adults demonstrated increased Stroop interference for the arithmetic stimuli compared to the younger adults. Also of interest was their investigation of practice effects. Although the older adult's overall reaction time decreased with practice, they did not demonstrate a reduction in Stroop interference, as the younger participants did. Rogers and Fisk (1991) suggest that the younger participants were learning to inhibit the automatic process, as well as perhaps learning to attend more specifically to the mathematical operation, while the older adults appeared to be impaired in their ability to inhibit the automatic process. They also discuss their results with regards to priority learning. This is the situation whereby automaticity can develop through a strengthening of the associations between relevant information and a weakening or inhibiting of irrelevant information. Rogers and Fisk (1991) suggest that elderly individuals may have a disruption in this form of learning, and this disruption could explain their findings. They propose that the young individuals demonstrate a reduction in Stroop interference with practice because they learn to inhibit the automatic access of the addition and multiplication facts and focus more on the operator in the stimulus.

Practice effects with regular Stroop stimuli were investigated in younger and older adults by Dulaney and Rogers (1994). They suggest three potential sources for the age difference observed on the Stroop paradigm. The first is that older adults may have more difficulty attending to the colors of Stroop words. The second is that the older individuals have difficulties in inhibiting well-learned automatic processes. Lastly, they may have difficulties in developing new automatic responses which may reduce Stroop-like interference. Dulaney and Rogers (1994) present evidence in support of age-related deficits in inhibiting automatic processes.

Dulaney and Rogers (1994) base their conclusions on the results of several experiments which investigated the effects of practice with Stroop stimuli on the amount of Stroop interference in younger and older adults. They found, contrary to the findings by Rogers and Fisk (1991), that the older individuals demonstrated decreased overall reaction time and a decrease in Stroop interference with practice. However, they suggest that the older participant's improvement was due to improvement in general task factors alone. They suggest this following two separate findings. The first indication that the older participants' did not really develop a reading suppression response was that the effect dissipated very quickly in older adults relative to the younger adults. Secondly, Dulaney and Rogers manipulated task factors such that a reading suppression response could not be developed through inconsistent practice with Stroop stimuli. Under these conditions there was still a reduction in Stroop interference, however, it was attributed to practice with general task factors aloone. The improvement for the younger participants, however, was attributed to both general task factors, as well as the development of a reading suppression response as their reading suppression effect did not dissipate as the older adults' did. Here, they concluded that older individuals have reduced inhibitory abilities in selective attention tasks.

Conclusions.

The Stroop paradigm has clearly been a very useful and widely used measure in cognitive psychology, and will most likely continue to challenge those who attempt to explain the findings. Of most interest here, is how it has contributed to the research in cognitive aging. The proposal by Hasher and Zacks (1988) which suggests that elderly individuals possess a deficit in the ability to inhibit irrelevant information gains support by citing the Stroop findings. The finding that older individuals demonstrate increased Stroop interference suggests that they are less able to inhibit the distracting information, or suppress the automatic reading process. Furthermore, the studies which investigated practice effects with Stroop stimuli indicate that older individuals may not only have difficulties inhibiting distracting, or irrelevant, information, but they may also have difficulties learning to inhibit previously well-learned, automatic processes.

Hasher and Zacks' (1988) proposal has also lead to an outburst of studies investigating the NP effect. The apparent NP-type effect observed with Stroop stimuli (e.g., Neill & Westberry, 1987) could be another measure which could provide beneficial insight into the processes involved in such tasks. If both tasks are measuring the same thing, that being the inhibition of irrelevant information, then it would be predicted that older individuals would demonstrate no NP-type effects with Stroop stimuli, corresponding to the other NP findings. That is, they should not demonstrate the increase in reaction time when the word for one trial becomes the color to be responded to on the very next trial.

On the other hand, how might the developmental findings contribute to the continuous challenge of explaining the Stroop phenomenon? It seems that any model currently accepted must allow some room for attentional mechanisms to play a role (e.g., the parallel distributed models). Just how big a role is probably more of a concern. Selective attention was once considered the active selection of relevant information. However, it is becoming increasingly clear that the active inhibition of irrelevant information must also take place. This, along with the possible deficit in inhibitory mechanisms in the elderly, and some clinical populations (e.g., schizophrenia), leads to the conclusion that inhibitory processes must be incorporated into the attentional modulation aspect of models of the Stroop paradigm.

Interference and Inhibition

Neumann and DeSchepper (1992) suggested that the better one is at inhibiting irrelevant information the faster one should be at detecting or identifying relevant information from irrelevant information. This suggests an association between interference effects and inhibition. Similarly, Salthouse and Meinze (1995), when discussing the Stroop task, suggest that the amount of interference observed can be used as an index of the effectiveness of inhibitory processes. Specifically, larger interference effects should indicate decreased inhibitory efficiency. The literature regarding this association is controversial, and confusing to say the least. Despite the suggestions by Neumann and DeSchepper and Salthouse and Meinze, some studies which have investigated the relationship between measures of interference and measures of inhibition have found no clear relationship (e.g., Stoltzfus et al., 1993).

Tipper and Baylis (1987) investigated whether efficient 'selectors' would employ active inhibition of distractors to a greater extent than less efficient 'selectors' through the use of the Cognitive Failures Questionnaire (CFQ) and NP paradigm. The CFQ is a measure of selection efficiency in everyday activities, and asks questions such as "Do you fail to notice signposts on the road?". Tipper and Baylis wanted to see whether selection efficiency, as measured by the CFQ, could predict performance on interference and NP tasks. The interference task consisted of a central target with distractor words or a row of XXXs (control) above or below the target word. The distractor words were not the same or semantically-related to the target word. The participants were required to respond as quickly as possible to the superordinate category of the target word (e.g., dog - animal; hand - body). Tipper and Baylis predicted that individuals with low CFQ scores (an indication of good efficiency) would demonstrate less interference effects and increased NP effects. Their results did demonstrate a significant correlation between interference effect and CFQ scores. That is, those individuals who were more efficient selectors demonstrated less interference.

In the second experiment, Tipper and Baylis added the NP paradigm in hopes to gain further support for their proposal that low scorers on the CFQ are better selectors due to more efficient inhibitory mechanisms. They used a similar set up to experiment one, except there was a prime display followed by a probe display. Following the probe display participants were to respond as quickly as possible to the category of the target, and then to recall the category of the target of the prime display as well. Of most interest is the ignored repetition condition. In this case the target of the probe display is the same as the distractor from the prime display (i.e., NP trial).

Tipper and Baylis found that the low CFQ group showed a significant NP effect which was demonstrated by an increase in reaction time in the ignored repetition trials compared to control trials where there was no relationship between target and distractors in the prime and probe displays. Furthermore, both the low and high CFQ groups demonstrated positive priming (i.e., facilitory effects; same target in both prime and probe displays).

Based on the results of these two experiments, Tipper and Baylis conclude that increased inhibition of internal representations of distractors may lead to an enhanced ability in selecting targets from distractors for the low CFQ group.

Stoltzfus et al. (1993) investigated the relationship between inhibition and interference in younger adults only, following their investigations of inhibition in younger and older adults. They used three interference measures along with a measure of inhibition. The interference measures included: 1) a letter naming task in which reaction times were compared for responding to a letter alone and responded to a letter when another letter (of a different color) was presented; 2) a classic Stroop color-naming task; 3) and a reading task similar to that used by Connelly et al. (1991) discussed above, in which participants are to read text with distracting text embedded within. The measure of inhibition was a letter-naming NP task, similar to that used in their first two experiments, as mentioned above. They predicted that there should be strong positive correlations between the measures of interference as well as negative correlations between the measures of interference and NP. It was found that all of the effects were elicited, that is, interference on all three tasks, as well as NP. However, the only significant correlation was found between the Stroop interference measure and the letter-naming interference measure. Therefore, these results suggest that there is no clear relationship between the degree of interference effects and amount of inhibitory involvement, as measured by NP.

Based on their results, Stoltzfus et al. (1993) conclude that interference measures from different tasks may arise from different sources. Furthermore, based on the finding that individuals can demonstrate a NP effect, which is thought to be demonstrative of inhibitory mechanisms, and still show interference effects, they conclude that interference is not always the product of inefficient inhibitory mechanisms. The relationship between interference and inhibition clearly needs further investigation.

Rapid Serial Visual Presentation

Interference and inhibition have both been implicated in a recent phenomenon termed the attentional blink (AB; Raymond et al., 1992), observed in rapid serial visual presentation (RSVP) procedures. RSVP tasks investigate the temporal allocation of attention. In such tasks, stimuli (e.g., letters, digits, words) are presented very briefly and in rapid succession on a computer screen. Stimuli are typically presented at a rate of 6 to 20 items per second. All stimuli appear in the same spatial location. In a single-task condition, one item in the stream is differentiated from the rest based on some specified dimension, such as color or letter case. In the dual-task condition, two items are differentiated by such means. These items are to be identified or detected by participants. In the dual-task condition, typically the first item (temporally) to be reported is called the 'target' and the second is termed the 'probe'. The RSVP task is a temporal visual search task, analogous to the spatial visual search task (Raymond et al., 1992).

One major area of interest with RSVP tasks is investigating the types of errors in identification which are made by participants (Raymond et al., 1992). In a single task, the most common identification errors are intrusions of the item immediately following the target (t+1 errors). According to Broadbent and Broadbent (1986, 1987) this finding occurs due to a two-stage detect-then-identify model. In the first stage the target-defining feature is detected. The second stage involves the identification of the to-be-reported feature (e.g., letter name) from items in the sensory store. T+1 errors presumably occur because processing of the target to an output stage extends about 100 ms beyond the time that the target is actually present (Shapiro, Raymond, and Arnell, 1994).

The AB has recently gained much interest (Raymond et al., 1992). The AB is the phenomenon, in the dual-task condition, where probe accuracy declines when it closely follows the correct detection or identification of the target, relative to a single-task condition in which only the probe must be detected or identified and the target is to be ignored (see Figure 1). Although the target is typically identified or detected with a high degree of accuracy there is a window in time following target presentation where attention seems to "blink" (Shapiro et al., 1994).

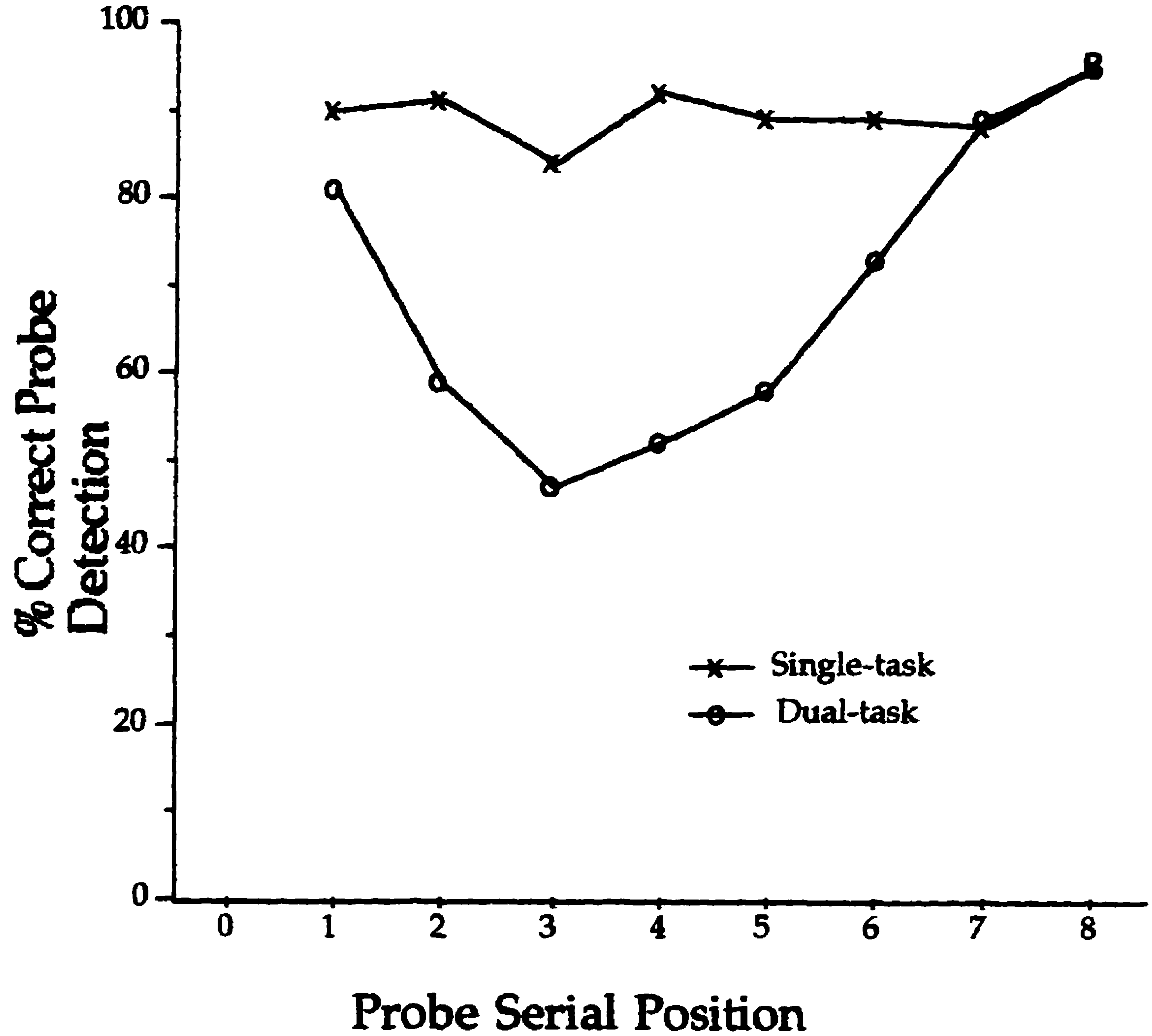

Figure 1. Example of typical attentional blink result.

A number of experiments have been conducted in order to investigate the characteristics of the blink. The effect appears to be fairly robust, occurring under a number of different experimental manipulations (Shapiro et al., 1994). It has been shown to occur both when the target must be detected and when it must be identified, and when the probe must be detected or identified. As well, when the target is an array of dots presented in a stream of letters and the target must be detected, an AB has been observed (Shapiro et al., 1994). Shapiro et al. has suggested that it is the presence of patterned information (i.e., an 'object') as a target that leads to a blink. Furthermore, Raymond et al. (1992) have shown that the blink is not due to sensory mechanisms (e.g., masking).

The AB has inspired research examining how we allocate attention over time and how quickly we can process information. There have been two main theories put forward to explain the blink. The first theory was inhibition based (Raymond et al., 1992) and the second was interference based (Shapiro et al., 1994).

The inhibition based model followed from the first set of experiments conducted by Raymond and her colleagues (1992), where the term AB was coined. It was suggested that when the target appears it is preattentively differentiated from the other items in the stream. A second stage then occurs in which attention is directed towards this item, in order to be identified. When the next item arrives (t+1) there is confusion in visual short term memory (VSTM) because there are two colors and two letters available. Due to this confusion the system no longer allows items to enter into VSTM (inhibitory mechanism) so that the target letter and color can then be matched. That is, the blink occurs because, upon presentation of the t+1 item, inhibitory processes set in and subsequent information can no longer be processed until the target letter and color are adequately conjoined. When the probe appears after identification of the target is complete then the probe can also be identified. This model is considered an early-selection model.

The second major theory is interference based and was put forth following some further experiments by Shapiro et al. (1994) and is considered a late-selection model. They suggest that upon presentation of the target an object analyzer is activated and this is what leads to the blink. They argue that identification of some form occurs even though a featural aspect may be sufficient to make presence/absence judgments. Competition arises between items in VSTM. The target, probe, t+1 and p+1 items are assumed to be given higher weightings and therefore, it is especially when these items are in VSTM together that there is competition, leading to increased errors in probe identification. Based on the model of spatial selection by Duncan and Humphreys (1989), the strength of the interference effects caused by competition between the items is suggested to depend on the similarity between the items. When the probe occurs at later intervals, the target and t+1 items are assumed to have already decayed from VSTM and therefore do no compete for retrieval of the probe.

We know that speed of processing slows with age (Salthouse, 1985), and this would be expected to influence performance on an RSVP task since it is a speeded task. It is of interest to see how an elderly population might perform on such a task since one of the proposed mechanisms for producing the blink is inhibition. If the blink is a product of inhibition of processing and older individuals do have a deficit in the ability to inhibit information, then it is predicted that older adults would not demonstrate a blink in a dual task RSVP procedure. However, it is proposed here that in order to do the task at all (even the single-task) one must be relatively efficient in selecting information and be a good inhibitor, as has been proposed as being necessary for such efficiency (Tipper & Baylis, 1987). Therefore, it is a clear prediction that anyone who can successfully do the single-task RSVP procedure will demonstrate a blink in the dual-task condition.

Only one unpublished study has used the RSVP paradigm with an older population. This study reported that younger and older adults demonstrated an equivalent AB (Zacks, Henderson, Stewart Mangum, & Hasher, 1994). The stimuli and procedure which Zacks et al. used were the identification of a letter surrounded by asterisks (e.g., **R**) as the target and the detection of the letter X as the probe. Zacks et al. chose to eliminate nine older participants from analyses because they did not meet a criterion of 89% probe accuracy in the single-task condition. With their remaining participants (N=16), it was found that there was no difference between the younger and older adults in the AB effect. That is, both younger and older adults demonstrated a similar probe accuracy deficit following the target in the dual-task condition, relative to the single-task condition. Zacks et al. suggest that the AB paradigm may be a useful tool to measure preserved cognitive abilities in older adults.

This appears to counter the predictions which might be made based on the inhibitory deficit hypothesis. An inhibition based account of the AB would predict that the blink would be attenuated for older adults, while the interference account might predict an increase in the processing deficit for older adults, both assuming an inhibitory deficit in older adults. Therefore, the result of no difference between younger and older adults found by Zacks' et al. study are surprising and warrant further investigation.

Inhibitory Deficits in Other Populations

The inhibitory deficit hypothesis is not unique to the older population. It has long been observed that schizophrenia patients display deficits in attentional mechanisms (McDowd, Filion, Harris, & Braff, 1993). One theory of why this is so is that there is a decrease in inhibitory abilities. Frith (1979) suggested that the symptoms of schizophrenia occur when the selective capacity of consciousness breaks down. When this happens, information which would normally remain preconscious comes into awareness. This abundance of information could lead to multiple interpretations of events, making it difficult for the individual to select and carry out appropriate actions. It could also lead to semantic difficulties (seen in thought disorder) by presenting the individual with multiple word meanings, once again making it difficult to carry out coherent actions (e.g., conversation).

Beech, Powell, McWilliam and Claridge (1989) conducted a study investigating inhibitory abilities of individuals with schizophrenia. They looked specifically at individuals demonstrating positive symptomatology. Positive symptoms refer to hallucinations, delusions, and thought disorder. According to Firth's (1979) model of schizophrenia, these symptoms may be due to reduced inhibitory abilities. Beech et al. (1989) used a NP task, similar to those mentioned earlier, as a measure of cognitive inhibition. They tested individuals with schizophrenia in comparison to a psychiatric control group. They found that the individuals with schizophrenia showed reduced NP effects compared to the control group. This finding therefore lends support to the reduced cognitive inhibition hypothesis of schizophrenia.

A similar study was conducted by Peters, Pickering and Hemsley (1994). They also used NP in order to measure inhibitory abilities in individuals with schizophrenia. They investigated the relationship between NP (inhibitory abilities) and positive symptomatology in schizophrenia (once again following Firth's (1979) theory about positive symptoms in schizophrenia). Positive symptomatology was measured using the Combined Schizotypal Traits Questionnaire (CSTQ). Their findings indicated that scores obtained

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They therefore concluded that inhibitory mechanisms are not yet mature in children of the approximate age of 8.

To conclude, inhibitory mechanisms appear to play a critical role in normal cognitive functioning, and a deficit in the mechanism may be associated with observed deficits in not only normal aged samples, but in other populations as well.

The Present Experiment

Although there has been a great deal of research which has been devoted to examining the proposal by Hasher and Zacks (1988) a number of questions remain. Much of the literature supports the inhibitory deficit hypothesis in an indirect fashion. That is, the discourse processing literature really provides indirect support for Hasher and Zacks' claim that there is an age-related deficit in the attentional system, which then causes problems with WM, which then leads to problems in discourse processing. The paradigm which has been most widely used as more direct evidence of an inhibitory deficit with age has been the NP paradigm. Still, there have been mixed results (e.g., Sullivan & Faust, 1993; Kramer et al., 1994), suggesting the need for further investigation Furthermore, the relationship between interference and inhibition measures is still a matter of debate which needs further investigation.

By employing a number of different measures of inhibition and interference, the present study aims to address some of the issues surrounding the inhibitory deficit hypothesis. Cross sectional samples of younger and older adults were tested on tasks intended to measure inhibitory mechanisms. Two different measures of suppression were be obtained from two different paradigms (Stroop and NP), as well as a measure of classic

Stroop interference. As well, the relatively new paradigm of RSVP elicited attentional blink patterns for younger and older adults.

According to the predictions of the inhibitory deficit hypothesis all tasks were predicted to indicate that the older adults' demonstrate an inhibitory deficit compared to the younger adults. This would lead to the following findings. The younger adults would demonstrate less interference on the Stroop task, and more suppression on both the Stroop and NP tasks. Younger adults would also have higher WM scores. For the RSVP tasks there were two possible patterns of AB results for the older adults. If the inhibition model of the blink is correct then the older adults would demonstrate an attenuated blink relative to the younger adults. However, if the interference model of the blink is correct then they would demonstrate an increased processing deficit on the dual-task (i.e., blink), relative to the younger adults. These predictions are based on the assumption that the older adults can successfully perform the single-task RSVP condition Lastly, according to an indirect relationship between interference measures and inhibition, it was expected that greater Stroop interference would be related to less suppression on the two measures of suppression from the Stroop and NP tasks.

METHOD

Participants Thirty young adults (aged 17-30 years, M = 21.3) and 25 old adults (aged 62-77 years, M = 68.7) participated in the study. The young participants were obtained through the University of Calgary Psychology Department Volunteer Research Participant Pool and participated on a voluntary basis. The old participants were obtained through responses to an advertisement placed in the Neighbors section of the Calgary Herald newspaper and received a $10.00 honorarium for their participation. All participants reported normal or corrected to normal visual acuity and normal color vision, as well as being in a good state of general health.

Younger and older adults did not differ in years of education (M = 14.3, SD = 2.3, and M = 14.2, SD = 3.3, respectively). All participants completed a thirty item multiple choice vocabulary test (Horn, 1985). Older adults (M = 24.6, SD = 3.2) performed significantly better than the younger adults (M = 18.4, SD = 4.2) on the vocabulary test, t (53) = -5.994, $p < .01$. Although younger (M = 3.18) and older adults (M = 2.88) did not perform significantly different on the loaded WM span task, t (53) = 1.456, $p = .1514$, the younger adults (M = 5.4) did perform better than older adults (M = 4.7) on the simple span task, t (53) = 3.128, $p < .01$.

Stimuli and Procedures

Tasks

RSVP. The RSVP tasks were adapted from Raymond et al. (1992). Each participant took part in both the control (single-task) and experimental (dual-task) conditions. Half of the participants in each age group performed the control task first and half completed the experimental part first. Each trial consisted of a series of 15 to 23 letters presented serially on a uniform gray field in the center of the computer screen. For both conditions the rate of presentation was 6 items per second, with a stimulus onset asynchrony (SOA) of 169 ms, and an interstimulus interval (ISI) of 65 ms. This rate of presentation is similar to that used by Zacks et al. (1994). All the items in the stream were block-style capital letters, and all were black except for the target letter which was white and present on half of the trials in each condition, and the probe letter, which was red and present in all trials (see

Figure 2). All letters were 0.95 X 0.76 degrees visual angle. The number of pretarget letters was randomly chosen by the computer for each trial and varied between 7 to 15 letters. Nine letters were always presented following the target letter (one of which was the probe). The target letters were B, L, and P, and were randomly chosen by the computer for each trial. The probe letters were A, F, and R, and were chosen in the same manner as the targets. The uniform gray field was viewed during the ISI and each trial began with the presentation of a small white fixation dot. Participants initiated each trial themselves by pressing the space bar or the mouse. Responses were made by pressing the appropriate key on the computer keyboard corresponding to the probe, and pressing the left arrow key for a response of "yes" to the detection of a white target letter, and the right arrow key to respond "no".

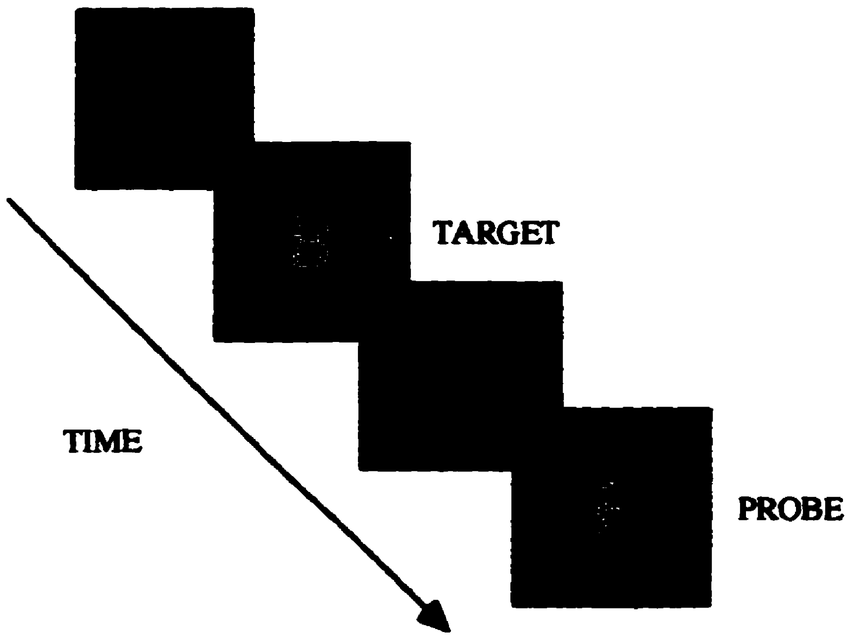

Figure 2. Example of rapid serial visual presentation stimuli, where the target is a white letter and the probe is a red letter.

The control task consisted of 144 trials, and the experimental condition consisted of 288 trials. In the control condition participants were instructed that letters would appear in the center of the computer screen one after the other at a rapid pace. They were instructed that one of the letters would be a red letter which they were to identify (single-task). In the experimental condition participants were instructed that there would always be a red letter which they were to identify, and sometimes there would also be a white letter. For each trial they are to say whether or not they saw a white letter, as well as identify what the red letter was (dual-task).

Stroop. The procedure used for the Stroop task was derived from Neill and Westberry (1987). The stimuli for the experimental conditions were the words red, blue, green, and yellow, presented in the colors red, blue, green, or yellow, with the condition that no words be presented in the color which they represent (e.g., red in red). For the control condition a series of XXXs was presented instead of a color word. There were either 3, 4, 5, or 6 XXXs in a row, corresponding to the lengths of the words red, blue, green, and yellow. All stimuli were presented in all capital letters in the center of the computer screen. Participants were instructed to respond to the color of the printing and ignore the word. There were two experimental conditions; the classic Stroop condition (a color word presented in an incongruent color, with the restriction that the color could not be the word from the previous trial), and a distractor repetition condition. The distractor repetition condition resulted when the color to be named was the color word from the previous trial (e.g., red in green, followed by yellow in red).

The task consisted of 3 blocks of 102 trials each, as well as 1 practice block of 25 trials. In each test block there were 34 trials of each condition (i.e., control, Stroop, and distractor repetition). The stimuli for each block were pseudo-randomly chosen such that the above requirement was met (i.e., 34 trials of each condition), as well as that there were no more than 3 trials of a given condition in a row, and there were no more than 3 same responses in a row (e.g., saying blue 3 times in a row). Participants sat approximately 30 cm from the computer screen. The visual angle of the stimuli ranged from 0.95 X 2.4 degrees for red to 0.95 X 5.0 degrees for yellow.

Negative Priming. The stimuli chosen for the NP task were based on those provided by Stoltzfus et al. (1993). The stimuli consisted of the letters A, B, C, D, E, J, K, N, O, S, and T. The procedure used for presentation of the stimuli was similar to that used by Tipper and Cranston (1985). Each trial consisted of a pair of letters presented slightly overlapping each other (i.e., superimposed) in fixed locations in the center of the computer screen. Each pair of letters consisted of one green letter and one red letter presented on a uniform white background. The total rectangle that the letters appeared in was 1.1 X 1.7 degrees visual angle and the overlapping portion was 0.57 X 0.38 degrees. Participants received 3 blocks of 50 trials each, following an initial practice block of 10 trials. Half of the participants in each age group were required to identify the red letter and half were required to identify the green letter throughout the task. The target (i.e., the letter which they are to respond to) appeared approximately equally often in each of the two positions. In each block, half of the trials were distractor repetition trials and half were control trials. A distractor repetition trial occurred if the target for that trial was the same letter as the distractor from the previous trial, regardless of position (see Figure 3). All other pairs were considered control trials. Pairs of letters were presented in a pseudo-random order such that any condition did not occur more than 3 times in succession and there were an equal number of control and distractor repetition trials in each block.

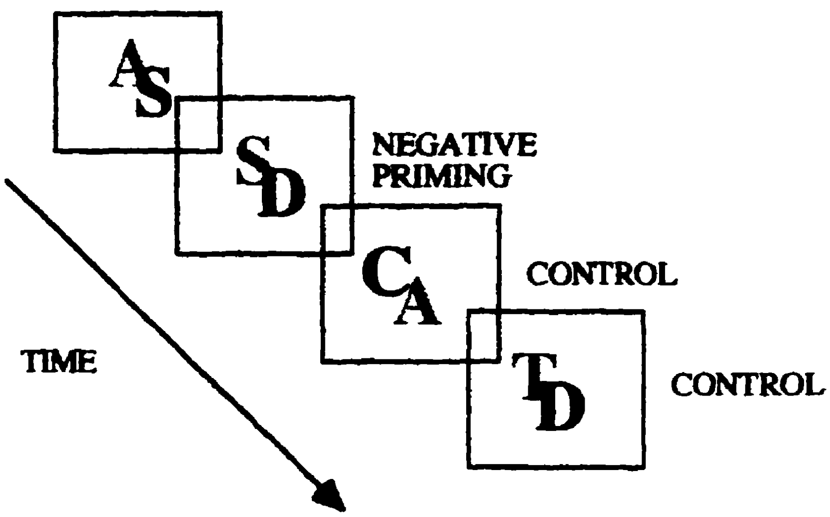

Figure 3. Example of negative priming stimuli. Here the light letters are the targets (e.g., green letters) and the dark letters are the distractors (e.g., red letters).

Working Memory and Simple Reading Span Tasks. A reading WM task was adapted from Stine and Wingfield (1987). The task requires participants to read aloud sentences presented in large bold type on flash cards, and at the same time they are required to remember the last word of each sentence for recall. At the end of a given grouping of sentences, participants are to report the last word of each of the sentences in that grouping. The task begins with two sentences and increases to a maximum of six sentences. The number of sentences prior to recall is blocked, such that the participant would begin by reading two sentences and then recall, followed by three sentences, and then recall, and so forth. There are three blocks of sentences for each level. Sentences are grouped into sets of three, so that there would be three sets of two sentences in a row, and then three sets of groups of three sentences, and so on. The participant continues as long as they are able to recall the last words of at least one of the groupings in a set. Simple reading span was also measured, in which participants read words aloud which are presented one at a time on flash cards, and they are to later recall. Again, the task begins with two words in a row and the number increases thereafter. Scores for this task are the maximum number of words which can accurately be recalled.

General Procedure and Apparatus

All participants were tested individually, and completed all tasks in one visit which lasted one to two hours. Participants began the session by completing both the single- and dual-RSVP tasks (half of the participants in each group received the single-task first and half received the dual-task first). Completion of these two tasks was followed by the two reading span tasks. All participants then performed the Stroop task followed by the NP task. They began with a block of 25 trials (of the Stroop task) for practice with the voice reaction time procedure. Following the three test blocks of the Stroop task, participants received a block of 10 practice trials for the NP task in order to familiarize themselves with the stimuli, before going on to the test blocks. Completion of the vocabulary test and a brief background information questionnaire completed the session.

For all computer tasks, participants sat approximately 30 cm from the screen and were asked to maintain fixation at the center of the screen. A Macintosh Quadra 800 presented to participants the stimuli on a Macintosh RGB 16 inch color monitor in a dimly lit room.

For the Stroop and NP tasks, voice reaction time was recorded while the experimenter recorded errors, hesitations in speech, and instances in which the microphone did not record the initial response of the participant. Blocks of trials for these two tasks began with "READY?" displayed in the center of the screen. Participants were instructed to press the space bar to initiate the first trial. The timer was initiated for each trial at the onset of the stimulus, and was terminated at the detection of a response by the microphone. For both the Stroop and NP tasks the ISI was 600ms, which was chosen based on previous research (Neill & Westberry, 1987). In both cases participants were instructed to respond as quickly as possible while maintaining accuracy. These were the instructions given to participants in which inhibitory effects have been elicited in the past (Neill & Westberry, 1987).

RESULTS

RSVP Tasks

Target Detection.

For younger adults, targets were correctly detected 96.9% of the time in the dual-task condition. Their false alarm rate was 4.1%. For older adults, targets were correctly detected 96.5% of the time in the dual-task condition. Their false alarm rate was 3.6%. Clearly, neither group had any difficulty detecting the target.

Probe Identification.

Figure 4 illustrates younger and older adults probe accuracy performance, as a function of probe serial position, for the single and dual task conditions. The graph illustrates that there is a deficit for both younger and older adults in probe identification accuracy in the dual task condition (i.e., when they must detect the target) relative to the single task condition. Separate 2 (single-, dual-task) X 8 (probe serial position) univariate repeated measures analyses of variance (ANOVAs), with probe accuracy as the dependent measure, were conducted for the younger and older adults in order to investigate this deficit. The younger adults showed a significant probe accuracy deficit in the dual-task condition (M = 81.8%, SD = 19.7%), relative to the single-task condition (M = 88.4%, SD = 13.6%), F (7, 217) = 11.46, p < .01. This deficit is known as the AB effect. To determine the length of the processing deficit, multiple post-hoc comparisons using Scheffe's method revealed that probe identification was less accurate (p < .05) on target-present trials in the dual-task condition than on trials in the single-task condition when the probe occurred at serial positions t+2 through t+6, inclusive, but not when the probe occurred at later serial positions. The exact same analyses revealed that the older adults also demonstrated a significant probe accuracy deficit in the dual-task condition (M = 66.7%, SD = 26.1%), relative to the single-task condition (M =81.9%, SD = 19.3%), F (7, 168) = 22.32, p < .01, with a significant deficit when the probe occurred at serial positions t+2 through t+6, as well.

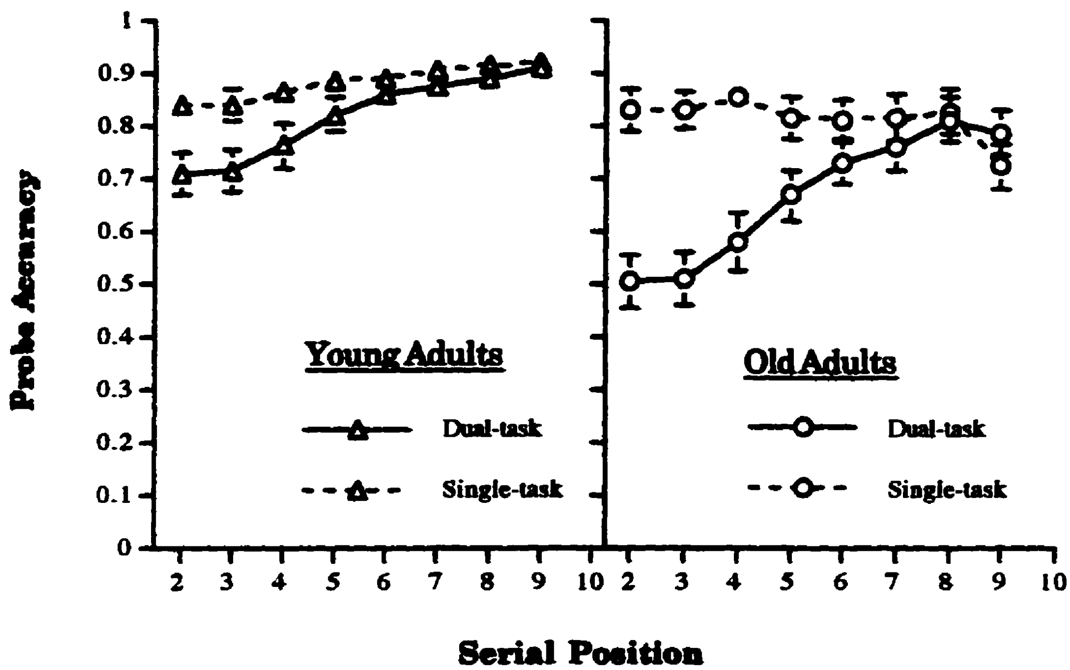

Figure 4. Probe accuracy by serial position for single- and dual-tasks, for younger and older adults.

Since both younger and older adults demonstrated an attentional blink, possible age effects were investigated. One area of interest was in determining the magnitude of the processing deficit ('blink magnitude'). Blink magnitude was determined, for each individual, by averaging the difference in probe identification accuracy between the single- and dual-tasks for the first six positions following the target. This method for determining blink magnitude was selected since these were the positions where the blink occurred for both the younger and older adults. A t test revealed that the older participants (M = 19.3, SD = 14.1) demonstrated a significantly 'deeper' blink magnitude than the younger participants (M = 8.5, SD = 10.7), t (53) = -3.25, $p < .01$. Figure 3 illustrates the difference in the processing deficit between younger and older adults. Figure 5 more clearly represents the difference, averaged across serial positions, in blink magnitude as a function of age.

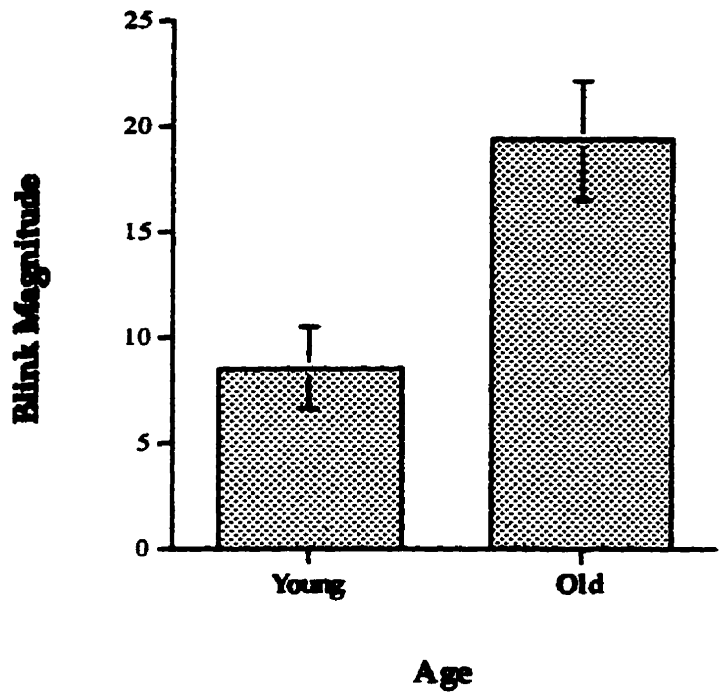

Figure 5. Mean blink magnitude as a function of age.

Using the mean blink magnitude across the entire sample of younger and older adults (M = 13.4) to split the data, each individual was classified as having a deep or shallow blink. This split resulted in 21 individuals classified as 'deep blinkers' and 34 as 'shallow blinkers'. Based on this split, a X^2 analysis revealed that the distribution of the younger and older adults into the two categories of blinkers was significantly different, $X^2 = 12.94$, $p < .01$. Among the older participants, 16 were classified as deep blinkers and 9 were classified as shallow. For the younger participants, however, only 5 were classified as deep blinkers, and 25 were classified as shallow. Figure 6 illustrates the percentages of deep and shallow blinkers for the younger and older adults, where it can clearly be seen that for the older adults, the greater part of the distribution is made up of deep blinkers, while for the younger adults, the greater part of the distribution consists of shallow blinkers.

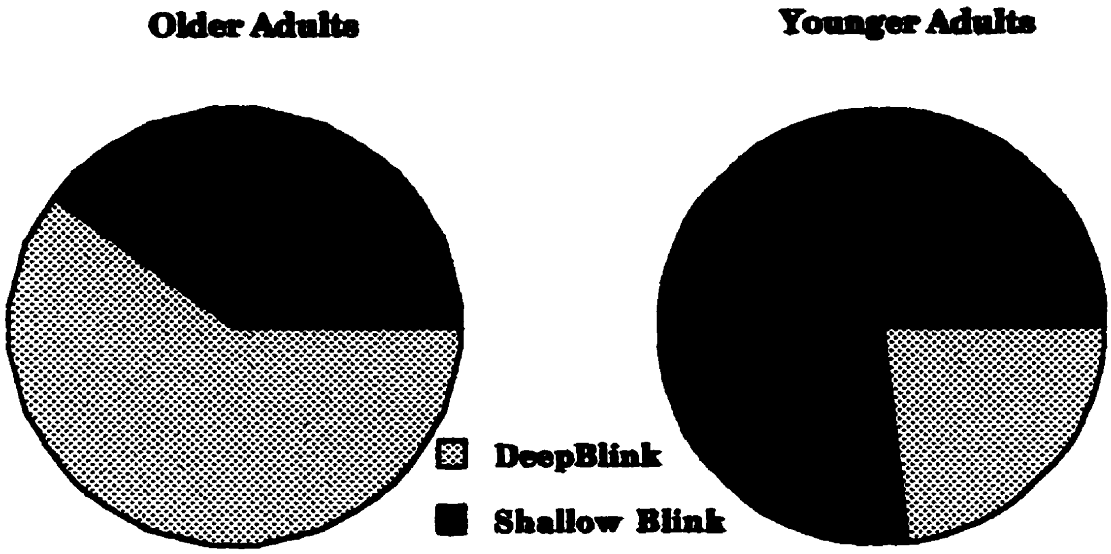

Figure 6. Percentages of younger and older adults with deep and shallow blink magnitudes.

Stroop and NP Tasks

Before analyzing the reaction times from the Stroop and NP tasks, the following trials were omitted: the first trial of every block, trials in which an error occurred and the very next trial, trials in which the microphone did not pick up the response or when the microphone picked up some noise other than the participant's response, and instances where the participant stuttered before responding. These omissions were based on previous research using vocal reaction time as a dependent variable (Kane et al., 1994). For the Stroop task, this resulted in 10% of the trials omitted for each of the younger and older samples. For the NP task, an average of 8% of the trials were omitted for the younger participants, and 7% for the older participants. Due to the fact that accuracy was stressed over speed, very few errors were made.

The means and standard deviations for the NP data appear in Table 1. A 2 (Age: Young, Old) X 2 (Condition: Control, Distractor Repetition) ANOVA revealed a significant condition effect, F (1,53) = 25.862, $p < .01$, and a significant age effect, F (1,53) = 19.880, $p < .01$, while the interaction was not significant. Both the younger and older adults responded faster to the control trials than the distractor repetition trials (i.e., demonstrated a suppression effect), while the younger adults responded significantly faster than the older adults for both types of trials. The difference scores for the younger and older adults, as seen in Table 1, demonstrate that the suppression effect for younger and older adults was not significantly different.

Table 1

Mean Reaction Times for Younger and Older Adults for the Negative Priming (NP) Task

	Trial Type		
	Control	Distractor Repetition	Difference (Suppression Effect)
Young	587 (12.1)	602 (12.7)	15
Old	683 (18.5)	695 (18.0)	12

Note. Standard deviations are in parantheses ().

Means and standard deviations for the Stroop task are provided in Table 2. A 2 (Age: Young, Old) X 3 (Condition: Control, Stroop, Distractor Repetition) mixed-model ANOVA was conducted on the reaction times. Younger adults responded significantly faster than the older adults, F (1,53) = 10.20, $p < .01$, and, for both younger and older adults, reaction times increased from control to Stroop to distractor repetition trials, F (2,53) = 329.02, p, < .01. There was also a significant Age X Condition interaction, F (2,53) = 7.98, $p < .01$. Figure 7 demonstrates the interaction effect where the suppression effect (i.e., the increase in reaction time from the Stroop to distractor repetition trials) for the Stroop task was not significantly different between the younger and older adults, while the Stroop interference effect (i.e., the difference in reaction time between control and Stroop trials) was larger for the older adults relative to the younger adults. This interaction can also be seen in Table 2, where the difference scores for younger and older adults for the suppression effect are 53 and 49 respectively, while for the interference effect the difference scores are 117 and 173 respectively.

Table 2

Mean Reaction Times for Younger and Older Adults for the Stroop Task

	Trial Type				
	Control	Stroop	Distractor Repetition	Interference	Suppression
Young	710 (20.9)	827 (27.5)	880 (31.1)	117	53
Old	783(19.0)	956 (22.7)	1005(22.3)	173	49

Note. The interference score is the difference between control and Stroop trial mean reaction times, and the suppression score is the difference in reaction times between the mean Stroop and distractor repetition trials.

Note. Standard deviations are in parantheses ().

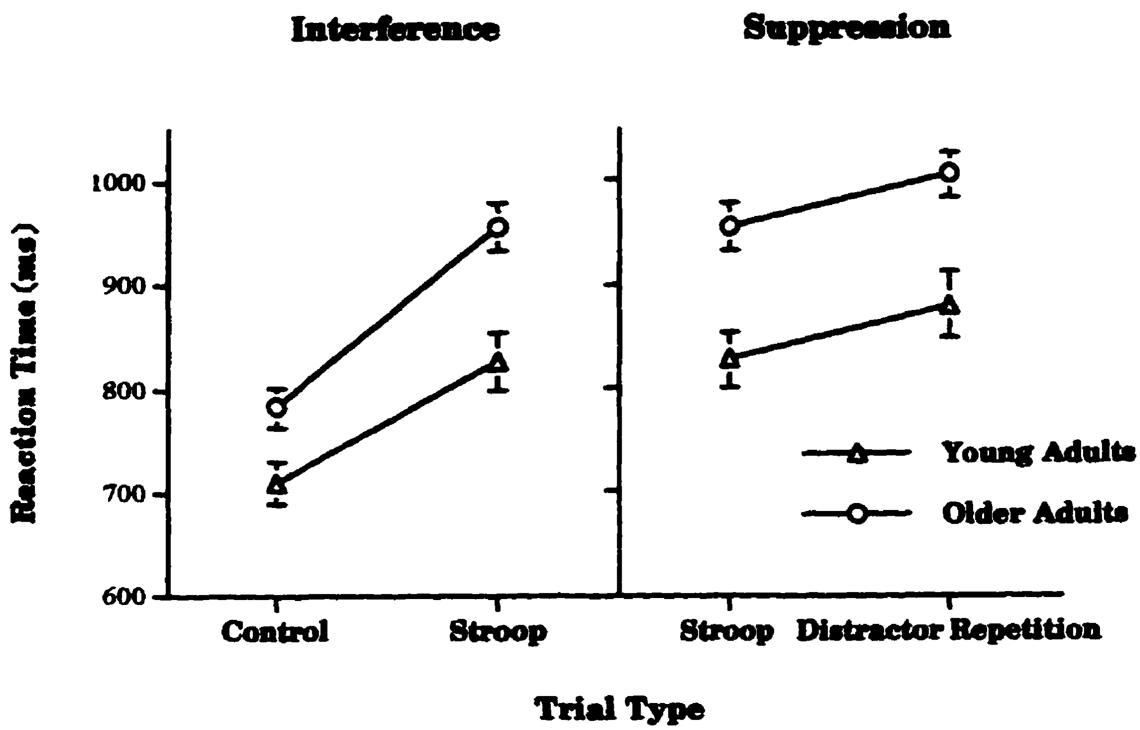

Figure 7. Reaction times plotted as a function of age group and Stroop trial type.

Correlational Analysis

Based on the assumption that inhibition and interference are directly related, the prediction would be that those individuals with better inhibitory abilities should experience less interference as they would be better able to inhibit distracting information. This would manifest as a negative correlation between measures of interference and inhibition. That is, increased inhibitory effects on the Stroop and NP tasks should be related to a decreased interference effect on the Stroop task. However, no significant correlations between the measures of inhibition (Stroop suppression effect, NP suppression effect) and interference (classic Stroop effect) were revealed by the Pearson r's.

DISCUSSION

The most widely used task to measure age-related inhibitory deficits has been the NP task. Although this task has generated a fair amount of support for the inhibitory deficit hypothesis (Hasher & Zacks, 1988) there are some inconsistent results reported in the literature (e.g., Kramer et al., 1994). One question addressed by the present study was whether such a deficit would be revealed not only by an NP task, but also by other attentional tasks presumed to capture the contruct of inhibition. To this end, we looked at the AB, a phenomenon observed in a dual-task RSVP procedure and which has been interpreted to reflect inhibitory mechanisms.

To summarize the major findings, it was found that younger and older adults performed equally well on a test of WM capacity, and demonstrated equivalent amounts of suppression on both the NP and Stroop (NP) tasks. While both younger and older adults demonstrated a Stroop interference effect, the older adults demonstrated a greater effect than did the younger adults. The older adults had increased difficulty, compared to younger adults, in responding to the color of a color word relative to responding to the color of a row of XXXs. Furthermore, while both younger and older adults demonstrated an AB, the blink magnitude was significantly greater for older participants compared to that of the younger participants. Analysis of the individual's blink magnitudes revealed that most older adults were deep blinkers, yet most younger adults were shallow blinkers.

Considering the RSVP results, we suggest that the age differences seen here in blink magnitude support the notion that older adults have an inhibitory deficit. This blink is larger in older adults presumably because of their poorer ability to inhibit competing items in visual short term memory. Since the inhibition based model of the AB directly predicts an attenuation of the blink in older adults, our results suggest an interference interpretation of the AB is more appropriate (it is important to note that inhibitory processes are involved in both the inhibition and interference based models of the AB). In other words, since the interference model of the AB suggests competition among items in VSTM leads to the blink, our data indicates that older adults find it increasingly difficult to 'sort out' the relevant from irrelevant items in VSTM during the blink interval. While the older participants did not demonstrate an inhibitory deficit as measured by the suppression effects from the NP and Stroop tasks, it may be that the RSVP task is a highly sensitive measure of an inhibitory deficit in older adults. Considering the AB as reflective of inhibitory efficiency (or deficiency) appears contrary to Zacks et al. (1994) suggestion that the AB phenomenon might represent preserved abilities in older adulthood.

In order to understand the difference in results between the present study and that by Zacks et al. (1994), we look to the experimental manipulations in the two studies. Zacks et al. used a relatively difficult dual-task condition, in which participants were to identify a letter surrounded by asterisks and detect a letter X as the probe. As well, they eliminated 9 older participants because they did not meet a criterion of 89% probe accuracy in the single-task condition. It is possible that if they had maintained these 9 older adults they may have found an age-related difference in blink magnitude. In fact, if inhibitory mechanisms are required in order to do the RSVP tasks, we might conclude that they eliminated the participants with a more pronounced inhibitory deficit. That is, they may have removed those individuals who are likely to blink deeply. Therefore, those who remained may have been exceptional older adults who did not possess an inhibitory deficit.

Our Stroop results also support the inhibitory deficit hypothesis. The age differences in Stroop interference we report are consistent with those reported in the literature (e.g., Cohn et al., 1984). Both younger and older adults demonstrated an interference effect, however, the older adults demonstrated an increased interference effect relative to the younger adults. That is, the older adults found it increasingly difficult to respond to the color of an incongruent color word relative to a row of XXXs.

The investigation of inhibitory mechanisms in older adults was also carried out here through the use of the commonly used NP task. Contrary to a number of findings (e.g., Hasher et al., 1991; McDowd & Oseas-Kreger, 1991) our older sample demonstrated equivalent amounts of suppression to the younger group on the NP task. Similarly, older and younger adults demonstrated equivalent amounts of suppression on the Stroop task. These findings could be interpreted as evidence that the older adults do not have a deficit in inhibitory mechanisms. Other researchers have also found a lack of age differences on tasks reflective of inhibitory capabilities. Kramer et al. (1994) also explored a number of different paradigms to investigate the inhibitory deficit hypothesis. Although they did find age effects on some of the tasks, their younger and older adults demonstrated equivalent amounts of suppression on the NP task. As well, Sullivan and Faust (1993) did not find evidence of an age-related inhibitory deficit when they measured younger and older adults suppression effects on a NP task. Lastly, a lack of inhibitory deficit observed in location-bearing information (Connelly & Hasher, 1993) has lead to the narrowing of the original theory to suggest that it may be only meaning bearing information ("what") that elicits an inhibitory deficiency for older adults. Taken together with previously reported findings, our results suggest that the suppression measures (from the NP and Stroop tasks) may not be as reliable or as sensitive in reflecting inhibition as researchers have hoped. Instead, some other measures we employed here (specifically, AB and Stroop interference) appear more sensitive in measuring inhibitory deficits in older adulthood.

It could be argued that the relative difficulty of the four tasks in this study likely affects performance. The instances where age effects arise are relatively difficult compared to the other two tasks. For example, within the Stroop task, it is noticeably more difficult to say the color of an incongruent color word relative to a row of XXX's. However, responding to a distractor repetition trial relative to a regular Stroop trial is not that noticeably more difficult. This is evident in the difference scores, yielding the interference effect of 174 ms, and the suppression effect of 53 ms. As well, the AB task is a particularly difficult task - presentation rates are rapid, and it is simply hard to pick out the correct item from the stream. Furthermore, the relative simplicity of the NP task is evident by the very small difference in RT between control and distractor repetition trials for both younger and older adults. Similarly, Lavie and Tsal (1994) suggest that variations in the perceptual load requirements of different tasks will affect task performance.

Our younger and older adults also performed equivalently on the measure of WM. Since a main goal of this research was to investigate an age-related inhibitory deficit it was important to include a measure of WM. The main premise of Hasher and Zacks' suggestion is that an attentional, specifically inhibitory, deficit allows more irrelevant information to enter and be maintained in WM, thus depleting potential resources for relevant information. They have suggested that this might make it appear that older adults have a deficit in WM capacity, evident in a decreased WM span, relative to younger adults. Our older adults did not demonstrate a deficit in WM, however they did demonstrate an inhibitory deficit based on the AB and Stroop interference measures.

Zacks and Hasher (1994) might suggest that the reason these older adults do not demonstrate a WM deficit is solely due to the nature of the WM task. They suggested that in instances where no differences in WM spans were found between younger and older adults it was due to the task not allowing for irrelevant information to enter WM, thus hampering capacity for relevant information. Salthouse (1991) has previously cautioned that a lack of age effect on a WM task may be due to sampling procedures in that the older samples tend toward being highly educated and very healthy. This could apply to our sample of older adults. Lastly, if the AB and Stroop interference paradigms are highly sensitive measures of attentional inhibition, then it might be that our older adults' attentional deficits are not severe enough to hamper their performance on this WM task. This is the explanation we favor as it fits well with our pattern of suppression findings. That is, it is possible that with a more severe inhibitory deficit, individuals might also demonstrate a lack of suppression effect on both the Stroop and NP tasks, and they may also demonstrate a WM deficit, along with a deep blink and increased Stroop interference. Future research should aim to sample a broad spectrum of younger and older adults to further investigate the individual differences in inhibitory mechanisms.

Results from our application of the RSVP paradigm also address other theories of age-related cognitive deficits. For example, since the task is perceptually very rapid, investigations with an older population might give some insight into the finding that processing speed slows with age (Salthouse, 1985; 1991). In the present study, during testing of the older adults on the RSVP tasks, a number of individuals would report "I want to say M but I know that is wrong, I think it's the one right before M" (where M is the P+1 item). In these cases it could be argued that this is a speed issue, and it is as if they see the color (red) triggering them that they must identify this item, but they cannot conjoin the color and letter fast enough, and therefore the color is conjoined with the next letter. This is an area which would be very beneficial to explore under more controlled conditions. For example, it may be beneficial to equate individual's on the P+1 to explore this possibility. Furthermore, a controlled and in-depth analysis of error patterns that may differ among age groups will likely provide important insights.

Also of interest at the outset of the present investigation was the relationship between measures of interference and inhibition. It was suggested that a correlational analysis might be beneficial in the disentanglement of the possible relationship. There were no significant correlations between the measures of interference and of inhibition or within them. To restate what would be predicted by certain models, a direct relationship between interference measures and inhibitory mechanisms would predict that the better one is able to inhibit irrelevant or distracting information, the less interference would be demonstrated. This would be apparent in a negative correlation. In general, it seems to make very good sense to say that the less able you are at inhibiting irrelevant or distracting information the more it will interfere with the relevant task at hand. So, for example, if you are studying writing, and listening to music at the same time, you must ignore the music to focus your full attention on the material you are writing. If you are not very good at doing this, then possibly words from the music will interfere with the words you are writing. However, to the extent that an NP task measures ones ability to ignore the music and focus attention on the writing and a Stroop interference task measures the degree to which the music interferes with writing is questionable. Furthermore, it is important to note that in the statement made above, one is investigating the relationship between a measure and a mechanism. In order to investigate this one has to assume an accurate measure of the mechanism. Based on our lack of significant correlations we are limited in our conclusions on this point. However, further research in this area, with larger samples and more measures, could be fruitful as the relationship between the current measures is still very unclear.

Conclusions

We found no evidence in our older adults of a WM deficit nor of an inhibitory deficit as measured by suppression effects in a Stroop and NP task. However, they did demonstrate increased Stroop interference and an increased blink magnitude in the RSVP paradigm, relative to the younger participants. We suggest this is indeed representative of older adults exhibiting some form of attentional deficit. Age effects seen in AB and Stroop interference suggest decreased inhibitory abilities with age, and these tasks may be more sensitive measures of the deficit compared to the suppression effects from the Stroop and NP tasks. The use of two different tasks to investigate suppression effects strengthens the claims which can be made with regards to these measures. In the future, further investigations of the RSVP paradigm with an older population could prove to be very fruitful in attempts to uncover the specifics of cognitive decline with age.

For example, many task manipulations (e.g., speed, target task, probe task, stream length) might assist in examining theoretical models of cognitive aging. Manipulations of probe and target task, plus the other stream items, and speed could address theoretical predictions in the aging literature. The ability to manipulate and investigate the speed is especially beneficial as there are strong proponents of the idea that the most important aspect of aging which affects everyday functioning is a decline in speed of processing (e.g., Salthouse & Meinze, 1995). One next step is to equate individuals on P+1 errors in order to control for speed of processing as we examine blink magnitude. Possibly if blink magnitude was different (i.e., if there was still an age effect) after controlling for P+1 errors this may suggest a speed component to the blink. We expect to explore this as one possibility. Therefore, the RSVP paradigm may allow for investigation of both the inhibitory deficit hypothesis and the speed of processing hypothesis within the same paradigm, thus leading to a better understanding of the processes of cognitive aging.

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