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Aging and Attentional Control in the Stroop Priming Task

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IN THE STROOP PRIMING TASK

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Abstract

This experiment was conducted to examine whether older adults are capable of developing attentional strategies to reduce interference from irrelevant information. Sixty young and 60 older adults were asked to name the ink color of a non-black neutral word, which was presented adjacent to a color word or a neutral word (Lowe & Mitterer, 1982). Twelve young and 12 older adults were assigned to 1 of 5 list compositions. The first list consisted of 100% congruent items (ink color of a neutral word compatible with the color word), and 0% incongruent items (ink color of a neutral word incompatible with the color word; 100C/0I). The remaining lists consisted of 75I/25C, 50I/50C, 25I/75C and 0I/100C, respectively. Participants' interference and facilitation scores were computed. The results indicated that older adults experienced more interference on incongruent trials than did young adults, which is indicative of inhibitory decline. However, both young and older adults showed decreased interference as the proportion of incongruent trials increased suggesting that increasing age does not impair the ability to adapt to contextual demands of a task. Facilitation effects were greater for older adults than for young

adults in the mostly congruent condition, indicating that they suffered no loss of activation ability. Overall, this study indicates that while older adults suffer from an inhibitory decline, they are capable of attentional control.

Chapter 1

Introduction

Inhibitory decline is commonly seen in the aging population. Hasher and Zacks' (1988) inhibition deficit theory suggests that normal aging is accompanied by an inability to ignore irrelevant information. When inhibitory processes are functioning, irrelevant information is screened out and does not enter working memory. However, when inhibitory processes fail, irrelevant information enters working memory and affects performance in tasks requiring selective attention.

Inhibitory decline has frequently been studied using the Stroop task. In a typical Stroop task, color names are printed in various ink colors and participants are asked to name the ink color of a word and to ignore the word meaning. There are three conditions: congruent (word meaning and ink color match), incongruent (word meaning and ink color conflict), and neutral (word meaning and ink color are unrelated). Individuals have little difficulty naming the ink color on trials in which the words are neutral or congruent with the ink color. Facilitation effects are seen in trials consisting of congruent stimuli, because both the relatively automatic word reading process and the more controlled color naming process are working in tandem to produce a correct response. However, problems become apparent when the ink color is different from the color word. Interference effects are seen in this incongruent condition because the word reading process works against the color naming process. A correct response can only be made by inhibiting the automatic process of word reading and activating the more controlled process of color naming.

Interference effects in the Stroop Word Task are generally more pronounced in the older population (Comalli, Wapner & Werner, 1962; Earles, Tabor-Connor, Frieske, Park, Smith & Zwahr, 1997; Cohn, Dustman, & Bradford, 1984; Houx, Jolles, & Vreeling, 1993). Hasher and Zacks (1988) suggest that this finding supports the idea that inhibitory ability declines with age. However, research suggests that this theory must be expanded to include an attentional component (MacLeod, 1991; Logan, 1980). Logan proposed a model that included both automatic and attentional components. The former accounts for automaticity of a dimension and the latter accounts for attention paid to each dimension. A response is based on the combined evidence of the two components. The automatic component in the Stroop task is the reading of the word. The attentional component is the decision to attend to the ink color or word name. In the case of the Stroop, the automatic component is assumed to be constant, while the attentional component is assumed to vary depending on purpose and intention. The amount of interference or facilitation the unreported dimension (i.e., word name) adds to the decision process is dependent on the magnitude of the attentional and automatic weights attached to it during the time it is available to influence the reported dimension (i.e., ink color).

In line with this idea, previous research indicates that younger adults vary their attention to stimulus dimensions in response to the proportion of incongruent trials (Lowe & Mitterer, 1982). Young adults were observed to have less interference when the proportion of incongruent Stroop trials was high rather than low, suggesting that knowledge of the proportional structure of this list led them to develop a strategy to direct attention away from the irrelevant word name. Older adults appear able to develop such a strategy. For example, Mutter and Patterson (1997) manipulated the proportion of congruent and incongruent trials and found that older adults also showed less

interference as the proportion of incongruent trials increased. Toth (1997) found similar results using a spatial location version of the Stroop task. In his task, inhibition fluctuated as a function of the sequences of congruent and incongruent proportions presented. Thus, attentional flexibility may not decline with age.

The present study further examined whether older adults are capable of developing attentional strategies to reduce interference from irrelevant information. It has been suggested that selective attention to parts of a complex stimulus is possible when the stimulus dimensions are separable and spatially separated rather than integral and spatially contiguous (Lowe & Mitterer, 1982). The Stroop priming procedure uses spatially separated dimensions. In this task, a color word printed in black is presented adjacent to either a neutral word or a color word printed in color. Participants can selectively attend to one or both of the stimuli presented. If participants can selectively attend to the stimuli, interference effects should decrease. If participants distribute attention over both stimuli, interference effects would be expected. To further clarify attentional effects in this task the proportion of incongruent trials was manipulated. Prior studies with the traditional Stroop task indicate that older adults modify attentional strategies in response to task demands, but age differences in interference effects remain (Mutter & Patterson, 1997; Toth, 1997; Patterson, 1995; West & Baylis, 1998). No research has addressed aging and attentional control in the Stroop priming paradigm. The present study should provide converging evidence that older adults are capable of developing attentional strategies to reduce interference from irrelevant information. As the proportion of incongruent trials increased it was expected that older adults as well as young adults would be able to reduce the size of interference by employing attentional strategies. However, if older adults are less able to flexibly deploy their attention, there should be a greater

decrease in interference for young adults than for older adults as incongruent trials become proportionally greater. This task may also show whether age differences in interference can be reduced in a Stroop task with perceptually separate stimulus dimensions.

Chapter 2

Review of the Literature

Inhibition - A Theory of Cognitive Aging

Much of the current research on the effects of cognitive aging has centered on a hypothesized inhibitory deficit in older adults. The inhibition-deficit-hypothesis, introduced by Hasher and Zacks (1988), suggested that normal aging is accompanied by an inability to ignore irrelevant dimensions of a) environmental detail, b) memories and thoughts of personal relevance, and c) non-goal ideations. When inhibitory processes are functioning appropriately, irrelevant stimuli are screened out and prevented from entering working memory. When inhibitory processes fail, according to this hypothesis, irrelevant information is allowed to enter working memory resulting in performance decrements in tasks requiring selective attention. Hasher and Zacks hypothesized that age-related deterioration of inhibitory mechanisms allows non-goal information to enter working memory where it remains activated for a prolonged period of time. A lack of inhibitory function allows these thoughts to receive more activation than if the inhibitory mechanisms were functioning properly. Hasher and Zacks suggest that loss of inhibitory function can explain age-related memory decline. It has also been noted that persons who suffer from an inhibitory decline show more distractibility and are more apt to make inappropriate responses similar to behaviors commonly seen in older adults.

Inhibitory decline in the aging population has been studied using two main procedures: the negative priming task and the Stroop task. Negative priming tasks require the participant to select

and name a target stimulus throughout consecutive trials while attempting to ignore a distractor stimulus that is similar to the target (Connelly & Hasher, 1993; Tipper, 1985). On successive trials, the distractor stimulus is switched to become the target stimulus. Participants are not as quick to name the target that was previously the distractor. The delay in naming the current target suggests the existence of an inhibitory process that is functioning during selective attention (Tipper, 1985). McDowd and Oseas-Kreger (1991) found negative priming effects for young adults, but not for older adults, suggesting that older adults exhibit an inhibitory deficit. Further support comes from a negative priming study conducted by Kane, Hasher, Stoltzfus, Zacks and Connelly (1998) whose results indicate that older adults process distractor information, but subsequently fail to use inhibitory mechanisms to reject these distractors. Kane et al. increased the length of stimulus exposure for the older participants to increase the likelihood of interference effects. No interference effects were seen. Older adults produced facilitation effects when the distractor was used repeatedly and when the target became the distractor.

The Stroop Task

The second common way to measure interference is by reaction time (RT) response in the Stroop Color Word Task (SCWT). In this task, participants are asked to name the ink color of a color word and to ignore the word meaning. There are three conditions: congruent, incongruent, and neutral. The ink color of the word may be congruent with the color word meaning (the word RED written in the ink color red) or the ink color may be incongruent with the color word meaning (the word RED written in the ink color blue). The third condition is a control condition in which the word meaning is neutral with respect to the ink color (the word RAKE written in the ink color red). A Stroop Effect is seen when the RT to name ink color in the incongruent condition is longer

than the RT in the congruent condition. Facilitation in the congruent condition is measured by the difference in RT between congruent and control items. Interference in the incongruent condition is measured by the difference in RT between incongruent and control items.

The automaticity view is one of the most prevalent theoretical accounts of the Stroop Effect. The automaticity account states that more attention is required for controlled events, than for automatic events. The color naming process (CN) is a controlled process, which means that these processes are slow and require attention. In contrast, the quick, well learned automatic process of word reading (WR) requires little attentional effort and once activated is difficult to inhibit or stop (Wingfield, Goodglass, & Lindfield, 1997). Much support has been given to the idea that the automatic WR process takes priority over the CN process (MacLeod, 1991; Hasher & Zacks, 1988; Wingfield et al., 1997; Lindsay & Jacoby, 1994; Dulaney, 1994). For example, Wingfield et al. (1997) found a substantial Stroop effect for a man whose reading speed was no faster than his speed of naming colors, indicating that word reading takes precedence over color naming and is not easily inhibited, even when it is not a highly developed response.

A Stroop-like effect can be seen in a variety of different tasks. For example, Logan and Zbrodoff (1979) used the positioning and meaning of two words, ABOVE and BELOW, which were presented either above or below a predetermined point of fixation, and observed a Stroop effect when the word meaning was not congruent with the positioning of the word (e.g., the word ABOVE presented below the fixation point). Thus, RTs were longer for trials that were contradictory in nature. Likewise, Walley, MacLeod, and Weiden (1994) used the words left, right, above and below, and presented these words at one of these points relative to the fixation point. They found that it was more difficult to name the position of the stimulus when it was

inconsistent with the word meaning. Toth et al. (1995) demonstrated a Stroop-like effect with the Simon task. In this task, one arrow was pointed in the right direction and one pointed in the left direction. The arrows were presented in a compatible position with their direction, an incompatible position, or a neutral position that was designated as the point of fixation. Longer RTs were seen when the position of the arrow was not compatible with its direction. According to Toth and his colleagues, although the form (controlled process) of the object must be processed to make the correct response, the spatial location pathway (automatic process) has already been activated automatically. The conflict between these processes increases RT.

Stroop and Aging

Interference effects in the SCWT, although seen in young adults, are generally more pronounced in the older population. Performance on tasks in which interference occurs is similar during the middle years of life until about the ages of 65 to 80 (Comalli, Wapner, & Werner, 1962; Earles et al., 1997). As adults age, an increasing amount of interference was found in the SCWT as shown by older adults' performance on incongruent items (Cohn, Dustman, & Bradford, 1984; Spieler, Balota, & Faust, 1996; Li & Bosman, 1996). A leading hypothesis is that older adults have a breakdown in inhibitory responses in working memory and therefore are less able to prevent the automatic word reading process from being activated during the color naming process (Hasher & Zacks, 1988; Spieler, Balota, & Faust, 1996; Lindsay & Jacoby, 1994; Mutter & Patterson, 1997).

Mechanisms other than the inhibitory breakdown hypothesis have been proposed. Cohn et al. (1984) noted that older adults, when compared to young adults, performed more poorly on color naming trials as well as incongruent trials. They wondered whether older adults might

simply demonstrate a general slowing of responses as seen in the Stroop conditions. However, older adults performed as well as young adults on simple reading tasks. These results led Cohn and colleagues to hypothesize that there was a more complex mechanism affecting Stroop performance than response speed. The researchers investigated whether this might be a reduction in older adults' sensitivity to color. They calculated the participant errors according to color but found no "error by color pattern" for older or young groups and concluded that interference seen by an increase in RT was not due to a sensory deficit in color processing.

A recent explanation for age differences in the Stroop task involves multiple inhibitory mechanisms. Duchek, Balota, Faust, and Ferraro (1995) looked at changes in young and older adults' ability to inhibit partially activated information in a picture-word interference paradigm. Participants were shown a cue that was either the word PICTURE or the word WORD indicating which stimulus to attend to in a picture/word collage. Each collage contained a picture with a superimposed word printed on it (i.e., a picture of a DEER with the word TEA printed over it). Participants were then exposed to a test picture or test word and asked to determine if the test stimulus was related to the cued stimulus in the picture/word collage. Older adults were faster at processing word stimuli than processing picture stimuli and the opposite was true for young adults. Older adults also showed more interference from a related distracting word stimulus than young adults did; that is, older adults had more trouble than young adults ignoring irrelevant word information when the 'to-be-ignored' word stimulus (e.g., SWEEP) was similar to the test display (e.g., BROOM). Older adults, however, did not show increased difficulty in inhibiting a 'to-be-ignored' picture when it was similar to a word test item. This finding cannot be attributed to a general slowing phenomenon because older adults and young adults displayed opposite patterns. It

has been suggested that older adults produce a smaller decline in speed of processing in lexical tasks as compared to non-lexical tasks (Lima, Hale, & Myerson as cited in Duchek et al., 1995). Duchek et al. (1995) suggest it is also possible that two-dimensional word patterns are seen with much more frequency than two-dimensional picture patterns. Older adults have approximately 50 years more exposure to these patterns, which may increase the fluency of processing lexical patterns and make it more difficult to inhibit them. These findings suggest that older adults may be less able than young adults to inhibit some, but not all response processes (Li & Bosman, 1996).

Graf, Uttl, and Tuokke (1995) investigated whether Stroop interference scores measure the same conceptual and perceptual processes in different types of Stroop tests and in different age groups. A group of healthy older adults (ages 65-95) were divided into 4 groups on the basis of their age. Groups consisted of ages 65-69, 70-74, 75-79 and 80-85. Two tests were administered, a Stroop Color Word Task (SCWT) and a Stroop Picture Word Task (SPWT). The SCWT instructed the participants to read/name the colors/words (indicated by the experimenter) printed on the card as quickly as possible. The SPWT instructed participants to name the pictures printed on the card as quickly as possible. The researchers found significant age-related effects in the picture word but not in the color word Stroop task; that is, participants between the ages of 65-69 responded much faster during experimental trials than participants in the 80-95 age range. Further statistical analyses revealed that the SPWT and SCWT did not measure the same cognitive functions in old age. First, various attention, perception and memory tests as well as the SPWT and SCWT tasks in a factor analysis provided different factor loadings. Stroop test performance loaded on four of five factors. Factor 1 reflected speed on tasks that were highly practiced. Word and congruent color-word cards of the SCWT as well as congruent card performance on the SPWT

loaded on Factor 1. All SCWT cards and incongruent picture-word cards loaded on Factor 2, which reflected speed at prompted naming. Factor 3, identifying insufficient strategic semantic memory searching, had negative loadings for performance on the picture-word and congruent color-word cards. Incongruent color-word performance loaded negatively on Factor 4, which reflected cognitive flexibility. Because all of these factors loaded differently, Graf et al. concluded that SPWT and SCWT performance are sensitive to different cognitive abilities. In line with this idea, causal modeling revealed that two different models best fit the data from the two tests; that is, performance on the Color and Picture Word tasks revealed different patterns of predictors.

Li and Bosman (1996) wanted to assess the possibility that age-related effects in the SCWT were due to the fact that older adults have a "greater breadth of spontaneous activation" (Hasher & Zacks, 1988). If this was the case, older adults would have "richer encodings" (pg. 273) of information as opposed to young adults and greater interference effects would result when the distractor was similar to the target. In their study, Li and Bosman used Stroop color words (BLUE), related color words (NAVY), related words (SKY), neutral words (REFER), and asterisks (***). Both older and young adults showed increased interference due to the semantic relatedness of word and ink color, but age differences were found only in the Stroop color word condition. These results provide evidence for a dissociation of reading activation suppression and response suppression. Older adults showed an inhibitory deficit for the reading of the color word but not for the color naming response. These findings suggest that multiple inhibitory mechanisms are responsible for age-related decline.

More recently, the role of inhibitory decline for word reading in older adults has been examined using a novel analysis called the process dissociation procedure (PDP, Jacoby, 1991).

The PDP allows one to measure the independent contribution CN and WR processes in the Stroop task. Historically, facilitation and interference effects of the SCWT have been studied in terms of RTs. According to Lindsay and Jacoby (1994), RT procedures are able to account for the existence of CN and WR processes, but are unable to effectively measure the contributions of each process. They contend that no measure of interference or facilitation can be correctly measured by baseline comparison procedures for RT responses. Control words themselves may elicit some type of interference with the color naming process and therefore, the word reading contribution would be underestimated in incongruent trials. This problem is eliminated in the PDP because CN and WR processes in the Stroop task are estimated by comparing the accuracy of performance when intended and unintended processes produce the same effect (the congruent condition of word reading and color naming) with accuracy of performance when intended and unintended processes produce opposite effects (the incongruent condition of word reading and color naming). In two experiments, Lindsay and Jacoby showed that CN and WR processes act independently of each other. For example, degrading the colors of Stroop stimuli decreased the influence of color naming but did not affect the process of word reading. In contrast, providing additional experience with incongruent trials had no affect on CN but reduced the influence of WR. Lindsay and Jacoby suggest that either WR or CN processes can control the response on a congruent item. Incongruent trials which require the subject to name the ink color of the word can be correct only if the color naming process controls the response.

Spieler, Balota, and Faust (1996) used the process-dissociation method to examine the separate contributions of CN and WR in Stroop performance of healthy older adults and individuals with dementia of the Alzheimer's type (DAT). Participants were divided into one of

five groups: young (17-26), young-old (58-79), old-old (80-93), very mild DAT (Clinical Dementia Rating Scale (CDR) score of 0.5), and mild DAT (CDR = 1.0). They were then exposed to blocks of trials consisting of 36 incongruent items, 36 congruent items, and 32 neutral items. Instructions were to name the color of the ink or to read the word on the screen. Accuracy was computed, as well as a deadline analysis technique used to determine the proportion of participant responses that occurred within a given time. PDP analysis replicated the findings of Lindsay and Jacoby (1994); that is, early processing was dominated by WR, due to a larger influence of lexical information processing when compared to CN, but CN dominated in longer deadline trials, indicating that the color-naming response process eventually overcame the word-naming process. Analysis of CN and WR estimates indicated that older adults had higher WR process estimates and that DAT patients demonstrate deficiencies for both types of estimates. Specifically, their CN estimates were lower and their WR estimates were higher than those for the other groups. Spieler et al. (1996) concluded that DAT individuals showed acceleration in the inhibitory breakdown process as evidenced by a poorer performance and increased interference effects.

Age-Related Changes in the Control of Inhibition

Interference effects seen by young adults in Stroop tasks may be reduced by practice (Stroop, 1935). For example, Ellis and Dulaney (1991) report significant changes in Stroop interference effects related to the amount of practice received. They suggest that with practice, people develop a “reading suppression response.” In order to name the colors of the Stroop words correctly, one must be able to inhibit or suppress the reading. With practice, the reading suppression response may become automatic. An interesting question is whether older adults are capable of developing this response. Dulaney and Rogers (1994) found that, unlike young adults,

older adults were not able to develop a reading suppression response. They suggested that young adults improve SCWT performance by general factors such as improvement in perceptual scanning as well by learning and using new automatic processes such as a reading suppression response that override older automatic processes. In contrast, older adults only learn to reduce the Stroop Effect by improving general factors. They are not able to create any new automatic processes and have difficulty modifying the automatic processes that already exist.

Logan, Zbrodoff, and Williamson (1984) have shown that when the proportion of congruent and incongruent trials is manipulated, different interference effects can be obtained. They devised experiments in which the proportion of congruent to incongruent items was varied as follows. In the first experiment, subjects only had to discriminate between two colors in the SCWT and pressed a button to respond. The second experiment was the same, except that the response was verbal. Results of the first two experiments indicated that increasing the proportion of incongruent trials relative to congruent trials produced faster processing times for incongruent items and reduced or eliminated typical interference effects in the Stroop task. Logan and colleagues suggested that this ‘Reverse Stroop’ effect might be strategy dependent. It seemed as if the subjects were taking advantage of "expecting" the next trial to be incongruent and had developed a strategy to attend to the color naming dimension as well as the word reading dimension before making a response. The third experiment involved the use of four colors; however no strategy dependent effects were found with this procedure. The authors suggested that strategies were abandoned in this condition, possibly because of cognitive and memory limitations.

West and Baylis (1998) used a procedure similar to that of Logan et al. (1984) to compare young and older adults’ attentional strategies in the Stroop task. A mostly congruent condition

contained approximately 66% congruent and 17% incongruent stimuli. A mostly incongruent condition contained the opposite proportions of congruent and incongruent trials. Older adults showed more interference than young adults in the mostly incongruent condition as this task required a CN strategy to override the automatic word reading process to ensure accurate performance. These findings suggest that older adults may have difficulty developing a CN strategy. Interestingly, older adults showed greater facilitation effects than did young adults in the mostly congruent condition, a task in which either WR or CN strategies could help task performance. Further, West and Baylis found that after correcting for general slowing, age-related increases in interference were accounted for in the mostly congruent conditions, but not in the mostly incongruent condition. This finding suggests that attentional efficiency is necessary to maintain a color naming strategy in the SCWT. When stimuli were mostly congruent, age-related differences in attentional employment to maintain a color naming strategy would not be expected because correct responses could be made by word reading or color naming strategies. Any observed age-related interference effects would be indicative of general slowing. In contrast, when stimuli are mostly incongruent, age-related differences in attentional deployment would be expected because a color naming strategy is required to respond correctly in naming the ink color of the word presented.

Mutter and Patterson (1997) manipulated the proportion of incongruent Stroop trials that were presented to both older and young participants, but found little or no age-related decline in attentional flexibility. Young and older adults performed the classic Stroop task for lists that were composed of either mostly congruent stimuli (100C/20I/20 control), mostly incongruent stimuli (20C/100I/20 control), or were equal numbers of congruent and incongruent stimuli (40I/40N/20

control). Process dissociation analysis indicated that CN estimates increased as the proportion of incongruent trials increased and that there were no age differences in CN estimates for any of the lists. Moreover, as the proportion of incongruent trials increased, WR estimates declined for both older and young adults. These findings suggest that older adults are able to adopt an attentional strategy to reduce the interfering effect of the word name. On the other hand, when the proportion of incongruent trials was very low, no difference in WR estimates was found for young or older adults, but when most of the trials were incongruent, older adults showed higher word reading estimates than did young adults. Thus, when a task requires the use of inhibition, age effects will be observed, but when the task requires little inhibition, age effects will be minimal. Moreover, despite the evidence of older adults' attentional flexibility, they nonetheless continue to be less effective than young adults in inhibiting the word name.

Finally, Toth (1997) has also investigated age-differences in attentional flexibility using the Simon task. He instructed both young and older participants to press a right response button when a right-pointing arrow was seen on the screen and to press the left response button when a left-pointing arrow was presented. In experiment 1, Toth manipulated the proportion of incongruent trials and switched the proportion after every 200 trials. The proportional sequence of incongruent trials was 50, 25, 75, 50. In Experiment 2, he manipulated the proportion of incongruent trials once again, but changed the proportion every 100 trials to produce the following sequence: 50, 25, 75, 25, 75, 25, 75, 50. As expected, older adults were less able to inhibit the automatic processing of spatial location and showed greater Simon effects than young adults. However, Toth's use of 'time-relative' analysis (an adjustment for older adults' slower processing ability) showed

inhibition increased and decreased as a function of the sequence of proportions presented--thus suggesting that older adults could flexibly deploy their attention.

Current Research

These findings on the control of inhibition suggest that the automaticity account of the Stroop phenomenon needs to be expanded to include an attentional component (MacLeod, 1991). The Stroop effect is an example of imperfect selective attention because the irrelevant dimension is being selected for processing rather than the relevant dimension (Toth et al., 1995). Logan (1980) proposed a model of the Stroop Effect that includes both attention and automaticity components. There are two weights within this model: an automatic and an attentional weight. The former accounts for automaticity of a dimension and the latter accounts for attention paid to each dimension. This theory explains Stroop effects by suggesting that a response is based on the combined evidence from the two components. An increase in interference will be seen when subjects must attend to two or more stimulus dimensions with conflicting weights (Walley et al., 1994). If we are less able to direct and control attention as we age, this inability may partially account for the increased interference seen in the SCWT.

When the proportion of incongruent Stroop trials are high, young adults perform better than when the proportion of incongruent trials are low, suggesting that they can develop a strategy to direct their attention away from the automatic processes and respond appropriately. Toth et al. (1995) and Mutter and Patterson (1997) provide evidence that older adults also develop a strategy to direct their attention away from irrelevant information. However, Dulaney and Rogers (1994) and West and Baylis (1998) find evidence for age-related differences in this ability. Further research is needed to discern whether there are age-related deficits in attentional flexibility. The

present study provides another look at this issue using a Stroop-priming methodology developed by Lowe and Mitterer (1982).

Lowe and Mitterer (1982) conducted three experiments in which they used a Stroop priming task to discover how attention would be deployed under different circumstances in the Stroop task. The authors were interested in whether strategies could be developed to inhibit distractor information. They reasoned that selective attention can be applied to parts of a complex stimulus when dimensions of the stimulus are separate, rather than integral, and when the stimuli are separated spatially, rather than spatially contiguous. In a traditional Stroop task, where conflicting stimuli are spatially contiguous, it is possible that the interference seen could be a result of an inability to effectively select a perceptual analyzer, and/or to an inability to inhibit automatic word encoding. These two sources of interference can be separated in Stroop tasks in which the incongruent stimuli are placed adjacent to each other to allow selective attention toward color information. Lowe and Mitterer ensured that selective attention could be employed by constructing stimuli in which word name and ink color were separate as opposed to integral and spatially separate as opposed to spatially contiguous (e.g., the word MOST in red paired with the word RED in black). This methodology ensured that the interference seen in the task could be a direct result of automaticity of word name encoding, and not to an inability to select a perceptual analyzer. In Experiment 1, subjects were briefly exposed to pairs of words, one word presented on the left and one on the right of a fixation point. One word was printed in black (a color word or a neutral word) and the other was a neutral word, printed in colored ink. Subjects were asked to name the ink color of the colored word. There were three possible relationships between the meaning of the word printed in black and the ink color of the neutral word: neutral, incongruent and congruent. A

neutral condition occurred when the item printed in black was a neutral non-color word. An incongruent condition occurred when the item in black was a color word that was not the same color as the ink of the neutral word, and a congruent condition was one in which the word printed in black was the same as the ink color of the neutral word. The experimenters also manipulated the proportion of congruent and incongruent trials in the list. Specifically, lists contained either 0C/100I%, 25C/75I%, 50C/50I%, or 75C/25I% congruent to incongruent trials. A conflict effect (interference) was measured by the RT difference between neutral and conflict (incongruent) trials. Average RTs for conflict trials were slower than neutral trials. Further, the conflict effect increased as the proportion of congruent trials increased and incongruent trials decreased. The congruence effect (facilitation), measured by the RT difference between congruent and neutral stimuli, revealed facilitation in color naming. That is, RTs were faster for congruent items than neutral items. There were no effects of list proportions. These findings suggest participants used a strategy as the proportion of mostly incongruent trials increased to ignore the distractor stimulus. Overall slowing of RTs as the proportion of congruent stimuli increased and incongruent stimuli decreased indicates that participants modified their attentional strategies.

In the current study, the Stroop priming procedure was used to determine whether older adults were capable of the same strategy development as younger adults. Young and older participants received lists composed of 0C/100I, 25C/75I, 50C/50I, 75C/25I or 100C/0I (all lists included 12 neutral stimuli per block). The amount of time (in ms) to name the color of the non-black word on the computer screen was measured. It was hypothesized that overall Stroop RT interference would be greater for older adults than young adults. Specifically, it was expected that older adults would show greater differences in RT for the incongruent trials relative to neutral trials

than would young adults. As the proportion of incongruent trials increased it was expected that older adults as well as young adults would be able to reduce the size of this interference effect by flexibly employing attentional strategies. However, if older adults were less able to flexibly deploy their attention, there should be a greater decrease in interference for young adults than for older adults as incongruent trials become proportionally greater.

The role of the frontal lobe in age-related differences was also explored. Neuropsychological evidence suggests the prefrontal cortex is the first area of the brain to decline during the normal aging process (Daigneault, Braun, & Whitaker, 1992; West, 1996; West, 1997). The frontal lobe plays an important role in inhibitory responses as shown by age-related deficiencies in the Self Ordered Pointing Task (SOPT) and Wisconsin Card Sorting Task (WCST) (Daigneault et al., 1992). Perseverative responses in these tasks indicate inhibitory deficits. The number of errors on the SOPT (incorrectly pointing to the same stimulus in the same series) and categories achieved on the WCST (correctly identifying form, number and color of the stimuli) are indications of perseveration. Diseased elderly patients reveal an accelerated rate of inhibitory deficits on Stroop tasks (Spieler, Balota, & Faust, 1996). Moreover, young adults with frontal lobe damage suffer from deficits (on Stroop tasks) that are similar to older adults that are seen as a normal consequence of aging (West, 1996). Since these effects are seen in both young brain damaged patients and older adults, it is probable that inhibitory deficits, due to prefrontal atrophy, accompany the normal aging process, with acceleration of decline due to disease. It was therefore hypothesized that poor performance on frontal lobe tasks and working memory tasks would be associated with increased Stroop interference and less effective attentional strategy deployment.

Chapter 3

Method

Participants

Sixty young adults (Age, *M* =19.67) and sixty older adults (Age, *M* =71.98) were recruited for participation in this experiment. Young adults were college students between the ages of 17-30 years who received course credit or payment for participation. Older adults were age 60-89 and were recruited from the community. The older adults and some young adults were paid a small stipend of $5.00. Older adults were screened for any cognitive impairments using a telephone version of the Mini Mental State Examination modified from Teng and Chui, (1987). All participants were screened for medications or health problems (e.g., stroke) that may have altered cognitive functioning. Nine participants who did not qualify based on these screening procedures had their data discarded from the study.

Participants were given several standard individual difference tasks including the Wisconsin Card Sorting Task (WCST), FAS Verbal Fluency Task, Reading Span Task, Mill Hill Vocabulary Task, and the Digit Span Backward and Digit Symbol subtests of the Wechsler Adult Intelligence Scale - Third Revision (WAIS-III). Mean scores on these tests for the 12 participants in each age group by list type combination are presented in Table 1. The data in Table 1 were examined using a 2 (Age: Young vs Older Adult) x 5 (List Type: 0C/100I vs 25C/75I vs 50C/50I vs 75C/25I vs 100C/0I) MANOVA. There was a main effect of age, but no main effect was found for list composition and no Age x List Composition interaction was observed. Separate analyses of the

individual scores demonstrated that older adults performed better than young adults on the Mill Hill Vocabulary test, F (1,106)=79.13, Mse=74.99, and that young adults performed better than older adults on Digit Span Backward, F(1,106)=.10.49, Mse=4.40, Verbal Paired Associates, F(1,106)=23.67, Mse=52.86, and Digit Symbol, F(1,106)=135.44, Mse=186.37. However, there were no significant age differences observed in the WCST task, FAS, or Listening Span. These findings are consistent with previous findings found throughout the literature showing that older adults are impaired on tasks of processing speed and working memory.

Design

The research design was a 2 (Age: Young vs Older) x 3 (Trial Type: Congruent vs Incongruent vs Neutral) x 5 (List Composition: 100 Incongruent/0 Congruent vs 75I/25C vs 50I/50C vs 25I/75C vs 0I/100C) mixed factorial design. Conditions 100 I/0C and 0I/100C consisted of two and not three trial types. Age and list composition varied between subjects, while trial type was a within subjects variable. The dependent variable was the amount of time (in ms) to name the color of the non-black word on the computer screen.

Materials

Participants were required to wear headphones with an attached boom microphone to record color-naming responses. Word pairs were presented in capital letters against a white background on the color Monitor of a Power Macintosh Computer (See Table 2). For each pair, one word was always a neutral word (FAR, MOST, SLANT) and was presented in either red, blue or green. The other word was presented in black, and was either a neutral word or a color word (RED, BLUE, GREEN).

Table 1

Means and Standard Deviations (in parentheses) of Young and Older Adults for Individual Difference Measures as a Function of List Type

	0C/100I	25C/75I	50C/50I	75C/25I	100C/0I
Young					
FAS	39.00 (8.07)	36.17 (10.64)	37.42 (9.62)	39.00 (8.61)	40.67 (8.55)
Digit Symbol	85.00 (9.60)	73.42 (9.60)	86.83 (15.21)	87.00 (9.64)	83.83 (16.68)
Listening Span	2.17 (.72)	1.75 (.62)	2.25 (.97)	2.17 (.94)	2.00 (.85)
WCST	70.67 (13.14)	68.33 (5.73)	69.92 (7.01)	72.58 (7.87)	67.17 (6.29)
Mill Hill Vocab	34.58 (5.84)	32.50 (5.62)	33.58 (6.05)	34.75 (6.81)	36.00 (6.25)
Digit Span B	7.58 (2.11)	7.08 (2.35)	8.50 (2.02)	6.92 (2.19)	8.67 (2.57)
Verbal Pr Ass.	26.33 (5.16)	22.00 (7.27)	21.08 (7.73)	21.17 (7.60)	21.83 (6.67)
Older					
FAS	34.73 (6.33)	44.91 (12.41)	38.83 (12.15)	40.60 (8.50)	35.42 (4.62)
Digit Symbol	56.82 (20.93)	67.82 (10.07)	53.42 (14.46)	49.50 (11.27)	50.83 (16.18)
Listening Span	1.55 (.69)	1.91 (1.04)	1.75 (.62)	2.10 (.88)	1.67 (1.30)
WCST	69.64 (17.22)	74.73 (9.44)	65.92 (12.26)	69.20 (14.75)	71.17 (14.89)
Mill Hill Vocab	43.82 (9.79)	44.82 (6.52)	53.08 (10.11)	54.60 (11.49)	46.75 (14.10)
Digit Span B	5.09 (2.12)	7.09 (1.97)	6.25 (2.05)	7.00 (1.76)	7.00 (1.60)
Verbal Pr Assoc.	14.36 (9.18)	16.00 (7.13)	18.42 (6.80)	18.40 (7.53)	12.33 (7.28)

Note. Mill Hill Vocabulary =Mill Hill Vocab, Digit Span Backward =Digit Span B, and Verbal Paired Associates =Verbal Pr Assoc.

Table 2

Stroop Priming Presentation of Word Pairs

Trial Type	Word Pair	Description
Congruent	RED FAR	*FAR* printed in the ink color red
Incongruent	RED FAR	*FAR* printed in the ink color blue
Neutral	SLANT FAR	The word *FAR* printed in red

Note. In this example, the second word presented in the pair is printed in black ink. During the experiment, all trials were counter balanced with regard to left/right presentation of the ink color.

Participants viewed 3 blocks of 60 trials that were repeated twice for a total of 360 trials. Five lists were created for each of the five congruent/incongruent conditions. The first list contained 100% congruent items, and 0% incongruent items (100C/0I). The remaining were made up of 75C/25I, 50C/50I, 25C/75I and 0C/100I. Lists included 12 neutral stimuli per block. The numbers of trial types required for each list are shown in Table 3.

List construction consisted of the following steps. First, items representing every possible color word (red, blue, green), neutral word (far, most, slant), and position (left, right) were produced. This provided 18 unique congruent, 36 unique incongruent, and 36 unique neutral word pairs. Congruent, incongruent, and neutral word pairs were then randomly divided into subsets of 6 items as shown in Table 4.

Table 3

Stimulus Combinations

List Composition	Congruent	Incongruent	Neutral
0C/100I	0	48	12
25C/75I	12	36	12
50C/50I	24	24	12
75C/25I	36	12	12
100C/0I	48	0	12

Table 4

Subset Division of List Construction

18 Congruent	36 Incongruent	36 Neutral
Set 1 = 1-6	Set 1 = 1-6	Set 1 = 1-6
Set 2 = 7-12	Set 2 = 7-12	Set 2 = 7-12
Set 3 = 13-18	Set 3 = 13-18	Set 3 = 13-18
	Set 4 = 19-24	Set 4 = 19-24
	Set 5 = 25-30	Set 5 = 25-30
	Set 6 = 31-36	Set 6 = 31-36

These subsets of 6 items were used to construct the 3 blocks of 60 trials for each condition as shown in Table 5.

Table 5

Trial Block Construction

Incongruent 48			Incongruent 36		
Block 1	Block 2	Block 3	Block 1	Block 2	Block 3
Set 1x2	Set 1x1	Set 1x1	Set 1x1	Set 1x1	Set 1x1
Set 2x2	Set 2x1	Set 2x1	Set 2x1	Set 2x1	Set 2x1
Set 3x1	Set 3x2	Set 3x1	Set 3x1	Set 3x1	Set 3x1
Set 4x1	Set 4x2	Set 4x1	Set 4x1	Set 4x1	Set 4x1
Set 5x1	Set 5x1	Set 5x2	Set 5x1	Set 5x1	Set 5x1
Set 6x1	Set 6x1	Set 6x2	Set 6x1	Set 6x1	Set 6x1

Incongruent 24			Incongruent 12		
Block 1	Block 2	Block 3	Block 1	Block 2	Block 3
Set 1x1	Set 5x1	Set 3x1	Set 1x1	Set 3x1	Set 5x1
Set 2x1	Set 6x1	Set 4x1	Set 2x1	Set 4x1	Set 5x1
Set 3x1	Set 1x1	Set 5x1	Set 4x1	Set 2x1	Set 6x1

Congruent 48			Congruent 36		
Block 1	Block 2	Block 3	Block 1	Block 2	Block 3
Set 1x3	Set 1x2	Set 1x3	Set 1x2	Set 1x2	Set 1x2
Set 2x3	Set 2x3	Set 2x2	Set 2x2	Set 2x2	Set 2x2
Set 3x2	Set 3x3	Set 3x3	Set 3x2	Set 3x2	Set 3x2

Congruent 24			Congruent 12		
Block 1	Block 2	Block 3	Block 1	Block 2	Block 3
Set 1x2	Set 1x1	Set 1x1	Set 1x1	Set 2x1	Set 1x1
Set 2x1	Set 2x2	Set 2x1	Set 2x1	Set 3x1	Set 3x1
Set 3x1	Set 3x1	Set 3x2			

This method of block construction ensured equal frequencies of occurrence for each word pair over the 3 blocks of trials. Several additional constraints were followed during list construction. Specifically, no consecutive color names or color words on the same side of fixation were presented in succession to avoid a priming effect, and ensuring that color words never preceded the same ink color controlled negative priming.

Procedure

The first contact with older participants consisted of a telephone version of the Mini Mental State Exam used to screen individuals for cognitive impairment. After arriving at the laboratory, the participants were asked to fill out an informed consent form that explained their rights about the study, and were then asked to fill out a biographical questionnaire, which collected data on age, socio-economic status, race, gender, years of education, and pertinent health-related issues. A brief test for color blindness was then administered (Ishihara, 1994). The participants were seated in front of the computer monitor at a distance of 16 inches and were asked to put on the headphones. Practice trials were administered before presentation of the experimental lists (See Appendix A for full text of instructions). Each trial began with a fixation point that remained on the

screen for 700 ms, followed by a blank white screen for 50 ms. The word pair stimuli were displayed for 120 ms and participants had 670 ms to make a vocal response to name the color of the non-black word. A beep was presented when a 670 ms deadline had elapsed in order to encourage quick responding. The experimenter then pressed one of three keys to code whether the participants' response was correct, incorrect, a false start (cough, sneeze, etc), or no response.

Chapter 4

Results

Prior to analyzing the data, errors were eliminated from the data set, and each participants' median RT was calculated. A criterion of $p \leq .05$ was used to evaluate statistical significance. Errors (an incorrect color response) occurred at an overall rate of 1% and 2% for young and older adults, respectively, and total errors (including false starts, coughs, equipment failure, or failure to respond) occurred at an overall rate of 4% and 5% for young and older adults, respectively (see Table 6). Separate Age x Trial Type ANOVA's were conducted for each list composition. No main effect for age was observed in the 0C/100I list, $F(1,22)=.166$, $MSe=.001$; however there was a main effect for trial type, $F(1,22)=6.88$, $MSe=.001$ indicating that more errors were made on incongruent trials than neutral trials. No Age x Trial Type interaction was observed, $F(1,22)=.71$, $MSe=.001$, indicating that the difference between neutral and incongruent trials were consistent for young and older adults. No main effect for age was found in list 25C/75I either, $F(1,22)=.001$, $Mse=.20$. A main effect for trial type was again observed, $F(2,44)=8.207$, $Mse=.10$, indicating that errors were higher for incongruent than neutral or congruent trials. No Age x Trial Type interaction was observed, $F(2,44)=.002$, $MSe=.10$. No main effect for age was observed in the 50C/50I condition, $F(1,22)=2.53$, $MSe=.40$. A main effect for trial type indicated that more errors were committed on incongruent than neutral or congruent trials. A marginal Age x Trial Type interaction was observed, $F(2,44)=2.72$, $MSe=.10$, $p=.07$ suggesting that the difference between incongruent trials was greater for older adults than young adults. A main effect

of age was not observed for list 75C/25I, *F*(1,22)=.006, *MSe*=.001. A main effect for trial type indicated that more errors were committed on incongruent than congruent or neutral trials, *F*(2,44)=10.74, *MSe*=.30. No Age x Trial Type interaction was observed. Finally, there was a main effect for age observed in the list 100C/0I, *F*(1,22)=14.58, *MSe*= .02, indicating that older adults produced more errors than young adults. No main effect for trial type was observed, *F*(1,22)=.15, *Mse*=1.0, and no Age x Trial Type interaction was seen, *F*(1,22)=3.15, *MSe*=.10.

Table 6

Mean Error Rates for Young and Older Adults as a Function of Trial Type and List Composition

	0C/100I	25C/75I	50C/50I	75C/25I	100C/0I
Young					
Incongruent	.028 (.046)	.021 (.019)	.013 (.010)	.024 (.039)	--
Congruent	--	.006 (.009)	.011 (.013)	.006 (.010)	.006 (.009)
Neutral	.002 (.005)	.010 (.016)	.011 (.009)	.019 (.030)	.012 (.008)
Older					
Incongruent	.025 (.017)	.021 (.018)	.029 (.020)	.034 (.029)	--
Congruent	--	.006 (.007)	.013 (.014)	.005 (.005)	.039 (.030)
Neutral	.012 (.014)	.014 (.012)	.016 (.021)	.008 (.011)	.031 (.021)

Since the design was not a complete factorial, interference and facilitation effects were analyzed separately. Interference was examined by a 2 (Age: Young vs Older adults) x 2 (Trial

Type: Neutral vs Incongruent) x 4 (List Composition: 100I/0C vs 75I/25C vs 50I/50C vs 25I/75C) mixed factorial ANOVA for median RT scores (see Figure 1). A main effect for age was found, indicating that older adults had slower RTs than young adults, $F(1,88)=32.77$, $MSe=12783.65$. A main effect for trial type was also found, $F(1,88)=196.46$, $MSe=12783.65$. That is, incongruent trials produced slower RTs (Young, M = 654.94; Older, M = 762.05) than neutral trials (Young, M = 626.91; Older, M = 706.63). A main effect of list composition was not observed, $F(3,88)=1.82$, $MSe=425.46$, however, the presence of a Trial Type x List Composition interaction suggests that interference effects decreased as the proportion of incongruent trials increased, $F(3,88)=3.15$, $MSe=425.46$. An Age x List Composition interaction was not observed, suggesting that the difference between young and older adults RT scores did not vary with regard to list, $F(1,88)=.82$, $MSe=12783.65$. However, an Age x Trial Type interaction was observed, $F(3,88)=21.17$, $MSe=425.46$, suggesting that differences between incongruent and neutral trials were greater for older adults than for young adults. A three-way interaction was not observed, suggesting that this age difference was consistent across all list compositions, $F(3,88)=.50$, $MSe=425.46$.

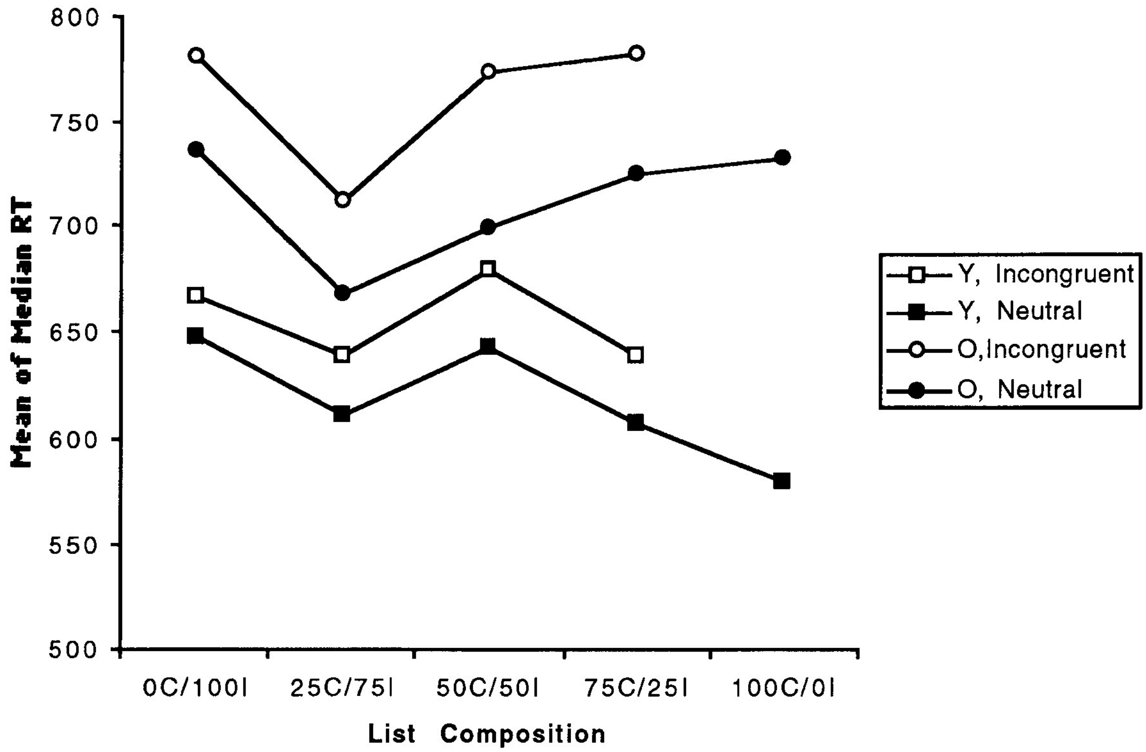

Figure 1. Interference scores for older and young adults as a function of list composition.

To present a clearer picture of the findings, interference scores (Median RT Incongruent – Median RT neutral) were analyzed using a 2 (Age: Young vs Older adults) x 4 (List Composition: 100I/0C vs 75I/25C vs 50I/50C vs 25I/75C) ANOVA. These scores are presented in Table 7. These scores revealed a main effect for age, showing that interference was greater for older adults than young adults, $F(1,88)=21.169$, $MSe=850.91$. A main effect for list composition was present, indicating that interference decreased as incongruent trials increased, $F(3,88)=3.153$, $MSe=850.91$. An Age x List Composition interaction was not observed, $F(3,88)=.50$, $MSe=850.91$, suggesting that age differences were consistent regardless of the composition of list.

To further examine the main effect of list composition, Tukey's post hoc analysis indicated that interference was higher for List 3 (50C/50I) than List 1 (0C/100I) and List 2 (25C/75I).

Table 7

Means and Standard Deviations (in parentheses) of Interference and Facilitation Scores

	0C/100I	25C/75I	50C/50I	75C/25I	100C/0I	Mean
Interference						
Young	19.58 (15.61)	25.75 (15.07)	36.54 (17.74)	30.25 (45.61)	--	28.03
Older	45.33 (22.48)	43.79 (29.68)	74.92 (23.66)	57.67 (44.67)	--	55.43
Mean	32.46	34.77	55.73	43.96	--	41.73
Facilitation						
Young	--	29.33 (17.61)	22.50 (14.31)	28.92 (17.31)	44.75 (23.74)	31.38
Older	--	29.33 (28.21)	21.67 (36.17)	55.38 (32.60)	71.46 (22.06)	44.46
Mean	--	29.33	22.09	42.15	58.11	37.92

To determine the relationship between interference and frontal lobe and working memory functioning, correlations between interference scores and WCST perseverative errors and categories completed, FAS, and Listening Span scores were obtained. Given that so many correlations were examined, the alpha level for each correlation was adjusted to $p \leq .001$ so that the familywise type 1 error range was held to $p \leq .05$. The result was a critical value of $r = .82$. As seen

in Table 8, neither frontal lobe, nor working memory was related to interference scores for young or older adults.

Table 8

Correlations Between Interference and Individual Difference Measures for Young and Older Adults

	0C/100I	25C/75I	50C/50I	75C/25I
Young				
WCST Categories Complete	-.27	--	-.25	.01
WCST Perseverative Errors	-.11	.22	-.05	.03
FAS	.20	.19	-.35	.52
Listening Span	-.05	-.29	.00	.18
Older				
WCST Categories Complete	-.07	-.59	-.44	.65
WCST Perseverative Errors	-.01	.61	.60	-.51
FAS	.40	-.05	-.58	.55
Listening Span	-.04	-.15	-.62	.32

The facilitation effect was measured by a 2 (Age: Young vs Older adults) x 2 (Trial Type: Congruent vs Neutral) x 4 (List Composition 75I/25C vs 50I/50C vs 25I/75C vs 0I/100C) analysis of variance (Figure 2). A main effect for age was found, indicating that young adults had faster RTs than older adults, $F(1,88)=42.70$, $MSe=9054.82$. RTs were faster for congruent items (Young, $M =$ 578.90; Older, $M =$ 663.00) compared to neutral items (Young, $M = 610.27$; Older, $M = 705.66$), $F(1,88)=209.20$, $MSe=314.42$. The effect for list composition was not significant, $F(3,88)=1.33$, $MSe=9054.82$, but there was a Trial Type x List Composition interaction showing

that differences between congruent and neutral items grew larger as congruent trials increased, $F(1,88)=10.45$, $MSe=314.42$. No Age x List Composition interaction was observed, $F(3,88)=2.02$, $MSe=9054.82$, but a significant Age x Trial Type interaction indicated that differences between neutral and congruent trials were greater for older adults than for young adults, $F(1,88)=4.86$, $MSe=314.42$. Finally, an Age x Trial Type x List Composition interaction revealed that this age difference for neutral and congruent items increased as the number of congruent items within the list increased, $F(3,88)=3.04$, $MSe=314.42$.

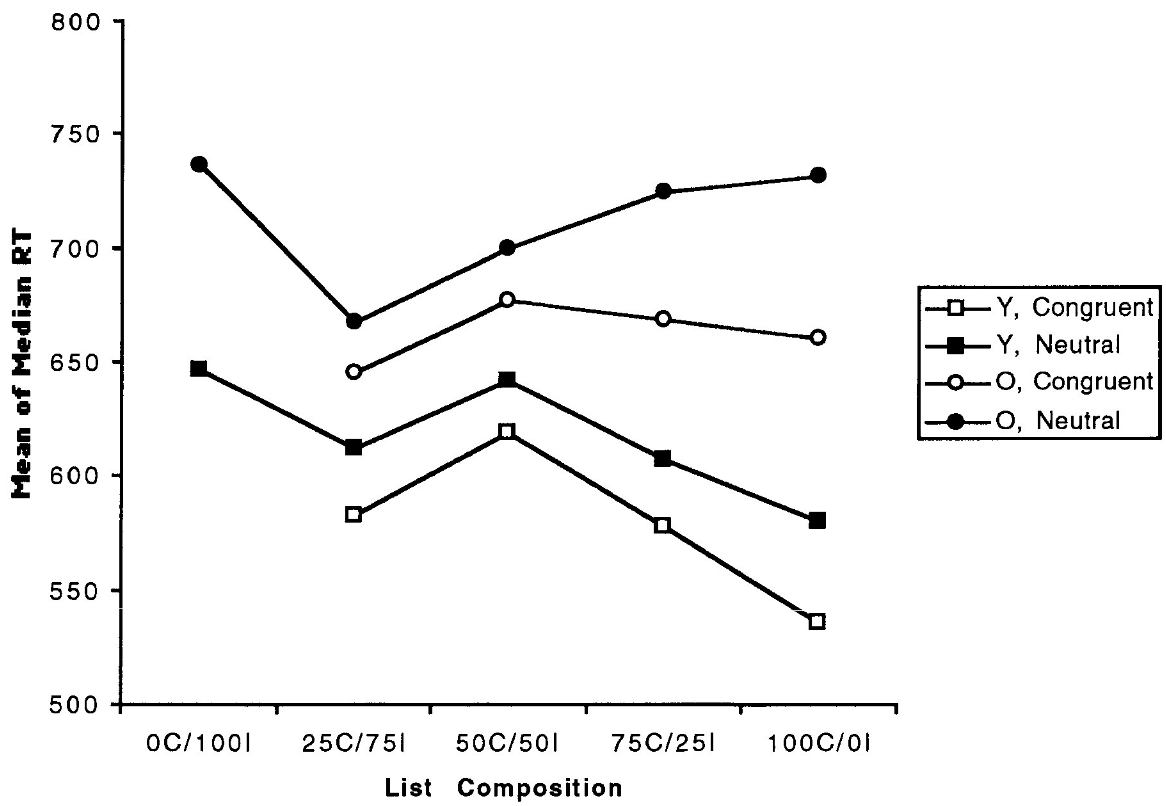

Figure 2. Facilitation scores for older and young adults as a function of list composition

To present a clearer picture of the findings, facilitation scores (Median RT Neutral – Median RT Congruent) were analyzed using a 2 (Age: Young vs Older adults) x 4 (List Composition: 75I/25C vs 50I/50C vs 25I/75C vs 0I/100C) ANOVA. A main effect for age was found, indicating that older adults produced more facilitation than young adults, $F(1,88)=4.86$, $MSe=628.85$. There was a main effect of list composition, indicating that facilitation increased as congruent trials increased, $F(1,88)=10.45$, $MSe=628.85$. Finally, an Age x List Composition interaction suggested that age differences in facilitation varied according to list composition, $F(3,88)=3.04$, $Mse=628.85$.

The effect of age within each list composition indicated that older adults showed more facilitation on List 4 (75C/25I), $F(1,22)=6.17$, $Mse=681.02$, and List 5 (100C/0I), $F(1,22)=8.15$, $Mse=524.95$ than young adults. To examine the Age x List Composition interaction, the effect of list composition was examined for each age group. An effect of list composition was observed for young adults, $F(3,44)=3.11$, $Mse=344.45$. Tukey's post hoc analysis was conducted on these means in order to determine significant differences between list composition. Results indicate that young adults had significantly higher facilitation effects in List 5(100C/0I) than in List 3 (50C/50I). A significant effect of list composition was also found for older adults. Tukey's post hoc analysis indicated that facilitation effects were higher for List 5 (100C/0I) than List 2 (25C/75I), and List 3 (50C/50I), and were higher for List 4 (75C/25) than List 2 (25C/75I), and List 3 (50C/50I).

To examine the relationship between facilitation and frontal lobe and working memory measures correlations between facilitation scores, WCST categories complete and perseverative errors, FAS, and Listening Span were obtained (see Table 9). As in the interference condition, the alpha level for each correlation was adjusted to $p \leq .001$ so that the familywise type 1 error range

was held to $p \leq .05$. This resulted in a critical r=.82. Facilitation scores for young adults did not correlate with any frontal lobe or working memory measures. For older adults marginally significant correlations were found in the 50C/50I condition. In this list, the greater the number of WCST categories completed, the higher the facilitation score. Likewise, the more words produced on the FAS verbal fluency task, the higher the facilitation score.

Table 9

Correlations Between Facilitation and Individual Difference Measures for Young and Older Adults

	25C/75I	50C/50I	75C/25I	100C/0I
Young				
WCST Categories Complete	--	.03	.12	--
WCST Perseverative Errors	.05	-.33	-.21	.56
FAS	.00	.35	-.20	.08
Listening Span	-.34	.38	-.12	-.11
Older				
WCST Categories Complete	.28	.79*	-.26	-.16
WCST Perseverative Errors	-.34	-.35	.12	.23
FAS	-.34	.81*	-.15	.05
Listening Span	.26	.57	-.42	.40

Chapter 5

Discussion

Overview of Findings

The present study was conducted to examine whether older adults are capable of developing attentional strategies to reduce interference from irrelevant information. It was predicted that overall interference would be greater for older adults than young adults. More specifically, it was expected that as the proportion of incongruent trials increased, older adults as well as young adults would be able to reduce the size of the interference effect by flexibly employing attentional strategies. On the other hand, if older adults are less able to flexibly deploy their attention, there should be a greater decrease in interference for young adults than for older adults as incongruent trials become proportionally greater.

Interference Effects. The results of this study indicate that older adults were capable of flexibly deploying attentional strategies to reduce interference from irrelevant information. For both young and older adults, interference was lower in lists comprised of mostly incongruent trials than in lists comprised of mostly congruent trials. Because interference effects decreased when the optimal strategy could only have been color naming and increased when the strategy could have been either color naming or word reading, it appears that when necessary, adults in both age groups developed a strategy that reduced the influence of the conflicting automatic word reading process. However, while both young and older adults adjusted to the composition of the list, older adults still showed greater overall interference effects than did young adults.

Frontal lobe and working memory performance appeared to be unrelated to Stroop priming interference for older and young adults. This finding suggests that inhibitory deficits may not be associated with frontal lobe or working memory decline.

Facilitation Effects. Facilitation increased as the proportion of congruent trials increased and was greater for older adults than young adults only in the mostly congruent lists (i.e., 75C/25I, 100C/0I). This finding suggests that older adults may have adopted a different strategy than young adults in the mostly congruent and all congruent lists. These conditions allow a correct response to be made by attending to either the word name or ink color. Older adults may have been less likely to adopt the more difficult strategy of inhibiting the word name in these conditions.

No significant correlations between individual difference measures and facilitation were found for young adults. Correlations were significant for older adults between facilitation and WCST Categories Complete, and FAS, in the 50C/50I condition. In this condition, frontal lobe function was strongly related to facilitation, i.e., the better the frontal lobe function, the greater the facilitation. Apparently, older adults who perform better on frontal lobe tasks are able to effectively deploy attention to relevant information in the task context. It is curious, however, that facilitation measures were only significant in the 50C/50I list. In this list, participants were not able to determine the trial type based on proportion. Other list compositions allowed participants to adopt a strategy based on the expectation of the next trial.

The Stroop Effect and Aging

The results of the present study reveal a Stroop Effect for both older and young adults, although interference effects were greater for older adults. This finding is consistent with the bulk of the literature reported on increased interference effects for older adults (Cohn et al., 1984;

Spieler et al., 1996; Li & Bosman, 1996, Dulaney & Rogers, 1994; West & Baylis, 1998) using the traditional Stroop task (i.e., color words printed in congruent or conflicting ink colors). According to Hasher and Zacks' (1988) inhibition deficit theory, interference effects increase when inhibitory processes fail and irrelevant information becomes activated. The present findings show that older adults also have difficulty inhibiting the irrelevant color word in the Stroop priming paradigm, although the ink color and color word are perceptually separate.

However, not all of the prior literature reports greater interference effects for older adults when stimuli are perceptually distinct. For example, Hartley (1993) devised an experiment using a version of the Stroop color word task which involved presenting a color word adjacent to a color block. Participants were asked to press a key that corresponded to the color of the block as quickly as possible. In the color-word version, participants were asked to press the key corresponding to the ink color of the word presented in a black outlined rectangle on the computer screen. A fixation point was seen, followed by a cue, indicating where the color block or word was to appear. Hartley found small age differences on the color-block version where the stimuli were spatially separated, but found large age differences on the color-word version in which the color and color word were integrated. However, there were two methodological differences between Hartley's study and the present study that could account for the different outcomes. First, the participants in Hartley's study were presented with location cues prior to trial exposure. These cues may have reduced the difficulty of the task because they alerted the participants to the location of the target. Participants were not alerted to the location of the next target stimulus in the present study. Second, Hartley used combinations of color-word and color-block stimuli within each trial. These stimuli

may have been easier to distinguish perceptually than the word-word stimuli employed in the present study.

The results of the present study also showed that facilitation effects were greater for older adults than young adults, especially in the mostly congruent conditions. Few studies have focused on age differences in facilitation effects, and therefore, there is little research with which to compare the current findings. Moreover, the two studies that have analyzed facilitation effects report different findings. Spieler et al. (1996) found no differences in facilitation for young and older adults. However, consistent with the present findings, West and Baylis (1998) report differences in facilitation for young and older adults. Specifically, in their mostly congruent lists, facilitation effects were greater for older adults than young adults. These researchers attribute this finding to older adults' greater propensity to use a word reading strategy when the task does not require the maintenance of a color naming strategy.

Aging and Attentional Control

The present study supports the idea that theories on the control of inhibition in the Stroop effect must include an attentional component (MacLeod, 1991; Logan, 1980). The operation of the attentional component can best be seen in the variation of interference effects as the proportion of incongruent and congruent trials within a Stroop task varies. Findings in the current study parallel earlier findings for young adults in showing that older adults are sensitive to the proportion of incongruent trials. Specifically, Lowe and Mitterer (1982) reported that interference effects decreased for young adults as the proportion of incongruent trials increased, suggesting that attention varied with contextual demands. The same finding is present in the current study for both young and older adults. These findings suggest that older adults were adapting to list composition.

If older adults were unable to control their attention, the size of the interference effects seen for this group would not differ in relation to list composition. Clearly, older adults were able to vary their attentional strategy to selectively attend to relevant stimuli and ignore the irrelevant stimuli.

The present findings are also similar to those observed in several recent studies on aging and attentional control. For example, West and Baylis (1998) manipulated the proportion of congruent and incongruent trials in a traditional Stroop task and found that interference effects were greater in a mostly congruent condition compared to the mostly incongruent conditions. Further, like the present findings, interference effects were greater for older adults than young adults in both conditions. Unfortunately, West and Baylis did not compare older and young adult response latencies between the mostly congruent and mostly incongruent conditions. As a result, their findings do not address the issue of age related changes in attentional strategy development as a function of list composition. The present results go further to show that older adults can adjust their attentional strategy based on list composition.

Facilitation was greater for both young and older adults in the mostly congruent condition than in the mostly incongruent condition. However, differences between young and older adults were greatest in the mostly congruent conditions. West and Baylis (1998) report similar findings in their research and suggest that this finding is due to older adults' difficulty in maintenance of a color naming strategy. The current findings suggest that older adults may deliberately choose to avoid the use of a color naming strategy and pay greater attention to the word name.

Mutter and Patterson (1997) also manipulated the proportion of congruent and incongruent trials in a traditional Stroop task and found little or no age-related decline in attentional flexibility. They applied a process dissociation analysis, which indicated that color-naming estimates increased

as the proportion of incongruent trials increased. Moreover, as the proportion of incongruent trials increased, word-reading estimates declined for both older and young adults. The current findings are consistent with these earlier results. Interference decreased for older adults as the proportion of incongruent trials increased, suggesting that older adults directed attention away from the irrelevant color word and attended to the color naming aspect of the task.

Finally, the present results are consistent with those of Toth (1997) who investigated age-differences in attentional flexibility using the Simon task. He found that interference increased and decreased as a function of the sequence of proportions of Simon trials. Older adults' interference scores fluctuated as a function of list composition. As the proportion of incongruent trials increased, interference effects decreased. Similarly, as the proportion of incongruent trials decreased, interference effects increased. Both young and older adults seemed to be adjusting to task context, however older adults' interference scores again remained higher than those of young adults.

Summary

It has been suggested that there are independently functioning mechanisms responsible for the suppression of word reading and the activation of word reading that function under the influence of a control mechanism (Faust, Balota, Duchek, Gernsbacher, & Smith, 1997). The current findings support the notion that older adults suffer from a decreased inhibitory ability and thus have increased difficulty suppressing word reading processes. However, older adults do not have similar difficulties with activation; that is, the mechanism responsible for the activation of word reading is not impaired. Moreover, it seems that older adults can shift their attention based on task context, suggesting that there is no age-related decline in the attentional control mechanism.

Future Research

Further research needs to be conducted using the Stroop priming paradigm as a measure of attentional control. The Stroop priming procedure should be examined by manipulating list proportion within subjects. This type of proportion manipulation would allow multiple attentional strategies to be deployed to record a true measure of attentional flexibility by examining interference and facilitation effects as a function of sequential proportions.

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Appendix

Stroop Instructions

Practice Trials. In this task, your job will be to name the ink color of the non-black words on the computer screen as quickly as possible. On each trial you will see a fixation point followed by two words. One word will be printed in black and the other in color. The ink colors used in this study are RED, BLUE and GREEN, so your responses should be either RED, BLUE or GREEN. The colored word will sometimes be on the left, and sometimes on the right. Try to name the color of this word as quickly as possible because your time to do this will be recorded. A tone will sound at the end of each trial to indicate that the time to respond has expired. It is important that you respond before this deadline, but try not to make any mistakes. In addition, on all trials, it is important that you look directly at the fixation point before the words appear on the screen. Do you have any questions before we begin? You will now receive several practice trials. The computer will indicate when these trials are over by displaying a grid of your reaction times.

Experimental trials. Now that you're familiar with the task, we will begin the experimental trials. There will be more experimental trials than practice trials, but you will be doing the same thing that you did in the practice trials. Remember to name the ink colors as quickly as possible, before the deadline, making as few mistakes as possible. Do you have any questions?

Stroop Debriefing. The present experiment is an attempt to discover whether there are age differences in the ability to develop a strategy to effectively inhibit automatic processes. In the first part of the experiment, you were presented with two words on the computer screen. You were told to name the ink color of the non-black word. However, an automatic response may

have interfered with this color naming, namely reading the color word beside it. In tasks like this, automatic processes of word reading frequently overpower the more controlled processes of color naming. Research shows that younger adults are capable of developing strategies that enable them to inhibit or stop automatic word reading in order to perform better at naming the color of ink. We are interested in whether this ability to inhibit automatic processes changes with age. Research has shown that when color words are the same as the ink color, young adults adopt a strategy of reading. However, when the ink color is not the same as the color word, they learn to ignore the color word because it will increase the amount of time it takes to name the color. Little research, however, has been performed to see if older adults develop an effective strategy of this sort.

We expect that both young and older adults will show interference from automatic word reading in their color naming performance. We also expect that both age groups will develop strategies to reduce this interference, but that the ability to do so may decline somewhat with age.