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The Effects of Practice on Stroop Inhibition: A Process Dissociation Approach

Emily Patterson
Western Kentucky University

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THE EFFECTS OF PRACTICE ON STROOP INHIBITION:
A PROCESS DISSOCIATION APPROACH

A Thesis
Presented to
the Faculty of the Department of Psychology
Western Kentucky University
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In Partial Fulfillment
of the Requirements for the Degree
Masters of Arts

by
Emily Ruth Patterson
December, 1996
THE EFFECTS OF PRACTICE ON STROOP INHIBITION:
A PROCESS DISSOCIATION APPROACH

Date Recommended 8/9/96
Sharon Mutter
Director of Thesis
Karlene Fall
Daniel L. Roes

Edward Craig 10/31/96
Dean, Graduate Studies and Research  Date
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THE EFFECTS OF PRACTICE ON STROOP INHIBITION:
A PROCESS DISSOCIATION APPROACH

Emily Ruth Patterson       December, 1996       96 Pages
Directed by: Sharon A. Mutter, Karlene K. Ball, and Daniel Roenker
Department of Psychology       Western Kentucky University

Abstract

Two studies were performed to investigate the effects of age and practice on Stroop inhibition. The first experiment examined the influence of age on the ability to ignore the meaning of words on Stroop items. Fifteen younger and 15 older adults were asked to name the color of congruent, incongruent, and control items appearing on a computer screen. Participants' interference and facilitation scores, error rates, and color and word process dissociation estimates were computed. The results indicate that older adults experienced more interference and facilitation than the younger adults and produced more errors than the younger adults on items where the meaning of the word and the color of the item did not match. Likewise, the process dissociation measures showed higher word estimates for older adults. Altogether these findings are indicative of a breakdown in older adults' inhibitory processes.

The second study examined the effects of practice on older and younger adults' ability to inhibit word reading in the Stroop. Twelve younger and 12 older adults were assigned to each of two list conditions. Participants in the mostly congruent list condition received 140 items, 100 of which were congruent, 20 of which were
incongruent and 20 of which were control. Participants in the mostly incongruent condition also received 140 trials, 100 of which where incongruent, 20 of which were congruent and 20 of which were control. The mostly incongruent list thus provided more practice in ignoring word meaning. Once again Stroop facilitation and interference scores, error rates, and process dissociation measures were computed. The results indicated that the mostly congruent list produced more facilitation and interference than the mostly incongruent list and that older adults again had higher facilitation and interference scores than younger adults. However, there was no evidence in the latency data that older adults benefitted less from practice than their younger counterparts. The process dissociation estimates demonstrated that older adults had higher word process estimates than the younger participants but that their color process estimates were similar to those of the younger adults. In addition, the mostly incongruent list produced lower word estimates and higher color estimates than the mostly congruent list. Moreover, this pattern did not differ across list types from that of the younger adults, again suggesting a similar benefit from practice for the two age groups. Taken together, these two studies suggest that while older adults are poorer at inhibitory skills, they do benefit from practice.
Chapter 1

Introduction

In 1935, Stroop observed that subjects may sometimes have difficulty attending to one aspect of a stimulus while ignoring other irrelevant aspects. In a typical Stroop task, subjects are asked to name the color of the ink in which words or neutral stimuli such as a string of percentage signs are printed. Individuals have little difficulty naming the ink color on trials in which the stimuli are neutral. They also perform well when a stimulus word matches the ink color (RED in red ink). However, difficulty arises when the ink color is different from the color the word signifies (RED in blue ink) (Dalrymple-Alford & Budayr, 1966; Stroop, 1935). The finding that subjects perform well when the word and ink color match is thought to display facilitation because both the automatic process of word reading and the controlled process of color naming are working together to produce the correct response. The difficulty observed when ink color and word meaning differ is thought to represent interference because the automatic word reading process works in opposition to the controlled color naming process. To answer correctly, the automatic process must be inhibited or dampened so that the controlled process can dominate.

An interesting finding is that younger and older adults display different patterns of responding on the Stroop task. Comalli, Wapner, and Werner (1962) discovered that although older and younger adults did not differ significantly on time taken to name the color of neutral items on a Stroop task, older adults did experience more interference.
than younger adults when asked to name the ink color of items where the color of the ink and the meaning of the word differed. This finding has been widely replicated (Cohn, Dustman, & Bradford, 1984; Houx, Jolles, & Vreeling, 1993; Panek, Rush, & Slade, 1984). Hasher and Zacks (1988) propose that this age difference is produced because older adults have poorer inhibition than younger adults. Specifically, the older adults are less able to inhibit the irrelevant stimuli (the words) and these stimuli enter working memory and compete with the relevant stimuli (the color names) for attentional resources. The purpose of the present study is to examine whether there are age differences in inhibitory processes in the Stroop task. The method used to study this effect will be the Process Dissociation Procedure developed by Jacoby (1991).

Lindsay and Jacoby (1994) have criticized past research on the Stroop for not incorporating a “pure” control measure on which to base the effects of interference and inhibition. They argued that even control conditions that incorporate the use of neutral symbols are not pure in that processing the symbol could produce some interference. Lindsay and Jacoby proposed a way of mathematically estimating a “pure” measure of color naming from which the contribution of word reading could be eliminated. Once a pure measure of color naming is obtained, the facilitating and interfering effects of word reading can be estimated. Their approach is called the Process Dissociation Procedure. The Process Dissociation Procedure provides a new way of assessing controlled and automatic processes in the Stroop task.

The first experiment in this study, therefore, examined what differences, if any, there were in the contribution of controlled and automatic processes in the Stroop task for
older and younger adults using the Process Dissociation Procedure. To date, only one article (Spieler, Balota, & Faust, 1996) has been published assessing the contributions of these processes in older adults using this technique. The second experiment examined age differences in the benefit of practice on the Stroop. Lindsay and Jacoby (1994) manipulated automatic word reading in younger adults by varying the probability of congruent (RED in red ink) and incongruent (RED in blue ink) trials. Younger subjects that experienced mostly incongruent trials were able to better inhibit the automatic word reading with this extra practice while leaving the controlled color naming process the same. However, research by Dulaney and Rogers (1994) suggests that practice on the Stroop task does not enable older adults to better inhibit the word reading process. They assessed the effects of practice on older and younger adults’ performance by comparing performance on posttest trials to performance on pretest trials. Although both age groups showed a decrease in response time with practice, it appeared that older adults’ increased performance on Stroop items was not due to increased inhibitory mechanisms but to general task factors. The question arises as to whether manipulating the probability of certain trial types will enable older subjects to inhibit automatic processes as readily as their younger counterparts. Therefore, the second study investigated the effects of manipulating the probability of congruent and incongruent trials on the word reading and color naming estimates for younger and older adults. This procedure is different from the one used by Dulaney and Rogers and should provide converging evidence on the effects of practice on Stroop performance as well as provide a clearer view of what mechanisms are involved.
In 1935, Stroop performed a series of experiments that had a great impact on how scientists study the effects of cognitive interference. In the task, he asked subjects to attend to one aspect of a stimulus with multiple dimensions (e.g., the word RED printed in green ink). He was interested in studying the effects of interference and what effect different manipulations and practice had on the interference process. In the first experiment, Stroop presented a series of experimental words consisting of color names written in incongruent ink colors on one card and control words printed in black on a different card. Subjects were asked to read the words on each of the cards. No differences were found in subjects' latency of response between the experimental and the control cards, suggesting that the ink color did not produce interference with reading. In his second experiment, Stroop changed the nature of the task subjects were required to perform. The experimental condition again consisted of experimental color words presented in incongruent ink colors while the control condition consisted of blocks of colors. This time participants were asked to name the color of the ink in which the items were printed. With this manipulation, Stroop found that subjects were significantly slower when naming the ink colors on the experimental card than on the control card which suggests that the word reading process was competing with the color naming process and producing interference. In his third experiment, Stroop gave subjects practice on naming the ink colors on incongruent items and found that their times on the
cards decreased with practice, suggesting that the interference of the word reading process for subjects could be decreased with practice.

The impact of Stroop's experiments is amazing. MacLeod (1991) reports that in excess of 700 articles examining the Stroop effect have been written. Perhaps one reason the Stroop task is so popular is that the results of the task are not dependent on the type of material used. As long as there are aspects of the stimulus that conflict, the Stroop effect can be obtained. For example, Hamers (cited in MacLeod) found that the Stroop effect can be shown with auditory stimuli. She required subjects to say “low” to items presented in a low pitch and “high” to items presented in a high pitch. The control condition consisted of simple tones at each to the two frequencies. The experimental condition consisted of the words LOW and HIGH presented with either compatible or incompatible low or high pitches. Strong interference effects were reported when LOW was presented in a high pitch and HIGH was presented in a low pitch. Dalrymple-Alford and Azkoul (1972) performed a study in which subjects had to determine whether two words printed on a card were the same color. They were to respond by saying either YES/NO or RIGHT/WRONG. Their subjects showed interference effects only when the words on the card were the same as those used by the participants to respond. In addition, Klein (1964) showed that the interference effect can be seen in items semantically related to the ink colors used in the experiments. He found that using words such as FIRE, GRASS, LEMON, and SKY produced interference when they were printed in semantically incompatible colors. Interference effects have also been found with
words that sound similar to the sound of the color names involved in the task (Dalrymple-Alford, 1972b) as well as with many other variations of the task (see MacLeod 1991 for review).

Another finding with the Stroop task was the discovery of facilitation when subjects are presented with items in which the different dimensions of the object are compatible. According to MacLeod (1991), these congruency effects were first studied by Dalrymple-Alford and Budayr in 1966. Dalrymple-Alford and Budayr incorporated congruent items with incongruent items on their experimental cards. Although they found no difference in overall response latencies between the mixed items list compared to the list consisting of all incongruent items, other studies examining the effects of congruent, incongruent, and control trials separately have found that subjects respond more quickly to trials consisting of all congruent items compared to control items lists (e.g., Dalrymple-Alford, 1972a; Klein, 1964).

Theoretical Explanations of the Stroop Task

Although the Stroop effect has been studied for 60 years, there is still speculation about what underlying processes contribute to the phenomenon. Younger adults display the quickest reaction time on trials in which the word and the ink color are congruent (e.g., RED in red ink) and display the slowest times on trials in which the word and ink color are incongruent (e.g., RED in blue ink). This pattern of responding is thought to reflect facilitation and interference processes. Facilitation occurs when both the process of word reading and the process of color naming work together to produce the correct response. Interference occurs when the word reading process works in opposition to the
color naming process. Although most theorists agree on these points, the exact location and cause of the interference is still under debate.

According to the speed-of-processing approach, both words and colors are processed in parallel; however, words are processed faster than colors. Interference occurs when the dimension that is processed the quickest is the one that is to be ignored. When this happens, a phenomenon known as response-competition occurs at the final output stage of processing (MacLeod, 1991). The output stage is limited because it will only allow one of the responses to enter at a time. Since words are processed faster than colors, they reach the output stage first and thus cause interference for the color response. Therefore, according to this theory, color should cause interference for the word if the color is presented long enough in advance for it to reach the output stage first. However, Glaser and Glaser (cited in Cohen, Dunbar, & McClelland, 1990) demonstrated that even when previewing the color 400 ms in advance of the word, color did not produce interference in subjects’ word reading. Thus, interference cannot be explained totally by the speed-of-processing approach.

Logan's (1980) model of the Stroop phenomenon is somewhat similar to the speed-of-processing approach in explaining interference. Logan suggests that the Stroop effect is dependent upon a decision gathering process in which evidence for a response is accumulated over time. Evidence for each dimension of an object is gathered independently and is processed at a rate determined by two weights, one that depicts the effects of automaticity and another that portrays the effects of attention. Evidence for
each dimension is then accumulated until a threshold is reached. Once this threshold is reached, the decision for one dimension is compared with evidence from other dimensions for consistency. If the evidence for the desired dimension is consistent with the other ones, then response speed is quickened. If the evidence from the other dimensions is inconsistent with the desired dimension, then response time is slowed (MacLeod, 1991). The theory also states that those irrelevant dimensions with larger weights attached will interfere more with the decision making process than those with smaller weights. Thus, in the Stroop task, inconsistent evidence from the word reading dimension will interfere more with the desired color naming dimension due to the large amount of weight attached to the word reading process. However, the same problem arises here as was seen in the speed-of-processing approach. Dimensions with heavier weights will be processed quicker and can thus affect decisions about later evidence, but not vice versa. Since the word reading threshold is reached first, it should affect decisions about the color naming process. However, as was mentioned before, even when the color naming process is started earlier than the word reading, color naming still does not interfere with word reading.

Another theory that has attempted to explain Stroop interference in recent years has been a parallel distributed processing model developed by Cohen et al. (1990). According to their model, processing of a stimulus takes place in a system of connected modules. When an individual is presented with a task, his or her accuracy and speed at performing the task is dependent upon which cognitive pathways between modules are activated and the strength of these pathways. Pathways that are assigned more strength...
will process the information faster and more accurately than pathways of lesser strength. The modules within the pathways contain units that are capable of receiving and sending information to other units within the system. Because modules can both receive input from and send information to several other modules, it is possible for an individual module to be a part of several different cognitive pathways. When one is presented with a stimulus, such as those in the Stroop task, two processes can be activated simultaneously. If both processes rely on a common module, an interaction can occur. According to Cohen et al., if both patterns of activation are similar at the module of intersection, facilitation will occur. However, if the two patterns are different, interference will occur. Interactions may be avoided by adjusting the information arriving on one of the pathways through attentional control. Attention can influence the responsiveness of individual units along the pathway and thus control individual processes. Therefore, the better control one has over a process, the less likely interference will occur. Although the parallel distributed processing approach appears promising in explaining the Stroop phenomenon, it is a relatively new theory with little empirical data to verify its stance.

Perhaps the most popular approach to explaining Stroop interference is the automaticity theory. According to this theory, interference occurs because one stimulus dimension requires more attentional resources to process than does the other dimension (MacLeod, 1991). The amount of attention needed is dependent upon the degree of automaticity of the processing for that dimension. The more automatic the process, the less attention it requires. In addition, processing becomes more automatic with practice.
In the Stroop task, words are processed more automatically than colors because of the extensive practice adults have with word reading and the relative lack of practice they have with color naming. According to the automaticity approach, automatic processes should interfere with more attention demanding processes, but the reverse should not occur. Thus, in the Stroop task, word reading interferes with ink color naming but ink color naming does not interfere with word reading. MacLeod states that the automaticity approach has much to offer in way of explaining Stroop interference but states that Stroop experiments have rarely offered measures of automaticity. Thus, the validity of the automaticity theory has not been tested to date.

**Age Differences in the Stroop Task**

Although the above theoretical explanations elucidate a great deal about the Stroop phenomenon and the interference seen in it, they do not provide an adequate explanation for why younger and older adults display different patterns of responding on the task. Comalli, Wapner, and Werner (1962) performed a study investigating changes in Stroop performance across the life span. They discovered that although older adults did not differ significantly from younger adults on time taken to name the color of rectangular color patches, they did experience more interference than younger individuals when asked to name the ink color of incongruent items. Cohn, Dustman, and Bradford (1984) also demonstrated that there is an age related decline in the Stroop task but only when subjects were required to name the color of the words, not the words themselves. Houx, Jolles, and Vreeling (1993) and Panek, Rush, and Slade (1984) found similar results in their studies, with older adults' times being slower than younger adults' on
incongruent items. The fact that these studies show a significant slowing with age only in the incongruent conditions suggests that the increased time taken to name incongruent ink colors may not be due to a decrease in response speed but to factors that decline with age.

Most researchers studying the effects of Stroop interference in younger and older adults have suggested that this factor is a decrease in inhibition with age. Harnishfeger (1995) defines inhibition as “a cognitive suppression that contributes to task performance by keeping task irrelevant information from entering and being maintained in working memory” (p.176). Hasher and Zacks (1988) propose that the deficits in older adults’ performance on tasks like the Stroop can be attributed to an age-related decline in inhibitory processes. This decline in inhibition leads to problems with selective attention. Once selective attention is compromised, task irrelevant information enters into and is maintained in working memory where it competes with relevant information for attentional resources. Response time is slowed due to this intrusion and increased errors in responding occur.

Evidence for Age Differences in Inhibitory Processes

Several studies investigating the relationship between aging and performance under distracting conditions support the view that the efficiency of inhibitory processes may decline with increasing age. McDowd and Filion (1992) studied both younger and older adults’ ability to ignore irrelevant material by instructing them to either ignore or attend to a series of intruding tones. Subjects’ skin conductance orienting responses to the tones over a period of time were recorded. The results show that the younger subjects were able to habituate to the tones quicker when they were given instructions to ignore
the noise than when they were to attended to it. Older adults, however, had a difficult
time habituating to the tone in both conditions, thereby suggesting that older adults have
more difficulty ignoring irrelevant stimuli than younger adults.

Kausler and Hakami (1982) observed increased distractibility for older adults in a
frequency judgment task. They presented young and older adults with a study list
containing relevant items in conjunction with irrelevant stimuli. On each trial, the
relevant word was underlined while the irrelevant words were not. Subsequently, older
adults and younger adults gave similar frequency judgments for relevant words when the
words were paired with one distractor. However, as the number of distractors increased
to two or three, older adults gave lower frequency estimates for relevant words than did
the younger adults. These results suggest that while older adults may be able to perform
well under simple distractor conditions, as the amount of distracting material increases,
their abilities are compromised.

Another area of study that has proven useful in studying age related differences in
inhibition is the negative priming paradigm. Negative priming occurs when the stimulus
to be ignored on one trial becomes the relevant stimulus on the next trial. Thus, subjects
have to inhibit the stimulus and then release it from inhibition. In younger adults, this
manipulation usually causes a slowing of time taken to complete the task (Tipper, 1985).
In older adults, there is a different pattern of responding. In Hasher, Stoltzfus, Zacks, and
Rypma’s (1991) study of negative priming with older and younger adults, older adults
were less affected by the negative priming procedure than were the younger adults.
Likewise, Tipper (1991) found similar results in a study designed to measure older adults'
performance on a negative priming and an interference task in which subjects were told to respond only to one target while ignoring all others. He found that the distracting information interfered more with the older adults’ performance than the younger adults’ performance. In addition, while younger adults displayed a negative priming effect, older adults demonstrated a positive priming effect. McDowd and Oseas-Kreger (1991) discovered similar results with their negative priming experiment. They found that older adults’ reaction times were slowed more than younger adults’ when distracting letters were present; however, older adults did not show a negative priming effect. These findings suggest that the inhibitory mechanisms in older adults are compromised.

Given the above evidence suggesting that older adults do have compromised inhibitory mechanisms, Kane, Hasher, Stoltzfus, Zacks, and Connelly (1994) designed a study to elicit distractor suppression in older adults. They manipulated a negative priming task in which familiar words served as both distractors and targets. List design was also altered to facilitate distractor suppression by adding conditions where the distractor was either repeated in the prime and the target trials or the target in the prime display became the distractor in the target trial. They found that while younger adults’ distractor suppression doubled, older adults’ suppression did not change. This effect was still present even when they increased the exposure duration of the stimuli for older adults. Therefore, it seems that the lack of distractor suppression in older adults is quite pervasive.

However, other evidence suggests that poor inhibition in older adults may be limited to certain types of tasks. Connelly and Hasher (1993) demonstrated that older
adults are capable of suppressing the location of distractors but not the identity of the
distractors. They found that both older and younger adults' reaction times were slowed
when the target of the current trial was presented in the same location as the distractor
from the previous trial. However, when the identity of the target was the same as the
distractor in the previous trial, only younger adults' times were slowed. Thus, the
inhibitory mechanisms responsible for preventing information from irrelevant locations
from being processed seems to be unaffected by age while the mechanisms responsible
for the inhibition of the identity of distractors appears to be compromised. Connelly and
Hasher proposed that inhibition is not dependent upon one system but that two visual
cortical inhibitory pathways, one ventral and one dorsal, exist and that only the dorsal
route is compromised with age. However, physiological evidence to support this view is
limited.

The frontal lobe model is a more popular explanation linking decreased inhibition
with changes in brain structure in old age. Dempster (1992) has suggested that the frontal
cortex plays a key role in inhibitory processes based on evidence that the frontal lobe is
the brain area most susceptible to normal aging (e.g., decreased brain weight, blood flow,
and cortical thickness to this area with age) and that patients with frontal lobe lesions
perform similar to older adults on many tasks measuring cognitive interference. Posner
(cited in Kramer, Humphrey, Larish, Logan, & Strayer, 1994) also proposed that frontal
lobe damage is responsible for inhibitory deficits in old age. He suggests that there are
two distinct attentional pathways in the brain: a posterior and anterior system. The
posterior system is responsible for orienting to an object based on its movement, shape,
color and location. Posner suggests it is possible to distinguish between relevant and irrelevant information based on these characteristics. The anterior pathway is composed mainly of regions within the frontal lobe and is responsible for processing semantic information and for processing and coordinating multiple streams of information. The decrease in inhibition tasks found with old age are more pronounced in tasks processed along the anterior pathways (frontal lobe) than the posterior pathway, suggesting frontal lobe damage does affect inhibition. Because the Stroop task relies heavily on the anterior pathway due to its semantic nature and its use of stimuli with multiple dimensions, the decrement in Stroop performance seen with age may well be a result of poorer inhibition due to diminished frontal lobe functioning.

Although there is a great deal of evidence for age-related changes in inhibitory processes, it is not entirely clear what role inhibition plays in older adults' performance on the Stroop task. Studies show that whereas Stroop interference is reduced with practice for young adults, this is not the case with older individuals. Dulaney and Rogers (1994) had older and younger adults practice naming the color of Stroop words and then compared subjects' performance on posttest trials to their performance on a pretest. Their results indicated that both older and younger adults showed a decrease in time taken to complete incongruent trials with practice. These results seemed to suggest that both older and younger adults were able to form a reading suppression response which inhibited reading with practice. To test whether older adults had formed this response, Dulaney and Rogers changed the pre- and posttest from naming the color of Stroop words to reading the words. It was hypothesized that if practice in naming colors of Stroop words
did lead to a reading suppression response, then this response should interfere with the posttest word reading task. Their results show that older adults quickly returned to their pretest reading rates within 3 blocks of trials while younger adults had not returned to their initial rates even after 11 blocks. Therefore, it seems that whereas younger adults’ increases in performance on the Stroop with practice were due to an increase in inhibitory mechanisms, older adults’ increased performance was not due to increased inhibitory mechanisms but to general task factors. However, the methodology used by Dulaney and Rogers does not provide a way to directly examine changes in inhibitory mechanisms, it only provides a way of assessing the length of the lingering effects of suppression.

**Process Dissociation in the Stroop Task**

In 1994, Lindsay and Jacoby published an article criticizing past research on the Stroop for not incorporating a “pure” control measure free from the effects of interference. They argued that even control conditions that incorporate the use of neutral symbols are not pure in that processing the symbol could produce some interference. Evidence that irrelevant stimuli, even neutral ones, are processed in the Stroop task comes from Keele (1972). He noted that although irrelevant stimuli may not interfere with the Stroop task, they are still processed and identified. In Keele’s experiment, neutral words (e.g., GLASS) and color words (e.g., GREEN) were printed in different ink colors. However, when subjects were asked to name the ink color, only GREEN caused noticeable interference. Keele attributed the interference to an automatic discrimination made by the subject as to the meanings of the two words. This discrimination could lead to interference. Lindsay and Jacoby therefore argue that past Stroop experiments
examining interference and facilitation based on differences in reaction time from control conditions are not providing pure estimates of the two processes.

Lindsay and Jacoby (1994) proposed a way to circumvent the above problem by mathematically estimating a “pure” measure of color naming from which the contribution of word reading can by eliminated. Once a pure measure of color naming is obtained, the facilitating or interfering effects of word reading can be estimated. Their approach is based on the Process Dissociation Procedure (PDP) developed by Jacoby (1991). The PDP assumes that both controlled and automatic processes independently contribute to performance. When the controlled and automatic processes lead to the same response, facilitation is seen and when they work in opposition interference is seen.

The Stroop task contains the conditions needed to use the Process Dissociation Procedure. It has an automatic process in word reading and a controlled process in color naming. It also contains conditions in which these two processes produce the same response (RED in red ink) for facilitation to occur and when they work in opposition (RED in blue ink) which leads to interference. By assuming that the word reading and color naming processes make independent contributions to the Stroop task, Lindsay and Jacoby (1994) developed two mathematical equations from which estimates of controlled color naming and automatic word reading can be derived. The first equation used to estimate the contribution of the two process in the Stroop task addresses the probability that a participant will respond correctly to a Stroop word in which the word and the color
name are incongruent. This equation assumes that the color naming process must be dominant in order for the subject to respond correctly. The equation is as follows:

\[ p(\text{correct/incongruent}) = \text{color} \times (1 - \text{word}) \]

where “p(\text{correct/incongruent})” is the proportion of incongruent trials on which the subject responded correctly and “\text{color} \times (1 - \text{word})” the contribution of the color naming process once the effects of word reading have been eliminated. The second equation addresses the probability that a subject will respond correctly to a Stroop word in which the word and color name are congruent. This equation assumes that either the word reading or the color naming process could produce the correct response. The equation is as follows:

\[ p(\text{correct/congruent}) = \text{word} + \text{color} \times (1 - \text{word}) \]

where “p(\text{correct/congruent})” is the proportion of congruent trials the subject responds to correctly, “\text{word}” the contribution of word reading, and “\text{color} \times (1 - \text{word})” the contribution of the color naming process after the influence of word reading has been removed. Once the proportion correct on congruent and incongruent trials is obtained, these values can be substituted into the equation and simple arithmetic can be performed to obtain estimates of the contribution of word reading and color naming to a subject’s performance (see Appendix for example).

The PDP thus provides a new way of assessing the contribution of controlled and automatic processes in the Stroop task. Lindsay and Jacoby (1994) have successfully used this method to examine the influence of the amount of practice on automatic word reading process in younger adults. They varied the probability of congruent (RED in red
ink) and incongruent (RED in blue ink) and found that younger subjects who experienced mostly incongruent trials were better able to inhibit automatic word reading with practice (e.g., their estimates of word reading decreased compared to control conditions) while leaving their estimates of the controlled color naming process unchanged.

In addition to the above research, Spieler, Balota, and Faust (1996) have also used the PDP to assess Stroop performance. They compared healthy young, young-old and old-old adults to those individuals with dementia of the Alzheimer’s type. Their results demonstrated that the increased interference seen in older adults performance was related to the increased word process estimates for this group compared to younger adults. The color estimates between the two age groups did not differ. This finding further suggests that the difficulty seen in older adults’ performance in the Stroop task is related to their decreased ability to inhibit irrelevant information.

Given the initial success of the PDP approach, it would be of interest to reexamine age differences in the Stroop using the PDP approach to more precisely establish whether or not inhibitory mechanisms are generally affected by adult aging and whether these mechanisms can be changed with practice.

Current Research

Two experiments were conducted. In the first, older and younger adults performed a modified version of the Stroop task with congruent, incongruent, and control items. The PDP method was used to assess what age differences, if any, there were in the estimates of controlled and automatic processes. To date, only one article (Spieler et al., 1996) has been published assessing the contributions of these processes in older adults.
using this technique. Using the PDP to obtain estimates for these processes allowed for a clearer examination of age differences in inhibition than has been provided in the past. It was hypothesized that (a) older adults would have larger Stroop interference scores (incongruent - control) than younger adults. With respect to the PDP estimates of controlled and automatic processes, it was hypothesized that (b) the controlled color naming process would make a similar contribution to Stroop performance for both older and younger adults. However, (c) there should be a difference in the contribution of the automatic word reading process between the groups with the older adults’ estimates being greater than the younger adults’ estimates. This finding would imply a decline in the ability to inhibit this process.

Measures of frontal lobe functioning (Wisconsin Card Sorting Task, FAS Verbal Fluency Task), working memory (Wechsler Adult Intelligence Scale - Revised [WAIS-R] Digit Span, Modified Version of Salthouse & Babcock’s Reading Span Task [cited in Earles et al., 1995]), and verbal intelligence (WAIS-R Vocabulary subtest) were collected in order to assess the relationship between these measures and Stroop inhibition measures. It was of interest to assess this relationship since the poor performance of older adults on measures of interference has been attributed to deficits in working memory due to declining inhibition with age (Hasher & Zacks, 1988). An alternative hypothesis is that the decline of inhibitory processes with age is a result of age related decrements in the frontal lobes (Dempster, 1992; Posner [cited in Kramer et al., 1994]). Correlations were obtained between these individual difference measures, Stroop interference scores, and Stroop estimates of color naming and word reading to assess how
frontal lobe functioning and working memory relate to Stroop interference. It was hypothesized that (d) poor performance on measures of frontal functioning and working memory would be related to increased Stroop interference and high estimates of word reading processes. However, based on past research (Rush, Panek & Russell, 1990), no relationship between verbal intelligence and Stroop performance was expected.

The second experiment examined age differences in the benefit of practice on the Stroop. Older and younger adults received practice with mostly congruent or mostly incongruent items to assess whether manipulating the probability of trial type would change older adults’ ability to inhibit automatic processes as readily as their younger counterparts. It was hypothesized that (a) measures of Stroop interference scores should be greater overall for older than younger adults and (b) that this difference should be largest in the mostly congruent list condition. It is also expected that (c) age would interact with list type in one of two ways: either the mostly incongruent condition would reduce the Stroop interference effect for the young but not for the old or this condition would reduce the effect for both groups but to a greater degree for young than old. As in the first experiment, (d) it was hypothesized that the estimates of color naming should not vary between older and younger adults. In addition, (e) estimates of color naming should not vary across list types. However, it was expected that, overall, (f) the word reading estimate should be larger in the mostly congruent list than the mostly incongruent list. (g) Estimates of word reading should differ between age groups with the older adults having higher estimates than their younger counterparts. Also, (h) it was expected that word reading estimates would be larger in the mostly congruent list than the mostly
incongruent one, but the difference should be larger for younger than older adults. As before, measures of frontal lobe functioning, working memory performance, and verbal intelligence were collected and correlated with Stroop interference scores and PDP estimates. The expected outcome of this procedure is the same as was mentioned in Experiment 1, hypothesis d.
Chapter 3
Experiment 1

Method

Participants

Fifteen younger (mean age = 20.9, SD = 2.64) and 15 older adults (mean age = 70, SD = 4.28) were recruited to participate in this study. Young participants were college students between the ages of 17 and 30 who volunteered in return for extra credit in their general psychology courses. Older participants were individuals age 60 and over, recruited from the community. These participants were paid a small stipend. All participants were given the Wisconsin Card Sorting Task (WCST), FAS Verbal Fluency Task, Reading Span Task, and the Digit Span and Vocabulary subtests of the WAIS-R. Data for the two age groups on these tests are presented in Table 1. Data for the WCST were not included due to experimenter error in administration of the task. Significant age differences between age groups on these tests were present only for the Reading Span Task and the Vocabulary test. Older adults performed more poorly on the Reading Span Task compared to younger adults, \( t(28) = 3.4, p = .002 \). However, older adults performed better on the Vocabulary task than did their younger counterparts, \( t(28) = -2.48, p = .019 \). Participants also completed a demographic questionnaire containing questions on age, exact years of education, and medications or diseases that may have affected cognitive functioning. Both groups were healthy as reported on the questionnaires.
Table 1

Mean Scores of Younger and Older Adults on Individual Differences Measures

<table>
<thead>
<tr>
<th>Task</th>
<th>Young M</th>
<th>Young SD</th>
<th>Old M</th>
<th>Old SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAS # Words</td>
<td>40.73</td>
<td>8.65</td>
<td>38.50</td>
<td>12.65</td>
</tr>
<tr>
<td>FAS # Errors</td>
<td>.60</td>
<td>1.30</td>
<td>1.93</td>
<td>2.09</td>
</tr>
<tr>
<td>Reading Span</td>
<td>6.93</td>
<td>1.67</td>
<td>4.73</td>
<td>1.87</td>
</tr>
<tr>
<td>Digit Span</td>
<td>15.07</td>
<td>3.35</td>
<td>15.07</td>
<td>4.40</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>44.33</td>
<td>10.43</td>
<td>52.60</td>
<td>7.58</td>
</tr>
<tr>
<td>Years of Education</td>
<td>14.20</td>
<td>1.86</td>
<td>15.00</td>
<td>2.07</td>
</tr>
</tbody>
</table>

Design

The study was a 2 x 3 mixed factorial design with age (older vs younger) and trial type (congruent, incongruent or control) as the independent variables. Age was a between subject variable and trial type was a within subject variable. The main dependent variables of this study were the time in ms to name the ink color of an item and the proportion of correct responses. The RT measure was used to determine Stroop interference scores while the accuracy measure was used in the PDP equations.
Materials

The experiment was performed using a Power Macintosh computer with a color monitor running MacLaboratory for Psychology version 3.0.2 software. Stimuli for the study were the words BLUE, GREEN, ORANGE, RED and YELLOW as well as a string of five percentage signs (%%%%%). On each trial, one of these items was presented in either blue, green, orange, red or yellow ink on a light gray background. Stimuli in which the word and the ink color were the same were presented in the congruent trials. Stimuli in which the word was printed in an ink color other than the color represented of the word stimulus were presented in the incongruent trials. Control trials consisted of a string of percentage signs printed in one of the five ink colors. Congruent, incongruent, and control items were presented in each of the possible colors equally often in each trial type condition. Therefore, each list consisted of four neutral items in each color, eight congruent items in each color, and eight incongruent items in each color.

Two presentation lists were developed for Experiment 1 with half of the subjects in each group randomly assigned to one list and half to the other. Each list contained 100 trials, 40 of these were congruent trials, 40 were incongruent trials, and 20 were control trials. Items were randomly assigned to list positions in each list with the stipulation that a color word name on the previous trial was not the same as the ink color of the item in the present trial. In addition, no ink color was presented twice in a row.

Procedure

Upon entering the laboratory, participants were asked to read and sign an Informed Consent form telling them of their rights as a participant in the study. They
were then asked to complete a demographic questionnaire which was followed by a screening for color blindness using Ishihara’s Test for Colour-Blindness (1994). One younger adult failed the color blindness test and was replaced. Participants were then seated in front of a computer and given instructions on how to perform the task. They first received 40 practice trials in order to familiarize them with the item presentation. The practice trials consisted of the same proportion of congruent and incongruent trials as the experimental list the participant received. After completing the practice trials, participants were then given the experimental trials.

In both the practice and experimental trials, the stimulus remained on the computer screen for a maximum duration of 1200 ms (or less if the individual responded before this time) for younger adults and 1500 ms maximum for older adults. Analyses of pilot data demonstrated that younger adults were able to respond to the majority of trials by 1000 ms and older adults were responding by 1200 ms. The above deadlines were chosen because the additional 200 - 300 ms ensured that the computer software would record the slowest responses. Participants were asked to name the color of the ink the items were printed in as quickly as possible. As soon as they vocalized their response for an item, the experimenter pressed a key on the keyboard that recorded the response time. In addition, each verbal response was recorded on audio tape for later examination of accuracy. To induce quick responding, if a response was not given within 775 ms for younger adults or 850 ms for older adults, an error tone sounded for 25 ms. At the 800 or 875 ms mark, the error tone ceased. After the participant's response had been recorded, they viewed a blank gray screen for 2000 ms after which the next trial began.
Results

All tests reported as significant both in this experiment and in Experiment 2 reached a criteria of \( p \leq .05 \).

Latency Analysis

Analyses performed on the latency and accuracy data in this study included assessment of age differences between RT for each of the three trial types, differences in facilitation (control - congruent) and interference (incongruent - control) scores, and differences in mean error rates. Reaction times for incorrect responses were not included in these analyses. Each participant’s RT data was examined for outliers. Reaction times falling three or more standard deviations above or below the mean were excluded from the data. This eliminated approximately 5% of the younger adults’ data and 2% of the older adults’ data. Mean response latencies for correct responses on congruent, incongruent, and control items were then computed for each participant. These data were calculated from the 40 congruent trials, the 40 incongruent trials, and the 20 control trials and are presented in Table 2. A 2 (age group) by 3 (trial type) mixed factors ANOVA for these data revealed a main effect of age group, \( F (1, 28) = 14.01, \text{MSE} = 17375.35 \), a main effect of trial type, \( F (2, 56) = 150.30, \text{MSE} = 870.88 \), and an Age Group x Trial Type interaction, \( F (2, 56) = 3.26, \text{MSE} = 870.88 \). Thus, on average, older adults responded more slowly than younger adults and across age groups, participants responded fastest to congruent items, followed by control and then by incongruent items. In addition, older adults responded differently to these items than did young adults.
Table 2

Mean Response Latencies (ms) as a Function of Group and Trial Type

<table>
<thead>
<tr>
<th>Condition</th>
<th>Young</th>
<th></th>
<th>Old</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Congruent</td>
<td>Incongruent</td>
<td>Control</td>
</tr>
<tr>
<td>Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>714</td>
<td>822</td>
<td>735</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>40</td>
<td>65</td>
<td>44</td>
</tr>
<tr>
<td>Old</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>797</td>
<td>944</td>
<td>842</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>104</td>
<td>109</td>
<td>88</td>
</tr>
<tr>
<td>M</td>
<td></td>
<td>756</td>
<td>883</td>
<td>789</td>
</tr>
</tbody>
</table>

Since facilitation (control - congruent) and interference (incongruent - control) measures were of primary interest in this study, separate one-way ANOVAs for age group were performed on each of these measures. The facilitation analysis revealed a main effect of age group, $F(1, 28) = 4.83, \text{MSE} = 1004.12$, indicating that the older adults benefitted more from congruent color-word stimuli. The interference analysis also produced a main effect of age group, $F(1, 28) = 4.37, \text{MSE} = 2546.96$, with the older
adults experiencing more interference from incongruent color-word stimuli than their younger counterparts.

Incorrect responses were analyzed separately for the control and incongruent trial conditions. Mean error rates for the 15 participants each age group were computed and are presented in Table 3. Because of the low error rates on the congruent items, they were not included in these analyses. A 2 (age group) x 2 (trial type) mixed factors ANOVA was performed on arcsine-transformed error rates. This analysis revealed a main effect of age group, $F (1,28) = 6.90$, $MSE = .01$, with younger adults having fewer errors than their older counterparts, a main effect of trial type, $F (1,28) = 62.17$, $MSE = .00$, with the incongruent items producing more errors than the controls, and an Age Group x Trial Type interaction, $F (1,28) = 7.37$, $MSE = .00$.

The Age Group x Trial Type interaction was examined by separate between-subjects ANOVAs for each trial type. This analysis revealed a main effect of age group, $F (1,28) = 7.93$, $MSE = .013$, in the incongruent trial type and no difference between the age groups in the control trials, $F (1, 28) = 1.77$, $MSE = .002$. These findings show that the older adults produced more errors than the younger adults, but this effect was present in the incongruent trial types only.
Table 3

Error Rates as a Function of Age Group

<table>
<thead>
<tr>
<th>Group</th>
<th>Condition</th>
<th>Congruent</th>
<th>Incongruent</th>
<th>Control</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td></td>
<td>.01</td>
<td>.11</td>
<td>.02</td>
<td>.05</td>
</tr>
<tr>
<td>M</td>
<td></td>
<td>.01</td>
<td>.08</td>
<td>.03</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td>.02</td>
<td>.13</td>
<td>.06</td>
<td></td>
</tr>
<tr>
<td>Old</td>
<td></td>
<td>.01</td>
<td>.17</td>
<td>.03</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td></td>
<td>.01</td>
<td>.17</td>
<td>.03</td>
<td></td>
</tr>
</tbody>
</table>

Process Dissociation Analysis

Response latencies were used to determine posthoc millisecond and z-score deadlines for each participant. Estimates of color naming process and word reading process were obtained using the PDP formulas given in the Appendix. Briefly, for each participant in each condition, the proportion correct at a given deadline was computed by dividing the number of correct responses at or below that deadline by the total number of possible trials for that condition in the list.
The data for the millisecond deadlines are presented in Figure 1. Estimates for deadlines below 700 ms could not be computed due to lack of responses by both age groups below this deadline. Likewise, estimates for deadlines above 1300 ms could not be computed due to ceiling effects. The figure suggests that as response time increases, the color naming process exerts a greater influence over the task than the word reading process for both age groups. In addition, it can be seen that older adults produced higher word process estimates than the younger adults but that the color process estimates for the two age groups do not differ. However, analyses were not performed on these data because of differences in RT both within individuals and age group. Instead, to control for overall speed differences between age groups and between individuals, z-score deadlines were computed for each participant using that individual's mean response latency collapsed across trial types. Process dissociation estimates were then derived for each of these deadlines (e.g., Spieler et al., 1996). These data are displayed in Figure 2 and the proportion of congruent and incongruent trials at each of the response deadlines are presented in Table 4.
MILLISECOND COLOR AND WORD ESTIMATES
EXPERIMENT 1

ESTIMATES

MS DEADLINES

- WORD OLD
- WORD YOUNG
- COLOR OLD
- COLOR YOUNG
Z-SCORE COLOR AND WORD ESTIMATES
EXPERIMENT 1

Z SCORE DEADLINES

ESTIMATES

-1.5 -1.0 -0.5 0.0 0.5 1.0 1.5

WORD OLD
WORD YOUNG
COLOR OLD
COLOR YOUNG
Table 4

Proportion of Congruent and Incongruent Trial Types at Each Z-Score Deadline

<table>
<thead>
<tr>
<th>Z-score Deadline</th>
<th>Group</th>
<th>-1</th>
<th>-.5</th>
<th>0</th>
<th>.5</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>Congruent Trials</td>
<td>.25</td>
<td>.54</td>
<td>.72</td>
<td>.80</td>
<td>.85</td>
</tr>
<tr>
<td></td>
<td>Incongruent Trials</td>
<td>.06</td>
<td>.13</td>
<td>.29</td>
<td>.49</td>
<td>.64</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>.16</td>
<td>.33</td>
<td>.51</td>
<td>.64</td>
<td>.75</td>
</tr>
<tr>
<td>Old</td>
<td>Congruent Trials</td>
<td>.27</td>
<td>.61</td>
<td>.77</td>
<td>.87</td>
<td>.92</td>
</tr>
<tr>
<td></td>
<td>Incongruent Trials</td>
<td>.07</td>
<td>.15</td>
<td>.23</td>
<td>.44</td>
<td>.66</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>.17</td>
<td>.38</td>
<td>.50</td>
<td>.64</td>
<td>.79</td>
</tr>
</tbody>
</table>

The process dissociation estimates were submitted to a 2 (age group) x 2 (process) x 5 (deadline) mixed factors ANOVA. This analysis revealed a main effect of deadline, $F(4, 104) = 228.68, MSE = .01$, indicating that the estimates were generally greater at the later deadlines for both age groups. Although there were no significant main effects of age group, $F(1, 26) = 1.08, MSE = .06$, or of process, $F(1, 26) = .30, MSE = .03$, the Age Group x Process interaction was significant, $F(1, 26) = 8.16, MSE = .03$, as was the
Deadline x Process interaction, $F (4, 104) = 222.92$, $\text{MSE} = .01$. In addition, the Age Group x Process x Deadline interaction was significant, $F (4, 104) = 4.62$, $\text{MSE} = .03$.

To further analyze the Age Group x Process x Deadline interaction, separate 2 (age group) x 5 (deadline) mixed factors ANOVAs were performed on estimates for each process. These data are shown in Figures 3 and 4. The analysis for the color process estimates revealed a main effect of deadline, $F (4, 104) = 388.81$, $\text{MSE} = .01$, but there was no effect of age, $F (1, 26) = .69$, $\text{MSE} = .04$, nor was there an Age x Deadline interaction, $F (4, 104) = 1.39$, $\text{MSE} = .01$. Thus, color estimates were higher at the later deadlines for both the younger and older adults and there was no difference in the color estimates for the two groups.

The word process analysis, however, revealed a main effect of age group, $F (1, 26) = 5.55$, $\text{MSE} = .05$, indicating that the older adults had higher word process estimates than did the younger adults. There was also a main effect of deadline, $F (4, 104) = 58.66$, $\text{MSE} = .01$, with word process estimates increasing across the longer deadlines. Finally, there was an Age Group x Deadline interaction, $F (4, 104) = 3.92$, $\text{MSE} = .01$. This interaction was examined by separate one-way ANOVAs for each deadline. These analyses revealed no effects of age x deadline, $F (1, 26) = .271$, $\text{MSE} = .01$, or at the -.5 deadline, $F (1, 26) = 1.61$, $\text{MSE} = .02$. A main effect of age was found at the 0 deadline, $F (1, 26) = 6.026$, $\text{MSE} = .02$, and the .5 deadline, $F (1, 26) = 9.16$, $\text{MSE} = .02$, but not at the 1 deadline, $F (1, 26) = 3.51$, $\text{MSE} = .02$. Thus the word estimates are similar for the two age groups at the earliest deadlines, diverge at the later deadlines, then begin to converge again.
Z-SCORE COLOR PROCESS ESTIMATES
EXPERIMENT 1

Z-Score Deadlines

Estimates

COLOR OLD
COLOR YOUNG
Correlational Measures

Measures of frontal lobe functioning (Wisconsin Card Sorting Task, FAS Verbal Fluency Task), working memory (Wechsler Adult Intelligence Scale - Revised [WAIS-R] Digit Span, Modified Version of Salthouse & Babcock's Reading Span Task (cited in Earles et al., 1995), and verbal intelligence (WAIS-R Vocabulary subtest) were collected in order to assess the relationship between these measures and Stroop inhibition measures. The results of the Wisconsin Card Sorting Task are not reported due to experimenter error in administering the task.

As can be seen in Table 5, for the 15 younger adults there was a significant relationship between the number of errors produced on the FAS task and the facilitation scores indicating that those subjects who produced the most errors on the FAS task also had higher facilitation scores. A relationship between FAS number of errors and the color process dissociation estimate was also present, with higher errors on the FAS associated with higher color estimates. However, there was no relationship between the working memory measures (Reading Span and Digit Span) and any of the facilitation, interference, or process dissociation measures. Finally, there was a relationship between interference scores and the process dissociation estimate for the word process, indicating that those participants who had the higher interference scores were poorer at ignoring the word meaning. This relationship provides evidence that the PD word estimate is measuring interference.
Table 5

**Correlations Between Individual Difference Measures and Measures of Interference and Facilitation for Younger Adults**

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAS # Words (1)</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
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<tr>
<td>FAS # Errors. (2)</td>
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<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
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<td>--------</td>
</tr>
<tr>
<td>Reading Span (3)</td>
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<td>-0.3799</td>
<td>--------</td>
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<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>Digit Span (4)</td>
<td>-0.1195</td>
<td>-0.2000</td>
<td>0.1540</td>
<td>--------</td>
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<td>--------</td>
</tr>
<tr>
<td>Vocabulary (5)</td>
<td>0.7245**</td>
<td>0.0062</td>
<td>0.4984</td>
<td>0.1129</td>
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<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>Interference (6)</td>
<td>0.2192</td>
<td>0.2023</td>
<td>-0.4109</td>
<td>-0.4282</td>
<td>0.0720</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>Facilitation (7)</td>
<td>-0.1204</td>
<td>0.7645**</td>
<td>-0.3514</td>
<td>-0.1770</td>
<td>-0.0831</td>
<td>0.2979</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>PD Word (8)</td>
<td>0.2460</td>
<td>0.2889</td>
<td>-0.3510</td>
<td>-0.1563</td>
<td>0.0359</td>
<td>0.7810**</td>
<td>0.3811</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>PD Color (9)</td>
<td>0.0438</td>
<td>0.7477**</td>
<td>-0.1589</td>
<td>0.0999</td>
<td>-0.1030</td>
<td>0.0533</td>
<td>0.4330</td>
<td>0.1283</td>
<td>--------</td>
</tr>
</tbody>
</table>


** = p < .01.  

** = p < .01.
As can be seen in Table 6, for the 15 older adults there were no relationships between measures of frontal lobe functioning and measures of interference, facilitation, or the process dissociation estimates. There were no significant correlations between the working memory tasks and these measures either. There was a significant relationship between the interference scores and the word estimates for the process dissociation procedure for the older adults, thus suggesting that the word estimate is measuring interference. Finally, there were correlations between facilitation scores and both color and word process dissociation estimates for the older adults, indicating that those individuals who had greater facilitation scores also had higher process dissociation estimates.
Table 6

Correlations Between Individual Difference Measures and Measures of Interference and Facilitation for Older Adults

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAS # Words (1)</td>
<td></td>
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<td></td>
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<tr>
<td>FAS # Errors (2)</td>
<td>.4600</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reading Span (3)</td>
<td>.3085</td>
<td>.0531</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digit Span (4)</td>
<td>.5466*</td>
<td>.1336</td>
<td>.5495*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vocabulary (5)</td>
<td>.2191</td>
<td>-.1467</td>
<td>.1634</td>
<td>.5538*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interference (6)</td>
<td>-.2497</td>
<td>.0132</td>
<td>-.2516</td>
<td>.0687</td>
<td>.1056</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Facilitation (7)</td>
<td>-.3423</td>
<td>-.2536</td>
<td>-.2477</td>
<td>-.0215</td>
<td>-.1857</td>
<td>.6825**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PD Word (8)</td>
<td>-.1379</td>
<td>.1200</td>
<td>-.1792</td>
<td>.0810</td>
<td>.0334</td>
<td>.9404**</td>
<td>.6730**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PD Color (9)</td>
<td>-.3454</td>
<td>-.3208</td>
<td>-.3619</td>
<td>-.1036</td>
<td>-.3847</td>
<td>.4139</td>
<td>.7485**</td>
<td>.3803</td>
<td></td>
</tr>
</tbody>
</table>


* = p < .05. ** = p < .01.
Discussion

The results of this study show that older adults experienced greater facilitation (control - congruent) and greater interference (incongruent - control) than the younger adults, suggesting that word meaning affected the performance of older adults to a greater extent than it did that of the young adults. Because of this reliance, when the color of the item matched the meaning of the word, the older adults' performance greatly benefitted from the word meaning. However, this reliance on word meaning also hurt the older adults when the color of the item and the meaning of the word did not match. With that occurrence, they experienced more interference than the younger adults. The reliance of the older adults on word meaning can also be seen in the error data. Compared to younger adults, the older adults had higher error rates on incongruent items where the meaning of the word and the color of the item did not match, again suggesting that the older adults were not able to ignore the meaning of the word as readily as their younger counterparts.

The idea that older adults were less able to ignore the meaning of the words was also supported by the results from the process dissociation procedure. There were no age differences for the color process estimates across the z-score deadlines and for both young and older adults, the influence of the ink color increased across the five deadlines. However, there was an age difference in word process estimates at the 0 and .5 deadlines, with the older adults having higher estimates than the younger. The indication is that word reading contributed more to the older adults' responding at these deadlines than it did in the responses of the younger adults. The age differences in interference declined at
the latest deadline, which suggests that older adults do overcome the word name interference but that it takes them somewhat longer to do so. This age difference can also be seen in Figure 2 where for the young adults color and word process estimates are equal at the 0 deadlines, but for the old adults the word and color process estimates are not equal until the .5 deadline.

The correlational data show that there is a relationship between the interference scores and the word estimates given by the PDP for both the older and younger adults. In addition, for the older adults, there was a relationship between facilitation measures and word estimates. This finding provides additional support for the idea that older adults are experiencing more interference and facilitation due to their added reliance on word meaning. However, there were no relationships between interference measures and measures of frontal lobe and working memory for older adults in the present study. These data are not consistent with the idea that the decreases in inhibition for older adults are due to a decline in working memory or impaired frontal lobe functioning. However, due to the low sample size used in this study, these results should be viewed with caution.

In summary, the hypothesis that older adults would experience more interference than younger adults was upheld by the latency analysis, the error analysis, and the PDP analysis. The controlled color naming process made similar contributions to Stroop performance in both older and younger adults. In contrast, the automatic word reading process was higher for the older adults than for the younger adults, implying that older adults’ have a decline in their ability to inhibit this process. Finally, the hypothesis that poor performance on measures of frontal functioning and working memory would be
related to increased Stroop interference and high estimates of word reading processes was not supported by the data.
Chapter 4

Experiment 2

Given the success of the PDP procedure in Experiment 1, and the age differences in the ability to inhibit the automatic word reading process, it was of interest to see if practice with incongruent items would enable older adults to better inhibit the word reading process. An earlier study by Dulaney and Rogers (1994) suggested that older adults would benefit less from practice; however, this study had no direct way of assessing inhibitory processes. Dulaney and Rogers had older and younger adults practice naming the color of Stroop words and then compared their subjects’ performance first on ink naming and then compared their performance on word reading in posttest trials to their performance on a pretest to assess inhibitory skills. Although both younger and older adults showed improved performance on ink color naming with practice, the older adults returned to their pretest word reading rates more quickly. Therefore, it was assumed that older adults’ enhanced performance for ink naming was not due to increased ability to inhibit word meaning but to "general task factors." However, the methodology used by Dulaney and Rogers did not provide a way to directly examine changes in inhibitory mechanisms. Thus, it was of interest to reassess this issue using the PDP to provide a clearer view of how practice affects the ability to inhibit word meaning.
Method

Participants

Twenty four younger adults between the ages of 17 and 30 (mean age = 23, SD = 3.36) and 24 older adults age 60 and above (mean age = 69.4, SD = 4.54) were recruited to participate in this study. Younger participants were college students who volunteered in return for extra credit in their general psychology courses. Older adults were individuals recruited from the community and were paid for their participation. As in Experiment 1, all participants were given the Wisconsin Card Sorting Task (WCST), FAS Verbal Fluency Task, Reading Span Task, and the Digit Span and Vocabulary subtests of the WAIS-R. Mean scores on these tests for the 12 participants in each age group and list type are presented in Table 7. The data in Table 7 was examined in a 2 (age group) by 2 (list type) MANOVA, the results of which demonstrate a main effect of age group, $F (7, 38) = 2.99, p = .013$, but no effects of list type, $F (7, 38) = .855, p = .55$, and no Age Group x List Type interaction, $F (7, 38) = .527, p = .808$. Univariate tests of the age effect indicated that younger adults performed better on the Digit Span Task, than did older adults, $F (1, 44) = 4.57, MSE = 17.53, p = .038$, and also generated more words on the FAS Verbal Fluency task, $F (1, 44) = 6.63, MSE = 90.85, p = .013$, than did the older participants. As in Experiment 1, the younger adults also performed better on the Reading Span Task than did the older adults, $F (1, 44) = 7.51, MSE = 5.87, p = .009$. Finally, there was a marginal age difference in favor of the older adults on the Vocabulary task, $F (1, 44) = 3.81, MSE = 89.51, p = .06$. Participants also completed a demographic questionnaire containing questions on age, exact years of education, and
medications or diseases that may have affected cognitive functioning. Both groups were healthy as reported on the questionnaires.

Table 7

Mean Scores of Younger and Older Adults on Individual Differences Measures as a Function of List Type

<table>
<thead>
<tr>
<th>Task</th>
<th>Mostly Congruent</th>
<th>Mostly Incongruent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Young</td>
<td>Old</td>
</tr>
<tr>
<td>WCST Categories</td>
<td>5.25 1.60</td>
<td>4.75 1.91</td>
</tr>
<tr>
<td>FAS # Words</td>
<td>43.92 8.98</td>
<td>33.67 10.28</td>
</tr>
<tr>
<td>FAS # Errors</td>
<td>.92 1.31</td>
<td>1.50 1.62</td>
</tr>
<tr>
<td>Reading Span</td>
<td>6.50 2.47</td>
<td>5.00 2.13</td>
</tr>
<tr>
<td>Digit Span</td>
<td>16.33 5.12</td>
<td>14.42 3.48</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>46.75 8.67</td>
<td>54.08 8.11</td>
</tr>
</tbody>
</table>
Design

The design of this experiment was a 2 x 2 x 3 mixed factorial with age (older vs younger), list type (mostly congruent vs mostly incongruent) and trial type (congruent, incongruent or control) as the independent variables. Age and list type were between subject variables, and trial type was a within subject variable. Twelve subjects from each age group were randomly assigned to the mostly congruent list type condition and the mostly incongruent list type condition. As in the first study, the main dependent variables for this study were the time in milliseconds to name the ink color of an item and the proportion of correct responses. The RT measures were again used to determine Stroop facilitation and interference scores while the accuracy measures were used in the PDP equations.

Materials

Congruent, incongruent, and control stimuli for this study were identical to those used in the first experiment. Two mostly congruent and two mostly incongruent presentation list types were developed for Experiment 2. Each list consisted of 140 trials. In the mostly congruent list, 100 trials were congruent, 20 trials were incongruent, and 20 trials were control. In the mostly incongruent lists 100 were incongruent trials, 20 were congruent trials, and 20 trials were control. Items were again presented in each of the possible colors equally often in each trial type condition. Therefore, in the mostly congruent list there were 4 neutral items in each color, 4 incongruent items in each color, and 20 congruent items in each color and in the mostly incongruent condition there were 4 neutral items in each color, 4 congruent items in each color, and 20 incongruent items
in each color. The items in each list were again assigned in random order with the same restrictions as in the first experiment. Half of the subjects in each group were assigned to one list and half received the other list.

Procedure

The procedure for this experiment was identical to that of Experiment 1.

Results

Latency Analysis

Analyses performed on both the latency and accuracy data in this study were similar to those performed in Experiment 1. Mean response latencies for correct responses on congruent, incongruent, and control items were computed after excluding responses three or more standard deviations above or below the mean. This procedure eliminated 3% of the data for the older adults and 6% of the data for the younger adults across list types. Table 8 presents these data. The data for the participants in the mostly congruent condition were calculated from 100 congruent items, 20 incongruent items, and 20 control items. The data for the participants in the mostly incongruent condition were calculated from 100 incongruent items, 20 congruent items, and 20 control items. A 2 (age group) by 2 (list type) by 3 (trial type) mixed factors ANOVA demonstrated a main effect of age group, $F(1, 44) = 41.01$, $MSE = 14019.83$, indicating that the older adults responded slower than the younger adults, a main effect of trial type, $F(2, 88) = 186.04$, $MSE = 1249.33$, with the incongruent trial type producing the slowest reaction times, an Age Group x Trial Type interaction, $F(2, 88) = 12.67$, $MSE = 1249.33$, and a List Type x Trial Type interaction, $F(2, 88) = 23.83$, $MSE = 1249.33$. There was no main effect of
list type, $F(1, 44) = 1.46$, MSE = 14019.83, no Age Group x List Type interaction, $F(1, 44) = .25$, MSE = 14019.83, and no Age Group x List Type x Trial Type interaction, $F(2, 88) = 1.01$, MSE = 1249.33.

Because facilitation (control - congruent) and interference (incongruent - control) measures are of primary interest, separate 2 (age group) by 2 (list type) ANOVAs were performed for each of these measures. The facilitation analysis revealed main effects of age group, $F(1, 44) = 8.78$, MSE = 1704.45, and of list type, $F(1, 44) = 8.90$, MSE = 1704.45, but no Age Group x List Type interaction, $F(1, 44) = .264$, MSE = 1704.45. Overall, older adults had more facilitation than the younger adults and the mostly congruent list produced greater facilitation effects than the mostly incongruent list. The interference analysis also revealed a main effect of age group, $F(1, 44) = 9.49$, MSE = 2381.77, and a main effect of list type, $F(1, 44) = 6.33$, MSE = 2381.77, but no Age Group x List Type interaction, $F(1, 44) = .291$, MSE = 2381.77, indicating that the older adults experienced more interference than the younger adults and that the mostly congruent list produced the most interference. These results are similar to those of Experiment 1 in showing that word naming had a greater effect on older adults’ performance. In addition, practice with the incongruent items improved performance, and older adults benefitted from practice just as much as the younger adults did.
## Table 8

**Mean Response Latencies (ms) as a Function of Age Group, List Type, and Trial Type**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Group</th>
<th>Congruent</th>
<th>Incongruent</th>
<th>Control</th>
<th>Facilitation</th>
<th>Interference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mostly Congruent</td>
<td>Young</td>
<td>M</td>
<td>679</td>
<td>818</td>
<td>733</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>23</td>
<td>75</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Old</td>
<td>M</td>
<td>751</td>
<td>982</td>
<td>847</td>
<td>96</td>
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<tr>
<td></td>
<td></td>
<td>SD</td>
<td>69</td>
<td>90</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>715</td>
<td>900</td>
<td>790</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mostly Incongruent</td>
<td>Young</td>
<td>M</td>
<td>735</td>
<td>797</td>
<td>740</td>
<td>05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>51</td>
<td>60</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Old</td>
<td>M</td>
<td>849</td>
<td>962</td>
<td>870</td>
<td>21</td>
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<tr>
<td></td>
<td></td>
<td>SD</td>
<td>114</td>
<td>104</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>792</td>
<td>880</td>
<td>805</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In addition to the above analyses, mean error rates for the 12 participants in each age group and list type were computed for the incongruent and control trials. These are presented in Table 9. As in Experiment 1, the data from the congruent items was not included in the subsequent analyses due to the very low error rates on these items. The remaining data were subjected to a 2 (age group) by 2 (list type) by 2 (trial type) mixed factors ANOVA. There was no main effect of age group, $F(1, 44) = .56$, $MSE = .02$, indicating that the younger adults had as many errors as the older adults. There was a main effect of list type, $F(1, 44) = 25.54$, $MSE = .02$, and a main effect of trial type, $F(1, 44) = 72.41$, $MSE = .02$, demonstrating that more errors were made with the mostly congruent list than with the mostly incongruent list and that more errors were made for the incongruent items than the control items. There was also a list type by trial type interaction, $F(1, 44) = 35.32$, $p < .000$, $MSE = .02$, but the Age Group x List Type, $F(1, 44) = .19$, $MSE = .02$, Age Group x Trial Type, $F(1, 44) = .05$, $MSE = .02$, and Age Group x List Type x Trial Type interactions, $F(1, 44) = .94$, $MSE = .02$, were not significant.

The List Type x Trial Type interaction was further assessed by separate one-way ANOVAs for list type under each trial type. These analyses revealed a main effect of list type, $F(1, 46) = 32.69$, $MSE = .04$, in the incongruent trials but not in the control trials, $F(1, 46) = 1.345$, $MSE = .00$, indicating that the mostly congruent list produced more errors than the mostly incongruent list for the incongruent items, but that error rates were similar for control items.
Table 9  
Error Rates as a Function of Age Group and List Type

<table>
<thead>
<tr>
<th>Group</th>
<th>Condition</th>
<th>Congruent</th>
<th>Incongruent</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mostly Congruent</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>.01</td>
<td>.41</td>
<td>.00</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>.01</td>
<td>.22</td>
<td>.02</td>
<td></td>
</tr>
<tr>
<td>Old</td>
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<td></td>
</tr>
<tr>
<td>M</td>
<td>.00</td>
<td>.41</td>
<td>.04</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>.00</td>
<td>.23</td>
<td>.06</td>
<td></td>
</tr>
<tr>
<td>Mostly Incongruent</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>.03</td>
<td>.08</td>
<td>.04</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>.05</td>
<td>.04</td>
<td>.05</td>
<td></td>
</tr>
<tr>
<td>Old</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>M</td>
<td>.01</td>
<td>.15</td>
<td>.04</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>.02</td>
<td>.11</td>
<td>.05</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>.02</td>
<td>.12</td>
<td>.04</td>
<td></td>
</tr>
</tbody>
</table>
Process Dissociation Analysis

As described in Experiment 1, each participants’ response latencies were used to determine post hoc millisecond and z-score deadlines and estimates of color naming and word reading processes for each of these deadlines were then obtained.

Data for the millisecond deadlines are presented in Figure 5 for the mostly congruent list and in Figure 6 for the mostly incongruent list. Once again, estimates below 700 ms could not be computed due to lack of responses by both age groups below this deadline. In addition, estimates below 800 ms for the older adults in the mostly incongruent list could not be computed due to lack of responding at this deadline. Estimates above 1300 ms could not be computed due to ceiling effects. Estimates for both the mostly congruent and the mostly incongruent lists show a pattern of responding somewhat similar to that seen in Experiment 1 (see Figure 1), i.e., for both age groups as the deadline increases the color naming process exerts a greater influence over the task than the word reading process. However, the color naming influence appears to be delayed in the mostly congruent list (see Figure 5) relative to that in Experiment 1 and in the mostly incongruent list, perhaps due to the fact that the faster word process can produce the correct response in this list and there is little or no need to inhibit this process in the majority of trials. However, estimates for the mostly incongruent list (see Figure 6) display a different pattern of responding. For both age groups in the mostly incongruent list, the dominance of color naming over the word reading process is clearly seen at early deadlines suggesting that with practice the color naming process may occur earlier.
MILLISECOND COLOR AND WORD ESTIMATES
MOSTLY CONGRUENT LIST - EXPERIMENT 2

ESTIMATES

MS DEADLINES

WORD OLD
WORD YOUNG
COLOR OLD
COLOR YOUNG
MILLISECOND COLOR AND WORD ESTIMATES
MOSTLY INCONGRUENT LIST - EXPERIMENT 2

- WORD OLD
- WORD YOUNG
- COLOR OLD
- COLOR YOUNG

MS DEADLINES
As in the first experiment, to control for overall speed differences between age groups and between individuals within the age groups, analyses were performed using z-score deadlines rather than ms deadlines. These data are displayed in Figure 7 for the mostly congruent list and in Figure 8 for the mostly incongruent list. In addition, the percent of congruent and incongruent trials for each list type at each of the z-score deadlines in presented in Table 10. These estimates were submitted to a 2 (age group) x 2 (list type) x 2 (process) x 4 (deadline) mixed factors ANOVA. Data for the -1 z-score deadline were not included in the analyses because six of the younger and seven of the older adults in the mostly congruent condition had no data at this deadline. Age group (young vs. old) and list type (mostly congruent vs. mostly incongruent) served as between subjects factors and process (color vs. word) and deadline (-.5, 0, .5 and 1) served as within subjects factors. This analysis revealed a main effect of age group, $F(1, 42) = 25.99, \text{MSE} = .05$, indicating that the older adults had higher overall estimates than the younger adults. There was also a main effect of list type, $F(1, 42) = 13.78, \text{MSE} = .05$, with the incongruent list producing higher estimates on average than the mostly congruent list. A main effect of process was also present, $F(1, 42) = 234.27, \text{MSE} = .01$, indicating that the color process estimates were higher across the two conditions than the word process estimates. Finally, there was also a main effect of deadline, $F(3, 126) = 20.06, \text{MSE} = .02$, with the estimates becoming higher as the deadline increased. However, these main effects were qualified by several significant interactions. The List Type x Process interaction was significant, $F(1, 42) = 24.05, \text{MSE} = .01$, as was the Age Group x Process interaction, $F(1, 42) = 9.81, \text{MSE} = .01$. In addition, the List Type x
Z-SCORE COLOR AND WORD ESTIMATES
MOSTLY CONGRUENT LIST - EXPERIMENT 2

Z-SCORE DEADLINES

ESTIMATES

Z-SCORE DEADLINES

WORD OLD
WORD YOUNG
COLOR OLD
COLOR YOUNG
Z-SCORE COLOR AND WORD ESTIMATES
MOSTLY INCONGRUENT LIST - EXPERIMENT 2

Z SCORE DEADLINE

ESTIMATES

-1.5 -1.0 -0.5 0.0 0.5 1.0 1.5

WORD OLD
WORD YOUNG
COLOR OLD
COLOR YOUNG
Table 10

**Proportion of Congruent and Incongruent Trials at Each Z-Score Deadline as a Function of Age and List Type**

<table>
<thead>
<tr>
<th></th>
<th>Mostly Congruent List</th>
<th>Mostly Incongruent List</th>
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<tbody>
<tr>
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<td>.56</td>
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<tr>
<td>Incongruent</td>
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<td>Total</td>
<td>.38</td>
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Deadline, $F(3, 126) = 189.39$, $MSE = .02$, Age Group x Deadline, $F(3, 126) = 6.28$, $MSE = .02$, Process x Deadline, $F(3, 126) = 103.58$, $MSE = .01$, and List Type x Process x Deadline, $F(3, 126) = 52.49$, $MSE = .01$, interactions were all significant. The List Type x Age Group, $F(1, 42) = .45$, $MSE = .02$, List Type x Age Group x Process, $F(1, 42) = .79$, $MSE = .01$, List Type x Age Group x Deadline, $F(3, 126) = .32$, $MSE = .02$, Age Group x Process x Deadline, $F(3, 126) = 2.44$, $MSE = .01$, and List Type x Age Group x Process x Deadline interactions, $F(3, 126) = .64$, $MSE = .01$, were not significant.

The Age Group x Process interaction was further analyzed by separate one-way ANOVAs for age group for the color and the word process estimates. These analyses revealed a main effect of age group for the word process estimates, $F(1, 44) = 9.90$, $MSE = .03$, but no effect of age group for the color process estimates, $F(1, 44) = 1.58$, $MSE = .05$. Thus, there were no age differences in the contribution of the color process to the Stroop task, but the word process made a greater contribution to the performance of the older adults compared to the younger adults. This finding is similar to that of Experiment 1.

The Age Group x Deadline interaction, though not particularly interesting, was also analyzed by performing one-way ANOVAs of age group at each of the response deadlines. These analyses revealed no effects of age group at the -.5 deadline, $F(1, 44) = 3.66$, $MSE = .01$, but main effects at the 0 deadline, $F(1, 44) = 14.01$, $MSE = .01$, the .5 deadline, $F(1, 44) = 23.328$, $MSE = .01$, and the 1 deadline, $F(1, 44) = 35.513$, $MSE =$
.01, indicating that at the zero deadline and above, older adults had higher estimates compared to their younger counterparts.

The three way List Type x Estimate x Deadline interaction was first analyzed by separate 2 (process) by 4 (deadline) repeated measures ANOVAs for each list type condition. For the mostly congruent list, there was a main effect of process, $F(1, 21) = 158.17$, $MSE = .01$, a main effect of deadline, $F(3, 63) = 56.15$, $MSE = .03$, and a Process x Deadline interaction, $F(3, 63) = 9.88$, $MSE = .01$. The Process x Deadline interaction in the mostly congruent list was further evaluated by separate one-way ANOVAs of process estimates at each of the deadlines. These analyses revealed main effects of process estimates at the -.5 deadline, $F(1, 21) = 96.56$, $MSE = .01$, the 0 deadline, $F(1, 21) = 58.45$, $MSE = .03$, the .5 deadline, $F(1, 21) = 36.86$, $MSE = .04$, and the 1 deadline, $F(1, 21) = 13.25$, $MSE = .03$. The interaction was due to the fact that the differences in the color and word process estimates were larger at the earlier deadlines than at the later deadlines.

The 2 (process) by 4 (deadline) analysis of the mostly incongruent list revealed main effects of process, $F(1, 23) = 48.04$, $MSE = .01$, and of deadline, $F(3, 69) = 191.55$, $MSE = .01$, as well as a Process x Deadline interaction, $F(3, 69) = 222.62$, $MSE = .01$. The Process x Deadline interaction for the mostly incongruent list was further analyzed in separate repeated measures ANOVAs of the estimates at each of the four deadlines. These analyses revealed no effects of process at the -.5 deadline, $F(1, 23) = 2.61$, $MSE = .02$, but a main effect at the 0 deadline, $F(1, 23) = 74.84$, $MSE = .01$, the .5 deadline, $F(1, 23) = 476.93$, $MSE = .01$, and the 1 deadline, $F(1, 23) = 1627.88$, $MSE = .01$.
Figure 8 demonstrates these results by showing a divergence of the color and word estimates at the zero deadline and beyond. These results are different from those seen in the mostly congruent list in that in the mostly congruent list the word reading process was higher than the color naming process at every deadline, whereas in the mostly incongruent list the color naming process was higher than the word reading process at the zero deadline and beyond. For both age groups in the mostly incongruent list, the dominance of color naming over the word reading process is clearly seen at early deadlines suggesting that with practice the color naming process may occur earlier.

The List Type x Estimate x Deadline interaction was also analyzed by separate 2 (list type) by 4 (deadline) repeated measures ANOVAs for each process estimates. For the color process estimate, there was a main effect of list type, $F(1, 44) = 256.88$, $MSE = .03$, a main effect of deadline, $F(3, 132) = 209.37$, $MSE = .01$, and List Type x Deadline interaction, $F(3, 132) = 14.21$, $MSE = .01$. The List Type x Deadline interaction in the color process estimate was further evaluated by separate one-way ANOVAs of list type at each deadline. These analyses revealed main effects of list type at the -.5 deadline, $F(1, 44) = 114.69$, $MSE = .01$, the 0 deadline, $F(1, 44) = 201.67$, $MSE = .01$, the .5 deadline, $F(1, 44) = 170.28$, $MSE = .02$, and the 1 deadline, $F(1, 44) = 107.05$, $MSE = .02$. The interaction was due to the fact that the differences in the list types were larger at the later deadlines than at the earliest one.

The 2 (list type) x 4 (deadline) analysis of the word process estimate revealed main effects of list type, $F(1, 44) = 25.30$, $MSE = .10$, and of deadline, $F(3, 132) = 12.75$, $MSE = .01$, as well as a List Type x Deadline interaction, $F(3, 132) = 75.68$, $MSE$
The List Type x Deadline interaction for the word process estimate was further analyzed in separate repeated measures ANOVAs of the list types at each of the four deadlines. These analyses revealed no effects of list type at the -.5 deadline, $F (1, 44) = .098$, $MSE = .002$, but main effects at the 0 deadline, $F (1, 44) = 11.84$, $MSE = .04$, the .5 deadline, $F (1, 44) = 41.64$, $MSE = .03$, and the 1 deadline, $F (1, 44) = 72.50$, $MSE = .03$, thus indicating that, with the exception of the earliest deadline, the mostly congruent list produced the higher word process estimates.

**Correlational Data**

Measures of frontal lobe functioning (WCST, FAS Verbal Fluency Task), working memory [WAIS-R Digit Span, Modified Version of Salthouse & Babcock's Reading Span Task (cited in Earles et al., 1995)], and verbal intelligence (WAIS-R Vocabulary subtest) were collected in order to assess the relationship between these measures and Stroop inhibition measures. The correlation between these measures for the mostly congruent list are displayed in Tables 11 and 12 for the younger and older adults, respectively. Table 13 displays the results for the younger adults in the mostly incongruent condition and Table 14 displays the older adults' data for this list type.

As can be seen in Table 11, for the younger adults with the mostly congruent list, there were no significant correlations between working memory measures and measures of interference, facilitation, or process dissociation estimates. However, WCST errors and the number or words given in the FAS task (both frontal lobe measures) were related to PD Color estimates such that the more errors reported on the WCST and the more words given on the verbal fluency task, the higher the color estimates. As in Experiment
1, the interference score was correlated with the process dissociation measure for the word process, such that the higher the interference measures, the higher the word estimate.

For the older adults in the mostly congruent list (see Table 12), there were no relationships between measures of working memory or frontal lobe functioning and measures of interference, facilitation, and process dissociation estimates. There was a relationship between the facilitation measure and the process dissociation estimates for color, showing that the higher the facilitation, the higher the color process estimate.

As can be seen in Table 13, there were no relationships between measures of working memory and measures of interference, facilitation, and the process dissociation estimates for younger adults in the mostly incongruent list. There was a significant correlation between the number of errors on the FAS task and facilitation scores, with higher errors associated with higher facilitation scores. The number of categories achieved on the WCST and the number of errors given on the FAS task were also related to the word process dissociation estimate, with fewer categories on the WCST and more errors on the FAS task associated with higher word estimates. Finally, there was a relationship between PD Word and PD Color with higher word process estimates associated with higher color process estimates.

For older adults in the mostly incongruent list (see Table 14), no significant correlations between working memory measures and interference, facilitation, and word process and color process estimates were present. There was a significant relationship
between FAS number of words and the PD Word estimate, with fewer words given in the fluency task associated with higher word estimates.
Table 11

Correlations Between Individual Difference Measures and Measures of Interference and Facilitation for Younger Adults - Mostly Congruent List

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PD Color = Process Dissociation estimate for color.
* = p < .05. ** = p < .01.
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* = p < .05. ** = p < .01.
Table 13

Correlations Between Individual Difference Measures and Measures of Interference and Facilitation for Younger Adults - Mostly Incongruent List

<table>
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<tr>
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* = p < .05. ** = p < .01.
Table 14

**Correlation Between Individual Difference Measures and Measures of Interference and Facilitation for Older Adults - Mostly Incongruent List**

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* = \( p < .05 \). ** = \( p < .01 \).
Discussion

The results of the latency analysis show that, overall, older adults experienced higher facilitation (control - congruent) and higher interference (incongruent - control) than the younger adults across both list types. Thus, similar to findings in Experiment 1, older adults relied more on the meaning of the words than did the younger participants. It is also of interest that the mostly congruent list produced higher facilitation and interference effects than the mostly incongruent list. In the mostly congruent list, the meaning of the word and the color of the item were identical the majority of the time, promoting reliance on word reading. When the color of the item matched the meaning of the word, this reliance led to greater facilitation. However, reliance on word meaning also hurt participants when the color of the item and the meaning of the word did not match. Finally, the absence of an Age Group x List Type interaction in either the facilitation or the interference data indicates that practice provided similar benefits to the two age groups.

The higher error rates in the mostly congruent list again show that this list promoted reliance upon the meaning of the word, whereas the lower rates in the mostly incongruent list suggest that practice led to less reliance on word meaning. It is also of interest that older adults did not have significantly higher error rates than their younger counterparts in either list, suggesting that they benefited from practice with the mostly incongruent items and that the young adults' responses were as disrupted as the older adults' by incongruent items in the mostly congruent list.
The finding that older adults were less able to ignore the meaning of the words in general but benefitted from practice in the same manner as the younger adults was also supported by the process dissociation analysis. There were no differences for the two age groups on the color process estimates across the two list types and deadlines. However, as in Experiment 1, there was an age difference in word process estimates, with the older adults having higher estimates than the younger. This difference in estimates indicates that word reading again contributed more to the older adults' responses than it did to the younger adults' responses. The PDP estimates also show differences in response patterns across the two list types. For both list types, there was a difference in word and color estimates. However, in the mostly congruent list, word reading was dominant at all deadlines, whereas in the mostly incongruent list the color naming estimate was dominant at the zero deadline and beyond. These findings suggest that the mostly congruent list led both younger and older participants to rely upon word meaning, thereby allowing the word reading process to dominate. The mostly incongruent list, however, gave participants more practice at ignoring word meaning, thereby allowing the color naming process to dominate. Moreover, although the older adults had higher word process estimates for both list types than the younger adults, they benefitted from practice in the same way as young adults.

The correlational data shows that for the younger adults' receiving the mostly incongruent list, there was a relationship between frontal lobe measures and facilitation scores, similar to those seen in Experiment 1. There were no correlations between frontal measures and interference scores for the younger adults in either list, also similar to the
correlational data for younger adults in the first experiment. These findings suggest that frontal measures were not related to interference scores for the younger adults. On the other hand, there was a relationship between the frontal measures and the process dissociation estimate for word reading in the mostly incongruent list but not in the mostly congruent condition. This finding is logical when considering that word meaning does not need to be inhibited in the mostly congruent list and suggests that for younger adults the relationship between frontal lobe functioning and inhibition may only be seen where inhibition is the strongest. In the younger adults' data for the both the mostly congruent and the mostly incongruent lists, there were relationships between measures of frontal lobe functioning and the Process Dissociation color estimate, mimicking results of the first experiment. A relationship between interference and PD word was present for the mostly congruent condition, providing further evidence that the process dissociation word estimate does relate to interference. Finally, there was a correlation between the process dissociation estimates for color and word in the mostly incongruent list.

As in Experiment 1, for the older adults there were no correlations between frontal measures and facilitation and interference scores in either list conditions. As for the young adults, there was a relationship between frontal measures and the process dissociation estimate for word reading, but only in the mostly incongruent list type. This relationship provides the only evidence that the frontal lobe may play a role in inhibiting word meaning for older adults and again suggests that this relationship may be strongest when inhibition in the strongest. In both list types, there were no relationships between frontal measures and the color process estimates. There were no correlations between the
interference measure and the process dissociation word estimate in the second experiment. This lack of correlation is contrary to findings in Experiment 1 and suggests that when practice is involved, the interference measures may not accurately reflect the ability to inhibit word meaning. Finally, there were no relationships between PD color and word process estimates in the second experiment, mirroring results of the first study.

In summary, with respect to our original hypotheses, as predicted, the latency data showed that interference (incongruent - control) was greater for older than younger adults regardless of list type condition and that interference was greatest in the mostly congruent list than in the mostly incongruent list. However, the prediction that older adults would not benefit from practice was not supported in that the older adults receiving the mostly incongruent list had lower word process estimates than their contemporaries in the mostly congruent list.

With respect to the hypotheses for the Process Dissociation estimates, the hypothesis that estimates of word reading would differ between age groups with the older adults having higher estimates that their younger counterparts was supported as was the hypothesis that estimates of color naming would not vary. These findings parallel those present in the latency data and are also consistent with the findings in Experiment 1. As predicted, the word reading estimates were greater in the mostly congruent list than in the mostly incongruent list. This finding suggests that the mostly congruent list led the participants to rely on the word name rather than the ink color to make their responses. This finding is consistent with Lindsay and Jacoby’s
(1994) research in which they found higher word estimates in the mostly congruent list with younger adults. Surprisingly, our hypothesis that the color naming process would be similar for both congruent and incongruent list types was not supported. The type of list clearly had an effect on the color process. Specifically, there was greater reliance on the ink color in the mostly incongruent condition than in the mostly congruent condition. This result is contrary to what Lindsay and Jacoby reported. The difference in results could be due to the fact that Lindsay and Jacoby only sampled 20 out of 100 congruent items on the mostly congruent list and 20 out of 100 incongruent items on the mostly incongruent list whereas we included all trials in every condition in our analyses.

Although our results are different from those of Lindsay and Jacoby, it seems more logical that since the faster word reading process would provide participants in the mostly congruent condition with the correct answer on the majority of trials that they would rely less on the color naming process than individuals in the mostly incongruent list where color naming is essential to correct responding.

Finally, the prediction that older adults would benefit less from practice was not supported. This finding is contrary to what Dulaney and Rogers (1994) found in their experiment on the effects of practice on the ability to ignore the meaning of words. The discrepancy in findings between this study and that of Dulaney and Rogers could be due to a number of factors including differences in item presentation (list vs. individual) and method used to analyze practice effects, as well as the operationalization of practice. Dulaney and Rogers defined practice in inhibiting word reading as receiving lists of strictly incongruent items and measured the improvement in ink naming performance as
well as the time to return to baseline word naming performance. In addition, as was mentioned before, Dulaney and Rogers had no way of directly assessing word inhibition in their older adults. In their study, they inferred less inhibition of word reading in older adults due to the quick recovery of this age group to pre-practice levels of word reading. We defined practice in inhibiting word reading as receiving mostly incongruent items and measured both the improvement in ink naming as well as the effects of practice on the process dissociation estimates for word naming, which is a more direct measure of inhibition. The PDP thus provided a way to break apart the separate contributions of color naming and word reading in the Stroop task.

Our hypothesis that measures of frontal lobe functioning and working memory would relate to Stroop interference and word estimates was evident only for the mostly incongruent list type, with WCST number of categories and FAS number of errors relating to the word estimate for younger adults and FAS number of words relating to word reading for the older adults. The fact that the FAS frontal lobe measure was related to Stroop performance in the mostly incongruent condition adds support to the hypothesis that the frontal lobe may play a role in inhibition, but this role may only be seen in tasks where inhibitory processes are, by necessity, dominant over other processes. Finally, there was no correlation between working memory measures and Stroop performance for either the younger or the older adults, suggesting that the decline in inhibition for older adults is not related to problems with working memory. However, as was mentioned in Experiment 1, these findings should be viewed with caution due to the low sample size in each condition.
Chapter 5

General Discussion

The results of the two experiments presented above add to the literature showing that older adults have decreased inhibitory skills compared to younger adults. Previous studies, whether incorporating the use of negative priming (Hasher et al., 1991; Kane et al., 1994; Tipper, 1991), frequency judgment (Kausler & Hakami, 1982), measurements of autonomic responses (McDowd & Filion, 1992), or the Stroop task (Cohn et al., 1984; Comalli et al., 1962; Houx et al., 1993; Panek et al., 1984), have shown that older adults have increased difficulty in ignoring distracting, irrelevant information. The two studies reported here not only support this earlier research but also expand the literature on inhibition in the Stroop task by using the process dissociation procedure to allow for a clearer view as to what contributes to declines in performance.

Theories of the Stroop Task

Evidence from the present studies address issues in both the speed-of-processing and the automaticity theories of the Stroop. The speed-of-processing approach to the Stroop task states that both words and colors are processed in parallel but that since words are processed faster than colors they produce interference for the color naming response at the final output stage of processing. Data from the present study support the theory in that word meaning is processed faster than color naming, as can be seen by the dominance of the word process estimates over the color process estimates at the earliest deadlines in both Experiments 1 (see Figure 2) and 2 (see Figures 7 & 8). The
automaticity theory of the Stroop states that inference occurs because one stimulus
dimension requires more attentional resources to process than does the other dimension
(MacLeod, 1991). The dimension that is more automatic is processed first and should
interfere with the slower, more attention demanding dimension. In the Stroop task, words
are processed more automatically than colors because of the extensive practice adults
have with word reading and the relative lack of practice they have with color naming.
Therefore, word reading should interfere with color naming but ink color naming should
not interfere with word reading. The present results suggest that extensive practice with
color naming may lead to the suppression of the automatic word reading process and an
increment in the controlled color naming process. However, it is unlikely that the
mechanism of suppression for word reading is interference from color naming as the two
processes appear to be relatively independent. Thus some evidence is provided for the
automaticity theory. On the other hand, it has been suggested that one hallmark of an
automatic process is its immunity to practice (Hasher & Zacks, 1988). Contrary to this
idea, the present results clearly show that practice affects automatic word reading.

Age and Inhibition

In order to perform the Stroop task correctly, the meaning of the words must be
ignored and the color of the items attended to. Thus word meaning becomes the
irrelevant information in the task. In both Experiment 1 and 2, there was evidence that
the older adults were attending to the meaning of the words more than their younger
counterparts. Specifically, when the meaning of the word and the color of the item
matched, the older adults showed greater facilitation from this congruency. However,
when the color of the item and the meaning of the word were not congruent, they experienced more interference. This finding is consistent with past research (Cohn et al., 1984; Comalli et al., 1962; Houx et al., 1993; Panek et al., 1984) in which older adults experienced greater interference than younger adults on incongruent items. Older adults also had higher error rates on incongruent items in Experiment 1, again suggesting that they are generally less able to ignore the irrelevant word meaning.

The above results are consistent with past literature on the effects of age on inhibitory skills. McDowd and Filion (1992) demonstrated that older adults had a difficult time habituating to distracting tones. Likewise, Kausler and Hakami (1982) found that presenting two or more distractors in conjunction with relevant items on a study list compromised older adults' frequency judgments of the relevant words. In addition, numerous studies using the negative priming paradigm (Hasher et al., 1991; McDowd & Oseas-Kreger, 1991; Tipper, 1991) have shown that distracting information interferes more with older adults' performance than with younger adults' performance. Although the results from the latency data of Experiments 1 and 2 add to the evidence for age-related changes in inhibition, greater clarification of the role inhibition plays in older adults' performance on the Stroop task is provided by mathematically estimating pure measures of the contributions of color naming and word reading using the PDP procedure. The results of both experiments demonstrated that while there was no age difference in the contributions of color naming, older adults had higher word reading estimates. Thus the inference made from the latency data that older adults were relying more on the meaning of the words than their younger counterparts was confirmed. These
findings also support Spieler et al., (1996) who reported that their older adults had higher word reading estimates than the younger adults but the contribution of color naming was similar for the two groups. It is also of interest that the decline in influence of the word process is delayed in the older adults compared to the younger adults (see Figure 2).

According to the speed-of-processing approach the word meaning is processed earlier than ink color. The younger adults’ advantage in the Stroop may also be due to the fact that they are able to inhibit the word meaning earlier than the older adults.

**Age and Practice**

Experiment 2 examined whether practice on incongruent items would allow older adults to suppress their word reading estimates. Lindsay and Jacoby (1994) demonstrated that younger adults who experienced practice with incongruent items were able to suppress their word reading process compared to those who experienced mostly congruent items. The present results demonstrate that older adults are also able to benefit from practice with the incongruent items. The results from Experiment 2 thus support and extend Lindsay and Jacoby’s findings. However, Lindsay and Jacoby found no differences in color naming across the two list types. In contrast, in our experiment color naming was clearly higher in mostly incongruent list (Figure 8) compared to the mostly congruent list (Figure 7). The discrepancies in findings could be due to the fact that we did not use the 600 to 800 ms cutoff that Lindsay and Jacoby did, opting instead to examine a wider range of responses. In addition, our analyses were performed using standardized score deadlines to control for individual variability in response times. We also used all 140 items in our analyses, whereas Lindsay and Jacoby only used 20 items
from each condition. It is possible that Lindsay and Jacoby's results may be a function of range restriction.

The results of Experiment 2 are also contrary to the findings of Dulaney and Rogers (1994). They found that after extensive practice at color naming both older and younger adults showed improved performance on ink color naming. However, the older adults still reverted to their pretest word reading times more quickly (within 3 blocks of trials) than younger adults (11 blocks of trials). Dulaney and Rogers thus inferred that the enhanced performance of older adults after practice on the Stroop was not due to increased inhibitory skills but to general task factors. The results from the present study suggest that older adult benefit from practice as much as young adults and that they do show an increase in inhibitory processes. Although older adults were generally less able to inhibit their word reading than their younger counterparts, their word process declined as much as the younger adults from the additional practice provided by the mostly incongruent list. This finding suggests that the ability to inhibit an automatic response does not decline with age.

Comparing the results of this experiment with those of Experiment 1 suggests a somewhat different interpretation. Specifically, the list structure of Experiment 1 included equal numbers of congruent and incongruent trials, it was difficult for the participants to form a response strategy that would reliably provide them with the correct response on the majority of trials. In the second experiment, the list structure of the mostly congruent list permitted participants to adopt a strategy of relying on word meaning. Likewise, the mostly incongruent list structure allowed participants to develop
a strategy of relying on color naming because this strategy provided them with the correct answer on the majority of trials in the respective list types. When comparing the facilitation and interference scores from Experiment 1 to those in Experiment 2, it can be seen that both the younger and the older adults experienced more facilitation with the mostly congruent list than with the equal congruent and incongruent list used in the first experiment. However, when comparing the interference scores for the mostly congruent list and the equal congruent/incongruent list, it can be seen that only the older adults experienced more interference. When comparing facilitation and interference scores for the mostly incongruent list from the second experiment with those for the list in the first experiment, it appears that both young and older adults facilitation scores decline. This finding is logical if the mostly incongruent list promotes a strategy of ignoring word meaning. However, when looking at the interference scores for the two list conditions, it can be seen that the younger adults' interference scores are lower with the mostly incongruent list but the older adults' scores remain the same, thereby suggesting that they may have been less able to acquire or use the appropriate strategy of relying upon color naming. Altogether, these findings suggest that whereas older adults may benefit from conditions which promote a strategy of reliance upon an automatic process (the mostly congruent condition), they may have difficulty when placed in conditions which require strategies relying upon a controlled process (the mostly incongruent condition).

However, the results of the analysis of error rates are not entirely consistent with this interpretation. When comparing error rates on the incongruent items from Experiment 1 to Experiment 2, both younger and older adults showed a decrease in error
rates on these items in the mostly incongruent condition. This finding suggests that older adults were able to adopt the appropriate strategy of relying upon the color naming. In addition, given the differences in the designs of the two studies (Experiment 1 having only 100 items in each list while Experiment 2 having 140 items in each list), it may be premature to address the issue of changes in strategies. In order to directly compare changes in strategies from Experiment 1 to Experiment 2, it would be desirable to compose lists in the first experiment consisting of 60 congruent items, 60 incongruent items, and 20 control items for a total of 140 items in this study. Once list lengths were equated, the comparison of strategies would be more appropriate.

Correlational Measures

Poor performance on measures of interference have been attributed to deficits in working memory (Hasher & Zacks, 1988) and age related decrements in the frontal lobes [Dempster, 1992; Posner (cited in Kramer et al., 1994)]. Data from the present studies do not support the hypothesis that deficits in working memory are associated with decrements in inhibitory skills. In both Experiments 1 and 2, there were no relationships between measures of working memory and measures of interference, facilitation, or the process dissociation estimates. In addition, there is little evidence of a relationship between frontal lobe measures and measures of facilitation, interference, and process dissociation estimates, with only the mostly incongruent list producing relationships between frontal lobe tests and the process dissociation estimate for word. This finding suggests that a relationship between frontal lobe functioning and inhibition may only be
present for the strongest manipulation of inhibition. However, these results could be a function of low sample size and should be viewed with caution.

Limitations of the Research

Although the results of the two studies add to the literature using the PDP in assessing Stroop performance, the use of the post hoc deadline methodology does present some problems. Specifically, the data are cumulative over the deadlines with data included in the -1 deadline also included at the -.5, 0, .5 and 1 deadlines and so on. The data in the present study were analyzed in this manner in order to replicate the study by Spieler et al. (1996). However, there are alternative ways of analyzing the data in order to adjust for the lack of independence. One could subject the data to a profile analysis, or analyses could be performed at each deadline with adjustment for Familywise error. One could also analyze only the data at the two extreme deadlines as did Lindsay and Jacoby (1994). Although some data would be reanalyzed using this method, the final deadline would include a majority of trials not present in the earliest deadline.

In addition to problems of using the deadline method to assess differences in process estimates, there is also the question of whether differences seen in the ability to inhibit word meaning in the Stroop are a function of age or of some other factor that varies between individuals. As seen in Figure 9 for Experiment 1 and Figures 10 and 11 for Experiment 2, there is some overlap in the distributions of older and younger adults' facilitation and interference scores in each list condition, suggesting that some older adults are performing as well as the younger adults. However, the present data do not encourage alternative explanations based on differences in working memory or frontal
DISTRIBUTIONS OF FACILITATION AND INTERFERENCE
EXPERIMENT 1

FACILITATION

INTERFERENCE

Note: The upper and lower boundaries of each bar represent the 75th and 25th percentiles, respectively. The Xs represent group means and the * represent maximum and minimum scores.
DISTRIBUTIONS OF FACILITATION AND INTERFERENCE
MOSTLY CONGRUENT LIST - EXPERIMENT 2

Note: The upper and lower boundaries of each bar represent the 75th and 25th percentiles, respectively. The Xs represent group means and the * represent maximum and minimum scores.
DISTRIBUTIONS OF FACILITATION AND INTERFERENCE
MOSTLY INCONGRUENT LIST - EXPERIMENT 2

Note: The upper and lower boundaries of each bar represent the 75th and 25th percentiles, respectively. The Xs represent group means and the * represent maximum and minimum scores.
lobe functioning that could be the underlying basis of age differences. The collection of additional data could stabilize the measures of working memory and frontal lobe functioning and provide clearer evidence on this issue.

Summary

The present results provide support for Hasher and Zacks' (1988) theory of decreased inhibitory skills in older adults. The information to be inhibited in the Stroop task is the word meaning, yet older adults had higher word estimates than the younger adults, demonstrating their decreased ability to suppress this information. The word meaning therefore entered working memory and competed with color naming for attentional resources. However, older adults were able to benefit from practice in the same manner as younger adults. Thus, although the inhibitory skills of older adults may be compromised, they can benefit from practice. That measures of working memory did not correlate with PDP word estimates suggests that the decreased ability to inhibit word meaning does not seem to be related to general deficits in working memory. In addition, there was little evidence to support Dempster's (1992) hypothesis of a relationship between frontal lobe functioning and inhibition. There was a relationship between the FAS frontal lobe measure and inhibition in the mostly incongruent list only, suggesting that a relationship between these measures may exist only when inhibition is the dominant process. However, these findings may be a result of low sample size.
References


Footnotes

1 In order to assess whether the participants in the two experiments were equivalent on the individual differences measures, the data in Tables 1 and 7 were examined in a 2 (age group) by 2 (experiment) MANOVA, the results of which revealed a main effect of age group, $F(5, 69) = 8.74, p < .000$, but no main effect of experiment, $F(5, 69) = .28, p = .92$, and no Age Group x Experiment interaction, $F(5, 69) = .90, p = .49$. The lack of a main effect of Experiment and an absence of an Age Group x Experiment interaction suggests that the participants in the two experiments were similar to one another.
Appendix

The data used below to explain the Process Dissociation Procedure in the Stroop task were taken from Lindsay and Jacoby’s (1994) third experiment, most congruent condition, and represent the raw proportions correct within deadline.

Proportion correct/congruent = .93  Proportion correct/incongruent = .37

These will be substituted in the equations established by Lindsay and Jacoby to estimate the contributions of word reading and color naming in the Stroop procedure.

\[ p(\text{correct/congruent}) = \text{word} + \text{color} (1 - \text{word}) \]

\[ p(\text{correct/incongruent}) = \text{color} (1 - \text{word}) \]

By substituting the above numbers in each of the equations, the equations are changed to:

\[ .93 = \text{word} + \text{color} (1 - \text{word}) \quad \text{and} \quad .37 = \text{color} (1 - \text{word}). \]

Since .37 is representative of “color (1 - word)”, .37 can then be substituted for this construct in the first equation which now reads as follows:

\[ .93 = \text{word} + .37. \]

By subtracting .37 from .93, an estimate of the contribution of word reading in the Stroop task (.56) is obtained. This amount can now be substituted for “word” in the second equation given by Lindsay and Jacoby to estimate the contribution of color naming to the task.

\[ .37 = \text{color} (1 - .56) \quad \text{or} \quad .37 = \text{color} (.44). \]

By dividing .37 by .44, an estimate of color naming (.84) is obtained.