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INHIBITION AND AGING: A CLINICAL APPLICATION

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ABSTRACT

INHIBITION AND AGING: A CLINICAL APPLICATION

By

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One hundred community dwelling older adults (half female, Mean age 73 years) were administered the Wisconsin Card Sort test, the Trail Making test, a verbal fluency measure and a reading with distraction measure in order to study age differences in inhibition. Factor analysis indicated that these measures all loaded on a single factor supporting the view that inhibition partly underlies performance on these neuropsychological tasks. In addition, hierarchical regressions were used to examine the role of inhibition in memory and attention. The relationship of age and inhibition was also examined. Implications of these findings were discussed in relationship to diagnosis and rehabilitation.

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INTRODUCTION

Declines in cognitive functioning with age have been extensively reported in the literature and encompass many realms of cognition including memory, attention and problem solving (Albert, 1984; Hochandel & Kaplan, 1984; Lezak, 1995). Currently, many theorists have invoked the concept of working memory to understand many of these deficits. Since working memory has been extensively reviewed elsewhere (Baddeley, 1995), for the purposes of this paper only a brief description will be provided. Working memory, as currently conceptualized by Baddeley, consists of three components: the phonological loop, the visuo-spatial sketchpad and the central executive. The first two components, often referred to as the slave systems, temporarily hold and maintain verbal and visual/spatial information respectively. The central executive, on the other hand, is viewed as an attentional control system, one that integrates and processes information from both long term memory and the two slave systems, and subsequently acts upon this information, being responsible for planning and response selection.

It has been argued that working memory has a limited capacity; performance on a particular task will depend upon the amount of resources available at a given time (Light, 1991). In addition, these resources are theorized to diminish with advancing age. Therefore, as older adults have less resources available to them, performance on tasks that rely on working memory capacity will be decreased as compared to younger adults (Craik & Byrd, 1982; Moscovitch, 1994). Although this point of view has been very fruitful for generating research, a number of issues have been recently highlighted (Hasher & Zacks, 1988; Light, 1991; Navon, 1984; Stoltzfus, Hasher & Zacks, 1994). One such problem deals with the resources of working memory. There is no consensus concerning the properties of this resource. For example, is it a general pool that is tapped in working memory tasks, or are there different available resources that are specific to certain cognitive domains? Although a number of measures have been developed that are purported to be good indicators of working memory capacity, often these measures do not strongly correlate with each other (Light & Anderson, 1985), leading some investigators to propose the presence of multiple domain-specific working memories (Light, 1991). Given this difficulty, to date there has not been a single agreed upon clinical or experimental measure devised that can be said to reflect the capacity of working memory and also predict behavior on other tasks that may be dependent on the availability of these resources. In addition, given that there is only a limited amount of capacity available to a person at any given time, performance on a dual task paradigm should be predictable. Performance on a single task is theorized to reflect a certain amount of capacity. Given the amount of resources or capacity a task is theorized to need when performed singly, and that overall capacity is limited, then when two tasks are performed simultaneously predictions concerning performance patterns can be made. If the proposed capacity necessary for both tasks when performed together exceeds total available capacity, then decrements in performance on at least one of the tasks should be evidenced. Research findings are contradictory on this point, with a number of studies not conforming to these predictions (Allport, 1989; Light, 1991; Navon, 1984; Salthouse, 1990).

One alternative to limited capacity in working memory as an explanation for age effects is generalized cognitive slowing (Salthouse, 1994, 1995). Salthouse argues that most of the performance decrements in older adults as compared to younger adults on a wide variety of tasks can be accounted for by an overall slowing of information processing abilities. It is not that older adults cannot perform tasks due to specific changes related to the cognitive domain that is being assessed, but that older adults are just slower at the tasks which can lead to poorer performance when compared to younger individuals. Although there is considerable research to support this claim, there are some age related changes on various tasks that cannot be fully explained by this account. For example, age related changes are reliably shown on various measures of executive functioning measuring the ability to effectively plan, execute and shift strategy sets as well as on certain tasks of problem solving, even though there are no time demands required of the tasks (Cronin-Golomb, 1990; Lezak, 1995). In addition, when partialling out response speed on tasks that show an age decrement, a generalized slowing of response only accounts for some of the variance suggesting the presence of other variables that are important to age differences (see Hartley 1992; Light, 1991 for reviews).

Alternatively, Hasher and Zacks (1988; Zacks & Hasher, 1994) proposed a view that centers on the contents of working memory rather than its capacity to help account for deficits seen due to aging. They argue that working memory efficiency is dependent on aspects of the selective attentional ability of an individual. Selective attention refers to the ability to focus or allocate effort to a specific stimulus in order to process and respond to it (Kausler, 1991; Sheer & Schrock, 1986). Some researchers have theorized that this ability is a reflection of two processes: activation and inhibition (Hasher & Zacks, 1988; Tipper, 1985; Tipper, Weaver & Houghton, 1994). Most theories of attention focus on the activational aspect of attention, which is intimately connected to the initiation and execution of the focusing mechanisms. Inhibitory processes, on the other hand, are central to Hasher & Zacks concept, and refer to the active 'ignoring' or suppressing of irrelevant stimuli. It is this second mechanism that inhibits the allocation of attention to irrelevant information in the internal or external environment, as well as disengages attention from what was previously important but now is no longer the target of processing (Hasher & Zacks, 1988; Zacks & Hasher, 1994). The process of inhibition suppresses access of irrelevant information to working memory and allows for efficient processing of the target information. It is thought that "inhibition helps maintain attention to selected information to enable the development of a coherent thought stream" (Zacks & Hasher, 1994, p.242). Hasher and Zacks (1988) have theorized that inhibition plays a central role in many aspects of cognition, including memory, language comprehension and speech production, and problem solving.

Given this framework for working memory, Hasher and Zacks have theorized that it is this inhibitory mechanism that becomes deficient with age. Instead of a reduced capacity in older adults that results in less information having access to working memory, this viewpoint states that in older adults, too much information may have access to working memory. Some of this additional information then may add an element of distraction. Inefficient inhibitory processes can lead to the increased access of irrelevant information into working memory or can maintain activation of information, originally relevant, but now no longer important to the task at hand (Hasher & Zacks, 1988;

Stoltzfus, Hasher & Zacks, 1994; Zacks & Hasher, 1994). The presence of irrelevant or distractor information in working memory can result in lowered performance due to interference effects and response competition.

EVIDENCE FOR REDUCED INHIBITORY FUNCTIONING

Based on this framework, a number of studies have been conducted that support the idea of reduced inhibitory functioning in older adults. Negative priming has been a classic paradigm used to study inhibitory processes in young adults. This procedure generally involves presenting two stimuli simultaneously with the instruction to respond to one stimulus (target) while ignoring the other (distractor). Then on the next trial, either two new stimuli are presented, or the distractor stimulus now becomes the target stimulus. Results clearly show that response time to the target is slower if it was a distractor on the previous trial, this effect being referred to as negative priming (May, Kane, & Hasher, 1995; Tipper, 1985). Negative priming is a fairly robust effect and has been shown to occur for a number of different stimuli (letters, words, pictures etc.) and across different response sets (May, et al., 1995). Currently two mechanisms have been proposed to account for negative priming; inhibition and episodic retrieval (May, et al., 1995; Neill, Valdes, Terry & Gorfein, 1992). These different mechanisms may be evoked under certain conditions. For the purposes of this paper, the role of inhibition in negative priming will be discussed. In the inhibition view, it has been theorized that one initially inhibits the distractor in order to more efficiently attend to the target stimulus. When on the next trial, the previously inhibited stimulus now becomes the target, the individual responds more slowly to this target because it is still being temporarily inhibited (May, et al., 1995; Tipper, 1985).

Hasher and colleagues (Hasher, Stoltzfus, Zacks & Rypma, 1991), among others, have employed this same paradigm to investigate inhibitory processing in older adults. If older individuals have deficient inhibitory processes, as suggested by Hasher and Zacks's theory (1988), then this age group should not exhibit negative priming. The findings from their study supported this hypothesis. Their group of young adults did show negative priming, replicating the many previous findings reported in the literature. However, the older age group failed to exhibit negative priming. Even when conditions were made optimal for the older adults (longer target presentation time, as well as longer inter-trial intervals; Kane, Hasher, Stoltzfus, Zacks & Connelly, 1994) negative priming was still not evidenced by the older age group, suggesting that the older adults did not inhibit distractors, as did young adults. Although there is evidence that older adults do not show negative priming, age differences can be attenuated if not eliminated when task demands are altered. For instance, if the negative priming task requires the individual to make a response based on the location of the stimulus rather than its identity, then older adults will show the same amount of negative priming as younger adults (Connelly & Hasher, 1992; Sullivan & Faust, 1993). In addition, not all results have shown an age decrement in identity negative priming tasks (Sullivan & Faust, 1993)

Distracting information does not have to be introduced from the environment but can also be thoughts and associations that are generated by the subject to the material being presented. One paradigm that has been used to examine this is the fan effect (Gerard, Zacks, Hasher, & Radvansky, 1991). Participants are presented sentences to learn (for example, the doctor cut the apple into six pieces), followed by a timed recognition test. The individual must choose the studied sentences from amongst other sentences that consist of new combinations of the concepts from the original sentences. In general, in young adults, the more sentences that are learned about a certain concept (for example, the doctor) the longer the recognition response time and the higher the error rate on the recognition task. This finding is referred to as the fan effect. Gerard and colleagues (1991) used this procedure to assess both young and old individuals. It was theorized that the older adults, due to a reduction in inhibitory processing, would not only exhibit interference as the number of sentences to be learned about a specific concept would increase, but would experience interference as a result of their own personal associations that would be generated to the sentences themselves. For example, not only would the older individual recall that the doctor cut the apple, but also perhaps that their own doctor works down the street, and is very nice, and owns a dog. Because of these increased associations it was hypothesized that the older adults would show a larger fan effect than the younger adults. Results supported this expectation. Both young and old individuals evidenced the fan effect, however, the older subjects did show a greater decrement in performance when the number of sentences learned about a particular concept increased.

SUPPRESSION OF NO LONGER RELEVANT INFORMATION

Another implication of reduced inhibitory functioning centers around the suppression of information in working memory that was once important but due to changing goals is no longer relevant to the task at hand. Once task demands change, in order to respond efficiently, one has to inhibit the original response and process the new information that has entered working memory in order to choose a more appropriate response. If older adults have difficulty suppressing the previously relevant information, then they should experience interference on tasks that require a change in response. Hartman and Hasher (1991; also see Zacks & Hasher, 1994), conducted an experiment using garden path sentences to test this hypothesis. Participants were asked to read sentences that had the last word missing. The sentences were constructed so that the individual would generate a specific ending with a high probability. Once the ending was generated, then either the consistent ending word or another, less likely ending was provided to the subjects with the instructions to remember only the word provided by the experimenter. After all of the sentences had been presented, the participants completed a priming task for the ending words. The task consisted of the presentation of additional new sentences with the ending word missing. These sentences were chosen so that there was an equal probability of the subject completing the sentence with either the provided word or the originally generated word. Priming in this task is exhibited when the subject completes the sentences with the target words more often than if (s)he were completing the task not having previously completed the experimental task. In this study, young adults only exhibited priming for the words provided by the experimenter. Older adults, however, showed priming for both the provided as well as the initial generated word. This study supported the idea that older adults maintained information in working memory that was not relevant to the task at hand. The same results have been found using garden path stories (Hamm & Hasher, 1992). Subjects are instructed to read various passages and then were asked to remember the stories. The wording of the text would lead the subject to interpret the story one way, but as the story progressed and additional information was provided, the correct interpretation becomes clear. Sometimes the original interpretation is confirmed (expected condition) and other times the original interpretation is invalidated with the additional information (unexpected condition). Results indicated that older adults remembered less of the correct interpretations on a cued recall task than younger subjects, but only in the unexpected condition. Cued recall performance was equivalent for the expected condition. In another condition, a speeded judgement task was administered at different points in the story. Either half way through a story when the subject had the original interpretation in mind or at the end of the passage when the correct interpretation had been attained, a word was presented and the subject had to respond yes or no if to indicate whether it was consistent with their interpretation of the story. When the word was consistent with the correct interpretation, there were no age differences in the number of yes responses. However, when the word was consistent with the original interpretation, older adults responded positively more often than did younger adults, suggesting that the older adults maintained both versions, whereas the young were more likely to forget or discard the original interpretation. The researchers were able to show that older adults held the incorrect interpretation longer in working memory than the young adults.

READING WITH DISTRACTION

Another paradigm that has been used to study the inhibitory processes in older adults is reading with distraction (Connelly, Hasher & Zacks, 1991). Subjects are presented with a passage to read in italic print and reading time is recorded. In some conditions, interspersed within the passage are short phrases and words that are presented in normal type. The subjects are instructed to ignore this distracting text and to read only the passage in italic print. After controlling for vocabulary levels, findings showed that although both young and old subjects were significantly slower to read the story when distractors were present, older adults exhibited a greater slowing in this condition. The type of distractor present was then varied. In one condition, the distractor consisted of words and phrases that were not related to the text (irrelevant), whereas in another condition the distractors were meaningfully related (relevant) to the passage being read. A third condition employed x's as the distractor. In the two distraction conditions with text, both groups exhibited slowing but the older group showed a differential increase in reading time. Of interest in this study was the difference in performance between the age groups with text distractors. The young subjects showed a significant but equal increase in reading time for both relevant and irrelevant conditions. The old however showed a different pattern. Distractors that were relevant to the passage slowed reading times more than irrelevant distractors. Once again, as compared to young adults, this study suggests that older individuals are more distractable and have difficulty ignoring irrelevant material, especially when that information is related in some way to the target material.

DIRECTED FORGETTING

One last area of research to be reviewed deals with a study that looked at the performance of older adults on tasks of directed forgetting. In a typical directed forgetting paradigm a list of words is presented to the subject. Either after each word or after a block of words has been presented, a cue is given that lets the subject know if the word(s) are to be remembered or forgotten. As the cues are presented after the word has been presented and the subject does not know if he/she will have to remember the particular item, it is assumed that the person must attend to each word and process it. Once the entire list has been presented, subjects are asked to recall all of the to-be remembered words. Young adults have little difficulty recalling the appropriate words and give few intrusions of the to-be forgotten words (Bjork, 1989; Geiselman & Bagheri, 1985). Also, if asked to recall the to-be forgotten words, young subjects' recall for these items is poor . A number of experiments have been conducted to examine performance in older adults (Zacks, Radvansky & Hasher, 1996). If older adults have less efficient inhibitory processes, and if inhibition is important to directed forgetting tasks, then they should have more difficulty ignoring those words that were cued as to-be forgotten. Results from these studies bore out the predictions. Regardless of the type of list presented (categorized or uncategorized), the timing of the cues (after each word or blocks of words), or the type of memory task employed (free recall or recognition or a speeded response task), the difference between the number of words recalled from the to-be remembered list and the to-be forgotten list was smaller for the older adults as compared to younger adults (Zacks, et al., 1996). This study lends additional support to the idea that older individuals have more difficulty inhibiting material that is no longer relevant to a goal.

In summary, research findings generally support the idea that inhibition processes are inefficient in older adults, although under certain circumstances older adults exhibit comparable performance to younger adults. Reduced inhibitory functioning can lead to an increase of irrelevant or extraneous information in working memory, thereby causing interference and increasing the risk of incorrect responses on a variety of tasks.

CLINICAL APPLICATIONS

Given the premise that older adults have reduced inhibition processes, to what extent do they underlie the deficits seen on a variety of clinical measures of cognitive functioning? Selective attention has been theorized to be very important for a variety of cognitive tasks (Kausler, 1991). As inhibition processes are important for efficient selective attentional ability, it follows that decrements in inhibitory processing may lead to poorer performance on these cognitive measures. The presence of irrelevant or distracting material, due to decreased inhibitory functioning can lead to deficient task performance. Therefore, those older adults who have less efficient inhibitory processing will be more likely to experience greater difficulty on these measures.

Little research however, has been done to examine the relationship of inhibition and aging within the clinical setting. This extension into the clinical realm can be useful to help elucidate the generalizability of the inhibitory viewpoint and make it more accessible to clinical applications. Often many of the experimental tasks that have been developed to assess a specific theory of attention are not feasible within a clinical setting, due to such things as time and monetary costs as well as lack of standardization procedures and normative data, factors that are invaluable in a clinical setting. Since experimental research is often focused on differences between two age groups (young versus old) , the experimental design may not be conducive to the study of individual differences within an age range. In addition, individual variables that can have an impact on task performance such as affective disorders, health status and physical ability often are not accounted for in experimental research. This last point is especially important to the study of older individuals as these and other factors can become more problematic with increasing age. Therefore an approach to the study of inhibition that takes into account some of these issues can assist in the further understanding of the role of inhibitory functioning in an older adult's performance on various cognitive tasks.

Many older adults do complain of difficulties with memory and selective attention as assessed by self-report measures (Crook & Larrabee, 1992). These types of difficulties also are evidenced on a variety of clinical neuropsychological measures; older adults show poorer performance than younger adults on a number of these tasks. Older adults have been shown to be more susceptible to distraction by irrelevant stimuli (Kausler, 1991) and have more difficulty with visual search tasks when distracting stimuli are present (Fisk & Rogers, 1991). This age group also experiences more difficulty switching response set (Cronin-Golomb, 1990) and can show increased perseverative behavior on tasks (Lezak, 1995) as well as increased verbosity (Arbuckle & Gold, 1993) even when there are no time demands on performance. Performance on divided attention tasks can also show declines with advancing age (Kausler, 1991). In addition research has demonstrated that older adults exhibit decrements on various tasks designed to measure selective attention (Hochandel & Kaplan, 1984; Kausler, 1991).

Working within the framework of reduced inhibition in older adults, Arbuckle and Gold (1993) examined the relationship of verbosity to various neuropsychological measures in older adults. The authors speculated that off-target verbosity reflected an inability to maintain focus; the person would originally respond appropriately to a question/statement but then would begin to talk about other loosely associated or non-related topics. Verbosity was hypothesized to be a reflection of the inability to inhibit irrelevant information or associations to the questions. In this study, a variety of neuropsychological measures were chosen to be administered to a large group of older adults, along with a measure of verbosity. Since research studies have shown (for reviews see Cronin-Golomb, 1990; Stuss & Benson, 1984) that patients with frontal lobe dysfunction often show deficits in inhibition (perseveration and inability to maintain set), a number of "frontal lobe" tests were included (WCST, verbal fluency and Trail Making as well as release from proactive interference), as well as measures of memory (logical passages) and simple attention (digit span). The authors found that the frontal lobe measures correlated highly with the measure of verbosity (the higher the verbosity, the lower the scores on the neuropsychological measures) whereas verbosity did not correlate with the memory or simple attention measures. The results of a factor analysis showed that these three neuropsychological measures (WCST, verbal fluency and Trails) fell out on one factor that was also highly correlated with verbosity. The authors hypothesized that this factor reflected inhibitory functioning in their sample.

The results from this study are intriguing as the authors apply the theory of inhibition to the clinical realm. Although previously the three neuropsychological tasks have been linked together as measures of executive functioning that is generally thought to be subserved by the frontal lobes (Cronin-Golomb, 1990; Stuss & Benson, 1984), the theoretical application of the role of inhibitory processes in verbosity and the neuropsychological measures can be seen as an advance in theoretical understanding of performance on these tasks.

Theoretically an argument can be made for the role of inhibition on performance of these standardized measures. All of the measures appear to require suppression of irrelevant or non-goal directed information in order to make an appropriate response. The Wisconsin Card Sorting Task (Heaton, Chelune, Tally, Kay & Curtis, 1993) requires the participant to sort cards according to one strategy and then after a predetermined number of responses the sorting principle changes unbeknownst to the subject who then must alter his strategy and attempt to discover the new sorting rule. For accurate performance, the participant must suppress the initial sorting rule and switch response sets as the demands of the test change. The Trail Making test (Reitan & Wolfson, 1993) also involves the alternating of response sets. On Trails B of this test, one is required to connect letters and numbers sequentially, alternating between the two sets (i.e. 1, A, 2, B etc.). Once the participant connects a number, then he/she must inhibit the number set in order to make the next response (to connect a letter). Both of these measures require the participant to suppress a response that was originally necessary for obtaining accurate performance but is no longer appropriate to the task goal. The additional measure, Verbal fluency requires the individual to generate as many words as possible that begin with a presented letter within a time limit (Lezak, 1995). The person must not only inhibit items previously generated but also associations to the generated items. Generated items may also activate other related items that are meaningfully associated in some way but are not appropriate to the task (i.e. do not begin with the target letter). Persons who have less efficient inhibitory processes may experience greater response competition due to these activated associations, much like the results seen in the fan effect paradigm.

The intent of the present study was to replicate and extend the findings of the role of inhibition in performance on the neuropsychological measures in a group of healthy older individuals. The initial aim of this study was to replicate the factor analytic results of Arbuckle and Gold (1993). For this study an experimental task was chosen, in lieu of the verbosity measure, that has been used previously to demonstrate inhibition processes in young and old participants, specifically the reading with distraction task as described above. The three neuropsychological tasks as employed in their study also were administered. As argued above, performance on these neuropsychological measures may be partially subserved by inhibitory functioning. If inhibitory processes underlie performance on all of these measures, then a strong relationship between all of the tasks should be evidenced.

The second purpose of this study was to examine the relationship between inhibition and additional neuropsychological measures, to determine the extent that inhibition plays a role in successful performance on these tasks. Generally the ability to shift set, alternate responses or suppress irrelevant information is evaluated with measures thought to reflect frontal lobe functioning (c.f. Cronin-Golomb, 1990). However, as inhibition is theorized to serve the general function of suppressing distracting or irrelevant information in working memory, then it could be expected that inhibitory processes are important for response selection in many other types of cognitive tasks. Therefore, the role of inhibitory functioning in the present study was explored in two additional neuropsychological tasks: a measure of memory and learning (California Verbal Learning Test; CVLT, Delis, D., Kramer, J. H., Kaplan, E. & Ober, B. A., 1987) and a measure of attentional capacity (Paced Auditory Serial Addition Test; PASAT, Gronwall, 1977). Both of these measures incorporate features that are similar to the directed forgetting procedures described above. In both tasks, information that was relevant becomes irrelevant to the task, and must be suppressed for good performance on the tests. The CVLT requires the learning of a categorized list over trials followed by another categorized list to learn. The participant must then recall the first list after a short delay as well as after a long delay. On this measure, memory and learning is assessed by free recall, cued recall (the category names are used as cues) and recognition. If inhibition is important for efficient performance on this measure then it was hypothesized that a decrease in inhibitory functioning would be reflected in a higher rate of intrusions and perseverations on both recall and recognition on the CVLT, as well as an overall decrease in learning. Reduced inhibition processes could lead to increased response competition from the second list that was presented as well as additional associations to the categories, resulting in increased intrusions and perseverations.

Poorer performance would also be expected on the PASAT. On this test, a list of numbers is presented one at a time, and the task is to add each number presented only to the preceding number and say out loud the total (but not keep a running total of all numbers presented). Once a sum has been presented, it must be "forgotten" so that the person can now complete the next response. It is a very demanding measure of attention requiring a continual suppression of responses. Reduced inhibitory functioning would be expected to be evidenced in a reduced ability to perform this task, as one would have difficulty suppressing the previous response in order to add the next two numbers. If performance on the memory and attention measures are influenced by inhibitory factors then a relationship should be evidenced between these two measures and the inhibition measure used in this study, as well as the three clinical measures. Specifically, as one exhibits more difficulty on the measures thought to reflect inhibitory functioning (specifically WCST, Trails B, Verbal Fluency and Reading with Distraction), then increased difficulty would be evidenced on the memory and attention measures to the extent that inhibition also partly underlies performance on these measures (i.e. higher rates of intrusions and perseverations and decreased rates of learning on the CVLT and more errors on PASAT). If this relationship is obtained then one can utilize these standardized measures in the clinical setting to examine inhibitory functioning in a wide population of patients.

The next aim of this study was to assess the relationship of age and inhibitory functioning. Although there are experimental studies comparing younger and older subjects on inhibition measures, with older individuals showing decreased inhibitory functioning, there is no data that has looked at the relationship of inhibition within an older population. There is an increasing body of literature that demonstrates that there are declines in cognitive functioning across the decades and normative data has been collected to reflect this (for an example see Heaton, Grant & McSweeny, 1991; Lezak, 1995) and it is possible that performance on measures thought to reflect inhibition may show the same pattern of results. A sample of community dwelling individuals between the ages of sixty and eighty-five were assessed in this study so that these age comparisons could be made. Therefore, the hypothesis stated, although more tentative, that as age of the individual increased inhibitory functioning as measured by the clinical tasks becomes less efficient. In addition, the possible differential role of inhibition and cognition with advancing age was assessed.

Just as age may account for some of the variance that may be evidenced in inhibitory functioning, so may other factors that are relatively independent of age. Depression is a growing concern in the older population and has been shown to impair performance on many neuropsychological measures (Austin et al., 1992; Sweet, Newman, & Bell, 1992). The final aim of the study was to examine the possible relationship between depression and performance on the measures thought to reflect inhibitory functioning.

METHODS

PARTICIPANTS

One hundred older volunteers were recruited from the greater Lansing, Michigan area. The participants were recruited from three local churches and the Foster Grandparents Association. A donation of 10 dollars was made to the church for every person who volunteered for this project. As an additional incentive, for every 20 volunteers that were recruited from the same church, an additional 50 dollars was donated. Volunteers from the Foster Grandparents Association were paid twelve dollars for their participation.

Mean age of the entire sample was 73.07 (SD = 7.16 ; range 60-85) with a mean education of 13.47 (SD = 2.51; range 8-20). Fifty males and 50 females were assessed. None of the participants were excluded on the basis of the presence of dementia as measured by the Mini Mental State Examination (Folstein, Folstein, & McHugh, 1975; M

= 27.9, SD = 1.67; range 24-30). In order to study the effects of age on inhibitory functioning, approximately equal numbers of individuals were recruited from five age ranges. Nineteen participants between the ages of 60 and 65 were assessed (M = 62.42, SD = 1.64), 19 in the 66-70 range (M = 68.58, SD = 1.39), 22 in the 71-75 range (M = 72.91, SD = 1.57), 21 in the 76-80 range (M = 78.19, SD = 1.44) and 19 in the 81-85 age range (M = 83.74, SD = 1.37). Education levels for the respective groups were 14.63 (SD = 3.3), 13.58 (SD = 2.17), 13.32 (SD = 2.15), 13.24 (SD = 2.70), 12.63 (SD = 1.80). Education levels were found not to differ significantly across age groups on a one-way analysis of variance, $F(4, 95) = 1.66$, $MSE = 6.15$.

Administration of the measures was performed by three graduate students from the clinical psychology program at Michigan State University. Consent was obtained from each volunteer prior to testing. The testing session took approximately three and a half hours to complete. Approval for this study was obtained from the Human Subjects Review Committee at Michigan State University.

MEASURES

Trail Making Test (Reitan & Wolfson, 1993). The Trail Making Test is one of the measures of the Halstead Reitan Neuropsychological Battery. This measure is thought to reflect one's ability to shift attention and sequence between two alternate response sets (LaRue, 1992). It is necessary to suppress one response set temporarily in order to shift to the alternate set. There are two components to this test. Trails A requires the participant to draw a line connecting 25 numbers, in order. Trails B, in contrast, presents a page of numbers and letters and the individual's task is to alternate between the numbers and letters in order. Time to complete both parts is recorded as well as the number of errors.

This test also requires visual conceptual and visual-motor tracking abilities, and deficits in these processes can lead to poor performance on this test, as can motor slowing, and poor motivation (Lezak, 1995). Older adults do show a general slowing on Trails A and B as compared to younger adults (Lezak, 1995; van Zomeren & Brouwer, 1994), and normal motoric slowing with age needs to be taken into account on this measure. As a result, Trails B - Trails A was calculated in an attempt to control for motoric differences in this older sample, and used in the subsequent analyses. A higher score represents more difficulty on this task.

Test-retest reliability coefficients vary across different studies but are generally fair ranging from at least .60 to as high as in the .90's (Lezak, 1995). Normative data for the older age ranges are available in the literature (Heaton et al. 1991), as age does effect performance. Education also has been found to be a factor in performance on this test (Lezak, 1995). Trails A and B can be very sensitive to brain damage, but taken alone one cannot indicate the source of the problems (Lezak, 1995).

<u>Wisconsin Card Sorting Test</u> (WCST; Heaton, Chelune, Tally, Kay & Curtis, 1993). Decision making and the ability to flexibly change response sets was measured by counting the number of perseverative responses from the WCST, with higher scores representing greater impairment. The participant was given a set of 128 cards on which are printed one to four symbols of either stars, crosses, triangles or circles in one of four different colors. The task was to place each of the cards under one of four stimulus key cards

according to a principle that the person must deduce from the pattern of the examiner's responses to the person's placement of the cards (i.e. color, form or number). After a run of ten correct placements in a row, the examiner shifted the to-be sorted principle, indicating the shift to the subject only in the changed pattern of his "right" and "wrong" statements. This was continued until six category shifts were achieved or all cards were used. Although many measures can be obtained from this test, it was felt that the Perseverative Response score was the best to reflect difficulties with set shifting. Perseverative Responses reflects the individual's inability to suppress the original set, perseverating on matching the cards by the category that is no longer correct.

The WCST has been shown to have a high interrater reliability of .93 for perseverative responses and an intrascorer reliability (defined as the consistency of scoring multiple tests of one rater) of .96 (Heaton et al., 1991). As reported in the manual, studies of concurrent validity have supported the idea of the WCST as a measure of executive function.

Normative data has been collected on a wide range of ages (6-90 years; Axelrod, Jiron, Henry, 1993; Heaton et al., 1993). As reported in one normative study, Mean perseverative responses for 70-79 year olds is 14.8 (SD = 5.4) and 20.4 (SD =13.2) for 80-89 year olds (Axelrod et al., 1993). In addition this test has been used diagnostically with a variety of samples such as patients with Parkinson's Disease, Multiple Sclerosis, Seizure disorders, Brain Damage, and psychiatric samples like Schizophrenia (Heaton et al., 1993).

Controlled Oral Word Association or Verbal Fluency (Lezak, 1995). Participants are asked to generate as many words as possible that begin with a certain letter in one minute. Three separate letters are administered, C,F,L and the total number of words generated for all three words are summed. Lower scores on this task represent greater difficulty. If an individual has less efficient inhibitory processes, as already discussed above, then one would expect that there would be difficulty suppressing items once they have been generated as well as associations to the generated items. Since these items are still active in working memory, then there may be increased response competition, which could be reflected in a lower number of valid generated items on this task.

Overall, performance is related to level of education. If education level is restricted to 13 years and above, then age is not correlated with performance, until over the age of 75 (Spreen & Strauss, 1991). Concurrent validity has been demonstrated (Spreen & Strauss, 1991). Using a different set of letters (FAS), inter-rater reliability has been shown to be very high with the re-test reliability being .70 (Spreen & Strauss, 1991).

Normative data is available for a range of ages (Lezak, 1995; Spreen & Strauss, 1991). Verbal fluency also has been administered diagnostically to a wide variety of populations such as patients with Alzheimer's Disease, Parkinson's Disease and various types of brain damage.

Reading with Distraction (Connelly, Hasher & Zacks, 1991). As described in the introduction, a reading with distraction task was administered to the participants. This task has been shown to be a good measure of inhibitory processes, though normative data is not available.

Stories were presented in italic print with the distracting material in upright print. Font was large (14 point) to compensate for visual problems commonly experienced by older individuals. Subjects were instructed to read each story accurately and carefully out loud, starting with the title, and told that they will have to answer four multiple choice questions about the passage just read. After an initial practice story, nine stories and multiple choice tests were administered. Time to read each story was recorded. Three of the passages had distracting text that was related to the story being read. Three of the passages had unrelated text as distractors and the remaining three stories did not have any distracting information embedded within the text. Across subjects, each story was used across the three reading conditions equally often and two order presentations were determined. This resulted in six versions that were randomly assigned to subjects. Each subject received all three distracting conditions. Passages were chosen to be approximately equal length and each story was spaced to be the same length regardless of the condition, to control for eye scanning speed. This task took approximately fifteen minutes to administer. The recognition test consisted of four multiple choice questions, each having six choices consisting of the correct response, the related response that was embedded in the relevant text condition, and four additional plausible words. The recognition test was scored for number of correct responses as well as the percentage of false alarms that were made to the related word. The specific measure to be used in the regression analyses was calculated by subtracting baseline reading times from the no distraction condition from the two distraction conditions to control for individual reading speed.

<u>California Verbal Learning Test</u> (CVLT; Delis, D., Kramer, J. H., Kaplan, E. & Ober, B. A., 1987). The CVLT was designed to examine categorized list learning over a series of trials. Short and long term recall are assessed using both free and cued recall as well as a recognition test. The use of categorized lists also allows for the examination of a person's learning and recall strategy.

The procedure consists of presenting a 16 item categorized list for learning (i.e. Monday's shopping list; consisting of four words from four different categories: vegetables, clothing, tools and spices and herbs). The list was read out loud five times and the subject was instructed to recall as many words as (s)he can from the list after each presentation. After the fifth trial, the subject was then given another 16 item categorized shopping list for recall (Tuesday's list). Two of the categories in this list were the same as Monday's list and two were new. Once recall of Tuesday's list was attempted, the subject was then instructed to recall all of the words from Monday's list once more. This was then followed by a cued recall trial, with the category names serving as cues. After a 20 minute delay, the subject was asked to recall Monday's list once more and was again given a cued recall trial. This was lastly followed by a recognition trial of words from Monday's list. The distractors in the recognition test consist of words from Tuesday's list that were from the shared categories, new words that also belong to one of the categories, new items that are phonemically similar to target items, and new unrelated words.

Various measures of learning and recall can be obtained. A number of the scores are of interest in this study. Total recall over the five trials, as well as short and long delayed recall was calculated. In addition the total number of intrusions and perseverations was measured. An intrusion is defined as a word recalled that was not part of the list to be remembered. A response is scored as a perseveration when the individual recalls the same word as if it is the first time that he/she has recalled it. On the recognition component, the number of hits and false positives were recorded. The false positives can be further analyzed to see the type of error made, be it an item from the Tuesday's list, or semantically or phonetically related.

Results from reliability and validity studies have been reported in the CVLT manual and will be summarized here (Delis et al., 1987). Internal Consistency has been measured three different ways obtaining values ranging from .70 to .92. Split half reliability coefficients of .77 and .86 have been reported. Test-retest reliability has also been calculated, and 13 of the 18 scores that were looked at were significantly correlated. As described by the authors, test-retest reliability will not be very high due to practice effects on this measure. Total recall over the five trials has been shown to be higher (averaging two words more) on second testing, and higher scores are also found with the short and long delay recall and the recognition tests.

Studies have confirmed the construct validity of the CVLT. Factor analytic studies have consistently found 6 factors: general verbal learning, response discrimination, learning strategy, proactive effect, serial position effect and acquisition rate. The authors suggest that "the results of the factor analyses indicate that the multiple indices assessed by the CVLT cluster into theoretically meaningful factors consonant with the experimental constructs they were designed to measure" (p. 43). The various measures also significantly correlate .60 with the Wechsler Memory Scale (WMS), another test designed to measure memory functions.

Normative data are available across a wide range of ages. The manual provides norms that are stratified by age and gender. Lezak (1995) has reported that education is also correlated .36 with test performance. This test has also been used with a variety of populations including patients with Parkinson's Disease, Alzheimer's Disease, Multiple Sclerosis, Head Injury patients and healthy job applicants.

Paced Auditory Serial Addition Test (PASAT, Gronwall, 1977) This test has been considered to be sensitive to information processing speed and concentrations skills (Gronwall & Wrightson, 1981; Roman, Edwall, Buchanan & Patton, 1991). A string a numbers was presented at predetermined intervals, and the task is to add each number to the number that was presented just before it, and say the total out loud. (Gronwall, 1977; Lezak, 1995). Presentation times of the digits range from 1.2 sec to 2.4 sec. Once a response has been given, the individual must in a sense "forget" or suppress the total he/she has just said out loud, in order to generate the next response (which is to and add the new number to the previous number presented). Total number correct was recorded. Although all age groups have difficulty with this task, older adults perform worse on this test as compared to younger adults (Roman, Edwall, Buchanan & Patton, 1991). In addition intelligence scores and educational level correlate with performance (Roman, Edwall, Buchanan & Patton, 1991; van Zomeren & Brouwer, 1994).

Vocabulary Subtest (Wechsler, 1981). The Vocabulary subtest from the Wechsler Adult Intelligence Scale- Revised (WAIS-R) was also administered. Subjects were asked to define a list of words. This test has been shown to be a good measure of vocabulary ability and is highly correlated with the verbal intelligence score from the WAIS-R (Lezak, 1995). As vocabulary level is significantly correlated with a number of the clinical measures and can also impact on the reading with distraction task, this test was administered to all subjects so that vocabulary ability could be statistically controlled.

RESULTS

All statistical analyses were done using the SPSS for Windows statistical package, Release 6.0 (1993). Unless otherwise specified, an alpha level of .05 was used for all the statistical tests.

Descriptive characteristics of the measures are presented in Tables 1,2 and 3. For this sample, the mean vocabulary score was 47.56 (SD = 10.69, range 17-65) out of a possible 70 points. Results of the remaining neuropsychological measures are reported in Table 1. Eight individuals were not administered the reading with distraction task. Two of the individuals were unable to visually discriminate the different fonts due to poor eyesight, one individual's reading comprehension was too poor to read the text, another discontinued testing during administration finding the task too difficult, and the remaining four participants were not administered the test due to time considerations. For the remaining 92 participants, no differences were found in reading times for the related and unrelated text conditions in the reading with distraction task, $t(88) = -.64$ (Table 2; M = 82.88, SD = 27.54; M = 83.97, SD = 28.55 respectively). Data obtained from these two conditions were combined to derive the reading with distraction score. Reading time from the no distraction condition was subtracted from the mean reading times for the distraction conditions and used in all of the subsequent analyses. The relationship between age and the neuropsychological measures are reported in Table 3.

As the first aim of this study was to replicate the factor analytic results of Arbuckle and Gold (1993), a factor analysis was done using the three clinical measures and the reading with distraction score. The correlational matrix for the three clinical measures of interest and the reading with distraction task is shown in Table 4. The correlations are very close to those found by Arbuckle and Gold (1993); the latter are listed in Table 4 in parentheses for comparison. A principal component factor analysis with varimax rotation was performed with the three clinical measures and the reading with distractor measure. The analysis showed that one factor had an eigenvalue greater than or equal to 1, accounting for 45.6% of the variance. The factor loadings for the individual variables were ..80, -.69, .68, .49, for Trails B-A, the verbal fluency score, the perseverative response score and the reading with distraction measure respectively.

The second goal of this study was to evaluate the role of inhibition in other cognitive tasks. Specifically it was hypothesized that given that inhibitory functioning partially underlies performance on many tasks, then performance on the four "inhibitory" measures should predict performance on additional neuropsychological measures. In order to examine this relationship between the three clinical measures and the reading with distraction measure hierarchical regressions were performed. The three clinical measures and the reading with distraction score were the independent measures. In order to control for possible differences in reading ability and education and their effects on the clinical measures and the reading with distraction task, vocabulary score and education level were entered into the equations first to control for these variables (subsequently referred to as control variables). Then verbal fluency, trails B-A, perseverative responses, reading with distraction and age were entered into the equation (referred to as predictor variables). Finally, to examine the possible effects of age on inhibition, the interaction terms for each independent variable and age were entered into the regression equations. Age was centered around the mean to increase the interpretabilty of the beta weights.

The results from the hierarchical regression analyses are summarized in Table 5. The hierarchical regression analysis for predicting the CVLT total recall score produced a significant overall $\underline{R}^2$ (.38), accounting for 38% of the variance. With regard to the individual predictor variables, entering in the control variables produced a $\underline{R}^2$ of .11. When the individual test measures were entered, $\underline{R}^2$ increased by .25. Only age was a significant individual negative predictor of total recall; as age increased the number of words recalled decreased. A trend was evidenced for perseverative responses ($\underline{p} < .09$) and reading with distraction ($\underline{p} < .06$), with greater impairment (i.e. reduced inhibitory functioning) being associated with a lower total recall score for the CVLT. The addition of the interaction terms resulted in an additional .02 increase in $\underline{R}^2$. None of the interaction terms were significant.

The regression analysis for predicting the CVLT total intrusion score produced a significant overall $\underline{R}^2$ (.38) accounting for 38% of the variance. The control variables accounted for 15% of the variance ($R^2 = .15$). With regard to the individual predictor variables vocabulary was found to be a significant negative predictor of the intrusion score. A higher vocabulary level was associated with a lower intrusion score. An increase of .10 was obtained in $\underline{R}^2$ when the individual measures were next entered. Trails B-A was found to be a significant positive predictor of the intrusion score. With the addition of the interaction terms, the amount of variance accounted for increased by 13%. Age x

Trails B-A was a significant positive predictor of the intrusion score. In order to understand the interaction, simple regressions were performed with just age, trails B-A and the interaction terms entered into the model as described in Cohen (1983). In order to plot the interactions, two values of age were chosen, ± 1 SD around the mean and using the beta weights from the simple model, I solved for the dependent measure. The interaction is plotted in Figure 1. Increased impairment, (i.e. reduced inhibition) as reflected in trails B-A was more strongly associated with intrusions in the older ages. The reverse association was seen for the younger age.

The regression analysis for predicting the CVLT total perseveration score produced a nonsignificant overall F value ($\underline{R}^2 = .11$, $\underline{F}(11,80) = .56$). The failure to find a significant regression analysis can partially be accounted for by the restricted range of scores for the CVLT perseveration score.

The regression analysis for predicting the number of false positives on the CVLT produced a significant overall $\underline{R}^2$ (.35) accounting for 35% of the variance. The control variables resulted in an $\underline{R}^2$ of .03. An increase in $\underline{R}^2$ of .24 was obtained when the individual test measures were entered into the equation. Both the perseverative response score and the reading with distraction score were significant positive predictors of the false positive score from the CVLT. For each significant individual predictor, greater impairment (i.e. reduced inhibitory functioning) was associated with a higher false positive score on the CVLT. A final increase of .08 was obtained with the addition of the interaction terms. Age x Perseverative Responses was a significant positive predictor of false positives. The interaction is plotted in Figure 2. For the younger age, perseverative responses did not predict false positives, however increased perseverative responses did predict increased false positives for the older age.

Since the CVLT has different subtypes of distractors on the recognition test, a one factor repeated analysis of variance was done to examine the types of false positives made in the recognition test and a significant F was obtained ($F(4,392) = 27.53$, $p < .0001$). Post hoc comparisons showed that the highest false alarms were made to words that were from the Tuesday list that shared the same category membership as Monday's list (M = 1.03, SD = 1.05). This score was significantly different from the four other subtypes (words from Tuesday's list, nonshared category membership, M = .34, SD = .73; words not on either list but share the same category membership, M = .52, SD = .77; words on neither list that were phonetically similar to items from Monday's list, M = .41, SD = .42; and unrelated words, M = .13, SD = .42). Analyses also showed that the number of false positives to the unrelated items were significantly lower than the other four types. Regressions analyses could not be performed using the subtypes of the false positive response due to restricted variability of responses.

The regression analysis for predicting the PASAT produced a significant overall R^2 (.44), accounting for 44% of the variance. An initial R^2 of .22 was obtained when the control variables were first entered into the equation. Vocabulary was found to be a significant positive predictor of PASAT. Higher scores on the vocabulary test were associated with higher scores on the PASAT. An increase of .17 resulted when the individual scores were entered. As a group, these measures accounted for a significant proportion of the variance, however none of the individual measures were separately significant. A trend was evidenced with the perseverative response score ($p < .08$). The addition of the interaction terms increased R^2 by an additional .05. Age x Reading with distraction was a significant negative predictors of PASAT. As age increased, perseverative responses and reading with distraction became less strongly associated with PASAT. However, this interaction should be interpreted with caution. When the simple regression analysis was done to plot the interaction, this interaction term became non significant.

The last aim of this study was to examine the relationship of age and inhibition. Specifically, it was hypothesized that inhibitory functioning would become less efficient with advancing age. As already discussed, to examine the possible age differences in the prediction abilities of the independent measures, interaction terms were entered into the regression analyses to evaluate this relationship. These results are reported above in the individual regression analyses. Also, correlations between age and the test measures were calculated and are presented in Table 3. Age was significantly correlated with all of the test measures except for the number of perseverations on the CVLT. In all cases, as age increases, performance on these tasks decreases. As vocabulary level has been found to effect performance on the reading with distraction task, the correlation between age and this measure was computed partialling out vocabulary. The correlation between age and the reading with distraction measure remained significant ($r = .27$, $p < .01$).

To examine the effect of depression on the test measures, the Geriatric Depression Scale (GDS; Brink et al. 1982) was administered. The mean GDS score for the entire sample was 3.88 (SD = 3.36, range 0 - 16). Only five of the sample could be classified as having mild depression as measured by this self-report questionnaire. Thus, for this sample the relationship between depression and inhibition could not be examined. None of the correlations between the GDS and the various neuropsychological measures were significant (r's = -.08, .06, .15, and .03 for verbal fluency, perseverative responses, trails B-A and reading with distraction score respectively).

DISCUSSION

The initial aim of the study, to replicate the factor analytic results of Arbuckle and Gold (1993) was achieved. As performance on the reading with distraction measure is thought to partially reflect the effects of inhibition, the finding of one factor in the analysis with the inclusion of this measure lends further support for the role of inhibition in the three clinical measures as theorized by Arbuckle and Gold (1993).

Although the factor analysis did produce one factor, the reading with distraction task had a lower factor loading score than the other measures. This was partly due to the low correlation between the reading with distraction task and the perseverative response score from the WCST. This correlation is surprising since initially, I would have thought that these two measures would have exhibited the strongest relationship. Although it is difficult to explain the small correlation between these two measures, several explanations are possible. First, the reading with distraction task is an experimental measure and no studies have been conducted looking at the reliability of this measure. The effects of distraction were found as in previous studies (Connelly et al., 1991), but the difference usually evidenced between the related and unrelated distractor condition (older adults show slower reading times in the related as opposed to the unrelated condition) was not obtained. The inability to replicate this finding leads one to question the reliability of this measure.

On the other hand, if the low correlation between reading with distraction and perseverative responses is indeed a replicable finding then another possible reason may be reflective in the different task requirements of these two measures. The reading with distraction task requires the focusing of attention towards the relevant words based on surface characteristics of the text, ignoring the irrelevant words. On the other hand, performance on the WCST is dependent on the ability to suppress information that was once important and activated in working memory but is now no longer relevant to the goal. Although speculative, these two tasks may reflect two different types of inhibitory mechanisms; one that promotes the ability to ignore extraneous stimuli and one that suppresses (internal) information that is already in working memory. Based on evidence in the literature, various researchers have in fact postulated the presence of (at least) two distinct attentional systems that may mediate in part two types of inhibitory mechanisms. The first attentional system is thought to be subserved by posterior areas of the brain (based on Posner & Peterson, 1990). This system has been hypothesized to be responsible for the orienting or focusing towards a stimulus on the basis of its characteristics such as location, shape, color and movement, integrating information from both of the dorsal and ventral visual systems (Kramer, Humphrey, Larish, Logan & Strayer, 1994; Posner & Peterson, 1990; Van Zomeren & Brouwer, 1994). By contrast the other mechanism is thought to be mediated anteriorly by the frontal lobes, and is involved in the suppression of information in working memory (either once relevant, or irrelevant associations to the task) allowing for the focusing of attention towards one line of thought/processing (Hartley, 1993; Kramer et al., 1994).

The posterior system consists of the parietal cortex, pulvinar nucleus of the thalamus and the superior colliculus (Kramer, et al., 1994; Posner & Peterson, 1990). It has been theorized that the parietal cortex disengages attention from a previous stimulus, then the midbrain area allocates attention to the area of the new target and the pulvinar is said to be involved in processing the information from the target location (Posner & Peterson, 1990). The processes of spatial selective attention seem to be mediated by this system (Kramer, et al., 1994).

Lesion studies have lent some support to this system although the applicability of the findings to normal adults is certainly speculative. Patients with damage to the posterior parietal lobe exhibit a syndrome known as unilateral or hemineglect, which is described as the tendency of decreased or absent awareness to one half of extrapersonal space (Lezak, 1995; Walsh, 1978). Damage to the posterior parietal lobe also effects the ability to disengage attention from one stimulus to another located on the contralateral side of the side of the lesion (Posner & Peterson, 1990). Patients who have progressive deterioration in the superior colliculus and/or surrounding areas show a deficit in ability to shift attention manifested in a slowing in allocating attention to a target stimulus. These patients also return attention to already examined locations just as readily as to new locations, suggesting that the inhibitory mechanisms of selective attention are impaired (Posner & Peterson, 1990). In addition, patients with thalamic lesions have difficulty in focusing attention towards a stimulus on the opposite side of the lesion suggesting problems in engaging target location in a way that allows responding to be fully selective (Posner & Peterson, 1990). Recent PET studies have also implicated the pulvinar nucleus of the thalamus in visual selective attention tasks (LaBerge, 1990a, 1990b).

As described above, the reading with distraction task may be partly mediated by this posterior system. Good performance on this task, as measured by reading times, relies in part on the ability to selectively attend to the text based on characteristics that discriminate the two fonts used in the task. Inefficient inhibitory mechanisms in this system would result in increased effects of distraction resulting in longer reading times. Although no differences were obtained in this study between the two distractor conditions, as described earlier, generally results show that older individuals have more difficulty inhibiting information when the irrelevant words are associated in some way to the target text (Connelly, et al., 1991). This seems to suggest that although the posterior system may initially be involved in the failure to inhibit attention towards irrelevant stimuli, once processed and activated in working memory, it is still necessary to suppress this information, perhaps involving the anterior system.

Information concerning the anterior system is less well developed (Van Zomeren & Brouwer, 1994). The anterior system involves structures located within the frontal lobe, specifically the anterior cingulate, prefrontal and supplemental motor areas (Posner & Peterson, 1990; Van Zomeren & Brouwer, 1994). It has been hypothesized that this system is responsible for a number of functions like planning, coordinating the processing of multiple stimuli, the initiation and cessation of thoughts and behaviors and the processing of semantic information (Kramer et al., 1994). Although speculative, this system may be involved in the suppression of already activated information in working memory. Researchers have argued for the role of the frontal lobes in working memory, although little has been focused on the role of inhibition (Goldman-Rakic, & Friedman, 1991; Moscovitch, 1994). It has been suggested that the two systems work within a hierarchical framework; the anterior cingulate being the more dominant of the two

(Posner & Peterson 1990; Van Zomeren & Brouwer, 1994). The anterior cingulate is particularly involved with target detection and has been shown to have increased projections to the dorsolateral prefrontal cortex and to the posterior parietal lobe (Posner & Peterson, 1990; Van Zomeren & Brouwer, 1994). Given the task components of the WSCT, performance may be partially reflective of frontal lobe functioning, although impaired performance can be evidenced with patients who have brain damage to other areas (Anderson, Damasio, Jones, & Tranel, 1991; Lezak, 1995).

However, studies that have supported the idea of two inhibitory mechanisms generally argue for the preservation of the posterior system in older adults whereas the anterior system declines with age. The results from this study do not support this claim. If there are two inhibitory mechanisms, then the findings from the multiple regression analyses suggest that both types of inhibitory mechanisms are affected with advancing age. Although the postulation of two attentional systems that subserve different inhibitory mechanisms is intriguing, if there are multiple systems it is unlikely that they will be independent of each other. As described above, neuroanatomically there are many interconnections between brain regions and specifically the frontal cortex projects to multiple areas including the posterior regions. In this study, the fact that both measures did come out on the same factor supports the idea that there is one underlying process, that I would propose is a general inhibition mechanism. It is still feasible that the differences in inhibitory functioning as a function of task demands is accountable in part by the engagement of additional processes that are reflective of different neuroanatomical regions, dependent upon the nature of the task.

Once the factor analysis had been replicated, the next goal of this study was to evaluate the role of inhibitory functioning in other cognitive domains. It was found that in a sample of community dwelling older individuals that the predictor variables (verbal fluency, perseverative responses, trail making test, reading with distraction) were predictive of performance on neuropsychological tasks measuring memory (CVLT subscores) and attentional performance (PASAT). In particular, the predictor variables accounted for an increase in variance (10 to 25%) on most of the memory scores (recall, the number of intrusions, and false positives) and the attention measure. Decreased performance on the predictor variables was related to decreased performance on the memory and the attention measure.

Reduced performance on the predictor variables was associated with greater numbers of errors on the CVLT. Individuals had difficulty suppressing semantically related items when recalling the list. This relationship was evidenced on the recognition task as well. The highest number of false positives were made to responses that were from the same semantic category that were presented in the second list. Although the relationship was not statistically significant with total recall, the alpha level reached .06 with the reading with distraction task. It is quite possible that with a larger sample size, this relationship would reach significance.

Why the predictor variables did not predict perseverations on the CVLT is unclear. The inhibition view would argue that decreased inhibitory processing would lead to an impairment in the ability to suppress the response, now considered to be irrelevant to the task goal, increasing the probability of repetition. This hypothesis was not supported in this study. On inspection of the data, one possible reason may be due to the fact that the range of perseverative responses for this sample was restricted, although quite similar to the normative data available for this age group (Delis et al., 1987). It is possible that a relationship would be evidenced in a population of older adults who are more impaired on this measure. Another possible explanation, although counter-intuitive, is that perseverations as measured by the CVLT may reflect a different process than errors due to intrusions on this test. In a factor analytic study of the CVLT, Wiens and colleagues (Wiens, Tindall, & Crossen, 1994) found that the perseveration score loaded on the same factor as the semantic and serial clustering scores, measures of learning strategies used in this task. By contrast, intrusions and false positives loaded on a separate factor, termed response discrimination. The factors obtained in their study suggested that number of perseverations may be more related to the learning strategy used by an individual. As inhibition is thought to be necessary for response selection, the relationship between the target variables and intrusions and false positives is understandable. By contrast, there is no reason to theorize that inhibitory processes would be important in determining the type of strategy used to generate the response. This may explain why there is no relationship between the perseveration score and the predictor variables, however future studies are needed to explore this further.

This study found support for the role of inhibition in tasks assessing memory and attention. On the other hand, Arbuckle and Gold (1993) did not find a relationship between their measure of verbosity, which was theorized to partially reflect inhibitory functioning and other measures of memory and attention. This difference in results could be due to the types of tasks used to assess memory and attention performance. In the Arbuckle and Gold study, the use of a paragraph learning task with a single trial presentation and no available measure of errors, may make this task less suitable for the assessment of inhibitory functioning. As reported above, inhibition processes were related to the number and certain types of errors produced on the memory test. The lack of this measure may reduce the sensitivity of the paragraph memory task to evaluate inhibitory functioning. Whether good performance on this memory task is not as reliant on efficient inhibitory functioning or whether the psychometric properties of this task do not lend itself to effectively measure inhibition is unclear. The same kinds of arguments can be used for their attention measure, digit span. The PASAT is clearly a more complex and difficult test, as opposed to digit span. The range of scores on digit span is quite limited, and again this task may not be sensitive enough for the assessment of inhibition.

The second hypothesis that was evaluated in this study was that there would be a significant relationship between age and inhibition, as measured by the predictor variables. The results show that this relationship is not a straightforward one and is at least dependent upon the characteristics of the various tasks being measured. As predicted, advancing age was related to reduced performance on all the individual predicted variables. However, in predicting performance on the memory and attention measures, the relationship between the predictor variables and the dependent measures, changed as a function of age and test measure. The relationship between the predictor variables and the types of errors made on the CVLT (i.e. intrusions and false positives) was generally stronger with age. This suggests that with advancing age, inhibitory functioning continues to decline, further impairing performance on the predictor and memory measures.

However, on the attention measure, contradictory findings were evidenced suggesting that for this study, the finding of an age interaction is unreliable for this variable. One possible reason may be the way in which the test was scored. A score of zero was entered regardless if the participant could not perform the task or if that person refused to do the task. These two results may not reflect the same processes, yet are coded the same way. In addition, the inclusion of the zeros also skewed the distribution of results. When these zeros were not included in the analysis, then the main effects were still found but the interaction was no longer significant. Thus, it would have to be tentatively concluded that there is no relationship between age and inhibition for this measure, but further study is necessary with a larger sample of adults, and perhaps a different coding system for the zero scores, before stronger conclusions can be made.

Although the results are mixed in this study, there is some evidence that the ability to ignore and/or suppress irrelevant information changes with advancing age. This is consistent with other findings that have found age differences between those participants who have been classified as "young-old" (generally between 60 and 74) and "old-old" (generally 75 and older) on various cognitive measures. Evidence has been accumulating in the literature showing that those individuals who are over the age of 75 exhibit lower levels of performance on a variety of neuropsychological measures as compared to the those individuals who are between the ages of 60 and 74 (Christensen, MacKinnon, Jorm & Henderson, 1994; Osterweil, Mulford, Syndulko & Martin, 1994). However, the nature of the relationship between age and inhibitory functioning was essentially the same across the decades.

Although this study has provided evidence that age is related to performance on the measures, other individual variables may also play a role. The recruitment process used in this study attempted to enlist older individuals living in the community who normally would not volunteer for research studies in an attempt to assess a more representative sample. As a result, many of the volunteers did not have a college education, and exhibited average ability on the vocabulary test. This sample may be different from those older individuals who answer advertisements in the newspaper, on variables such as education and vocabulary knowledge. These individual differences, generally ignored in relation to inhibition, may partially account for the findings of reduced efficiency in both inhibitory mechanisms. There is some suggestion that individual difference variables can partially account for inhibitory functioning even in young adults. For example, in one study, Gernsbacher (1993) reported finding reduced suppression on tasks of reading comprehension requiring the suppression of inappropriate meanings of ambiguous words, in adults who are classified as less skilled readers. Based on these findings, it would be important to further study the role of individual differences in the efficiency of inhibitory functioning. One individual difference variable, the presence of depressive symptoms, did not appear to be related to performance on the neuropsychological and experimental measures in this study. However only five individuals in this sample scored in the mildly depressed range on the Geriatric Depression Scale as classified by a score of 11 or above. Incidence rates for depression have been reported to be anywhere from 1 to 29% (Gomez & Gomez, 1993). Although this study attempted to assess a more representative sample of the older population, the recruitment procedure still relied on volunteers for the study. It is quite possible that this study was affected by self selection problems; those individuals who could be classified as depressed probably did not volunteer for this study. This self-selection bias has in fact recently been reported (Thompson, Heller, & Rody, 1994). The absence of individuals with diagnosable depression in this study limits the generalizability of the current findings. A more systematic approach that attempts to measure and control for other individual variables, such as reading skill or health status is necessary to understand the impact of individual difference variables on inhibitory functioning.

Although inhibitory processing was interpreted as being the underlying link between the neuropsychological measures employed in this study, it is possible that other factors also could explain the relationship among these measures. The most noteworthy is that of a general slowing of information processing speed that has been hypothesized to occur with age (Salthouse, 1994, 1995). Many of the neuropsychological measures did have a timed component but a number of them did not have time constraints, such as the CVLT and the WCST. However, the WCST did load on the same factor as the other timed neuropsychological measures. In addition, if speed of processing was the most important underlying factor to the neuropsychological tasks, then it would follow that the reading with distraction task would have loaded higher on the factor than it actually did (and possibly higher than the WCST perseverative response score that does not have a speed component). In this study although none of the tasks used were optimal measures of speed of processing, Trails A, a measure with a large speed component, did not significantly correlate with either verbal fluency or the number of false positives on the CVLT. Yet hierarchical regression analyses supported the hypothesis that performance on the tasks were related, with the predictor variables accounting for a significant proportion of the variance of most of the memory scores and the attention measure. Although a generalized cognitive slowing theory could still be used to account for some of the findings of this study, it is proposed that the construct of inhibitory processing can more thoroughly account for the significant results.

Given that inhibition does partly subserve performance on the neuropsychological tasks, these results demonstrate that one's ability to ignore or suppress irrelevant information is associated with performance on many cognitive tasks, and can be assessed using clinical measures. The ability to use clinical measures to assess inhibitory functioning in older adults can allow for a broader test of this theory, with a wider range of ages and patient populations with cognitive disorders such as Alzheimer's disease and Parkinson's disease. There is some preliminary data suggesting that inhibitory functioning is greatly reduced in patients with Alzheimer's disease as compared to old healthy individuals. For example, patients with Alzheimer's disease show evidence of impaired inhibitory functioning on tasks of identity negative priming and the Stroop effect (Spieler, Balota & Faust, 1996; Sullivan, Faust & Balota, 1995). Although to my knowledge, no research has been specifically conducted looking at the relationship between inhibition and Parkinson's disease, there is some evidence to suggest that these patients may also have difficulties in suppressing irrelevant information. Research has shown that patients with Parkinson's disease have difficulty shifting set and alternating response sets (Flowers & Robertson, 1985; Raskin, Borod, & Tweedy, 1992) and produce an increased number of perseverative responses on the WCST as compared to age-matched healthy older individuals (Lees & Smith, 1983; Taylor, Saint-Cyr & Lang, 1986). These findings suggest that these patients may have deficient inhibitory mechanisms. Future research can help elucidate the role of efficient inhibitory functioning in these and other patient groups. If inhibitory functioning is impaired in certain patient groups, it is possible that the assessment of inhibitory functioning may become part of the diagnostic assessment battery in dementia and other disorders.

Aside from diagnostic considerations, to understand the role of inhibition and selective attention in cognition may help in the selection and development of techniques or strategies that could be utilized by older individuals and patients to compensate for inefficient inhibitory processing. For example, if older individuals have more difficulty processing information when presented together with extraneous material, then one simple intervention would be to present the pertinent information succinctly and relatively free of irrelevant material to reduce the impact of distraction. In one study employing the reading with distraction task, Carlson and colleagues (Carlson, Hasher, Connelly & Zacks, 1995) showed that when the distracting material was placed in predictable locations in the text, then the age differences usually seen on this task were greatly reduced.

In summary, although in need of replication, the findings from this study suggest that easily available neuropsychological measures can be used to assess inhibitory functioning in older adults. The use of clinical measures can allow for the assessment of inhibition in a wider range of ages and patient populations to further understand the role of inhibition and general cognitive functioning. This increased understanding can possibly lead to the development of interventions that can help older individuals to ignore distracting information so that they can selectively attend to the necessary information to complete the task at hand. The findings of differences in inhibition with age, within a group of older adults emphasizes the need to conduct future research on the relationship of age and additional individual variables and inhibition.

APPENDIX

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Table 1.

Means and Standard Deviations for the Neuropsychological Tests Administered to 100 Older Individuals

Test Measure	Mean	(SD)
Vocabulary Score from the WAIS-R	47.56	(10.69)
Verbal Fluency Total Score	37.17	(12.08)
WCST Perseverative Responses	22.52	(19.06)
Trails B - Trails A	65.54	(40.68)
California Verbal Learning Test (CVLT)		
Total recall over 5 trials	40.82	(10.12)
Total Perseverations	3.81	(4.02)
Total Intrusions	5.28	(5.80)
Recognition Hits	13.52	(1.84)
Recognition False Alarms	2.5	(2.68)
Paced Auditory Serial Addition Test (PASAT)	90.43	(46.03)

APPENDIX

Table 2.

Means and Standard Deviations for the Reading with Distraction Test Administered to 92 Older Individuals

Test Measure	Mean (SD)
Reading Time	
Related Condition	83.03 (27.37)
Unrelated Condition	84.16 (28.43)
No Distraction	56.45 (17.80)
Correct Responses on the Recognition test (out of 4)	
Related Condition	2.71 (.61)
Unrelated Condition	2.95 (.52)
No Distraction	3.03 (.55)
Percent Foils	
Related Condition	53.05 (26.44)
Unrelated Condition	31.62 (26.62)
No Distraction	31.89 (25.72)

APPENDIX

Table 3.

Correlations between Age and the Neuropsychological Measures

	1	2	3	4	5	6	7	8
1. Age	--							
2. Education	-.25*	--						
3. Vocabulary	-.17	.54*	--					
4. Verbal Fluency	-.21*	.33*	.47*	--				
5. Trails B-A	.45*	-.27*	-.43*	-.35*	--			
6. WCST	.26*	-.22*	-.24*	-.31*	.39*	--		
7. Reading with Distraction	.28*	-.09	-.07	-.15	.31*	.08	--	
8. CVLT Total Score	-.46*	.30*	.30*	.29*	-.45*	-.36*	-.33*	--
9. CVLT Perseverations	-.12	.18	.08	.10	-.16	-.01	-.02	.36*
10. CVLT Intrusions	.24*	-.17	-.39*	-.21*	.43*	.23*	.08	-.37*
11. CVLT False Positives	.33*	-.09	-.17	-.22*	.31*	.41*	.29*	-.69*
12. PASAT	-.37*	.32*	.46*	.41*	-.46*	-.38*	-.27*	.48*

*significant at $p < .05$; n=100

APPENDIX

Table 3 (cont'd).

	9	10	11	12
9. CVLT Perseverations	--			
10. CVLT Intrusions	-.01	--		
11. CVLT False Positives	-.15	.59*	--	
12. PASAT	.05	-.31*	-.39*	--

*significant at p < .05; n=100

APPENDIX

Table 4.

Intercorrelations between the clinical measures and the Reading with Distraction task (n = 100)

Test Measure	1	2	3	4
1. Verbal Fluency	--	-.35 (-.33[b])	-.31 (-.29[c])	-.15
2. Trails B- Trails A		--	.39 (.38)	.31
3. Perseverative Responses			--	.08
4. Reading with Distraction [a]				--

[a] n = 92 for this measure

[b] correlations in parentheses are those obtained by Arbuckle and Gold (1993)

[c] perseverative errors instead of perseverative responses was used by Arbuckle and Gold (1993)

APPENDIX

Table 5.

<u>Results from the hierarchical regression analyses</u>

Dependent variable	Controlled Variable	R^2	Increase in R^2
CVLT Total Recall			
	Control Measures	.11*	
	Predictor Variables	.36*	.25*
	Interaction Terms	.38*	.02
CVLT Intrusions			
	Control Measures	.15*	
	Predictor Variables	.25*	.10
	Interaction Terms	.38*	.13*
CVLT False Positives			
	Control Measures	.03	
	Predictor Variables	.27*	.24*
	Interaction Terms	.35*	.08
PASAT			
	Control Measures	.22*	
	Predictor Variables	.39*	.17*
	Interaction Terms	.44*	.05

* $p < .05$

APPENDIX

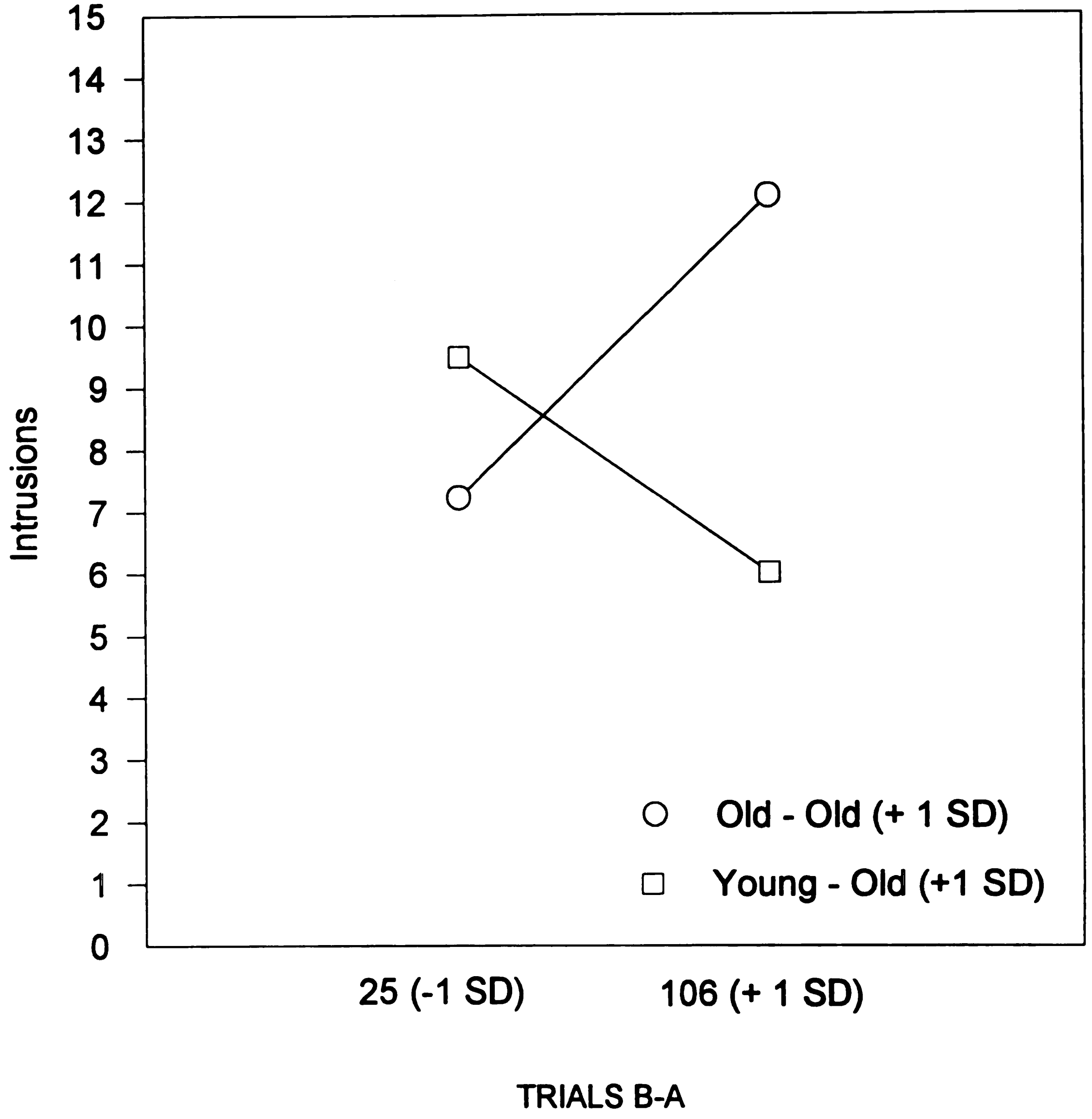

Figure 1

Interactions of Age and Trials B - A in Predicting Intrustions

APPENDIX

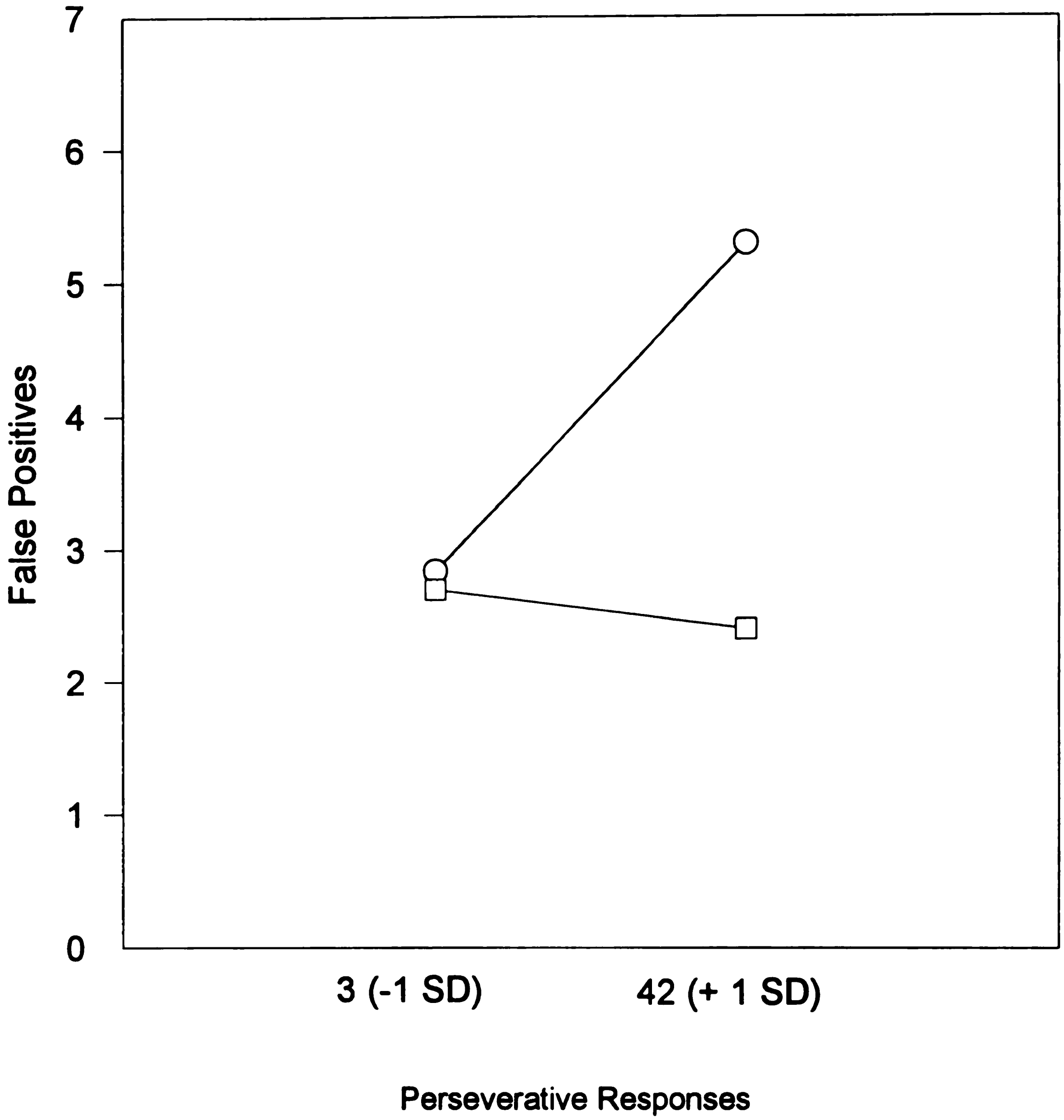

Figure 2

Interactions of Age and Perseverative Responses in Predicting False Positives

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