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INVESTIGATING AGE-RELATED INHIBITORY DEFICITS IN SPATIAL WORKING MEMORY

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ABSTRACT OF THESIS

INVESTIGATING AGE-RELATED INHIBITORY DEFICITS IN SPATIAL WORKING MEMORY

Age-related inhibitory effects were investigated during spatial memory performance. In Experiment 1, 15 young (*M* = 20 years) and 16 old adults (*M* = 70 years) completed two spatial tasks (i.e., Block Suppression Test, Corsi Block Tapping Test) that differed in need for inhibitory processing. Accuracy differences within each task revealed age-related differences in spatial working memory and between task differences revealed that older adults had difficulty ignoring irrelevant items. Experiment 2 (10 young, 10 old adults) examined whether the distractibility of irrelevant items in the inhibition task (i.e. BST) accounted for the age-related inhibitory effects. Findings were largely consistent with the initial experiment indicating that inhibitory function was affected by adult aging.

KEYWORDS: Inhibition, Spatial Working Memory, Cognitive Aging, Block Suppression Test, Corsi Block Tapping Test

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THESIS

Joann Lianekhammy

The Graduate School

University of Kentucky

2006

INVESTIGATING AGE-RELATED INHIBITORY DEFICITS IN SPATIAL WORKING MEMORY

THESIS

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the College of Arts and Sciences at the University of Kentucky

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for John, Khamphone, and Phonesavane

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CHAPTER ONE: INTRODUCTION

Aging and Cognition

A major focus in aging research is the examination of age-related deficits in cognitive abilities. Verhaeghen & Salthouse (1997) revealed the widespread nature of cognitive declines in older adults by conducting a meta-analysis of 91 aging research studies. Each of these studies measured one of five different cognitive functions: a) working memory, b) speed, c) spatial abilities, d) episodic memory or e) reasoning. Results from this analysis indicated that adult aging affected all five cognitive measures. The implication behind this finding was that deficits in cognitive functions exist as a consequence of aging. The exact causes of these deficits are unclear, but several theoretical constructs have been proposed as potential mediators between aging and cognitive declines.

One particular theory proposes that cognitive declines in aging occur because of a deficit in inhibitory mechanisms (Hasher & Zacks, 1988). Inhibition is defined as an active suppression process which serves to suppress activated cognitive contents or processes no longer of relevance, and to prevent processing of goal-irrelevant information. Hasher & Zacks proposed that older adults' inhibitory mechanisms decline with age which leads to increased interference in the selective processing of goal-relevant information. This would result in less efficient processing exhibited as poorer performance in different tasks measuring cognitive functions such as selective attention, memory, reasoning, and language ability.

Inhibitory Deficit Research

Age-related inhibitory deficits have been investigated in many different contexts. One important area of research has been in the context of negative priming. The negative priming paradigm is often used to research inhibition because it is assumed to index the efficiency of inhibitory processes. In negative priming tasks, participants are presented with a series of paired trials referred to as prime and probe trials. For prime trials, a target and distractor is presented in which participants are instructed to respond to the target and ignore the distractor. During probe trials, a target and distractor is also presented, but the target now shares the identity of the distractor from the preceding prime trial. The relationship between the target and the preceding distractor should cause a slowing of response, also referred to as negative priming or suppression effect. This slowing of response is taken to be a measure of inhibition because previous instruction to ignore the irrelevant item makes the stimulus less available during response selection. The magnitude of suppression effects is interpreted as the efficiency of the inhibitory process.

Several studies have identified an inhibitory deficit in older adults using the negative priming paradigm (e.g., McDowd & Oseas-Kreger, 1991; Hasher, Stoltzfus, Zacks, & Rypma, 1991). To gain a better understanding of age-related inhibition declines using negative priming, Kane, et al. (1994) tested 40 young adults and 37 older adults on word identification tasks requiring the inhibition of distractor items. The word list consisted of nine three-letter nouns, with each word paired with one another. During the presentation of these pairs, one word was regarded as being a distractor (colored in red) and the other was distinguished as the target (colored in green). In the control condition, prime trials and probe trials contained paired words that shared no relationship with one another. In the distractor suppression condition, probe trials contained a target that shared the same identity as the previous distractor in the prime trial. Participants were instructed to verbally respond to the target while the onset latency of response was recorded. Inhibitory processes required to complete this task were analyzed by comparing the mean reaction time for probe trials in the control condition to the mean reaction time in the distractor suppression condition within each age group. Results revealed that younger adults were reliably slower in the distractor suppression trials than in control trials, but older adults did not show any reliable differences between the two conditions. Another analysis was conducted comparing suppression effect sizes shown by younger and older adults. Suppression effects were difference scores obtained by taking the average reaction time in the distractor suppression trials and subtracting that value from the average reaction time in control trials. Results indicated reliable differences between younger and older adults’ suppression effects. Kane, et al. concluded that older adults either failed to engage in the suppression of irrelevant information or had more difficulty doing so, thus lending support for an age-related inhibitory deficit.

In addition to age-related inhibitory deficits found with negative priming, the results of some aging studies have suggested that there may be separable inhibitory mechanisms. Connelly and Hasher (1993) found that older adults consistently showed suppression for the location of a distractor during a negative priming task, but were not able to show suppression for the identity of the distractor. This result indicated that inhibition may not be a unitary construct as once thought, but is comprised of multiple mechanisms that operate on the characteristics of the goal-irrelevant object such as identity and location. The mechanism responsible for age-related deficits, however, is unclear and remains under debate.

Contrary to Connelly and Hasher's (1993) findings, the ability to significantly suppress an object's identity has been found in older adults using negative priming tasks (e.g., Sullivan & Faust, 1993; Kieley & Hartley, 1997). The proposal that inhibition of location is well preserved in aging has also been challenged by McDowd and Fillion (1995) who were able to show age-related deficits for location suppression with negative priming. These discrepant findings call into question why inhibitory deficits have been found in some studies, but not found in others.

Methodological Problems

One explanation for inconsistent findings may concern negative priming as a measure of inhibition. Kane, et al. (1993) addressed one issue about the magnitude of suppression effects found in inhibition and negative priming research. Response time differences indexing inhibitory processing found in some studies were around 10 milliseconds for younger adults (i.e. Hasher, et al., 1991; Stoltzfus, et al., 1993). This small of an effect size along with small sample sizes could be problematic due to low statistical power, making it more difficult to detect the presence of weaker suppression effects in the older adults (Verhaeghen & De Meersman, 1998).

Another methodological problem common to negative priming research concerns the interpretation of results obtained by using reaction time as a dependant measure. Measures of reaction time (RT) yield estimates of the actual duration of processing and have been widely used to investigate age-related differences in cognitive function. However, there are ambiguities with this type of measurement regarding what the proper units should be used in analysis such as raw effect size of RT or effect size proportional to total RT (Gottlob & Madden, 1998).

McDowd (1997) identified another concern in which the slowing of response time found in negative priming tasks may not only be produced by inhibitory processes, but could also be caused by an episodic retrieval mechanism. Slower reaction times could reflect interference produced by retrieving information about past responses made to that stimulus. If the information retrieved is congruent with the current demand of the task, response is facilitated. Conversely, if the memory retrieved contains non-response information, current response will be slowed. This is problematic because negative priming has been assumed to index active inhibition during selective attention involved during the priming trial. If retrieval of episodic memories occurs during time of response, then reaction times will also index the influence of variables other than active inhibition such as memory traces of past negative priming over intervening trials (Neill, Valdes, Terry, & Gorfein, 1992). These issues presently discussed warrant caution towards the use of negative priming as a definitive test of age-related inhibitory deficits.

Other Age-related Inhibitory Deficit Research

Although several problems were identified concerning the use of the negative priming paradigm to investigate inhibitory mechanisms, those issues do not completely explain the discrepancies found in the literature on aging and inhibition. Research examining age-related inhibitory deficits outside the context of negative priming has also shown inconsistent results. Two studies showing conflicting results were conducted by West (1999) and McCabe and Hartman (2003). West (1999) tested 20 younger and 20 older adults on a task in which participants were required to recall the location of a target. The target could appear in four possible locations and participants were instructed to respond according to the location of the target. On some of the trials, a target and distractor appeared simultaneously. Participants were instructed to ignore the distractor and only respond according to where the target was located. Results revealed that older adults made more errors than younger adults in accurately responding to the location of the goal-relevant target when a distractor was present. This finding was consistent with the idea that inhibitory processes may be compromised as a result of aging. More efficient inhibitory mechanisms should serve to prevent irrelevant items from interfering with processing goal-relevant information. However, results indicated that the presence of a distractor decreased performance for older adults to a greater degree than the younger adults.

In contrast, McCabe and Hartman's (2003) study investigating complex span task performance in young and old adults failed to show support for age-related inhibitory deficits. In this study, 48 young and 48 old participants were presented with a reading span task, a list span task, and a dual-task word span task. For the reading span task, participants were asked to read sentences consisting of 8-12 words and respond according to whether the sentence was meaningful or not. Each sentence also held a final to-be-recalled word. At the end of each trial, participants were asked to recall all final words presented in each sentence in the order of presentation. For the list span task, participants were presented with five-word lists containing zero to two animal names in each list and irrelevant non-animal words. At the end of presented lists, participants were required to recall each animal word in the order of presentation. For the dual-span task, participants were instructed to read animal and non-animal words out loud as they were presented serially. When an animal name was read, participants were instructed to press a specified key. At the end of each trial, the participant was asked to recall all presented animal words in the order of presentation. For all tasks, span size of the to-be-remembered words or sentences started at two and increased after three correct responses were made at that span size. The task ended after participants failed to make two correct responses at that given span size.

To investigate inhibitory deficits, McCabe and Hartman (2003) examined the amount of intrusion errors made in the reading span and list span tasks. Intrusion errors were defined as responses made for non-target words. It has been suggested that an increase in intrusion errors or responses made for non-target words may be attributed to inhibitory deficits because efficient inhibitory processes should serve to suppress resources from irrelevant information, making them less available for response selection. Results showed no age differences in intrusion errors made in either the reading span or the list span task.

McCabe and Hartman (2003) also investigated age-related inhibitory deficits by comparing performance in the list span task and the dual-span task. In the list span task, participants were required to inhibit irrelevant words presented along with target words, while the dual-task span task did not involve inhibition. Researchers argued that if older adults suffered from inhibitory deficits, age differences in list span tasks would be larger than in the dual-task span task because of increased interference caused by the irrelevant information. However, age differences in the list span task were no larger than in the dual-task span. This finding did not support an age-related inhibitory deficit.

Inconsistencies in age-related inhibitory deficit research have highlighted the need to find a valid and reliable measure of inhibitory functioning. The primary aim of this thesis is to further examine the role of inhibition in older adults using two similar measures of working memory, the Corsi Block Tapping Test (Corsi, 1972) and the Block Suppression Test (BST) (Beblo, Macek, Brinkers, Hartje, & Klaver, 2004). Before the two tests are discussed, working memory and aging will be reviewed.

Working Memory and Aging

Working memory is a system that temporarily stores and manipulates information essential to the execution of cognitive tasks such as learning, reasoning, and comprehension (Baddeley, 2003). Baddeley describes working memory as a three-component structure that facilitates a range of different cognitive activities. Working memory is comprised of three components known as the phonological loop, which stores and manipulates verbal information; the visuospatial sketchpad (VSWM), responsible for the storage and manipulation of visual and spatial information; and the central executive attentional control system, which allocates resources to manage processing between the two storage units (McCabe & Hartman, 2003). Inhibitory processes in this context prevent irrelevant information from entering working memory and/or prevent information that is no longer relevant from remaining in the contents of working memory. Impairment of inhibitory mechanisms would lead to the increase of irrelevant information entering or remaining in working memory. The consequences of an inhibitory deficit should, therefore, result in poorer task performance due to the increase of interference during goal-relevant processing.

The present study involves two similar measures of spatial working memory, the BST and Corsi task. In both tasks, participants are presented with an array of 9 blocks at fixed locations. The experimenter then taps out a sequence of blocks that participants must reproduce. For the Corsi task, participants must reproduce the sequence in the exact order the blocks were presented. Sequence length usually begins at two and continues to increase with each accurate sequence reproduction until the participant makes two consecutive errors. Procedures for the BST are similar to the Corsi task in that participants are presented with a sequence using an array of 9 blocks at fixed locations, but participants are asked to only reproduce every other block. For example, if a sequence of 3 blocks were shown to participants, they would be expected to remember the location of the first and third block in the sequence. The location of the second block (an irrelevant piece of information) would, thereby, be suppressed.

Although the BST involves an inhibitory component, it has not yet been researched in the context of age-related inhibitory declines. Using the BST and Corsi task may be more suitable than negative priming to investigate age-related inhibitory deficits because performance is measured by accuracy. The advantage of using accuracy as a measure rather than reaction time is that there are no ambiguities about which unit of measurement is most appropriate. Inferences can be made between amounts of processing and measured amounts of accuracy in that zero amount of processing should lead to chance level of accuracy and maximum amount of processing should lead to accuracy at the data limit (Norman & Bobrow, 1975).

Since the BST and Corsi task are both measures of spatial working memory, a secondary aim of the current study was to investigate age-differences found in working memory. It has been well documented that declines in working memory are found with aging (e.g., Salthouse, 1994; Verhaeghen & Salthouse, 1997). More specifically, research has shown age differences in spatial working memory. One study supporting this age difference was conducted by Chen, Hale, and Myerson (2003) who investigated spatial working memory in young and old adults. Participants performed a task in which a series of 5 or 6 “X”s were presented in different cells in a 4 x 5 grid. Each “X” was presented for 750ms at a 300ms inter-item interval. Once all “X”s were presented, every “X” in the series appeared simultaneously in the same position of presentation except for one. Participants were then required to identify the “X” that appeared in a different location. Older adults had more difficulty than younger adults in identifying the new location of the target. Even though performance in both age groups declined when series length increased from 5 items to 6 items, younger adults still outperformed the older adults at both series lengths. Results confirmed an age-related decline in spatial working memory.

Present Investigations

Two experiments were presently conducted. Experiment 1 examined age-related inhibitory deficits were investigated using the BST and Corsi task. In accordance with the evidence found supporting age-related declines in working memory, it was predicted that age-related differences would also be found in the performance of these two spatial memory tasks. In order to investigate the effects of inhibitory deficits, age differences in Corsi task performance was used as a baseline in which age differences in the BST were compared. If older adults exhibit inhibitory impairment, the present thesis would expect to find larger age differences between young and old performance in the BST than the Corsi task since the BST requires the inhibition of irrelevant item locations. Experiment 2 was conducted to address a concern with the low distractibility of red (to-be-ignored) blocks in the BST used in Experiment 1. A stimulus that holds information that is significant or that is novel will elicit an orienting response or preparatory response that prepares the visual system for further voluntary processing (Cowan, 1995). Since red blocks were consistently used as distractor blocks in the BST, it is possible that attention towards these blocks were gradually reduced no longer requiring mental attention. This was problematic because inhibition is considered to be an important function of selective attention (Neill, Valdes, & Terry, 1995). The primary goal of the second experiment was to investigate age-related inhibitory deficits with the BST and Corsi task when the distractibility of the red (to-be-ignored) items in the BST was increased. Distractibility was increased by making a small procedural change that drew attention to all presented blocks in a sequence. This provided a stronger case that the distractors were being processed and inhibited rather than filtered out by the visual system.

CHAPTER TWO: EXPERIMENT 1 METHODS

Participants

Participants were 15 young adults ranging from 19-25 years of age (M =20.33, SD = 1.99), and 16 older adults ranging from 60-76 years of age (M =70.00, SD = 4.66). Young adults were enlisted by placing fliers throughout the University of Kentucky campus as well as placing an ad in the university's newspaper. Older adults were residents of the Lexington, Kentucky area, recruited using a directory from the Sanders Brown Aging Center. All paid participants had normal to corrected vision ranging from 20/20 to 20/40 and also passed a color blindness screening. A computerized version of the Mill Hill Vocabulary and the Digit Symbol Substitution Test was administered. Mean score on the Mill Hill was 18.38 (SD = 3.10) for older adults and 13.80 (SD = 3.69) for younger adults, $t(29)= -3.750$, $p<.001$. Accuracy across Digit Symbol scores was not significantly different between groups, $t(29) = -1.096$, $p > .05$. Younger adults yielded a mean accuracy of 93.73% (SD = 4.935) and older adults obtained a mean accuracy of 95.44% (SD = 3.67). Reaction time in the Digit Symbol task, however, was significantly different, $t(29) = -6.335$, $p < .001$, with younger adults (M = 1066.60, SD = 229.60) completing the task at an average of 467ms faster than older adults (M = 1533.56, SD = 179.207). All participants received ten dollars as compensation for the one hour session.

Apparatus and Stimuli

The Block Suppression Test (BST) and Corsi Block Tapping were computerized variants of the traditional tasks created using E-Prime programming software. Both tasks were presented via a personal computer on a 14" Sampo KM-511-1 Series color monitor. Participants' responses were made using a computer mouse and were recorded in E-Prime. Eye to screen distance was 1.5 feet. Participants viewed three different configurations of nine 1" x 1" black squares, fixed in their positions and presented in pseudo-random locations. Sequence set sizes (number of squares in each sequence) were 3, 5, 7, 9 and 11. For each trial, E-Prime randomly chose 1 out of the 30 possible sequences from one of the five set sizes. At the start of each trial, participants viewed a sequence consisting of 3-11 squares changing from black to either red or green. For the BST task, participants were asked to remember the sequences and serial positions of the green squares only. Red squares were to be ignored. The Corsi task required all blocks that appeared in the sequence to be remembered, regardless of color. Note that each of the nine squares could appear in a sequence more than once.

Procedures

Participants viewed a short instruction guide which contained an example of the task, and how to correctly respond. A short period was also allocated for questions to ensure that all participants were clear on how to perform each task. Participants viewed 8 sequences from of each of the 5 set sizes, making up a total of 40 sequences. In each trial, runs of color greater than two were not presented (e.g. Set Size 5: green, green, red, green, red; not green, green, green, red, red).

To begin each trial, participants were required to press the right mouse button. Once the sequence had been initiated, a 1 second delay occurred before the series of red and green squares began to light up in one of the 9 fixed locations. Each red or green square remained onscreen for 1 second with approximately 50 ms between the presentations of each square in the series. After the sequence was complete, the same display of those 9 fixed squares was presented to participants to make their response by reproducing the given sequence. Responses were made by moving the mouse directly over a square and pressing the left mouse button. There were no time constraints involved in the response portion of the experiment. Coordinates for each mouse press were later used for scoring. Each trial response was ended by pressing the right mouse button to continue on to the next sequence.

CHAPTER THREE: EXPERIMENT 1 RESULTS

Introduction

A repeated measures analysis of variance (ANOVA) was conducted for the BST and the Corsi task with age group as the between-subjects variable and set size as the with-in subjects variable. Set size was identified as two different types of variables: encoding set size and retrieval set size. The encoding set size represents the overall number of blocks presented in a sequence which were the same for both tasks--3, 5, 7, 9, and 11. Retrieval set size represents the amount of blocks that must be recalled in order to make a correct response. Since the BST required all red blocks to be ignored, accurate sequence recall was regarded as those responses made replicating all presented green blocks in their serial order, while a correct response for the Corsi task required the replication of all presented items regardless of color. Due to this instructional difference, retrieval set size was 2, 3, 4, 5, and 6 for the BST and 3, 5, 7, 9 and 11 for the Corsi task. Encoding set size was arbitrarily used in the following ANOVAs and retrieval set size was used in a non-linear regression analysis which will later be explained in greater detail.

The dependent measure in both tasks was the number of trials (out of a total of 8 at each set size) completed with 100% accuracy. A score of 1 was given for each correct trial. There were 8 trials at each set size so the maximum accuracy score possible at each sequence length was 8.

BST Results

In the BST condition, a main effect of age was present, $F(1, 29) = 13.258$, $p < .001$, such that younger adults ($M = 6.61$, $SD = 1.13$) performed at higher accuracy levels than older adults ($M = 5.24$, $SD = 1.05$). A main effect of set size, $F(4, 116) = 67.308$, $p < .01$, was also found. Post hoc analysis revealed that mean accuracy were constant for set sizes 3 and 5, but began to decrease significantly as the sequence length increased. An Age x Set Size interaction was also found, $F(4, 116) = 10.624$, $p < .001$. Simple main effects showed that both young and old adults were less able to correctly recall the presented sequence when set sizes increased, but age group differences were not significant until set size reached 9 and 11, older adults performing poorer than younger adults. Refer to Table 1 for mean accuracy values at each set size by age group.

Error Types

All incorrect trials were scored for two types of errors: omission and intrusion. Omission errors were defined as an individual block presented in a sequence that was not recalled by the participant. Intrusion errors were identified as a block response that was not presented in the sequence. Since errors were marked according to each incorrect block made in a response, it was possible for a single trial to have both types of errors more than once.

BST Errors

Omission Errors

There was a main effect of age $F(1, 29) = 7.244$, $p < .05$. Overall, older adults left out more blocks during sequence recall than young adults. Results also revealed a main effect of set size, $F(4, 116) = 79.352$, $p < .001$. As sequence length increased, the number of omission errors increased as well. An Age x Set Size interaction, $F(4, 116) = 13.729$, $p < .001$, was found. Simple main effects showed that older adults made significantly more errors only when set size equaled 11 blocks.

Intrusion Errors

Although intrusion errors were defined as block responses made that were not included in the sequence, responses made for red blocks presented in the BST condition were also counted as intrusion errors because participants were told to ignore them. Analysis for intrusion errors including responses made for red blocks yielded a main effect of set size, $F(4, 116) = 18.808$, $p < .001$. Much like the pattern found in the set size effect for omission errors, the number of intrusions increased as sequence length increased. No other significant effects were found.

A separate analysis was conducted for intrusion errors made only for red blocks presented as part of the sequence. A main effect of set size, $F(4, 116) = 12.160$, $p < .001$, was found. Post hoc comparisons revealed that as sequence length increased so did the number of intrusion errors made. There were no other significant effects.

Corsi Task Results

There was a main effect of age, $F(1, 29) = 2.068$, $p < .01$, in that younger adults had a higher overall mean accuracy ($M = 3.017$, $SD = .741$) than older adults ($M = 2.438$, $SD = .538$). There was also a main effect of set size, $F(4, 116) = 319.861$, $p < .001$. Post hoc analysis showed that as sequence length increased, mean accuracy decreased for trials correctly recalled. Overall, participants were able to recall one or less sequences at set sizes 9 and 11. An Age x Set Size interaction, $F(4, 116) = 4.495$, $p < .05$, was present. Simple main effects showed that while both age groups performed well at a sequence length of 3, mean accuracies for set size 5 and 7 began to decrease, but older adults declined at a faster rate than the younger group (See Table 1). Accuracies for set sizes 9 and 11 did not show age group differences, but only because all performance at that sequence length was near or at zero.

Corsi Task Error

Omission Errors

Omission errors in the Corsi task yielded a main effect of age, $F(1, 29) = 21.006$, $p < .001$. Older adults omitted blocks from the task at an overall average of 14.075 errors ($SD = 3.554$) compared to younger adults whose mean average was 8.613 errors ($SD = 3.040$). An effect of set size, $F(4, 116)= 220.405$, $p < .001$, was present. As expected, when sequence length increased, the amount of blocks omitted increased as well. An Age x Set Size interaction, $F(4, 116) = 13.621$, $p < .001$, supported the main effects found. As set size increased, both groups made more errors, but the older adults yielded higher levels of error than the younger adults.

Intrusion Errors

Analysis for intrusion errors showed a main effect of set size, $F(4, 116) = 54.597$, $p < .001$. This finding described the pattern that as set size increased, so did the number of errors. There were no other significant effects found for intrusion errors.

Age-Group Performance Between Conditions

For analysis comparing BST and Corsi performance, accuracy data was graphed using both set size variables. When the encoding set size variable was used as the x value, the curve for the BST measure was higher than that of the Corsi task (see Figure 1 and Figure 2). Observing the relationship between the two conditions using encoding set size was not as meaningful and perhaps somewhat misleading because the number of blocks correctly reproduced to make an accurate response for the BST was not comparable to the Corsi task. Recall that the BST required less blocks to be reproduced at each encoding set size than the Corsi task because the participants were instructed to ignore the red blocks presented in the sequence. When retrieval set size was used as the x-value variable, the accuracy data remained the same, but the difference in x-values allowed the curve for the BST data to shift closer and nearly overlap the other conditions curve (see Figure 1 and Figure 2). This provided a much better illustration of the relationships between the two conditions. Thus, retrieval set size was used rather than encoding set size in the following non-linear regression analysis. An ANOVA was not used to examine performance between conditions because the dependant measure reflected different retrieval set sizes between the two conditions. For example, in both conditions an encoding set size of 5 would be equal to a retrieval set size of 3 for the BST and 5 for the Corsi task. For the non-linear regression analysis, the logistic function model was applied due to the functions characteristic “S” shape curve which was observed in the graphical representation of the current data (see Figure 1). The mathematical representation of this function is:

$$P(c) = a /(1 + be^{-x})$$

The model consists of two parameters. The first, *a,* is often referred to as a limiting value among populations. In this case, participants could not achieve a score greater than 8 at each set size so 8 was substituted for the *a* parameter. The parameter *b* is known as the y-intercept which was a free parameter in the current model.

As applied to the current data, *P(c)* represents predicted accuracy. The base *e* refers to the natural logarithm (2.718281828…) raised to the *-x* power, in this case, retrieval set size. Predicted accuracies were calculated by taking the mean *b* values for each age group, parameter estimates obtained by the non-linear regression analysis, and substituted into the equation. Since the current function begins at 8 and decreases to 0 instead of 0 to 8, it was necessary to subtract the value obtained in the equation by 8. The logistic function used analyzing the current data had the form:

$$\textit{Accuracy} = 8 - [8 / (1 + b^* e^{(-\text{set size})})]$$

Predicted accuracy scores at each retrieval set size were computed and graphed for each age group. Actual accuracy scores were also graphed to compare the fit of the model.

The point of critical change in the logistic function is called the inflection point. The inflection point of the curve will always occur at the midpoint of the y-value, and is mathematically defined as the natural log of the *b* parameter. Since the y-value represents trials correct, the inflection point applied to the current data describes the predicted set size in which 50% accuracy will be achieved.

With ln(*b)* values for each observer as the dependent variable, age group differences in the BST and Corsi task were examined using an ANOVA. Results revealed a main effect of age, $F(1, 29) = 13.706$, $p \leq .001$, in which younger adults were able to correctly reproduce a higher number of blocks at a 50% accuracy rate than older adults. A main effect of task, $F(1, 29) = 5.274$, $p < .05$, showed that the inflection point in the BST was significantly higher than that of the Corsi task. The Age x Task interaction, $F(1, 29) = 8.042$, $p < .01$, showed that only the younger adults performed differently between the two tasks. Paired t-test analysis was used to probe this interaction, showing that young adults had a higher inflection point ($M = 6.60$, $SD = 1.350$) in the BST compared to the Corsi task ($M = 5.78$, $SD = 1.121$), $t(14) = 3.531$, $p < .01$. Older adult performance did not change significantly between the two conditions, $t(15) = -.392$, $p = .701$. Performance reached a 50% accuracy level around the same number of blocks for the BST ($M = 4.94$, $SD = 0.751$) and the Corsi task ($M = 5.02$, $SD = 0.709$). Overall, the logistic function model fit well with the accuracy data for both age groups in both conditions. The goodness of fit values for the model, expressed as R^2, were 0.96 and above (See Table 2).

Table 1

Experiment 1

Mean Accuracy Values for BST and Corsi Tasks

	BST		Corsi	
Set Size	*M*	*SD*	*M*	*SD*
		Young (*n* = 15)		
3	7.87	0.35	7.40	1.06
5	7.27	0.70	5.80	1.74
7	6.93	1.28	2.07	1.58
9	6.27	1.75	0.27	0.59
11	4.73	2.43	0.00	0.00
		Old (*n* = 16)		
3	7.63	0.81	7.31	0.87
5	7.50	0.73	4.12	1.89
7	5.94	2.14	0.75	0.86
9	3.88	2.28	0.00	0.00
11	1.25	1.61	0.00	0.00

Note. Mean accuracy values are based on the average number of trials correctly replicated. Maximum score possible at each set size is 8.

Table 2

Experiment 1

Goodness of Fit Values for Logistic Function Model

	BST		Corsi	
Group	R^2	*SD*	R^2	*SD*
Young	0.98	0.04	0.96	0.05
Old	0.96	0.03	0.98	0.02

Note. Values were calculated by averaging the sum of each individuals mean R^2.

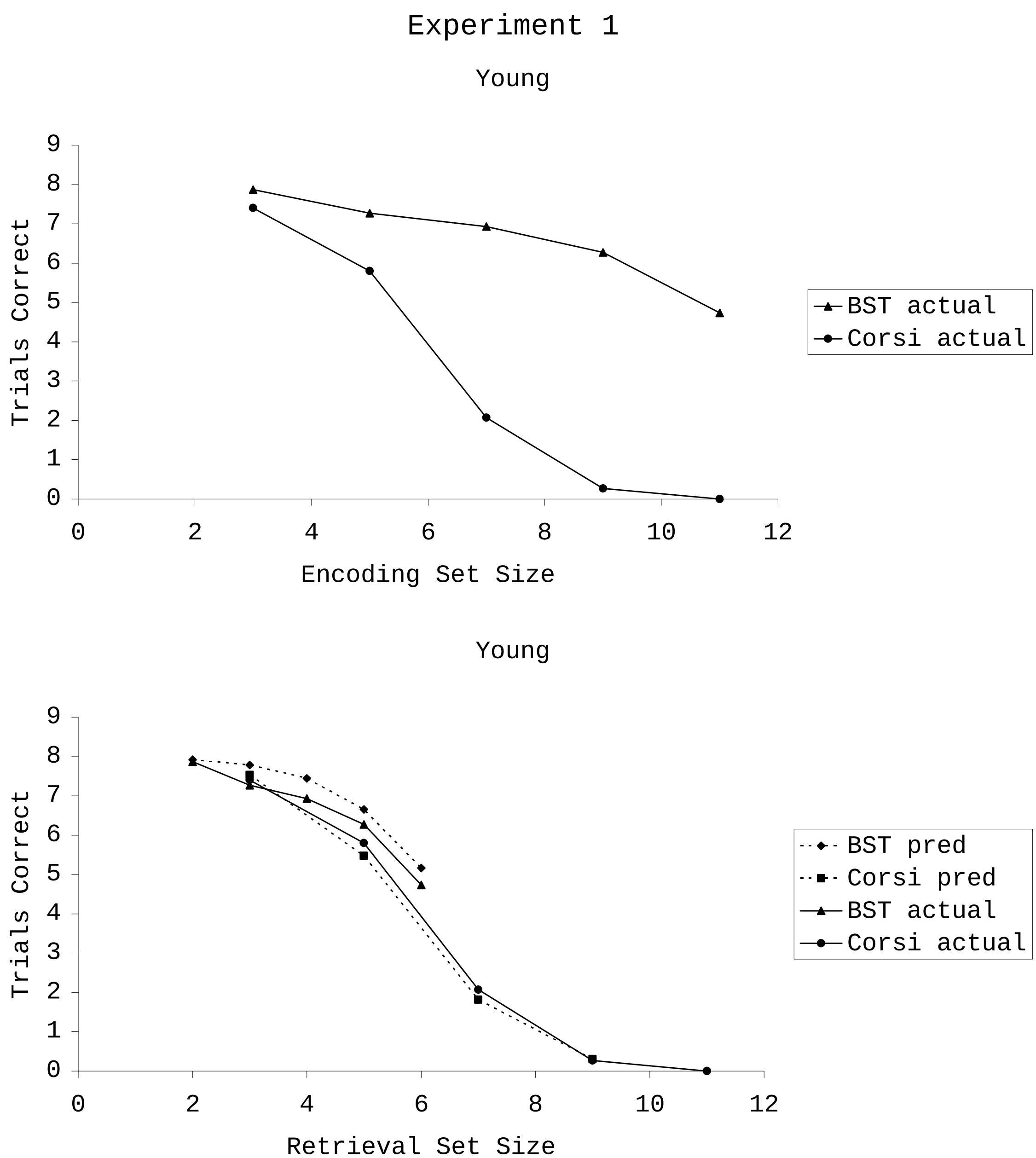


Figure 1. Experiment 1 predicted and actual accuracy scores for young.

Note. Top figure shows accuracy scores at each encoding set size while the bottom figure scores were computed using retrieval set size. Fits are shown in the bottom graph.

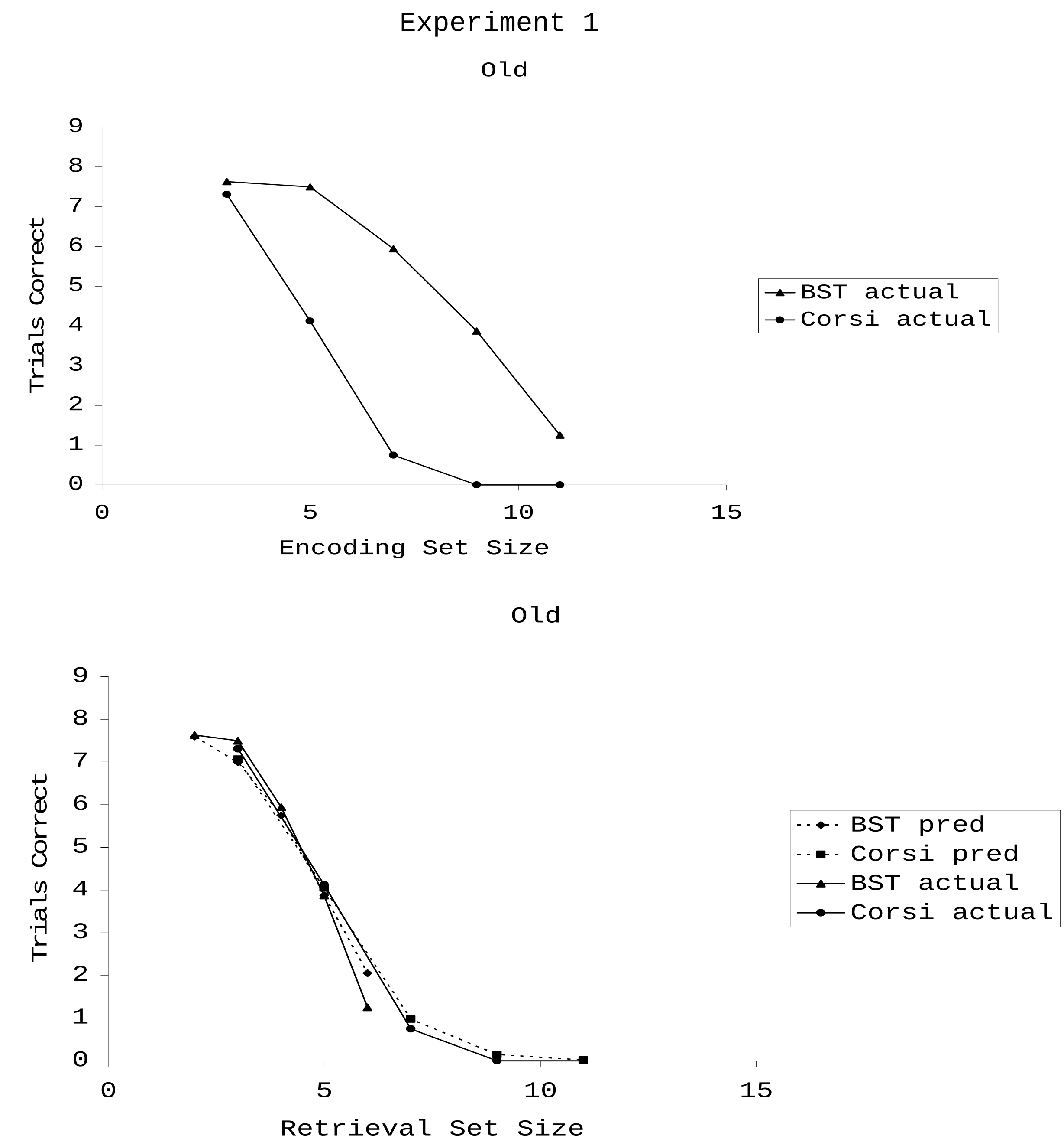


Figure 2. Experiment 1 predicted and actual accuracy scores for old.

Note. Top figures shows accuracy scores at each encoding set size while the bottom figure scores were computed using retrieval set size. Fits are shown in the bottom graph.

CHAPTER FOUR: EXPERIMENT 1 DISCUSSION

Implications

The main goal of the current experiment was to investigate inhibitory deficits using two similar working memory tasks, one that required the inhibition of irrelevant items and another that did not. Results showed that younger adults had a slightly higher inflection point in the BST than the Corsi task (6.6 vs. 5.8). One explanation for this task difference could be due to the availability of extra encoding time in the BST. At any given retrieval set size in either task, the encoding set size for the BST will always be greater than in the Corsi. For example, retrieval set size 5 has an encoding set size of 9 in the BST and 5 in the Corsi task. Therefore, the extra encoding time in the BST could improve performance compared to the Corsi task as shown by the younger adult results. However, that same pattern of results did not hold true for older adults who performed similarly in the BST and Corsi, as evidenced by equivalent inflection points across the two tasks. There are a couple of explanations for why the same effect for younger adults was not found in older adults. The difference between inflection points was possibly undetected in the older adults due to power issues. Another reason for the lack of difference between inflection points in the older adults could indicate either a slight difficulty in inhibiting the red items leaving little time for extra rehearsal or the inability to take advantage of additional encoding time.

It is possible that older adults did not show this task advantage due to a slight inhibitory impairment reducing their performance in the BST to where the two conditions were equal. However, this result does not provide strong evidence of an inhibitory deficit in older adults. The strongest evidence for an inhibitory deficit would have been poorer performance in the BST than in the Corsi task. This was not found. Older adults' BST capacity was actually equivalent to Corsi capacity, even when the analysis used the most relevant measure, retrieval set size. Strong evidence for an age-related inhibitory deficit would also have been exhibited by older adults making more intrusion errors than the younger adults, but results did not show any group differences for this type of error.

Strong support for an age-related inhibitory deficit may not have been found because of several reasons. One may concern the type of inhibitory process required in the BST. If inhibitory mechanisms are separable for identity and location (Connelly & Hasher, 1993), then the type of inhibitory processes primarily used to complete the BST may not be susceptible to age-related declines. This argument, however, is difficult to support due to discrepant findings in the specific mechanism older adults show deficits in (i.e. McDowd & Fillion, 1995). Further research investigating the effects of aging on identity and location suppression may be worthwhile in understanding the implications behind the current results.

Another concern for why strong evidence for an age-related inhibitory deficit was not found could be explained by the low level distractibility of red (to-be-ignored) items in the BST. It is highly possible that the use of a constant red distractor allowed participants to filter out the distractor stimulus with minimal effort. The second experiment of this thesis examined this issue by changing the presentation of the stimuli in a way that would increase the distractibility of red blocks in the BST sequences.

The current results also revealed a main effect of age group collapsed across both conditions. The inflection point for the younger group was 6.19 blocks, while the older group inflection point was 4.98 blocks. This result is consistent with other findings that older adults show deficits in spatial working memory (Chen, Hale, & Myerson, 2003). The implication of the age effect may be that younger adults have a higher working memory capacity than older adults. However, this age effect could also be attributed to an increased decay of information because of older adults' slower response times. While there were no time constraints involved in responding, it was noted that the older adults took longer to make a response than the younger adults.

To date, the BST has only been tested among young adults and neuropsychological patients (Beblo, et al., 2004). The current age effects found indicate that the BST measure is sensitive to detecting age-related declines in spatial memory. The other task used in the current experiment, the Corsi Block Tapping Test, has not been widely tested in the context of aging and spatial working memory. However, the Corsi task has been used in a different context, investigating age differences in sequence learning which also lends support to the current findings. Sequence learning is acquiring knowledge about the ordering of objects or events and is demonstrated by faster reaction time or higher accuracy for trials with sequences repeated a number of times over performance compared to trials with randomly created sequences presented only once. Since all sequences were randomly presented in the BST and Corsi task, learning was not an issue in the present study. However, sequence learning relies in part on working memory and can be discussed with some relevance to the current experiment. For example, Turcotte, Gagnon, and Pourier (2005) used a variant of the Corsi task to investigate the effects of aging on the sequence learning of visuospatial stimuli. Young and old participants were presented with both repeated sequences and non-repeated sequences. Note that trials for non-repeated sequences would be most comparable to the Corsi task. The result for performance in non-repeated trials revealed that older adults reproduced fewer blocks than the younger adults, providing further support for the current age effect found.

Summary

In summary, the current experiment showed that the young adult inflection point was higher than the older adult inflection point in both the BST and the Corsi task, which confirmed an age-related decline in spatial working memory. The current results also found differential performance between age groups across the BST and Corsi task. Older adults’ inflection point was equivalent across tasks, while the younger adults’ inflection point was higher in the BST than the Corsi task. This pattern of results indicated the presence of a small age-related inhibitory deficit; older adults may have had difficulty inhibiting irrelevant information reducing their inflection point in BST to where a task advantage was not shown. Results, however, did not show the strongest evidence of an age-related inhibitory deficit, possibly due to the low distractibility of the red to-be-ignored blocks used in Experiment 1. Therefore, a second experiment was conducted observing BST and Corsi task performances when the distractibility of to-be-ignored items was increased.

CHAPTER FIVE: EXPERIMENT 2 METHODS

Introduction

In this present experiment, the distractibility of the red (to-be ignored) objects in the BST condition was increased. This was accomplished by using the same materials and procedures for Experiment 1 and only changing the way blocks were presented in each sequence. Thus, the procedure remained the same as Experiment 1 except that each square in the given sequence first changed from black to white for 300 ms before appearing green or red for 700 ms. The reasoning for this change was to ensure that participants were not filtering out the red blocks. The white blocks were designed to attract attention automatically by orienting responses to all blocks in the given sequence (Cowan, 1995).

Participants

Participants were 10 young adults ranging from 19-22 years of age (M = 19.60, SD = 1.43), and 10 older adults ranging from 68-75 years of age (M = 71.90, SD = 2.60). Young adults were enlisted through the Psychology 100 subject pool at the University of Kentucky and received course credit for their participation. Older adults were recruited through the same methods as in Experiment 1.

All participants had normal to corrected vision ranging from 20/20 to 20/35 and also passed a color blindness screening. Mean score on the Mill Hill Vocabulary Test was 19.90 (SD = 4.50) for older adults and 12.00 (SD = 2.00) for younger adults, $t(18)= -5.07$, $p < .001$. Accuracy across Digit Symbol scores were not significantly different between groups, $t(18) = -0.70$, $p > .05$. Younger adults yielded a mean accuracy of 94.80% (SD = 2.53) and older adults obtained a mean accuracy of 95.80% (SD = 3.76). Reaction time in the Digit Symbol task, however, was significantly different, $t(18) = -0.54$, $p < .001$, with younger adults (M = 1213.30, SD = 181.70) completing the task at an average of 370 ms faster than older adults (M = 1582.90, SD = 276.23).

CHAPTER SIX: EXPERIMENT 2 RESULTS

Non-Linear Regression Analysis

Refer to Table 3 for a summary of the mean accuracy values in the BST and Corsi task. A non-linear regression analysis was conducted using a logistic function model. The free parameter *b* obtained from this analysis was log transformed for each participant in order to obtain the inflection point for each individual in the BST and Corsi task. An ANOVA was conducted using these inflection points as the dependant measure. Results revealed a main effect of age, $F(1, 18) = 16.340$, $p < .001$, showing that overall, spatial working memory performance was higher for younger than older adults. The effect of task, $F(1, 18) = .703$, $p > .05$, was not significant. An interaction between age and task was found, but was only marginally significant, $F(1, 18) = 4.061$, $p < .06$. Paired t-test analyses were used to probe this interaction, showing that young adult inflection points did not differ between the BST ($M = 6.16$, $SD = 1.26$) and Corsi task ($M = 5.93$, $SD = .93$), $t(9) = .707$, $p > .05$, whereas the older adults' inflection points differed, $t(9) = -2.571$, $p < .05$. For older adults, the inflection point in the BST ($M = 4.33$, $SD = 0.63$) was lower than in the Corsi task ($M = 4.86$, $SD = 0.67$). As in Experiment 1, the logistic function model fit well (See Figure 3). Refer to Table 4 for mean R^2 values by age group.

Analyses across Experiments 1 and 2

In order to increase the distractibility of red-to-be-ignored blocks in the BST, it was necessary to add the white blocks, which consequently reduced the amount of encoding time for the green and red blocks to 700 ms (from 1000 ms in Experiment 1). Note that this procedural difference in Experiment 2 only affected the BST because the Corsi task required participants to encode every block in the sequence despite the color used, which allowed them to begin encoding at the presentation of the white square. An ANOVA was conducted to observe whether these presentation changes had an impact on age group performances in each of the tasks across Experiments 1 and 2.

For the ANOVA, the between-subject factors were age group and experiment and the dependant measures were the $ln(b)$ values (inflection points) for each individual in each condition. Results showed a main effect of age, F(1,

47) = 28.46, $p < .001$. Overall, younger adults performed better than older adults on the spatial working memory tasks. Two significant interactions were found. The first was Age x Task, $F(1, 47) = 11.08$, $p < .05$. Subsequent simple main effects showed that younger adult performance collapsed across experiments was different between the BST and Corsi task ($p < .05$). Older adults did not show differences in performance collapsed across experiments between the two tasks ($p > .05$).

The second interaction, Experiment x Task, $F(1, 49) = 4.41$, $p < .05$, was also analyzed further using simple main effects. Results showed that there were no performance differences within the BST across Experiments 1 and 2 ($p > .05$) and no performance differences within the Corsi task across experiments ($p > .05$). The effect behind the Experiment x Task interaction was found in performance differences between the BST and Corsi task in Experiment 1 ($p < .05$). Overall, BST inflection point was higher than the Corsi inflection point. Task differences in Experiment 2 were not significant ($p > .05$).

An effect of experiment was not found, $F(1, 47) = 1.13$, $p > .05$, suggesting that overall performances in Experiment 1 were similar to overall performances in Experiment 2. No interaction was found between age and experiment, $F(1, 47) = .24$, $p > .05$, or between age, task, and experiment, $F(1, 47) = .381$, $p > .05$. Young and old adult performance in the BST and Corsi task were not significantly different across Experiments 1 and 2.

Table 3

Experiment 2

Mean Accuracy Values for BST and Corsi Tasks

	BST		Corsi	
Set Size	*M*	*SD*	*M*	*SD*
		Young (*n* = 10)		
3	8.00	0.00	7.60	0.52
5	7.70	0.68	5.60	2.50
7	6.30	1.57	2.20	1.48
9	5.70	2.21	0.20	0.42
11	4.20	1.75	0.00	0.00
		Old (*n* = 10)		
3	7.80	0.42	6.80	1.03
5	6.80	1.69	4.00	2.06
7	4.40	1.58	0.20	0.63
9	2.70	1.70	0.00	0.00
11	0.70	1.06	0.00	0.00

Note. Mean accuracy values are based on the average number of trials correctly replicated. Maximum score possible at each set size is 8.

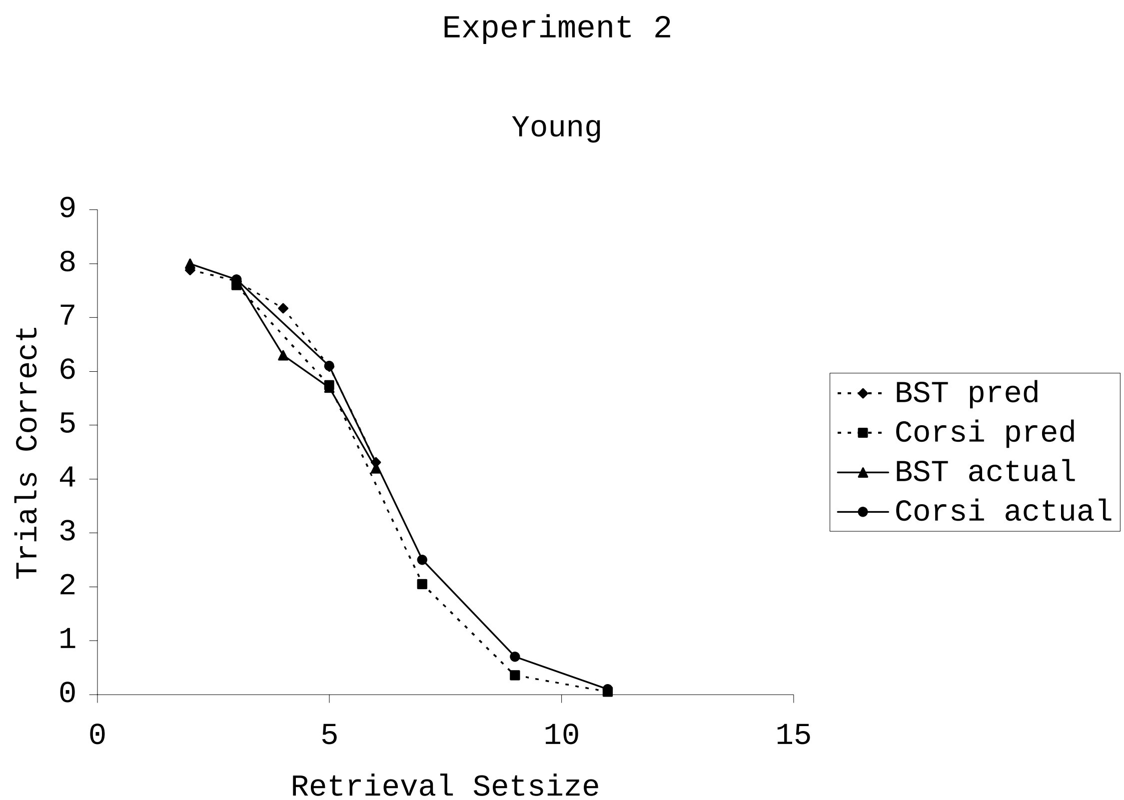
Table 4

Experiment 2

Goodness of Fit Values for Logistic Function Model

	BST		Corsi	
Group	R^2	*SD*	R^2	*SD*
Young	0.98	0.02	0.96	0.04
Old	0.96	0.02	0.96	0.06

Note. Values were calculated by averaging the sum of each individuals mean R^2.



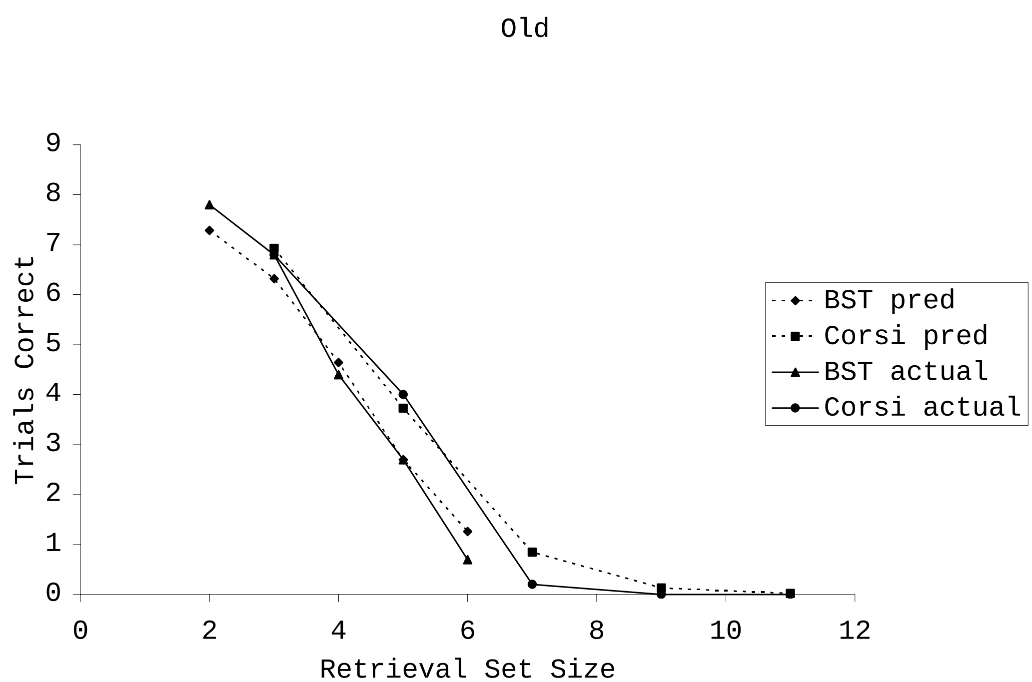


Figure 3. Experiment 2 predicted and actual accuracy scores for young and old participants.

CHAPTER SEVEN: EXPERIMENT 2 DISCUSSION

The purpose of Experiment 2 was to address the possibility that participants in Experiment 1 were filtering out distractor stimuli in the BST with little mental effort. This concern was met by changing the presentation of sequences in a way that would automatically draw attention to all presented blocks, thereby increasing the distractibility of irrelevant BST items.

The results from Experiment 2 indicated that participants were not filtering out the distractor stimuli, but that increasing the distractibility of irrelevant items in the BST made the task more challenging than in Experiment 1. In Experiment 1, the trend for younger adult performance showed a task advantage for the BST over the Corsi task, while older adults showed no performance difference between the two tasks. The current results now show younger adults as having no differences in performance between the two conditions and older adults performing more poorly in the BST than in the Corsi task.

While the interaction between age and task was only marginally significant in Experiment 2, it is likely the statistical power of the small sample size (10 per age group) did not detect performance differences at a 95% confidence level. The marginal effect likely reflects true age differences in task performance. The implications behind this result, had it reached a conventional significance level, will be discussed. However, since this effect was only marginally significant, the implications behind its interpretation should be taken cautiously.

Results were consistent with Experiment 1 findings in which larger age differences were observed in the BST than in the Corsi task. One implication of the current results is that older adults likely have more difficulty than younger adults inhibiting irrelevant items. This was evidenced not only by larger age differences in the BST compared to age differences in the Corsi task, but also by older adults showing a lower inflection point in the BST than in the Corsi task (4.33 blocks vs. 4.86 blocks). It was expected that if older adults exhibited inhibitory impairment, the presence of irrelevant items would result in lower BST performance than in the Corsi task, which did not involve irrelevant items. Results indicate support towards an age-related inhibitory impairment.

One other explanation for the current results concerns encoding time. In the current experiment, the distractibility of the red (to-be-ignored) items in the BST was increased by preceding each block in the sequence with the color white for 300 ms. Participants' attention would then be automatically drawn to the block before the appearance of green or red for 700ms. Since participants were instructed to recall all blocks in a presented sequence for the Corsi task, encoding time could begin at the appearance of a white block. However, in the BST, participants had to wait until the white block turned green or red before encoding could begin. This was problematic because essentially, participants were given 1000 ms to encode each block in the Corsi task, compared to 700 ms of encoding time per block in the BST. It is possible that having less encoding time was more consequential to older adults than younger adults. Less encoding time could have reduced the older adult BST inflection point lower than in the Corsi task, while younger adults were still able to perform equivalently between the two tasks.

CHAPTER EIGHT: GENERAL DISCUSSION

Overall Summary

Two spatial working memory tasks, the BST and the Corsi task, were used to investigate whether older adults showed inhibitory impairment. The two tasks were similar to one another in that participants were instructed to recall block sequences. The main difference was that the BST involved an inhibitory component and the Corsi task did not. It was concluded that support for an age-related inhibitory deficit was found.

In Experiment 1, younger adults showed better performance in the BST than in the Corsi task. This indicated that the younger adults were able to take advantage of the extra encoding time available in the BST. Older adults showed no differential performance between the two conditions. This suggested that either older adults failed to utilize the extra encoding time available in the BST or they experienced difficulty inhibiting irrelevant items which reduced any task advantage that might have been shown. Although results indicated that an age-related inhibitory deficit may have been present, the strongest evidence for inhibitory impairment was not found. The strongest indicator of an age-related inhibitory deficit would have been older adults performing more poorly in the BST than in the Corsi task, due to presence of irrelevant items. It was unclear whether the low distractibility of the to-be-ignored items masked this finding, so a second experiment was conducted to address this issue.

In Experiment 2, small procedural changes made to the presentation of distractor stimuli reduced the ability to filter out the red (to-be-ignored) blocks. Results revealed a marginally significant interaction between age and task. This finding likely reflected true age differences between the BST and Corsi task, but the marginal significance of the effect did not allow for a definitive interpretation. Given the reduced sample size of Experiment 1 compared to Experiment 2, 10 participants per age group may not have yielded enough statistical power to detect age differences between tasks at the traditional p value of .05. Simple effects comparisons probing the interaction showed that the younger adults' inflection points did not differ between conditions, while older adults had a lower inflection point in the BST than the Corsi task. This indicated that older adults had greater difficulty inhibiting irrelevant information than the young, supporting an age-related inhibitory deficit.

The findings from Experiments 1 and 2 are consistent with other studies showing evidence of an age-related inhibitory deficit (e.g. Kane, et al., 1994; Hasher, Stoltzfus, Zacks, & Rypma, 1991; West, 1999). Older adults appear to be at a disadvantage in efficiently inhibiting irrelevant information. This deficit could underlie many of the age-differences found in cognitive aging. Inefficient inhibitory processes would result in the increase of interference during goal-relevant information processing, making the completion of cognitive tasks more difficult for older adults.

A secondary goal was to examine age-differences in spatial working memory. Analyses from Experiment 1 showed that younger adults performed better than older adults in both the BST and the Corsi task. Results were consistent with the finding of age-related differences in spatial working memory performance (Chen, Hale, & Myerson, 2003). The implications behind this age-related decline may be that younger adults have a higher working memory capacity than older adults or that older adults were more susceptible to information decay due to longer observed response times. The exact causes underlying age-related differences in spatial working memory still remain in question.

Limitations

While the present thesis provided some insights into spatial working memory and inhibitory processing, several limitations to this study should be addressed. Statistical power was one limiting factor in Experiment 2, likely due to the small sample size. In Experiment 2, only marginal effects were found for the Age x Task interaction. While the collection of more data was not possible due to time constraints and resources, larger sample sizes are needed in order to fully understand the implications behind the results in Experiment 2.

Another limitation involves the differences in encoding time found between the BST and Corsi task. Encoding time will always be different in the BST than in the Corsi task because the BST contains irrelevant information. This presents an obstacle in fully understanding the effects of aging on inhibitory function using the BST and Corsi task. Although evidence found from both experiments showed support for an age-related inhibitory deficit, another explanation for the findings could be attributed to the differences in encoding time available between the BST and Corsi task.

In Experiment 1, results showed young adults having a task advantage in the BST. It is possible that the young adults were able to take advantage of the extra encoding time available in the BST, which resulted in a higher BST inflection point than in the Corsi task. The older adults, who did not show performance differences, may have failed to take advantage of the extra encoding time.

In Experiment 2, the distractibility of irrelevant items was increased which could have reduced the amount of extra encoding time available in the BST over the Corsi task. Encoding time for each block was reduced in the BST from 1000 ms to 700 ms because each block in the sequence appeared white for 300 ms before it appeared green or red. Encoding time for the Corsi task remained the same. It is possible that these changes in encoding time were more consequential to older adults than younger adults. Less encoding time could have reduced the older adult BST inflection point to where performances were lower than in the Corsi task, while younger adults were still able to perform equivalently between the two tasks.

Although the differences in encoding time still remains an issue in the present thesis, the analyses comparing performances across Experiments 1 and 2 show some support that the decrease in encoding time did not have a large impact on BST performances in Experiment 2. Results showed that performances in each of the two conditions were similar across experiments for both young and old adults (See Table 5). If the decrease in encoding time greatly influenced BST and Corsi task performance in Experiment 2, then it would be likely that performances in each task would be different across Experiments 1 and 2. However, this outcome was not found. Further investigations should be conducted that test the effects of performance at different levels of encoding time. Results may provide additional information concerning the age group differences found in the BST and Corsi task performance.

Future Directions

Several future directions are apparent in light of the current findings. One theoretical issue that still needs to be addressed is whether inhibition is actually the combination of multiple inhibitory mechanisms. Research by Connelly and Hasher (1993) found that older adults showed deficits in suppressing the identity information of distractor stimuli, but were able to show equivalent performance compared to younger adults for suppressing irrelevant location information. The proposal of separable inhibitory mechanisms has been met with discrepant findings (e.g., Sullivan & Faust, 1993; Kieley & Hartley, 1997; McDowd & Fillion, 1995), but further testing on this topic could provide a better understanding of the inhibitory construct.

It is still unclear why some studies show evidence towards inhibitory impairment with age while others do not. The discrepancies may be attributed to many of the methodological problems found within measures used to index inhibitory function. Whatever the cause, it is clear that inhibitory function cannot fully be understood without a reliable measure.

Conclusions

The main goal of the thesis was to investigate age-related inhibitory deficits using two similar measures of spatial working memory not yet tested in this context, the BST and the Corsi task. By using these two measures, it was possible to examine age-related inhibitory deficits without several of the methodological problems involved with one of the primary methods of investigating inhibitory processes, negative priming (i.e., proper units of reaction time, episodic retrieval mechanism). However, the two tasks presented methodological problems of their own.

The inconsistencies found in aging and inhibition research, as well as limitations in the present study, highlights the need for future research in this area. Nevertheless, the present thesis has shown the BST and Corsi task measures were sensitive to detecting age-related inhibitory deficits. Further research with these two measures of spatial working memory may be a step towards finding a more reliable measure of inhibition and gaining a better understanding in age-related changes in inhibitory function.

Table 5

Mean Inflection Points Across Experiments

	Experiment 1				Experiment 2			
	BST		Corsi		BST		Corsi	
Group	*ln(b)*	*SD*	*ln(b)*	*SD*	*ln(b)*	*SD*	*ln(b)*	*SD*
Young	6.60	1.35	5.78	1.12	6.15	1.26	5.93	0.93
Old	4.94	0.75	5.02	0.71	4.32	0.63	4.86	0.66

Note. Mean values were calculated from the log transformed *b* parameters of each individual obtained through a non-linear regression analysis.

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Publications:

Norman, J. F., Norman, H.F., Lianekhammy, J., Clayton, A. M., Zielke, G.(2004). The visual and haptic perception of natural object shape. *Perceptions & Psychophysics, 66*, 342-351.

Conference Presentations:

Norman, J. F., Norman, H.F., Lianekhammy, J., Clayton, A. M., Zielke, G.The visual and haptic perception of natural object shape. Abstract accepted for presentation at the 2003 annual meeting of the Vision Sciences Society, May 9-14, Sarasota, FL.

Vagnini, V.L., Lawson, A.L., Liu, X., Lianekhammy, J., Bylica, K.E., Joseph, J., Kelly, T.H., & Jiang, Y. (2005, June). *The effect of sensation seeking on a novelty detection task: An ERP study.* Poster presented at the National Institute on Drug Abuse Satellite Meeting entitled: Translating Basic Research From Neural, Behavioral, & Social Sciences to Prevention: Challenges & Opportunities, Orlando FL.

Community Service

Volunteer Judge	Glendover Elementary School Science Fair Lexington, KY 40504	2003-2004
Volunteer	Christian Sayre Village Assisted Living Facility Department of Activities	2006