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THE IMPACT OF DISTRACTOR DURATION ON SPATIAL WORKING MEMORY
IN EARLY CHILDHOOD

by

Brian A. Keiser

A THESIS

Presented to the Faculty of
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Major: Educational Psychology

Under the Supervision of Professor Eric Buhs

Lincoln, Nebraska

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THE IMPACT OF DISTRACTOR DURATION ON SPATIAL WORKING MEMORY
IN EARLY CHILDHOOD

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University of Nebraska, 2012

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Spatial attention appears to act as a rehearsal mechanism in spatial working memory (Awh, 1999; Awh & Jonides, 2001) as adults have trouble maintaining spatial information in their mind when required to shift their attention to locations unrelated to the to-be-retained location. Furthermore, adults increase intentional directed attention to the to-be remembered location when warned ahead of time that distractors will be present during the memory delay (Awh, 2003). Our initial study looked at the presence of a distractor and its impacts on spatial working memory in children. We found that the distractor did impact three and six year old memory of target locations, but not four and five year olds. There are two goals for the current study. First, we wanted to replicate the results of our initial study where the presence of a distractor had an impact on the spatial working memory performance of three and six year olds leading them to make errors on trials when the distractor was present. Secondly, we want to see if the amount of time the distractor is on will lead to larger errors in the present age groups. We hypothesized that the longer the distractor remains on the more it will be associated with larger errors than in previous studies. The first goal of our initial study was confirmed because the errors made by the three and six year olds were replicated. We found that there was no effect of distractor duration on age but distractor location was still significant for making errors towards or away from the distractor location.

Dedication

To my wife, Mattie Keiser, for your love, support, and patience during these last few years. To my son, Colin Keiser, for being my inspiration to return back to school and pursue an advanced degree in the field of child development . I could not have completed this project without them.

Acknowledgements

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Chapter 1: Introduction

There are times when we have to remember the location of an object, for example, a set of office keys. We remember this location because it is important to us, and if we forget the location of our keys we will not be able to leave the house on time, or get into our office, ultimately making us late for work. Not only is it important to remember the location of the keys, it is important to remember their location in relation to other objects in the immediate space. What were the keys near? Were they on the counter next to the coffee pot, or were they on the dresser next to the alarm clock? We use our spatial working memory to encode the location of the office keys, and the surrounding objects. This process can be interrupted by competing stimuli, leading a person to forget the location of the keys, and focus on the competing stimuli. For example, when you arrive home, after a long day at work, and your spouse presents you with a minor emergency, you throw your keys down on the closest surface and address the emergency. This small interruption can interrupt the spatial working memory process, and ultimately, lead you to forget the location of your keys the next day. This example demonstrates our ability to inhibit, or not inhibit, competing stimuli.

Why is spatial working memory important? It is a process, and when functioning properly, it will be quite effective in remembering the location of relevant objects. However, there can be impairments in spatial working memory performance. A person may not be able to inhibit competing stimuli, making it difficult to attend to the target object. This is similar to ADHD, the inattention subtype. This study aims to build on spatial working memory research, and add to a broader research program that will hopefully provide more tools for accurately diagnosing ADHD at a younger age. In order

to do this, we have to have a clear understanding of spatial working memory, and its relations to other higher order executive functions

Working memory is a system that enables the temporary maintenance of limited information, where that information is kept on-line or available for immediate access by other cognitive processes (Awh & Jonides, 2001). Working memory is assumed to provide both temporary storage and active processing in human cognition (Rudkin & Pearson, 2007). Much like working memory, spatial working memory has a limit on the amount of information it can process.

Spatial working memory is a cognitive brain mechanism that enables the temporary maintenance and manipulation of *spatial* information (Jha, 2002). Like working memory, spatial working memory actively maintains information and keeps it available for immediate access. The ability to briefly maintain and interact with information held in memory is one of the pivotal qualities ascribed to “working memory”, and using this ability is functionally important for bridging the gap between perception and action (Munneke et. al., 2010). Working memory uses many active maintenance strategies, such as rehearsal, to hold information in short-term memory in and process this information into long-term memory. The maintenance strategy of rehearsal in spatial working memory is accomplished, in part, via covert shifts of spatial selective attention to memorized locations (“attention-based rehearsal”) (Postle et.al., 2004).

Selective attention determines how limited mental resources are allocated to the most important piece of information in the environment, and memory maintains this information in order to allow past experience to guide future behaviors (Chan et. al,

2009). Awh and colleagues (1998) highlighted the importance of spatial selective attention, stating it is a rehearsal mechanism for spatial working memory. These covert shifts of attention are part of the active rehearsal process, and objects present in the perceptual space during these shifts are encoded into spatial working memory. When a target or object is present in our immediate spatial field, the mechanisms for remembering the location of this target are activated, and all the objects in relation to this object are inhibited.

One way to understand spatial working memory performance is to look at how children and adults view their perceptual space and how this influences spatial memory processes. In spatial recall, memory for targets near reference frames shows systematic distortions, referred to as geometric biases (e.g. Huttenlocher et al., 1991). These biases show an interesting developmental pattern: early in development, children show memory biases *toward* frames of reference, whereas older children and adults show biases *away from* reference frames (Simmering & Spencer, 2008). The dominant account of this developmental transition is the Category Adjustment model proposed by Huttenlocher and colleagues (1991). According to this account, young children treat large spaces as a single category and are biased toward the center of the space (ie: prototypical locations), whereas older children and adults sub-divide large spaces into two categories and show biases toward the centers of the left and right regions (Simmering & Spencer, 2008). For young children it is likely that they have only one central prototype, a central prototype on the midline of a perceptual space. Older children and adults, are likely to have multiple prototypes due to dividing the space into separate, smaller regions. Due to this

division, they are biased toward multiple locations and not just toward one central prototype.

According to the Category-Adjustment (CA) model proposed by Huttenlocher, Hedges, and Duncan (1991), retrieval of locations from memory is a hierarchical process that involves the use of both fine-grained (direction and distance of a location from a reference point) and categorical (i.e., a visible spatial region or a mentally imposed region or reference axis, and the central prototype(s)) information. When trying to remember a previously learned location, people make estimates based on their memory of fine-grained, metric information such as distance and direction from an edge (Hund & Plumert, 2002). Fine-grained information (perceived distance) is inexact because of how we view the object, and from what angle. If a person looks directly at object they will create a perceived distance from category prototypes, but if they adjust, and indirectly look at an object, they will create a perceived distance that is either closer, or farther away from category prototypes. In relation to this, the presence of competing stimuli, and/or delay in spatial recall, also cause the fine-grained information in memory to deteriorate. When fine-grained information is inexact, adjustments are made based on categorical information which leads to systematic distortions toward the spatial prototypes at the center of the spatial category (Hund & Plumert, 2002).

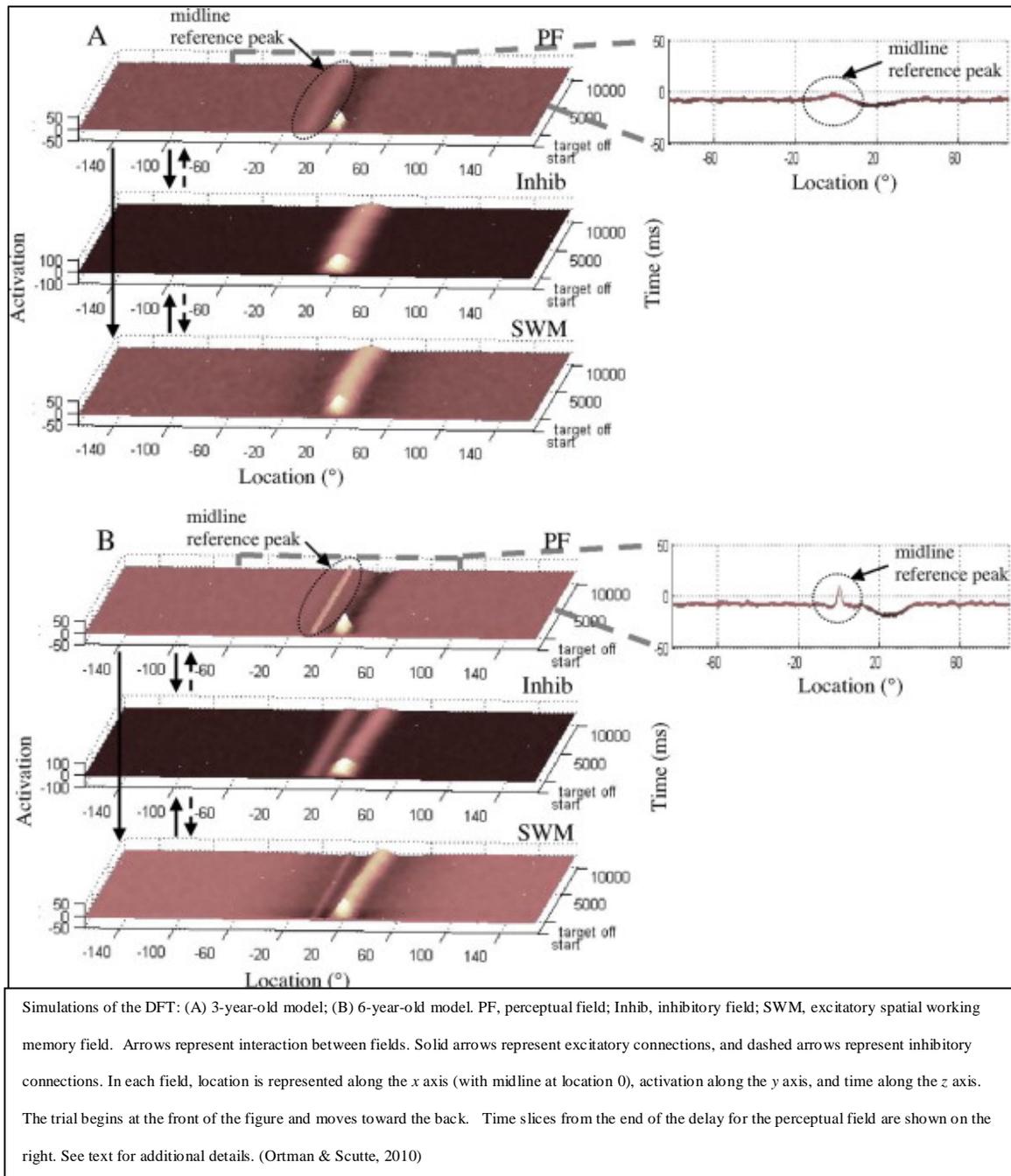
Based on the category adjustment model, the magnitude of distortion toward prototypes depends on the certainty of the fine-grained, metric information. When memory for fine-grained information is relatively certain, categorical information receives a low weight, resulting in only small distortions toward prototypes; conversely, when memory for fine-grained information is relatively uncertain, categorical

information receives a high weight, resulting in large distortions toward prototypes (Hund & Plumert, 2002).

In the study conducted by Hund & Plumert (2002), they examined whether imposing a relatively long delay between learning and reproducing locations would lead to significant increases in distortion toward prototypes for both children and adults. The results clearly showed that imposing a delay between learning and reproducing locations led to increases in geometric bias for both children and adults. These findings indicate that children and adults rely more on categorical information to estimate location as fine-grained memory degrades over time.

Another way to understand the precision of spatial working memory over development is with the Dynamic Field Theory (DFT). The DFT is a dynamic systems approach to spatial working memory that has been implemented in a type of neural network called a dynamic neural field (DNF). Dynamic field theory has three neural fields: the perceptual field, the spatial working memory field, and the inhibitory field.

Figure 1: Simulations of the DFT and Neural Fields

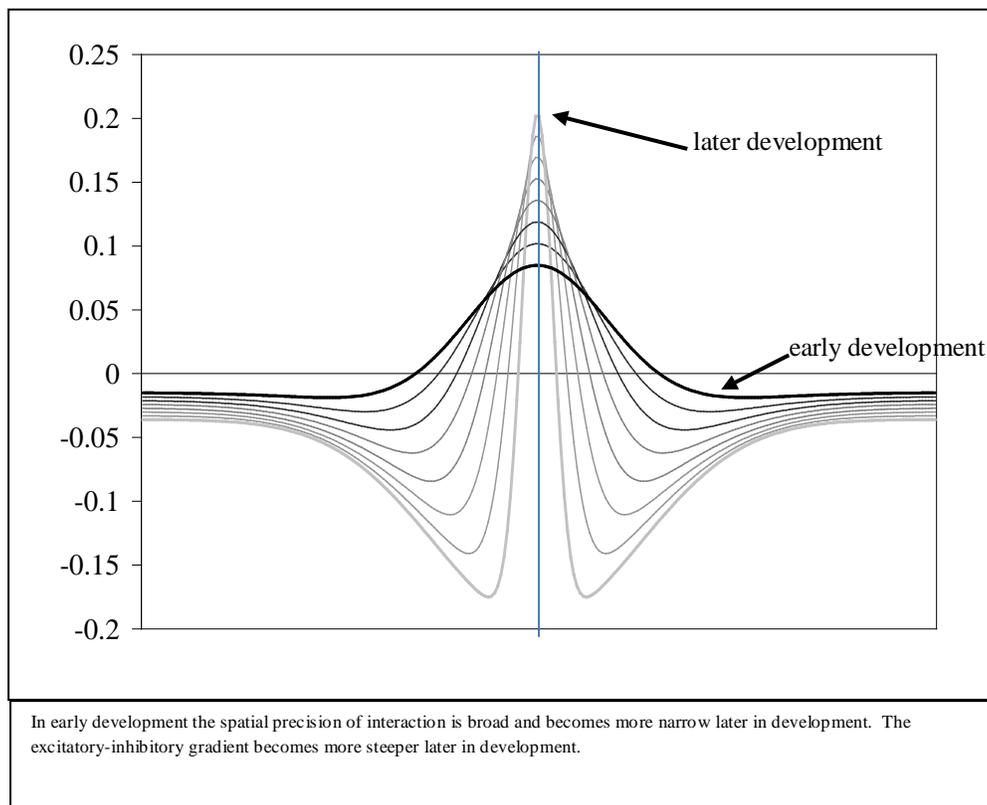


Neurons in each field send positive activation to nearby neurons and, through the inhibitory field, send inhibition to neurons farther away (Ortman & Scutte, 2010). The result of these interactions is a form of local excitation/lateral inhibition that allows the

spatial working memory field to sustain a peak of activation in the absence of input (Ortmann & Schutte, 2010). These narrow and precise peaks can inhibit other inputs to the field, such as inputs from locations encoded in long-term memory or distractors perceptually present in the task space. For example a distractor that appears in the visual field can be inhibited by the neural activation of a target location previously encoded in the spatial working memory field, therefore allowing the present location to be maintained in spatial working memory and the distractor location to be inhibited.

A key component of the Dynamic Field Theory is the spatial precision hypothesis which explains changes in spatial working memory over development. According to the spatial precision hypothesis, over development neural interactions becomes stronger and more precise (Spencer et. al., 2006)

Figure 2: Spatial Precision Hypothesis



When a neuron is activated, it excites neurons that code for nearby locations and inhibits neurons that code for locations far away (Schutte & Spencer, 2009). According to the spatial precision hypothesis, two critical changes to these interactions are apparent. First, as the interaction functions move from early development to later development, the spatial precision of interaction narrows. Second, the excitatory – inhibitory gradient becomes steeper. In the case of 3- year-olds, the activation at a target location is weaker and covers a much larger neural field. As children get older, these neural interactions become much stronger and more precise (Simmering, Schutte, & Spencer, 2008). Importantly, the changes in neural interaction captured by this developmental hypothesis also have consequences for how locations are remembered near reference frames, specifically, these changes lead to developmental changes in geometric biases in the model (Schutte & Spencer, 2009).

According to the DFT, when children become adults these neural interactions are at their strongest. For example, an infant or a young toddler may get distracted easily, and this accounted for in the model through changes in neural interaction. In the model, weak activation reduces the ability of the model to inhibit competing stimuli, i.e., the model gets “distracted” easily, but as interaction becomes stronger and more precise over development, the model is able to inhibit competing stimuli and maintain a peak at the target location. We start to see these changes from three to six years of age with a notable variability in between these ages. The spatial precision hypothesis is a good way of gaining an understanding of how the brain develops from infancy on up.

This neural network model demonstrates how the neurons in a working memory field activate and interact with each other. In younger children these activations are

weaker and the peaks are broader, covering more of the memory field, see black line in Figure 2. As neural interactions become stronger, input to the model builds a narrower, more precise peak, see light gray line, Figure 2. Stronger activation at a particular location in the field reflects a stronger representation of the associated location in space; the model responds to the location associated with the highest activation at the end of the memory delay (Schutte et al., 2003). The dynamic field theory models the rehearsal process that occurs during a delay after a target appears through maintaining the peak that was created by the target input.

Ortmann & Schutte (2010), investigated developmental changes in the perception of the midline symmetry axis by asking children to view a target on a large monitor and determine on which half of the monitor the target was located. The results of their study showed that between 3 and 6-years of age, there were small developmental changes in the ability to categorize locations around midline. Specifically, there was a small but significant increase in the number of targets categorized correctly. According to the dynamic field theory, the transition in the direction of geometric biases occurs due to two developmental changes: stronger neural interactions and changes in the perception of the symmetry axis. Interestingly, the largest change was not between 3- and 4-years of age, which is when the transition in geometric biases occurs. Instead, the largest change in performance occurred between childhood and adulthood, which was also the largest age difference in the study. Children, however, were biased away from midline when the targets were 20° from midline before they were biased away when the targets were 30° or 50° from midline (Schutte & Spencer, 2009).

Schutte and colleagues (2011) examined the type of errors children made when asked to remember the location of a target after a delay. They tested children in the age range of three, four, five, and six years old in two of three spatial working memory tasks that used a touchscreen attached to a large monitor. Children completed two of three spatial memory tasks: Bubble Burst, Treasure Hunt, or Finding a Spaceship. The sequence of events that occurred during one trial of a task was, first, a command was prompted (“Let’s look for a spaceship”, “let’s burst a bubble”, or “let’s hunt for treasure”). Second, the target appeared at a designed location, for a programmed duration, and then turned off. Third, there was a delay of zero, one, five, or ten seconds. During the 5, and 10 second delays, one of two things happened: a distractor appeared at a programmed location, or a distractor did not appear. The distractor appeared on half of those trials for one second. Fourth, once the delay ended, another command (“Go, Go, Go”) was initiated, prompting the child to use the stylus and point to the location of the target. Lastly, if the child accurately remembered the location of the target, they received positive feedback (“Good job”, or “Excellent!”), and they received encouraging feedback if they were inaccurate.

Based on research being done with dynamic field theory, we hypothesized that children would make different errors on the trials where a distractor was presented than on the trials a distractor was not presented. We found that for 3- and 6-year-olds, there was a significant difference between trials where a distractor was presented during the delay versus trials where no distractor was presented. Thus, the presence of a distractor during a delay influenced the child’s memory of the target location. Specifically, when a distractor was present near the target, 3-year-olds’ responses were biased toward the

distractor and 6-year-olds' responses were biased away from the distractor. The results for the 4- and 5-year-olds were variable, most likely due to the fact that these children are going through a period of rapid developmental change in spatial working memory.

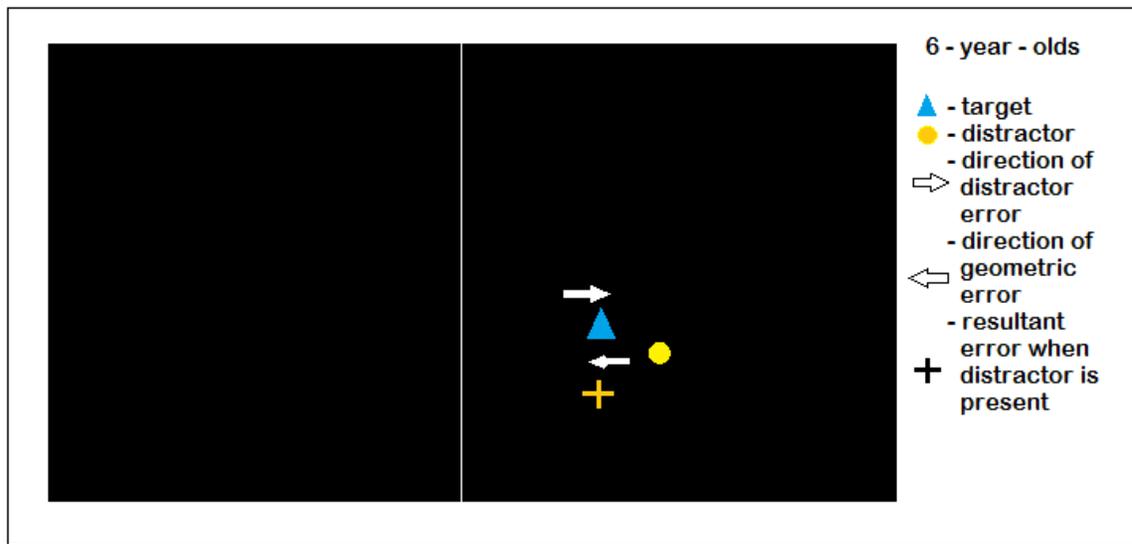
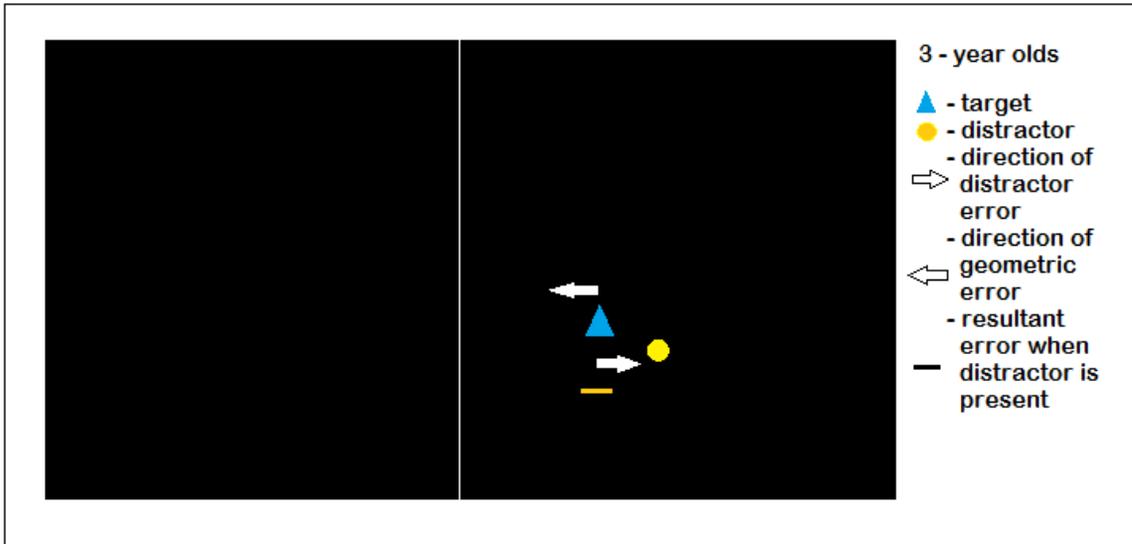
In the current study, we examined the effect of distractor duration. We added two different time components to the distractor duration: one second and three seconds. We compared the errors made on trials when the distractor was on for one second versus when it was on for three seconds to determine if the duration of the distractor would lead to larger errors.

The current research had two goals. The first goal was to replicate the previous study for 3- and 6-year-olds. We hypothesized that 6-year-olds would be biased away from the near distractor and 3-year-olds would be biased towards the near distractor. Based on the DFT, we expected memory errors to occur due to spatial drift during the delay which would result in either a bias towards (3-year-olds) or away from (6-year-olds) the distractor and also towards (3-year-olds) or away from (6-year-olds) the midline axis. Based on the spatial precision hypothesis, we would expect the 3-year-olds to make larger errors due to their inability to inhibit competing stimuli. According to the spatial precision hypothesis, the older children should be able to inhibit nearby competing stimuli, because of their more stable peak activation compared to 3-year-olds with unstable activation. The same would hold true in this study as in the first for the spatial precision hypothesis in that their precision will be impacted by their inability to inhibit the competing stimuli.

The second goal was to determine if the length of time the distractor is present, one second versus three seconds, would result in children making larger errors. Typically

6-year olds are biased away from midline so we hypothesized that the longer the duration of the distractor the larger the errors will be, with a bigger shift away from the near distractor, and less of a shift away from midline

Figure 3: Geometric Error Differences Due to the Presence of a Distractor



Shows 3-year olds' bias toward the geometric center, and toward the near distractor, resulting in a larger error. For 6-year-olds, it shows their bias away from the geometric center, and away from the near distractor, resulting in a smaller, more reduced error.

In essence the midline error would be reduced. For 3-year-olds we hypothesized larger errors and bigger shifts toward the near distractor when it is on for a longer duration. This research would provide insight on how the duration of a distractor in our perceptual field impacts our spatial working memory performance leading to less overall errors and more precise spatial memory as children. In essence, a distractor with a longer duration would correct errors made when inhibiting other competing stimuli, such as the midline symmetry axis. For 6-year-old, distractor duration could have a positive effect on their SWM performance, as seen in Figure 3.

Chapter 2: Method

Participants

Thirty-four 3- and 6-year-olds participated. There were 20 3-year-olds (11 males, 9 females; $M = 3:5.9$, $SD = 2.6$ mos), and 14 6-year-olds (8 males, 6 females; $M = 6:5.2$, $SD = 3.0$ mos). Participants were recruited by flyers, word-of-mouth and from previous studies. The participants came from several communities surrounding the local university and were from primarily middle-class families. Participant's received a toy of their choice and the participant's parent(s) received \$15 for participating in the study. All parents provided informed consent. An additional six participants (4, 3-year-olds and 2, 6-year-olds) completed the study, but were not included in the analyses due to a computer error that resulted in the data not being recorded correctly.

Materials/Apparatus

Two flashcards were used for a warm up game before the onset of the computer game. One flashcard had a picture of the distractor, a yellow dot, and the other flashcard had a picture of the target, a spaceship, treasure chest, or bubble. The flashcards corresponded to the game that was played on the computer.

The computerized tasks took place on a large 29 in x 42 in (74 cm x 107 cm) liquid crystal display (LCD) computer monitor (Sharp, Inc) which was surrounded by black curtains to block the view of any landmarks. The monitor was tilted up 15 degrees from horizontal in order to keep it at the same orientation as in the spatial working memory tasks. The LCD monitor had a resolution of 1024 x 768 pixels, and a Smartboard touchscreen overlay that responded to the touch of a stylus.

Task and Procedure

A background questionnaire was completed over the phone, prior to arrival. When a participant arrived at the laboratory with his or her parent(s) the informed consent form was explained to the parent(s) while the child played with toys. After the parent signed the consent form, the child was told they were going to play a game (consisting of “hunting for treasure,” “bursting a bubble,” or “looking for a spaceship”). The three spatial working memory tasks were identical in design, but differed in the cover story. The stories were different in order to provide some variation for the child, in an attempt to keep their interest.

The child was given a stylus to use when selecting the target. The experimenter went through a warm up game where they showed the child two flash cards. On one card was the picture of the target: a spaceship, bubble or treasure chest. The other card had a yellow dot which represented the distractor. The experimenter told the child to ignore the yellow dot and to remember which flashcard had the picture of the target. Both flashcards were then placed face down and the experimenter explained to the child that they had to wait for the command “Go Go Go,” before they could point to where the target was with the stylus. Two successful warm-up trials had to be completed before the child could move on to the actual game.

After the completion of two successful flashcard trials, they moved to the monitor. Each game started with a demo trial that was performed by the experimenter. The demo trials helped familiarize the children to the game so they would know what to expect. Usually one demo trial was done, but more could be administered by the experimenter if needed.

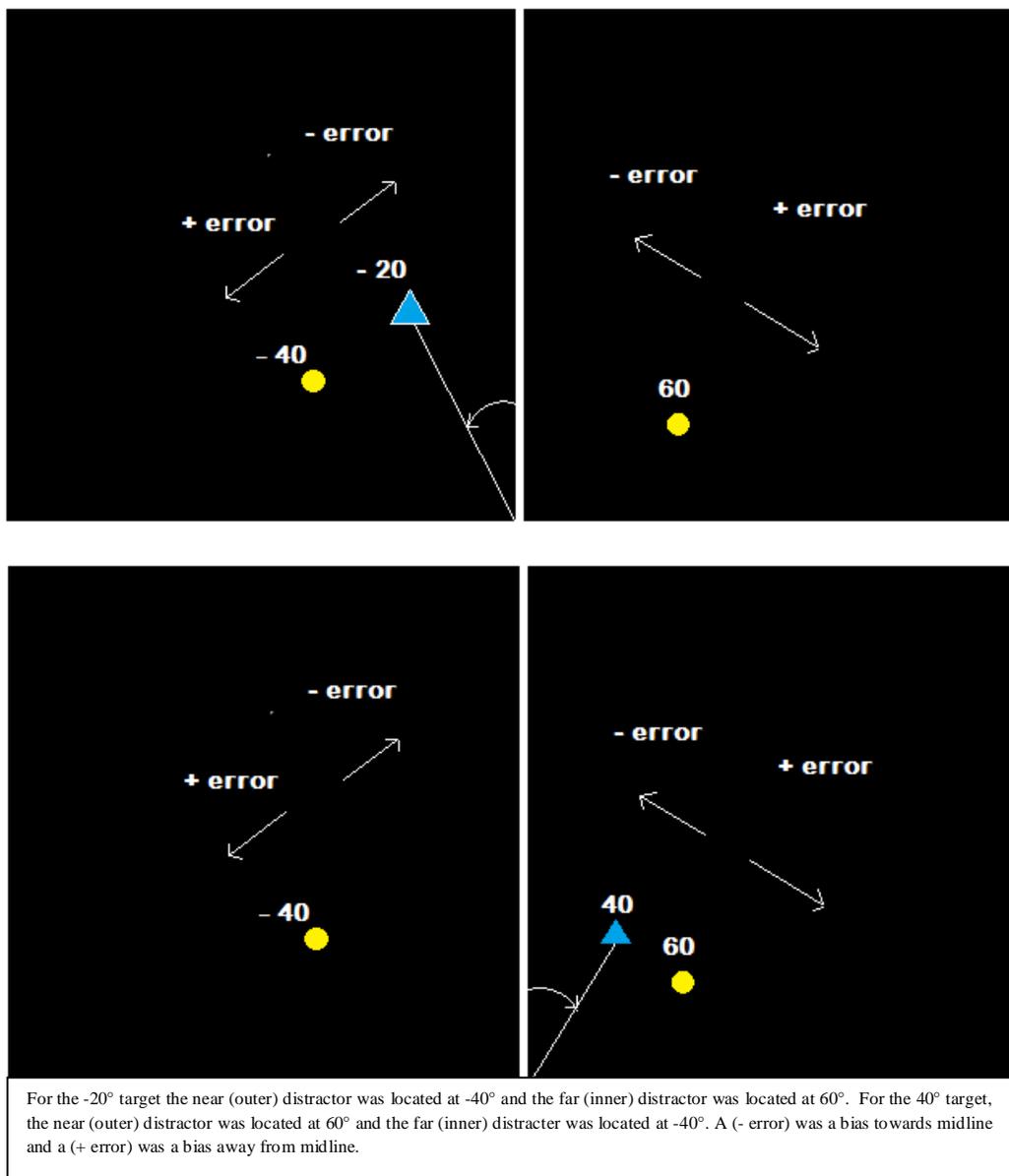
The demo trials were exactly the same as the test trial. When the experimenter finished the demo, the participant completed 26 trials that consisted of 2 practice trials and 24 test trials. The sequence of events that occurred during one trial of a task were, first, a command was prompted (e.g., “Let’s look for a spaceship”, or “let’s burst a bubble”). The target would appear at a designated location, for 2000ms, and then turn off. Then, there would be delay of 0, 1, or 10 seconds. During one-third of the 10 second delay trials, a distractor appeared at a designated location. The distractor would appear on half of distractor trials for 1 second, and on half of the distractor trials for 3 seconds. Once the delay ended, another command (“Go, Go, Go”) was initiated, prompting the child to use the stylus and point to the location of the target. Lastly, if the child accurately remembered the location of the target, they received positive feedback (e.g., “Good job”, or “Excellent!”), and they received encouraging feedback if they were inaccurate. The procedure for the second game was identical to the first game. The participant completed a different second game after a 10 minute break.

Experimental Design

Children were randomly assigned to play two of three games. The children responded to two target locations. One target appeared 40 degrees to the right of midline and the other target appeared -20 degrees to the left of midline. The children responded to desired target location after delays of 0 s, 1 s, and 10 s. On two-thirds of the 10s delay trials a distractor appeared during the delays. The distractors appeared at a location near or far from the target. The near (outer) distractor for the targets appeared away from midline and the far (inner) distractors appeared at a location towards midline. For the -20

degree target, the near distractor appeared at -40 degrees and the far distractor appeared at 60 degrees.

Figure 4: Design of Target Locations, and Distractor Locations



For the 40 degree target, the near distractor appeared at 60 degrees and the far distractor appeared at -40 degrees. When the distractor appeared, it remained on for 1000ms or 3000ms. The onset for both distractor durations was the same.

The participants were given feedback from the game and the experimenter after successful and unsuccessful trials to help encourage the participants to complete the trials. If a child found the target, the computer provided feedback such as “Good job, you found the spaceship” and if they missed the target but were close, the computer would respond “You were so close to that spaceship, good try.” A picture also showed up on the screen when the computer responded during the correct trials and near correct trials. The experimenter also gave the participants words of encouragement.

Method of Analysis

Mean constant errors were computed for each participant for each target, distractor, delay, and distractor duration combination. A multi-level model was used to analyze the overall data for both age groups.

Chapter 3: Results

An analysis was conducted to test the predictions that the errors the 3- and 6-year-olds made in the initial study would be replicated in this study. The multi-level model showed an overall Distractor x Age interaction, $F(1,210) = 7.46, p = .007$. The 3-year olds demonstrated a bias toward the distractor when it was presented near the target location

Table 1: Summary of 3-year-old Distractor Location Effects

Distractor location	Univariate Summary	
Near (outer)	$M=0.602$	$s=14.947$
Far (inner)	$M=-2.688$	$s=16.521$
No	$M=-2.386$	$s= 14.722$

Specifically, when the target was presented at 40° the 3-year-olds were biased towards the distractor presented at 60° . When the target was presented at -20° , the 3-year-olds were biased towards the distractor presented at -40° . The 6-year-olds still demonstrated a bias away from the distractor when it was presented near the target location as they did in the initial study (Schutte et al., 2011).

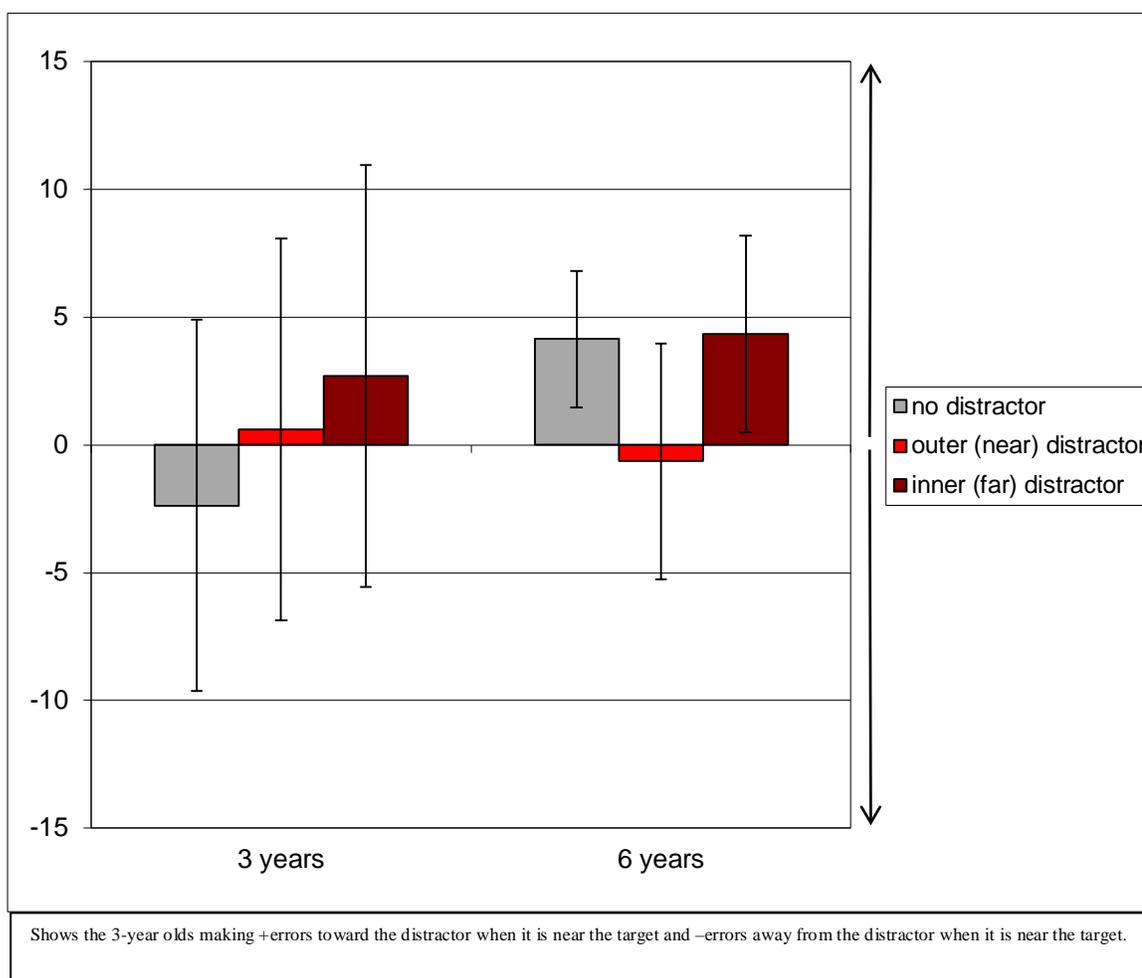
Table 2: Summary of 6-year-old Distractor Location Effects

Distractor location	Univariate Summary	
Near (outer)	$M=-0.641$	$s=9.224$
Far (inner)	$M=4.336$	$s=7.690$
No	$M=4.146$	$s= 5.367$

When the target was presented at 40° , the 6-year-olds were biased away from the near distractor at 60° and towards midline. When the target was presented at -20° , the 6-

year-olds were biased away from the near distractor presented at -40° and back towards midline. When there was no distractor present during the delay the 3-year-olds made error towards midline and the 6-year-olds made errors away from midline. A graph of the data is shown in Figure 5.

Figure 5: Graph of the Results



When examining distractor duration we found no significant results. We found no significant interaction when examining target location, and distractor duration $F(1,210) = 0.15, p = .696$. We found no significant interaction when examining distractor location, and distractor duration $F(1,210) = 0.44, p = .507$. We found no

significant interaction when examining target, distractor location, and distractor duration

$F(1,210) = 0.62, p = .433.$

Chapter 4: Discussion

Our first hypothesis was confirmed. We replicated the findings found in our previous study for 3- and 6-year-olds, where 3-year-olds demonstrated a bias toward the distractor when it was presented near the target and 6-year-olds demonstrated a bias away from the distractor. Our second hypothesis, that the longer the distractor was on, one second versus three seconds, would lead children to make larger errors, did not prove to be significant.

The overall purpose of this study was to test a prediction of dynamic field theory, by singling out one variable, the distractor, and analyzing its impact on spatial working memory performance by altering how long it appeared. Based on the theory, we predicted different errors in the trials in which the distractor was on longer overall. For 3-year-olds we expected to see a larger shift toward the near distractor. For 6-year-olds we expected to see the shift away from midline be reduced due to the shift away from the near distractor, which was on the opposite side of the target from midline. For both 3- and 6-year-olds, however, there was no significant difference between the different distractor times. The results provide evidence on how the distractors are processed during spatial working memory tasks, and the results suggest that it is not the duration of time the distractor is on, but the onset of the distractor that has the effect on the errors overall. In dynamic field theory, the activation in the perceptual field when the target is presented at one of the two select locations is modeled based on neuronal firing strength and precision. Activation in the spatial working memory field when the distractor is presented appears as another peak of neuronal activation. No matter how long the distractor stays

on, the onset appears to be what is encoded in the spatial working memory field, and is what causes the effect on memory.

Before concluding that distractor duration does not influence memory, it is important to note several limitations that may have influenced the overall results. One limitation of this study is the number of participants. Adding more participants to the study to increase the overall power may increase the likelihood of obtaining significant effects of distractor duration. A second limitation is the difference in the duration of distractors. In the current study the distractors were on for one second or for three seconds. When observing the distractors in real time, there did not appear to be a notable difference in the length of time the distractors were presented. One possibility is that duration would have a significant effect if the distractor time was increased such that the difference between the distractors was larger, e.g., 6 seconds. If a longer distractor influences memory there would be more information for dynamic field theory, in regards to the neural mechanisms operating during the delay. If there are significant effects for distractor duration after a longer distractor it would provide additional support for dynamic field theory and the neural mechanisms that are associated with spatial drift. If the effects are not significant it would be evident that the neurons only fire at the onset of the distractor and not fire after that, perhaps due to an inhibiting mechanism not currently modeled in dynamic field theory.

To examine the influence of the onset, future research could compare errors on trials where a distractor has one onset during the delay to trials where a distractor that has multiple onsets. The multiple-onset distractor may be associated with larger errors, compared to a single onset distractor, even when they are presented for the same total

amount of time. The findings would provide us with more insight into how the underlying neural mechanisms might work in spatial working memory. It also would give us more insights into how these mechanisms appear in the dynamic field theory.

Future studies can also use neural imaging to assess active neural mechanisms, spatial working memory capacity, and spatial working memory performance. With the advancements in neural imaging techniques, researchers will undoubtedly gain additional insight into how the brain works during spatial working memory tasks.

Neural imaging has already provided insights into spatial working memory. For example, Fusser and colleagues (2011) examined the common capacity-limited neural mechanisms of selective attention and spatial working memory encoding using functional Magnetic Resonance Imaging (fMRI). Attention-based models of working memory hold that memory's limited capacity is due to common capacity limited resources shared with selective attention (Fusser et. al.). This view is supported by findings of functional interference observed in behavioral tasks that concurrently place demands on both processes indicating common limited cognitive processes (Fusser et. al.). Fusser and colleagues combined visual search and delayed discrimination of spatial locations to investigate interactions between attention and object WM encoding on behavioral and neural levels. They manipulated the demands on selective attention and working memory encoding together within one single task by implementing two search conditions in which target items had either unique features (ES; low attentional demand) or shared most of their features with the distractors (DS; high attentional demand).

Based on what they found concerning the neural activation during target onset, that the initial encoding in spatial working memory is important. During this initial

encoding, neurons are at their peak activation and this peak activation is important for SWM precision and performance. Fusser and colleagues (2011) manipulated the demand on working memory capacity and attention in order to identify brain regions which show an interaction effect. Such an interaction effect would provide strong evidence for common cognitive and neural resources shared by spatial working memory encoding and spatial attention. They expected to find an interaction effect between attentional demand and working memory load, (i.e. a less than additive increase in blood oxygen level-dependent (BOLD) activation with increasing demands on working memory and visual search). Conversely, regions that mediated both processes and were well within their processing limits should be associated with main effects for task manipulations or increased task demands and an additive increase in BOLD activation under simultaneous working memory and attentional demands.

Fusser and colleagues (2011) identified an interaction effect between WM and attention manipulations that reflects the competition for shared resources that is consistent with the notion of common processing limitations of visual attention and the encoding of objects into WM. The interaction between attention and visual WM occurred in the premotor and posterior regions. One key finding of this study was that the prefrontal cortex (PFC) was not part of the activation pattern that reflected the common processing limitations of visual WM and attention, but it formed stable representations of spatial patterns when attentional and memory demands were competing for more posterior neural resources. These findings are important for DFT because they provide insights about the attentional demands on neural resources when competing stimuli enter the perceptual field during SWM processing.

The findings by Fusser and colleagues (2011) are important, because they present a way to image spatial working memory functions using fMRI. The DFT is a model of how neurons activate during a spatial working memory task, but the use of fMRI can provide us with a concrete visual of spatial working memory processes. Neuroimaging can provide additional evidence for how DFT accurately models spatial working memory processes.

Campo and colleagues (2005) examined the encoding process in spatial working memory using magnetoencephalography (MEG). Campo and colleagues focused on the medial temporal lobe because it has been found to be activated during episodic encoding. In order to determine whether the medial temporal lobe is contributing to the encoding processes of spatial working memory or if its activation is simply due to the processing of spatial-perceptual information, the authors contrasted a spatial working task and a perceptual task that minimized memory demands while presenting identical stimuli. Using MEG, they recorded the neuromagnetic brain patterns of eight adult volunteers while they performed these tasks. MEG is a fine-grained temporal resolution technique that offers a unique contribution to the understanding of the relationship of functional activity, cognitive processes and brain anatomy (Helenius et al., 1998; Simos et al., 2002).

One of their findings was that most of the activity in the temporal lobes was restricted to the posterior part in both tasks. This activity became noticeable very early (~200 ms), after a bilateral occipital activity, and resolved around ~400 ms. Campo and colleagues' (2005) results suggest that the involvement of the medial temporal lobe during the encoding process of a spatial working memory task is influenced by the

memory demands of the task, although early activation could be more related to attentional components. The data also indicated that spatial working memory elicited a greater activation over the right medial temporal lobe. Thus, by using a non-invasive functional neuroimaging technique such as MEG, which allows a virtually instantaneous localization of activity sources (Papanicolaou et al., 2002), differences in the progression of activation of the medial temporal lobe between tasks can be shown.

The finding that the medial temporal lobe is involved during the encoding process of a SWM task with early activation related to attentional components, contributes to the growing body of evidence that suggests a great degree of overlap between the neural networks that subserve spatial attention and those that subserve spatial working memory (Awh & Jonides, 2001; Coull & Frith, 1998; Okada & Salenius, 1998; Postle & D'Esposito, 1999; Campo et al., 2005b).

Campo and colleagues (2005) findings are important to research being done with DFT, because it highlights structures that are active during spatial working memory tasks. In this case, the medial temporal lobe is active during these tasks, suggesting that other regions of the brain (besides the PFC) are important for spatial working memory performance. It begins to provide us with an image of how to model SWM using DFT.

With the continual findings of SWM performance we will start to see these findings become applicable in the clinical setting. For example, there are several factors that go into successfully diagnosing ADHD, and deficits in SWM performance could be added to the ADHD clinical assessment in order to accurately diagnose a child with ADHD at a young age. For a child to be diagnosed with ADHD they must demonstrate all three critical symptoms: inattention, hyperactivity, and impulsivity.

In a study done by Ferrin & Vance (2012) they examined the neurological subtle signs in ADHD as a clinical tool in diagnosing their relationship to spatial working memory. Neurological subtle signs (NSS) are minor neurological abnormalities that have been shown to increase in a number of neural developmental conditions (Ferrin & Vance, 2012). These minor abnormalities occur in motor, sensory and integrative functions. The smoothness and accuracy of fine motor movements are impacted by NSS and there are supported deficits in neuronal circuits involving subcortical structures such as the basal ganglia and limbic system. They found that NSS may be used as a possible sign of ADHD. They also found an association between NSS and SWM components in children and adolescents with ADHD. The predictive power of NSS for detecting these cognitive components, both support the contention that these motor and cognitive features may be an expression of underlying neurodevelopmental anomalies that subserve ADHD (Ferrin & Vance, 2012). The attentional component of ADHD is shown to impact working memory performance and is associated with SWM impairments, and an accurate diagnosis of ADHD at a young age would be beneficial for the appropriate interventions and treatments to be implemented before the child enters the school system, because working memory and attention deficits are associated with poor academic achievement (Ferrin & Vance, 2012). This research and future studies like it, along with DFT research, will continue to investigate the relationship between SWM impairments and ADHD. Furthermore, the findings will assist in successfully diagnosing ADHD at a younger age before a child enters the school system.

Future studies on spatial working memory performance and dynamic field theory could also have clinical implications. Spatial working memory research will continue to

develop as more and more improvements in technology come forward. The results of this study provide more information about the underlying mechanisms of SWM performance. As we continue to study these mechanisms, we learn things about the physiological reactions that occur during a SWM task.

Chapter 5: References

- Awh, E., Jonides, J., & Reuter-Lorenz, P. A., (1998). Rehearsal in spatial working memory. *Journal of Experimental Psychology: Human Perception and Performance*, 24(3), 780-790.
- Awh, E., Jonides, J., Smith, E. E., Buxton, R. B., Frank, L. R., Love, T., Wong, E. C., & Gmeindl, L. (1999). Rehearsal in spatial working memory: Evidence from neuroimaging. *Psychological Science*, 10(5), 443-437.
- Awh, E., & Jonides, J. (2001). Overlapping mechanisms of attention and working memory. *Trends in Cognitive Sciences*, 5(3), 119-126.
- Awh, E., Matsukura, M., & Serences, J. (2003). Top-down control over biased competition during covert orienting. *Journal of Experimental Psychology: Human Perception and Performance*, 29(1), 52-63.
- Campo, P., Maestu´, F., Capilla, A., Fernandez, S., Fernandez, A., & Ortiz, T. (2005). Activity in human medial temporal lobe associated with encoding process in spatial working memory revealed by magnetoencephalography. *European Journal of Neuroscience*, 21, 1741-1748.
- Campo, P., Maestu´, F., Ortiz, T., Capilla, A., Santiuste, M., Ferna´ndez, A. & Amo, C. (2005b). Time modulated prefrontal and parietal activity during the maintenance of integrated information as revealed by magnetoencephalography. *Cerebral Cortex*, 15, 123–130.
- Chan, L. (2009). Spatial working memory maintenance: Does attention play a role? A visual search study. *Acta Psychologica*, 132(2), 115.

- Coull, J. T. & Frith, C. D. (1998) Differential activation of right superior parietal cortex and intraparietal sulcus by spatial and nonspatial attention. *Neuroimage*, 8, 176–187.
- Ferrin, M. & Vance, A. (2012). Examination of neurological subtle signs in ADHD as a clinical tool for the diagnosis and their relationship to spatial working memory. *Journal of Child Psychology and Psychiatry*, 53(4), 390-400.
- Fusser, F., Linden, D. J., Rahm, B., Hampel, H., Haenscel, C., & Mayer, J. S. (2011). Common capacity-limited neural mechanisms of selective attention and spatial working memory encoding. *European Journal of Neuroscience*, 34(5) 827-838.
- Helenius, P., Salmelin, R., Service, E. & Connolly, J. F. (1998) Distinct time courses of word and context comprehension in the left temporal cortex. *Brain*, 121 (6), 1133–1142.
- Hund, A. M., & Plumert, J. M. (2002). Delay-induced bias in children's memory for location. *Child Development*, 73(5), 829-840.
- Huttenlocher, J., Hedges, L. V., Duncan, S. (1991). Categories and particulars: Prototype effects in estimating spatial location. *Psychological Review*, 98(3), 352-376.
- Huttenlocher, J., Newcombe, N., & Hollister-Sandber, E. (1994). The coding of spatial location in young children. *Cognitive Psychology*, 27, 115-147.
- Jha, A. P. (2002). Tracking the time-course of attentional involvement in special working memory. *Cognitive Brain Research*, 15(1), 61-69.
- Landers, W. F. (1971). Effects of differential experience on infants' performance in a Piagetian Stage IV object-concept task. *Developmental Psychology*, 5, 48-54.

- Maestu´, F., Simos, P. G., Campo, P., Fernandez, A., Paul, N., Gonzalez-Marque´s, J. & Ortiz, T. (2003). Modulation of brain magnetic activity by different verbal learning strategies. *Neuroimage*, *20*, 1110–1121.
- Munneke, J. (2010). Spatial working memory effects in early visual cortex. *Brain and Cognition*, *72*(3), 368.
- Okada, Y. C. & Salenius, S. (1998). Roles of attention, memory, and motor preparation in modulating human brain activity in a spatial working memory task. *Cerebral Cortex*, *8*, 80–96.
- Ortmann, M. R., & Schutte, A. R. (2010). The relationship between the perception of axes of symmetry and spatial memory during early childhood. *Journal of Experimental Child Psychology*, *107*(3), 368-376.
- Papanicolaou, A. C., Simos, P. G., Castillo, E. M., Breier, J. I., Katz, J. S. & Wright, A. A. (2002). The hippocampus and memory of verbal and pictorial material. *Learning and Memory*, *9*, 99–104.
- Postle, B. R. & D’Esposito, M. (1999). ‘‘What’’-Then-Where’’ in visual working memory: an event-related fMRI study. *Journal of Cognitive Neuroscience*, *11*, 585–597.
- Postle, B. R., Awh, E., Jonides, J., Smith, E. E., & D’Esposito, M. (2004). The where and how of attention-based rehearsal in spatial working memory. *Cognitive Brain Research*, *20*(2), 194-205.
- Rudkin, S. J., Pearson, D. G., & Logie, R. H. (2007). Executive processes in visual and spatial working memory tasks. *The Quarterly Journal of Experimental Psychology*, *61*(1), 79-100.

- Schutte, A. R., Spencer, J. P. (2002). Generalizing the dynamic field theory of the A - not - B error beyond infancy: Three-year-olds' delay- and experience-dependent location memory biases. *Child Development, 73*(2), 377-404.
- Schutte, A. R., Spencer, J. P., & Schoner, G. (2003). Testing the dynamic field theory: Working memory for locations becomes more spatially precise over development. *Child Development, 74*(5), 1393-1417.
- Schutte, A. R. & Spencer, J. P. (2009). Test of the dynamic field theory and the spatial precision hypothesis: Capturing a qualitative developmental transition in spatial working memory. *Journal of Experimental Psychology: Human Perception and Performance, 35*(6), 1698-1725.
- Schutte, A. R., Keiser, B. K., Ortmann, M. R., & Kobza-Guerrero, C. (2011). *The Impact of Attentional Shifts on Spatial Memory in Early Childhood*. Manuscript in preparation.
- Simmering, V. R., & Spencer, J. P. (2008). Generality with specificity: The dynamic field theory generalizes across tasks and time scales. *Developmental Science, 11*(4), 541-555.
- Simmering, V. R., Schutte, A. R., Spencer, J. P. (2008). Generalizing the dynamic field theory of spatial cognition across real and developmental time scales. *Brain Research, 1202*, 68-86.
- Simos, P. G., Breier, J. I., Fletcher, J. M., Foorman, B. R., Castillo, E. M. & Papanicolaou, A. C. (2002). Brain mechanisms for reading words and pseudowords: an integrated approach. *Cerebral Cortex, 12*, 297-305.

Spencer, J. P., Simmering, V. R., & Schutte, A. R. (2006). Toward a formal theory of flexible spatial behavior: Geometric category biases generalize across pointing and verbal response types. *Journal of Experimental Psychology: Human Perception and Performance*, 32, 473-490.

Appendices

Appendix A
Background Questionnaire

Database ID: _____

Age Group _____

Other: _____

ire

CHILD'S NAME _____ PARENT/GUARDIAN NAME _____

DATE ____/____/____ Staff Initials: _____

Phone Numbers Home: _____ Cell: _____ Work: _____

Best Time to Call _____

First, I would like to ask you a few questions. This information will be used to make sure we enroll families from a variety of backgrounds.

What is your child's date of birth? ____/____/____ (child is ____ years ____ months now)

What is your child's sex? M F Race/Ethnicity (optional): _____

Is your child right- or left-handed? RH LH

(They can participate in the study if they are right- or left-handed, but we need to know ahead of time so we can roughly balance the number of right- and left-handed children in each condition.)

Now I have some questions about your child's medical history.

Was your child born early, before your due date? Y N *If yes, how many weeks early?* _____ What was your child's birth weight? _____

How long was your child hospitalized after birth? _____

Has your child ever been screened/tested for lead exposure? Y N *If yes, what was the level?* _____

At what age did your child first do the following?

Sat Alone _____ (months) Spoke First Word _____ (months)

Walked alone _____ (months) Toilet Trained _____ (years)

Next, I am going to read you a list of medical conditions. Please tell me if your child has experienced, or currently is experiencing, any of these medical conditions.

Check	Illness or Condition	Age	Check	Illness or Condition	Age
	Visual problems If yes, ask if they have corrected-to-normal vision (Glasses or contacts are okay)**			Intraventricular or brain hemorrhage/disorder	
	Learning Disability			* Autism or other Pervasive Developmental Disorder	
	* Fetal Alcohol Syndrome			*Developmental Delay Mental Retardation	
	Attention Deficit/ Hyperactivity Disorder			Conduct, Oppositional, or Behavioral Disorder	

* Excluding condition **Excluding condition if not corrected *Screener: For any condition checked, ask if the child was diagnosed by a pediatrician or psychologist, if the child received any treatment or intervention, and note the child's age(s).*

Thank you for your interest. *If child does not have fetal alcohol syndrome, Autism or other Pervasive Developmental Disorder, Mental Retardation, or non-corrected vision problems schedule child for session.*

Additional notes:

Appendix B
Informed Consent



DEPARTMENT OF PSYCHOLOGY

PARENTAL INFORMED CONSENT FORM

THE IMPACT OF DISTRACTER DURATION ON SPATIAL WORKING MEMORY IN EARLY CHILDHOOD

Purpose of the Research:

This is a research study. We are inviting children to participate in a research study investigating the development of spatial memory and attention being conducted by Brian Keiser and his associates under the supervision of Anne R. Schutte, PhD. The purpose of this research study is to examine the development of location memory in children 3 and 6 years of age. More specifically, we are examining how children remember where hidden objects are located when asked to remember these locations for different amounts of time.

We are inviting your child to participate in this research study because you and your child reside in this community, and your child is either 3 or 6 years of age. As we discussed when we scheduled your appointment, your child will participate in one session which will take place in the Spatial Memory Laboratory in Burnett Hall, room 58. Your visit to the laboratory will be finished in approximately one hour and 15 minutes, allowing time for you and your child to feel comfortable in the laboratory setting and for us to answer any questions. Your child will also be asked if he/she is willing to participate.

Procedures:

If you agree to participate, your involvement will last for 1 session that will last for about an hour and 15 minutes.

The following procedures are involved in this study. Children agreeing to participate will complete two of three possible location memory tasks. The three possible tasks are spaceship search, treasure find, and bubble burst. In each task participants will play a game in which they tell a computer where spaceships/treasure chests/ bubbles are located on a large monitor by touching the surface of the monitor in front of them with a stylus. Participants will see a spaceship/treasure chest/ bubble light up and then go away, but they won't point with the stylus until the computer says, "go." On some of the trials a dot will appear on the screen during the delay. This dot can be ignored by the child. The important thing to remember is to always wait to move until the computer says, "go," and to point to the location as quickly and accurately as possible. Each task will take about 10



15 minutes to complete. After completion of the first task the participant will be given a 10-15 minute break, and then will complete the second task. Children who become bored, frustrated with the task, or indicate in some way that they are not interested in continuing to participate will be allowed to stop participating.

Risks and/or Discomforts:

There are no known risks associated with this research. We are careful to ensure that you are safe and that our equipment works well.

Benefits:

There will be no personal benefit for participating in this study. However it is hoped that, in the future, society could benefit from this study by helping researchers and clinicians identify spatial attention and location memory deficits in certain patients and design successful interventions.

Confidentiality:

Any information obtained during this study which could identify your child will be kept strictly confidential. To ensure confidentiality, your child's information will be identified only by an identification code, and all information will be stored in a secure storage area. In the event of any report or publication from this study, your identity will not be disclosed. Results will be reported in a summarized manner in such a way that you cannot be identified.

Compensation:

You will be compensated for participating in this research project. You will receive \$15, and your child will receive a small gift at the end of each session to compensate you for the time involved in participating in this research study. You will receive the \$15 and your child will receive the toy regardless of whether or not your child completes the task.

Opportunity to Ask Questions:

Your child's rights as a research subject have been explained to you. If you have any additional questions about the study, please contact me at 472-3411 or Dr. Anne Schutte at 472-3798. If you have any questions about your child's rights as a research participant that have not been answered by the investigator or to report any concerns about the study, you may contact the University of Nebraska-Lincoln Institutional Review Board (UNL IRB), telephone (402) 472-6965.

Freedom to Withdraw:



Participation in this study is voluntary. You are free to decide not to enroll your child in this study or to withdraw your child at any time without adversely affecting their or your relationship with the researchers or the University of Nebraska-Lincoln. Your decision will not result in any loss of benefits to which your child is otherwise entitled.

DOCUMENTATION OF INFORMED CONSENT

YOU ARE VOLUNTARILY MAKING A DECISION WHETHER OR NOT TO ALLOW YOUR CHILD TO PARTICIPATE IN THE RESEARCH STUDY. YOUR SIGNATURE CERTIFIES THAT YOU HAVE DECIDED TO ALLOW YOUR CHILD TO PARTICIPATE HAVING READ AND UNDERSTOOD THE INFORMATION PRESENTED. YOU WILL BE GIVEN A COPY OF THIS CONSENT FORM TO KEEP.

Child's Name

Signature of Parent

Date

IN MY JUDGEMENT THE PARENT/LEGAL GUARDIAN IS VOLUNTARILY AND KNOWINGLY GIVING INFORMED CONSENT AND POSSESSES THE LEGAL CAPACITY TO GIVE INFORMED CONSENT TO PARTICIPATE IN THIS RESEARCH STUDY.

Signature of Investigator

Date

IDENTIFICATION OF INVESTIGATORS

PRIMARY INVESTIGATOR: Brian A. Keiser Office: 472-3411