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HANDS, AND NUMBERS, AND DOTS OH MY! EXAMINING THE EFFECT OF NEARBY-HANDS ON COUNTING AND SUBITIZING

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ABSTRACT

The “nearby-hand” effect (Tseng, Bridgeman, & Juan 2012), an alteration of performance caused by the presence of our hands in the visuospatial area, has been found in learning, attention, and working memory tasks (Brockmole, Davoli, Abrams, & Witt, 2013a). However, no work to date has been published demonstrating a relationship between the nearby-hand effect and judgments of magnitude, including subitizing and counting. It is suggested by Tseng, Bridgeman, and Juan (2012) that nearby-hands affect attentional disengagement, yet little experimental evidence is available to support this notion. Given the serialized nature of counting, which requires attentional disengagement from item to item being counted, the following experiments extend the nearby-hand research using a counting task and further explain the relationship between attentional disengagement and nearby-hands. The results of this study demonstrated an effect of nearby-hands on subitizing (i.e. enumerating quantities of 1 to 3), further contributing to the canon of existing literature examining the attentional requirements of subitizing in an ecologically valid manner not previously implemented in other tasks to this end (Egeth, Leonard, & Palomares, 2008; Poiese, Spalek, & Di Lollo, 2008). Lastly, relationships have been found in developmental studies linking math ability and attention (Anobile, Stievano, & Burr, 2013; Steele, Karmiloff-Smith, Cornish, & Scerif, 2012), however little work has examined the trajectory of this into adulthood. The following selection of tasks further demonstrates that this relationship still persists into adulthood, despite the causal connection between these two constructs still being up for debate.

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CHAPTER 1
INTRODUCTION

Imagine yourself living 2 million years ago in Southern Africa as one of our ancestral species, the *Homo habilis*. Once believed to be the first primate to construct a rudimentary stone tool, *Homo habilis,* a name that literally translates to "handy man," made crude handaxes, blades, and scrapers to serve their hunting and foraging needs. Typically these implements were constructed by starting with a stone core and striking a larger stone upon it to produce smaller usable flakes to be further refined for specific uses. Banging two rocks together to produce a tool millions of years ago would be a risky endeavor, as wounding one's hands would result in dire survival circumstances. One could also imagine that in a culture with no other material assets to speak of, being a proficient tool producer would be a valuable trait in mate selection. Thus, some underlying cognitive mechanism increasing attentional focus on or near the hands would be a valuable trait for the survival of the individual and the greater group of tool users. Early scenarios like these would be the foundational experiences upon which many of our underlying cognitive mechanisms evolved, and one such mechanism has resulted in what has been coined as the "nearby-hand" effect, the focus of the experiments in this paper.

The "nearby-hand" effect refers to how having one's own hands near a visual stimulus, as opposed to far away and out of view, can have an effect on cognitive performance. First found in an experiment by Reed, Grubb and Steel (2006), it has been demonstrated since that nearby-hands have an effect in many classic experimental paradigms. While it seems intuitively logical from an evolutionary standpoint that protective mechanisms near the hands would be a beneficial cognitive trait, the nature of the mechanism is yet to still be fully explained. Given that the field of "embodied" cognition is a relatively new within cognitive psychology, this is not surprising. In Wilson's (2002) seminal paper describing six fundamental tenets of embodied cognition, it is argued that we offload cognitive work onto our environments. A strong version of this theory is that cognition is not simply situated within the mind, but distributed across the entire situation in which we are interacting, including the mind, physical environment, and our bodies. While few cognitive psychologists would hold this view in its strong form, that cognition is distributed across the physical non-human environment, the research has demonstrated that, at the very least, the manipulation of our bodies, whether through physical posture (Carney, Cuddy, & Yap, 2010; Riskind & Gotay, 1982; Stepper & Strack, 1993), gesture (Goldin-Meadow, 2003; Novack, Congdon, Hemani-Lopez, Goldin-Meadow, 2014; Goldin-Meadow, Levine, Zinchenko, Yip, Hemani, & Factor; 2012), or hand placement (Reed, Grubb, & Steele, 2006; Tseng, & Bridgeman, 2011; Tseng, Bridgeman, & Juan, 2012), can have a profound effect on our cognition.

Recent experimental evidence has shown that keeping our hands in the visuospatial area can improve perceptual sensitivity in tasks requiring the assessment of figure-ground relations, the detection of objects by individuals with visual deficits, and judgments of magnitude in the classic Ebbinghaus illusion (Cosman & Vecera, 2010; Schendel & Robertson, 2004; Vishton et al., 2007). Further experiments have demonstrated that having our hands within our visual space draws our attention to and increases detection of targets near the hands (Davoli, & Brockmole, 2012; di Pellegrino & Frassinetti, 2000; Reed, Grubb, & Steele, 2006), and affects recall performance for items displayed near the hands (Davoli, Brockmole, & Goujon, 2012; Tseng, & Bridgeman, 2011). Curiously, while we see performance benefits for nearby-hands in the aforementioned tasks as well as many others (Cosman & Vecera, 2010; Linkenauger, Ramenzoni, & Proffitt, 2010; Schendel & Robertson, 2004), deficits have been found in others tasks measuring visuospatial acuity (Gozli, West, & Pratt, 2012). Similarly, in a task requiring participants to judge the sensibleness of sentences, as well as in the classic Stroop task, performance deficits with nearby-hands have been found (Davoli, Du, Montana, Garverick, & Abrams, 2010). In a review of the effects of hand posture on cognition by Brockmole, Davoli, Abrams, and Witt (2013), the authors take an agnostic approach toward these discrepancies. As such, more research is clearly needed to understand the mechanism behind the nearby-hand effect.

While a consensus has not been established as to the precise mechanism at work here, Tseng, Bridgeman, and Juan (2012) have argued in their recent review that given the current evidence, nearby-hands improve attentional engagement but slow down attentional disengagement, which may account for some of the curious discrepancies found with nearby-hands. Further, while effects have been found with nearby-hands in attentional, perceptual, and memory tasks, a relationship has not yet been shown between hand posture in tasks involving judgments of magnitude including enumeration and subitizing. With that in mind, the following experiment implements a counting task to examine whether diminished attentional disengagement with nearby-hands can affect subitizing and counting, and whether the type of information to be enumerated interacts with this phenomenon. Counting is a serialized process, as we must refocus our attention on the next object in a set to be counted, disengaging from the previous object. Thus given Tseng et al.'s notion, differences for nearby-hands should be found in counting tasks.

Subitizing, the rapid and accurate enumeration of small sets of objects (Chi & Klahr, 1975; Kaufman, Lord, Reese, & Volkman, 1949), was once thought to be an automatic process and pre-attentional in nature (Trick & Pylyshyn, 1993, 1994). However recent research has shown that the process is not pre-attentional, demonstrating that the subitizing is weakened within the attentional blink (Egeth, Leonard, & Palomares, 2008; Olivers & Watson, 2008; Xu & Liu, 2008), hindered in masking paradigms (Poiese, Spalek, & Di Lollo, 2008), and negatively affected by semantic and non-semantic numerical distractors (Moore, Allred, Semmel, Ashcraft, 2014; Poiese, Spalek, & Di Lollo, 2008). The aforementioned studies suggest that the mechanism behind subitizing is not automatic and is dependent on purposeful attention. Given the notion that subitizing is attentionally driven, adding a nearby-hand manipulation to an enumeration task is a novel way to explore the relationship between nearby-hands and attention, and may provide further evidence that subitizing does require attentional resources. Additionally, a relationship between attention and math ability has been demonstrated (Anobile, Stievano, & Burr, 2013; Hassinger-Das, Jordan, Glutting, Irwin, & Dyson, 2014; Steele, Karmiloff-Smith, Cornish, & Scerif, 2012) and the following study explored whether nearby-hand manipulations interact with math ability in a counting task.

The Nearby-hand Effect on Cognition

Several studies have examined how the placement of the hands affects performance on tasks typically designed to examine attention. In one such study, hand position was manipulated in visual search, inhibition of return, and attentional blink tasks (Abrams, Davoli, Du, Knapp, & Paull, 2008). In the visual search task, subjects searched through visual displays of stimuli for a target letter with their hands either holding the computer monitor, or with their hands on their laps, distanced from the search array. Each search array consisted of between four and eight letters presented in random screen locations, with a target latter in each array (either *H* or *S*). Subjects indicated which target they found by responding with one of two buttons as quickly as possible. The other letters of the array were *U*s and *E*s randomly selected. The results indicated that visual search was slower when participants' hands were next to the display compared to in their laps. Abrams et al. interpreted this as either being a product of "delayed engagement" of attention to objects during visual search or "delayed disengagement" of attention from each object during serialized search.

To explore this matter further, Abrams et al. (2008) employed an inhibition of return (IOR) task (Posner, Rafal, Choate, & Vaughan, 1985) with a nearby-hand manipulation. In IOR paradigms, peripheral visual cues are presented at either long or short delays before the appearance of a central target, to which participants respond. Reaction times for trials with a short delay between the initial cue and the target are considered a measurement of attentional engagement (i.e., the ability to refocus the attentional spotlight on a new stimulus). Conversely, reaction times after long delays between the cue and target reflect are a measure of attentional disengagement (i.e., the longer the cue is presented, the harder it is to disengage the attentional spotlight from). The notion here is that longer cues are harder to disengage from, whereas shorter cues require a quick refocusing of attentional engagement, each relying on separate underlying cognitive mechanisms. The inhibitory effect of the longer cue is what is known as the inhibition of return. In Abrams et al.'s adaptation of the task, participants again completed the experiment with their hands either near the visual display or away in their laps. What they found was that hand posture had no effect in the short delay cued condition, but interestingly, the magnitude of the inhibition of return decreased when participants' hands were holding the computer display. This seems to indicate that when the hands are near the display, a delay of the disengagement of attention occurs, suggesting an attentional preference for the cued objects.

Lastly, in order to examine the effects of hand position on the allocation of attention over a duration, Abrams et al. (2008) tested participants in an attentional blink task (Raymond, Shapiro, & Arnell, 1992). The attentional blink paradigm (otherwise known as rapid serial visual presentation or RSVP) requires subjects to find two targets in a stream of quickly presented alphanumeric characters. Typically, participants are impaired at detecting the second target when it is presented within a few hundred milliseconds after the first. This impairment is known as the attentional blink. The results indicated that when the hands are on the display, a greater deficit was found for identifying the second target. Curiously, hand position did not affect identification of the first target, thus demonstrating that the engagement of attention is not affected by hand posture, but again disengagement is.

Another recent study examined how manipulating the placement of the hands altered the ability of participants to remember visual material in scenes composed of fractal patterns (Davoli, Brockmole, & Goujon, 2012). In the two experiments, participants located a target hidden within pictures of complex fractals and spiraling geometric patterns while holding their hands either close to or far away from the study stimuli. When the type of geometric patterns remained the same between the images to be learned, no differences were found in rates of learning regardless of whether participants' hands were placed near or far from the to be remembered stimuli. However, when the to be remembered images maintained structural congruity (i.e. the same geometric patterns) but changed in color, participants demonstrated considerably slower rates of learning while holding their hands near to the study material. Davoli et al. interpreted these findings as evidence that the hands impair learning in instances where information must be abstracted from novel imagery, suggesting a bias toward "detail-oriented," item specific processing with nearby- hands. This item specific processing may be related to the deficits of attentional disengagement in Abrams et al. (2008), wherein item specific processing hinders analysis of an entire scene, or delays attentional engagement with subsequent objects in a serial search.

While diminished performance was found in the aforementioned studies for nearby-hands when attentional disengagement is required, enhancements related to nearby-hands have been found in other attentional tasks. In a flanker task in which participants identified a central letter located between two distractor letters with varying levels of compatibility with a target letter, participants either held their hands surrounding the target or away from the display (Davoli & Brockmole, 2012). It was found that when the participants' hands were held near the stimuli, flanker interference was considerably reduced. The same effect was not found when dummy hands were placed next to the stimuli as a control, suggesting that this enhancement was caused by the activation of a neural network associated with having the hands in the visuospatial area, and not caused by the hands simply acting as a visual barrier. Davoli and Brockmole argue that having the hands near the stimuli alters visual attention, thus enhancing performance on the task. One possibility suggested by Davoli and Brockmole is that the "protection" that the hands provide is specific to scenarios in which resolution of targets from distractors is required. This suggests that in the flanker task, the hands diminish perceptual interference, even when compared to other visual barriers implemented as a control in the task. This would be consistent with Abrams et al.'s (2008) theory that the hands hinder attentional disengagement, which in Davoli and Brockmole's task would be disengagement from the center target, thus facilitating faster response times and diminished attention to the distracting flankers. Further they argue that the hands focus how attention is allocated to distal objects, and provides greater resources for the space within the hands via cross-modal or bimodal neural mechanisms underlying the effect.

Weidler and Abrams (2014) found a comparable effect in a flanker task, with increased performance when the hands were next to the visual stimuli.

Another attentional enhancement was found for nearby-hands by Reed et al. (2006). In this study based on work by Posner, Walker Friedrich, and Rafal (1987), participants completed a task in which a fixation point was flanked by two boxes horizontally. Participants' attention was oriented to one side by changing the border color of one box. Following this cue, a single box was then presented on either side of the fixation point and participants were instructed to respond as to which side of the screen the target appeared. Researchers manipulated whether the participants held their left or right hand close to the respective left or right side of the screen. What they found was an interaction such that individuals were quicker responding with their hands near to the targets than when their hands were away. Reed et al. took these findings as evidence that having a hand present could potentially influence two different components of visual attention. First, there is a prioritization of the area near the hand, and second, the placement of the hand allocates attention toward the hand in space. This facilitation was paricular to the hand and was not found for arbitrary objects placed in the visual field. Additionally, targets displayed away from the hand showed decrements in processing, again relating Abrams, et al.'s (2008) theory that the ability to attentionally disengage is hindered for objects near the hands.

Another nearby-hand effect has been found in a visual attention experiment conducted by Cosman and Vecera (2010). Participants in this task were asked to judge between two shapes as to whether they were seen in a previously viewed figure-ground display. In one condition, one of the participants' hands was within the visuospatial area of the display, whereas in a control condition, a dowel, acting as a comparable sized item in the viewable area was used in lieu of their hand. The results showed that when the participants' hand was near the scene that they later had to make a judgment about, their reaction times decreased compared to the dowel condition. The authors argue that this suggests that the bimodal representations for the area near the hand, coding for both the visual field around the hand, and the tactile use of the hand, increases available attentional resources to contribute to the figure-ground assessment. The neurological evidence for these bimodal neural structures will be discussed later in this introduction.

Lastly, it has been found that having the hands in the visuospatial area can enhance executive functions in a task requiring attention to be shifted from one stimulus attribute to another on a trial by trial basis (Weider & Abrams, 2014). Participants in this experiment switched between two basic tasks, identifying either the color or the shape of colored objects with their hands placed either near or far from the task's monitor. Typically, participants have impaired performance on a subsequent trial when asked to attend to a different attribute of the stimulus that they had to attend to on a previous trial. What was found in this experiment was a reduced residual switch cost (e.g., Rogers & Monsell, 1995), such that participants responded faster in trials requiring a switch with their hands near the screen. Weidler and Abrams argue that their findings demonstrate overall "increased cognitive control" near the hands, but fail to relate this to Abrams's previous notions about attentional disengagement.

Neurological Evidence for the Nearby-Hand Effect

While all of the former review has covered the curious effects of the nearby-hand in behavioral tasks, several neurophysiological studies have been conducted that may explain the underlying neural mechanism of the effect. One such study has found a specific bimodal set of neurons integrates tactile and visual information for the area near the hand. Graziano and Gross (1993) demonstrated that the putamen of the macaque contains neurons that respond to somatosensory stimuli including joint movement, light touch, and deep muscle pressure. Additionally, some of these same neurons in the putamen were found to respond to visual stimuli falling within ten centimeters of their tactile receptive field, demonstrating a bimodal coding of specific neural sets to both visual and tactile stimuli. Curiously, they found that these neurons were not sensitive to the shape or color of the visual stimulus presented, which is consistent with Davoli, Brockmole, & Goujon's (2012) findings demonstrating decreased performance when the color of the stimuli was altered during study.

A study of a lesion patient has found the same bimodal coding for both visual and tactile stimuli (di Pellegrino, Ladavas, & Farne, 1997). In a patient with severe left tactile extinction (the inability to identify sensory stimuli) caused by stroke damage in his right frontotemporal cortex, it was found that ipsilesional visual stimuli could cause extinction of the perception of contralesional tactile stimulus. That is, when a visual stimulus was presented near the patient's right hand while the patient was receiving tactile stimulation to the left, the patient failed to identify the physical stimulation to the left hand. In this instance, the patient's neurological deficits resulted in a cross-modal extinction of the less intense of the two stimuli, which seemingly supports the notion that humans too have neurons with bimodal coding for both tactile as well as visual processing.

Further evidence for this bimodal neural set underlying the nearby-hand effect comes from a study of 10 right-hemisphere lesioned patients suffering from a form of tactile extinction (Làdavas, di Pellegrino, Farnè, & Zeloni, 1998). Again, it was found that visual stimulus presented near the right hand inhibited the processing of tactile stimulus on the left hand. Of the

10 lesion patients in this study, 7 incurred some damage to parietal and temporal areas within the right hemisphere. Importantly, neurological evidence has demonstrated activation in right temporo-parietal areas of the brain during subitizing (Ansari, Lyons, van Eimeren, & Xu, 2007; Vuokko, Niemivirta, & Helenius, 2013). If the same regions are becoming active when the hands are in the visual space, we could expect a change in subitizing performance when the hands are nearby.

Subitizing and Attention

Subitizing, the rapid assessment of small numbers of objects, was once believed to be an automatic process, utilizing a separate cognitive mechanism than that used for counting (Trick and Pylyshyn, 1994). This theory included the “FINgers of INSTantiation” mechanism or FINST, which binds small sets of visual objects in a scene even if they move about, much like wiggling fingers on a hand (an ironic name, given the nature of the present experiment). The idea here being that as a visual “top-down” process, we can bind small groups of objects together into sets prior to the engagement of attention, thus facilitating the rapid response times of subitizing compared to counting. This FINST system is limited to small sets of up to four objects, and if this number is exceeded, counting is required to assess the number of objects present, and in turn, attentional engagement must occur.

More recent research however has demonstrated that subitizing also requires attentional resources to occur. In a study investigating the role of attention in subitizing, a rapid stream of visually presented letters (RSVP) task was utilized (Egeth, Leonard, & Palomares, 2008). In this task typically used to explore the attentional blink, the participant was shown a series of rapidly presented colored letters, in which a red target letter appeared. Either simultaneously with the target red letter, or with a lag of 100 to 400 ms, a array of green dots appeared on the display, ranging in quantity from 0 to 9. After watching the letter series, the participant needed to name the red letter and the number of dots that were presented. In the lag conditions, participants are typically hindered by the interceding stimuli between the target letter and the information to be assessed following it, indicative of attentional demands. The results demonstrated that within the subitizing range, there was an effect of lag on the participants' ability to assess the number of dots, a trend similar to those found in the counting range, and participants had further difficulties as the set size increased within the subitizing range. This demonstrated that there are attentional demands to subitizing, even when as few as two objects were present. Olivers and Watson (2008) found similar results in a comparable RSVP task, in which short lags prior to the presentation of numbers (1-4) to be counted negatively affected responding. Conversely, they also demonstrated that when presenting numerical stimuli within the subitizing range prior to a target letter, increased deficits were found as the number of objects in the set increased.

In a clever stimulus masking task, it was also demonstrated that subitizing required the activation of attention (Poiese, Spalek, & Di Lollo, 2008). In this experiment, participants viewed a display with either 0, 1, or 2 targets, composed of slanted line segments in an array of distractors composed of vertical line segments. This presentation was followed by the appearance of a masking pattern (at 50, 83,100, or 150 ms), which covered an element of the display, but never more than one of the targets to be counted. Tilted line segments stand out when viewed in a field of vertical lines, as line orientation is considered to be a primitive visual feature that is processed without attentional engagement. Thus when the total number of tilted distractors increases from 1 to 2, both should be counted as rapidly and effortlessly as one, and the expected accuracy between the number of targets should be flat. What was found however was that the accuracy for counting two objects was lower than for that of one, and that this performance improved as the time before the mask increased. If subitizing is preattentive, there should have been no difference in performance between the timing conditions of the masking.

Additionally, Moore and Ashcraft (2015) demonstrated in a study of elementary and college aged students that number naming (i.e. verbally stating the number presented on a screen) was consistently faster than subitizing in all of the age groups tested. Regardless of the quantity being counted or Arabic numeral being named, 1, 2, or 3, participants across all age groups were faster to name the digit, than to enumerate that same quantity of dots. Interestingly, participants' response latencies were faster for number naming even when counting one dot or naming the numeral 1, which discounts notions that the faster latencies in the number naming task were accounted for by eye movements made between dots in the counting task. These findings again demonstrate that subitizing is not an automatic process, but requires attentional engagement to occur, even when only enumerating one object.

Collectively, these studies seem to demonstrate that subitizing requires attention to occur, and that the process is neither preattentive nor automatic. In typical counting tasks, the response times for totals within the subitizing range (i.e. quantities of 1 to 3 items) is typically flat, increasing at most from 40 to 100 ms per item to be counted, whereas quantities in the counting range increase from 250 to 350 ms per additional item (Atkinson, Campbell, & Francis, 1976; Mandler & Shebo, 1982). Such quick response times for quantities within the subitizing range have made it challenging to test the attentional aspects of subitizing within standard counting tasks, resulting in the aforementioned approaches to exploring the problem.

Attention and Math Ability

Developmental research has investigated the relationship between attention and success in mathematics. In one study examining this relationship, children between the ages of 8 and 11 completed an object tracking task which measured visual sustained attention, along with a battery of math tasks including Arabic numeral reading, writing, multiplication, addition, subtraction, and counting, as well as a measure of reading ability (Anobile, Stievano, & Burr, 2013). Importantly, it was found that students with better performance on the attentional task had greater math ability, even when controlling for such factors as nonverbal intelligence and gender. Curiously, the same relationship was not found between attention and reading ability. Relatedly to the study in this paper, it was found that complex addition and subtraction loaded on the same factor as counting, all of which were affected by differences in the children's attention.

In a series of experiments examining various attentional components and mathematical ability in children ages 3 to 6, researchers found further relationships between math ability and attention (Steele, Karmiloff-Smith, Cornish, & Scerif, 2012). For their purposes, Steel et al. utilized tasks examining "sustained attention" or vigilance, which is a measure of a participant's ability to engage consistent attention over a duration, "selective attention," selecting task-relevant stimuli within distractors, and executive attention, controlling attention on a target while ignoring conflicting information. What they found was that executive attention was predictive of a child's current mathematical ability tested via basic arithmetic and counting tasks. Curiously, sustained and selective attention was predictive of children's mathematical ability one year later, demonstrating a relationship between attention and the early development of mathematical fluency. An additional study has also linked executive attention to later math performance in children (Hassinger-Das, Jordan, Glutting, Irwin, & Dyson, 2014).

Pertinent to the experiments discussed study in this paper, the finding that individuals with mathematical deficits may have less attentional resources than their peers may be indicative that individuals with low math ability will yield more pronounced effects in tasks with nearby-hand manipulations. Additionally, in a study conducted in the Math Cognition Lab at UNLV, participants had to count numbers of dots ranging from 1 to 9 presented with salient distractor words designed to interfere with counting (e.g. 3 dots presented with the word FOUR behind them), it was found that individuals with lower math ability performed worse, thus demonstrating an inability to inhibit the distracting stimuli, presumably driven by deficits in attention. (Moore, Allred, Semmel, Ashcraft, 2014).

CHAPTER 2

CURRENT STUDY

In order to examine the effect of nearby-hands on subitizing and counting, and further examine the relationship between attention and enumeration, particularly whether changes in the ability to attentionally disengage will affect counting, the following experiment implemented a modified version of the “counting Stroop” task. In the counting Stroop, participants enumerate small sets of objects presented as Arabic digits, which may be congruent (e.g. three number 3s), incongruent (e.g. four number 3s), or composed of irrelevant letters (e.g. three letter As). This design is popular among researchers using functional neuroimaging (Bush, et al., 1998; Muroi & MacLeod, 2004), as it yields consistent performance differences between the conditions in healthy control subjects, and is often used in assessment of those with traumatic brain injury or other deficits. For our purposes, an added nearby-hand manipulation was implemented for the counting Stroop, with participants completing the task with their hands nearby and far-away.

First, it was expected that when participants’ hands were near to the counted stimuli rather than far-away, performance would be hindered, due to diminished attentional disengagement near the hands. Counting is a serial process, and one must purposefully redirect their attention to subsequent items in the set, requiring disengagement of each counted item. As such, slower response times were expected with the hands near the stimuli, along with increased error rates, particularly in trials where the to be counted stimulus was incongruent with the total number of items (e.g. four number 5s). These performance decrements were expected in the subitizing as well as the counting ranges. Further, the study was designed in order to be the first task to demonstrate that by manipulating participants’ ability to attentionally disengage, via placement of the hands near or far from the stimuli, subitizing speed can be affected, thus further demonstrating that subitizing is neither preattentional nor automatic.

Second, given the relationship between attention and mathematical ability, it was expected that those individuals with lower math achievement would be slower and more prone to errors than their high math achievement peers when their hands were near the stimuli to be counted. These results are a further demonstration of the relationship between math achievement and counting in adults, of which there is little in the literature compared to child samples.

CHAPTER 3

METHOD

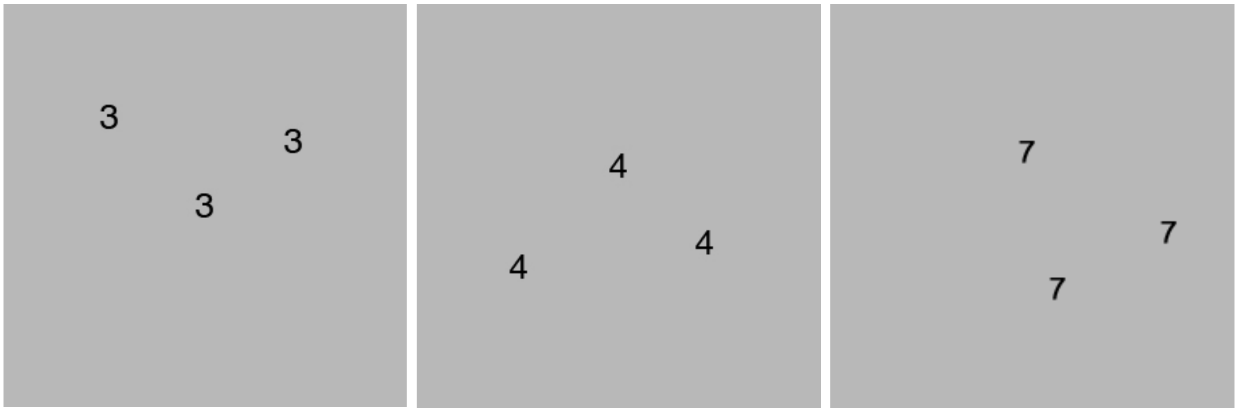
Participants

Ninety-three undergraduates (75 female, 18 male, mean age = 19.6 yrs.) from the University of Nevada, Las Vegas participated in this study. Participants were recruited from the psychology subject pool and received course credit upon completion. The experiment was completed during an hour session in the math cognition lab on the UNLV campus. In previous experiments exploring the nearby-hand effect, effect sizes have ranged from 21 ms to 150 ms (Davoli & Brockmole, 2012; Davoli, Brockmole, & Goujon, 2012). As such, this larger sample of ninety-three was collected in order to detect differences between the hand conditions within the task, establish sufficient high and low math achievement groups, and to have the statistical power to detect some of the more complicated four-way interactions in the study (e.g., hand position x stimulus type x number of items x math achievement).

Materials

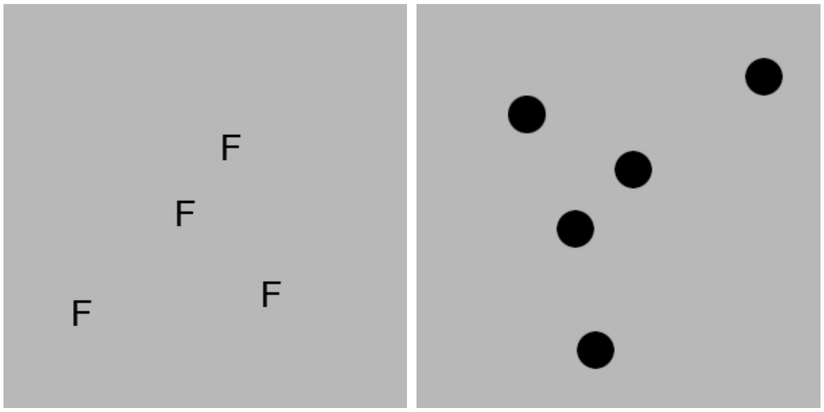
The stimuli were presented on an LCD monitor placed approximately 24 inches from the viewer. The monitor was tilted at a forty-five degree angle on a table in order to not induce physical fatigue in the participants while their hands were on the display in the nearby-hands condition. Stimuli were presented using E-Prime 2.0 software (Schneider, Eschman, & Zuccolotto, 2012). The stimuli for each trial were created using Adobe Photoshop. Stimuli consisted of a random array of items to be enumerated upon a light-grey background. The number of items to be counted in each trial ranged from 1 to 6. Sets of items counted consisted of Arabic numerals, letters, or dots.

One item type was presented per trial, ranging in quantity from 1 through 6. For each quantity of Arabic numeral presented there was a “congruent” condition in which the number of numerals matched with the Arabic numeral displayed (e.g., six numerals composed of number 6s). In the “1-away” condition, the Arabic numbers were one above or one below the total number to be counted (e.g., six numerals composed of number 5s, or three numerals composed of number 2s). The third Arabic numeral trial type is a “4-away” condition, in which the numerals were four above or four below the total number to be counted (e.g., five numerals composed of number 1s, or two numerals composed of number 6s). All possible combinations of the congruent, 1-away, and 4-away conditions were presented, for a total of 24 Arabic numeral trials. An example of each Arabic numeral trial type is presented in *Figures 1, 2,* and *3*.



Figures 1, 2, & 3. Arabic numeral trial (congruent), Arabic numeral trial, (1-away), Arabic numeral trial (4-away)

In addition to the Arabic numeral trials, letter trials and trials with dots were presented. Letter trials were generated using the consonants FGKNPRTX, with each trial matching one of the quantities presented in Arabic number format for a total of 24 letter trials. Dots-only trials presented dots, matching the quantities presented in the other conditions for a total of 24 dot trials. All three trial types sum to a total of 72 trials, all presented in a single experimental block, in a random order for each participant. An example of the letter and dot trial types is presented in *Figures 4*, and *5*.



Figures 4 & 5. Letter trial, Dots trial

Responses were recorded via a microphone connected to a Serial Response Box for accurate response time recording. Markers on the computer screen denoted where participants were to keep their hands in the nearby hand condition. In order to obtain a measure of each participant's attention, an antisaccade task was administered on the same computer also in E-Prime 2.0. Lastly, paper versions of the Wide Range Achievement Test 3 (WRAT) were administered to measure each participant's math achievement. This mathematics assessment is a fifteen-minute test containing 40 items. Problems range in difficulty from simple arithmetic, to solving for unknowns in linear equations. Participants were granted a single point for each correct answer, up to a total of 40.

Procedure

Participants were instructed by the experimenter that they were going to see slides with items presented on them. Participants were instructed to silently count the items on each slide and then speak the total number into the microphone as quickly and as accurately as possible. They were then presented with an example stimulus from the experiment for three seconds. Participants responded to three practice trials to ensure they understand the procedure.

Each trial began with a short slide with the word “ready” displayed centrally for 500 ms, followed by the presentation of the stimuli to be counted. The stimuli remained until the participant spoke his or her response into the microphone. At this time, a response box appeared where the researcher typed the participant’s numeric response. The researcher striking the enter key after entering the participants’ response triggered the beginning of the next trial. Response times and error rates for each trial were recorded. Participants completed the task twice (144 trials between 2 blocks), once with their hands on the computer monitor within several inches of the stimuli on the display, and a second time with their hands in their laps and completely out of view (see *Figure 6* for examples of this). The task order of nearby-hands versus far-away-hands conditions was counterbalanced across participants.

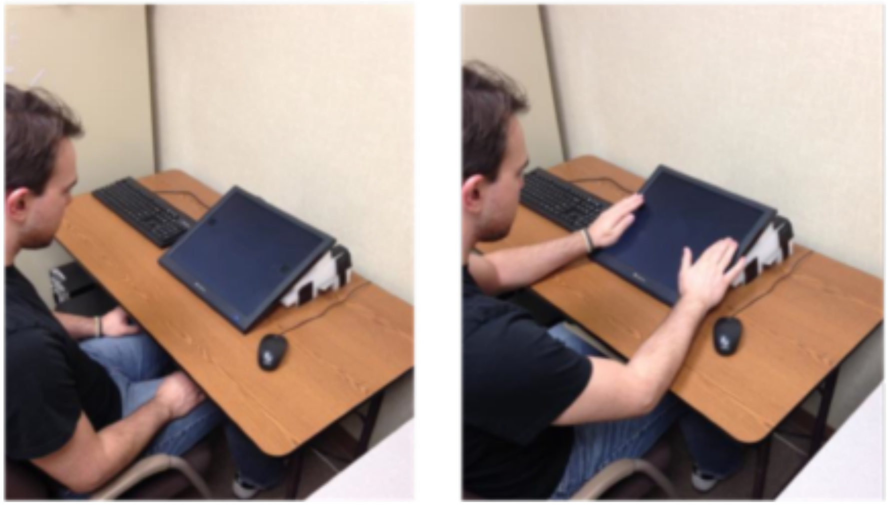


Figure 6. Far-away-hands vs. Nearby-hands

Participants' attentional control was measured using an antisaccade task. Antisaccade tasks have been shown to be a reliable measure of attention and executive control and have been used in conjunction with other experimental paradigms to examine the effects of attention on various cognitive abilities (Kane, Bleckley, Conway, Engle, 2001; Klein, Rauh, & Biscaldi, 2010; Roberts, Hager, & Heron, 1994; Unsworth, Schrock, & Engle, 2004). This additional measure was added to potentially explain any floor or ceiling effects found between the high and low math achievement participants. In this task participants were instructed to press a key when they identifed a masked target stimulus. The target on each trial in this task was either a left or right arrow (← or →), which denotes which button the participant needs to respond with using one of two buttons. Participants also completed this task twice (48 trials between 2 blocks), once with their hands on the computer monitor within several inches of the stimuli on top of 2 buttons attached six inches apart on the display, and a second time with their hands in their laps and the buttons mounted on a small board and completely out of view but also six inches apart (again see *Figure 6* for examples of this). Each trial began with a slide displaying the word "ready" presented centrally for 500 ms, after which, a central fixation point (+) would appear on the screen and varied in presentation time randomly from 200, 600, 1,000, 1,400, 1,800, and 2200 ms, consistent with other antisaccade tasks. Following the presentation of the central fixation point, a cue (=) appeared to the left or right of the fixation point for a duration of 100 ms. This cue was followed by the presentation of the target (← or →) on the opposing side of the screen for 150 ms, and then masked by a square until the participant pressed the button that corresponded to the direction that the target arrow was pointing. Participants completed three practice trials followed by 24 experimental trials in which each target was presented four times on each side of the screen. As noted previously, this task was completed twice, manipulating the participants' hand position, in order to also examine any potential effects of hand position on antisaccade performance. Whether they completed the task with hands nearby or far away first was again counterbalanced between participants.

Participants first completed the nearby- and far-away-hands counting task followed by the nearby- and far-away-hands antisaccade task, and then finished with the WRAT. The experiment ended with a debriefing answering any questions the participant had about the study. The experiment took approximately one hour to complete.

Data Preparation

Prior to analyzing the data, 515 microphone errors (3.8% from a total of 13,392 total observations) resulting in incorrectly recorded reaction times (RTs), and 224 incorrect responses (1.6 % of total trials) were excluded from the analysis RT analyses of the counting task. Dixon's (1953) outlier analysis was used on the remaining trials, excluding an additional 112 trials (0.83% of total trials). After these exclusions, 93.6% of the collected dataset was available for RT analysis. Incorrect responses were examined in a separate analysis of participants' accuracy. To determine high and low math achievement groups for analysis, participants were split at the WRAT score median of 29, resulting in 46 participants in the low math achievement group (WRAT mean = 24.73), and 41 in the high math achievement group (WRAT mean = 33.53). Dixon's outlier analysis was also used on the RTs of the antisaccade task, excluding a total of 61 trials from analysis (1.4% from a total of 4,320 observations).

CHAPTER 4

RESULTS

Subitizing Range (quantities 1-3), Arabic Numeral Trials

Looking particularly at the trials containing Arabic numerals, a 2 (hand position: near/far) x 2 (math achievement: high/low determined by median split) x 3 (stimulus type: (congruent, 1-away, and 4-away trials) x 3 (number of items: 1-3) mixed analysis of variance (ANOVA) using participants' response times found a significant main effect of hand position, such that participants enumerated faster with their hands in their laps (mean = 687 ms) than in the nearby screen condition (mean = 705 ms), $F(1, 85) = 4.69$, $p < .05$, $\eta_p^2 = .05$ (see *Figure 7*). This finding that participants responded faster with their hands away from the screen supports the basic hypothesis about nearby-hands, and further demonstrates the attentional requirements of subitizing. A significant main effect of stimulus type was found with congruent trials (e.g. three 3s; mean = 676 ms) being counted faster than both the 1-away (e.g. three 4s; mean = 720 ms), and 4-away trials (e.g. three 7s; mean = 692 ms), $F(2, 170) = 24.81$, $p < .001$, $\eta_p^2 = .23$ (see *Figure 8*), indicative of a delay in processing one expects to find with incongruent distractors present. Pairwise comparisons revealed that the congruent condition, in addition to being faster than the 1-away condition ($p < .001$), was significantly faster than the 4-away condition ($p < .05$). Importantly, these results demonstrate that the presence of distracting stimuli (1-away or 4-away trials) is effective in causing a slow down in participants' ability to subitize, congruent with our hypothesis, and a novel finding among the few studies examining how subitizing can be hindered.

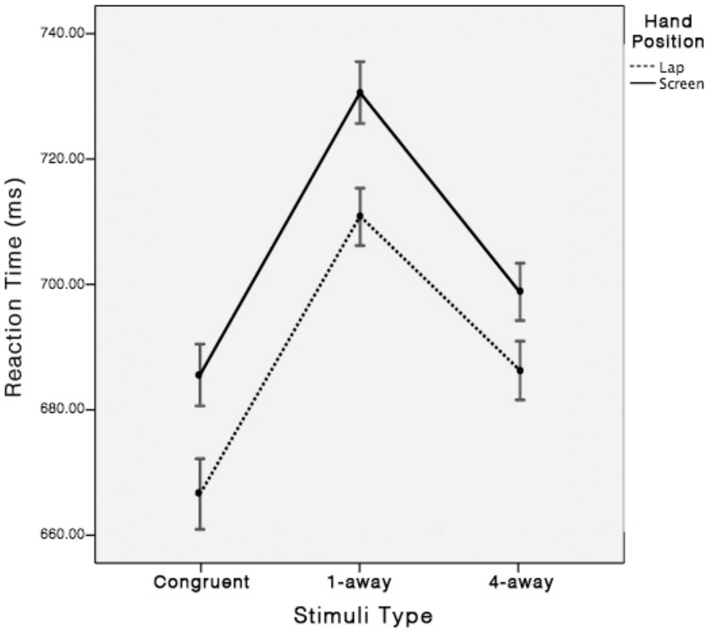


Figure 7. Significant main effect of hand position within the subitizing range for Arabic numeral trials with standard error bars (reaction time)

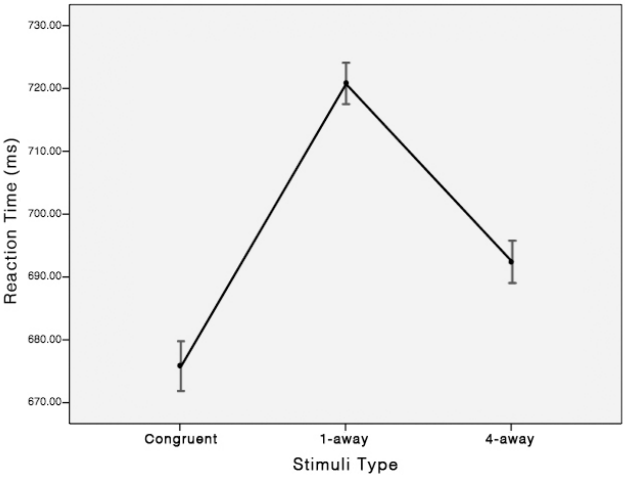


Figure 8. Significant main effect of stimulus type within the subitizing range for Arabic numeral trials with standard error bars (reaction time)

As expected, a main effect of the number of items displayed was found as well, $F(2, 170) = 53.15$, $p < .001$, $\eta_p^2 = .39$. No significant main effect was found between the high math achievement participants compared to their low math achievement peers within the subitizing range, which is not entirely surprising given the ease at which adults can subitize. An interaction between math achievement and hand position was trending but failed to reach significance $F(1, 85) = .98, p = .08, \eta_p^2 = .03$, with low math achievement participants demonstrating inflated response times when enumerating with their hands on the screen (far-away-hands mean = 685 ms, nearby-hands mean = 715 ms) compared to high math achievement participants (far-away-hands mean = 690 ms, nearby-hands mean = 694 ms). While this trend did not reach statistical significance, it was in line with the prediction that those with lower math achievement, and potentially lower attentional resources, would show diminished performance deficits with their hands nearby.

Importantly, a significant interaction between hand position, stimulus type and math achievement was found [$F(2, 170) = 3.69, p < .05, \eta_p^2 = .04$] (see *Figure 9*). Post-hoc tests revealed that for participants in the high math achievement group, no significant differences were found between any of the stimuli conditions (congruent, 1-away, 4-away) while their hands were in their laps, however with their hands on the screen they exhibited some delay in reaction times caused by the distracting 1-away stimuli (mean = 729 ms; $p < .001$) compared to the congruent (mean = 668 ms) and 4-away conditions (mean =684 ms; $p < .01$). The low math achievement group however showed significant differences in reaction times between the 1-away (mean = 715 ms) and congruent conditions (mean = 654 ms) in the far-away hands condition ($p < .05$), while having no significant differences across the stimulus types within the nearby-hands condition, yet exhibiting overall elevated response times with nearby-hands as indicated by the trending hands x math achievement interaction. This seems to suggest that the nearby-hands manipulation caused the low-math achievement group's reaction times to reach a ceiling that washed out reaction time differences between stimulus types, a result not found within the high-math achievement group. Again, this supports the hypothesis that those with low math achievement would show worse performance than their high math achievement peers when completing the task with nearby-hands. Collectively, the reaction time results for Arabic numeral trials support the general hypothesis that nearby-hands slow subitizing ability, and that individuals with lower math achievement would be even more hindered than their peers with nearby-hands.

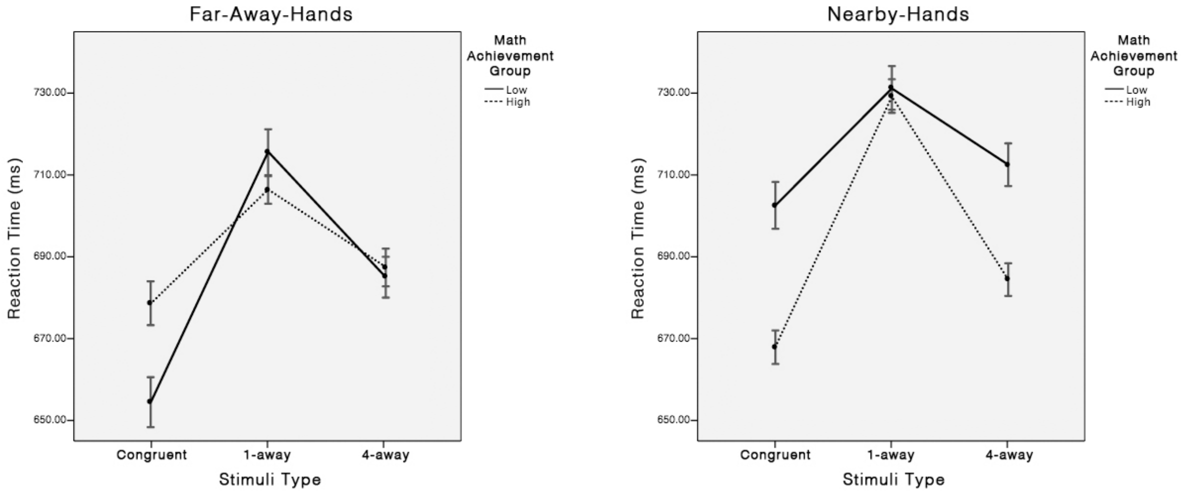


Figure 9. Significant interaction of hand position, stimulus type, and math achievement within the subitizing range for Arabic numeral trials with standard error bars (reaction time)

To examine participants' accuracy during Arabic numeral trials within the subitizing range, the same 2 (hand position: near/far) x 2 (math achievement: high/low determined by median split) x 3 (stimulus type: (congruent, 1-away, and 4-away trials) x 3 (number of items: 1-3) mixed ANOVA was conducted using the percentage of errors made as the dependent variable. No main effect was found for hand position, as participants committed an error on 1.3% of trials with their hands in their lap, and only 0.6% of the time with hands on the screen. Again, this is unsurprising given the ease with which adults can subitize. A significant main effect for stimulus type was found, $F(2, 166) = 5.36, p < .01, \eta_p^2 = .06$ (see *Figure 10*), with participants committing more errors in the 1-away condition (2% of trials), compared to the 4-away (0.9%) and congruent (0%) trials, indicating that the 1-away trials were the more difficult and distracting of the conditions. While this finding was interesting, it was rather unexpected considering the simplicity of the task. Recall that only 1.6% of total trials were errors, as such, no other significant main effects or interactions within the subitizing range were found for accuracy on Arabic numeral trials.

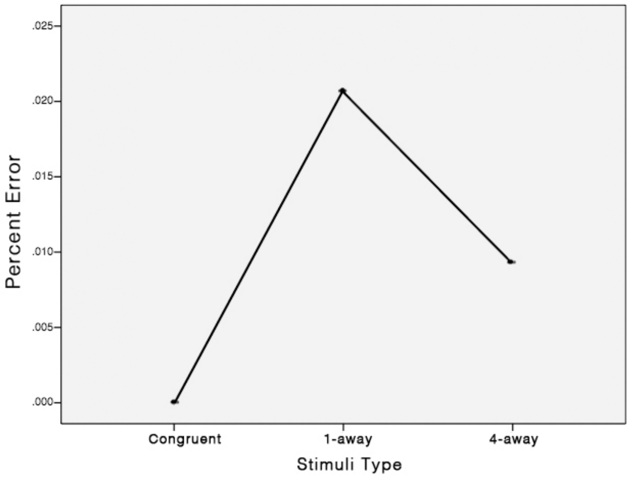


Figure 10. Significant main effect of stimulus type within the subitizing range for Arabic numeral trials with hardly visible standard error bars (accuracy)

Subitizing Range (quantities 1-3), Dots, Letters, and Congruent Trials

As the dots and letters trials were included in the experiment both as control conditions and to determine whether the mere presence of semantic information caused distraction, it was necessary to perform a separate analysis comparing these trial types to the congruent number condition. Further, in doing so, it could be determined whether the effects found between numerical conditions were partly driven by a facilitation effect of the congruent number condition (i.e., congruent numbers facilitated faster responding), or whether the distraction of the incongruent numerical displays was causing a slow down in reaction speed.

Examining the response times within the subitizing range consisting of trials containing stimuli of either dots, letters or the congruent number condition, using a 2 (hand position: near/far) x 2 (math achievement: high/low determined by median split) x 3 (stimulus type: (dots, letters, or congruent Arabic numeral trials) x 3 (number of items: 1-3) mixed ANOVA we again find a significant main effect of hand position, $F(1, 85) = 7.13, p < .01, \eta_p^2 = .08$, with faster reaction times in the far-away-hands condition (mean = 665 ms) compared to the nearby-hands condition (mean = 681 ms), congruent with our hypothesis (see *Figure 11*). This is particularly striking given that there were no intentionally distracting items among this set of stimuli. Additionally, a main effect of stimulus type was found, $F(2, 170) = 3.77, p < .05, \eta_p^2 = .04$, with post-hocs revealing that participants responded significantly faster ($p < .001$) during trials containing dots (mean = 665 ms) compared to letters (mean = 678 ms), but not significantly faster than congruent Arabic number trials (mean = 676 ms; $p = .08$), indicating that the letters caused some delay in response time compared to dots, and that congruent number trials did not facilitate faster responding. The finding that congruent numbers were not counted faster is important, as it suggests that it was the presence of the incongruent stimuli (1-away or 4-away trials) within the Arabic numeral trials that was responsible for our effects in the analysis of all Arabic numeral trials. Again as expected, a main effect of the number of items displayed was found, $F(2, 170) = 87.82, p < .001, \eta_p^2 = .51$.

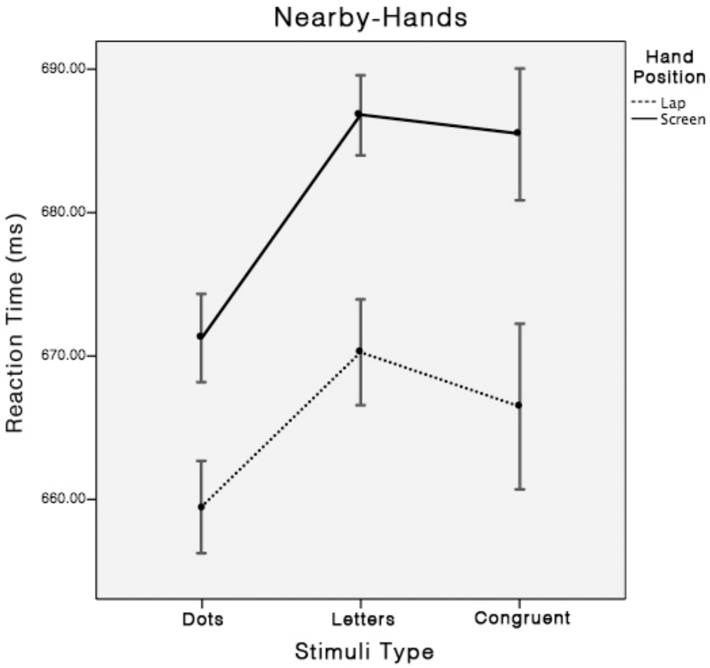


Figure 11. Significant main effect of hand position within the subitizing range for dots, letters, and congruent number trials with standard error bars (reaction time)

A significant interaction between hand position and math achievement was found, *F*(1, 85) = 6.07, $p < .05$, $\eta_p^2 = .07$, with post-hoc tests revealing that for the low math achievement group, reaction times were slower when participants' hands were on the screen (far-away-hands mean = 663 ms, nearby-hands mean = 693 ms; $p < .001$; see *Figure 12*), further supporting the notion that math achievement may be related to attention, a topic that will be explored later in our discussion. The high math achievement group showed no such difference between far-away (mean = 667 ms) and nearby-hands conditions (mean = 668 ms). This interaction was in line with the hypothesis that low math achievement individuals would be hindered by nearby-hands, even when subitizing items that are not designed to be distracting, as in the case here with dots, letters, and congruent numbers.

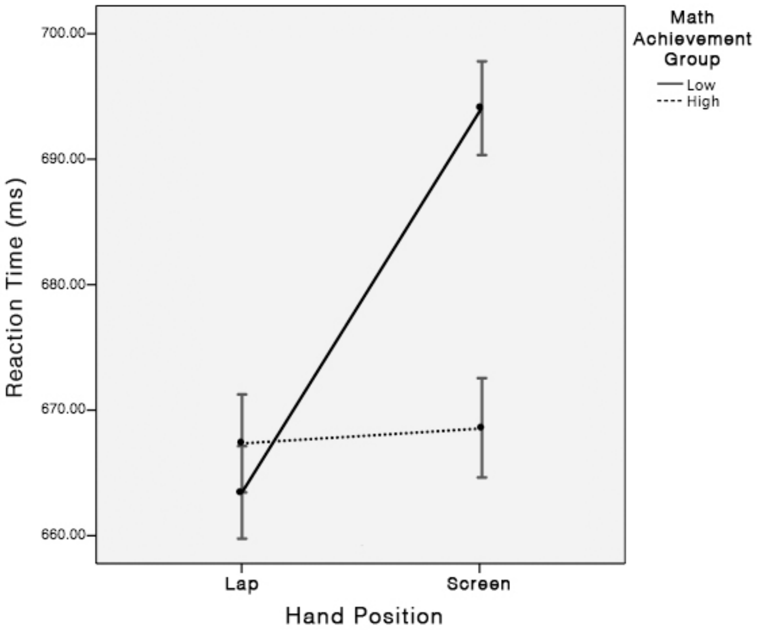


Figure 12. Significant interaction of hand position and math achievement within the subitizing range for dots, letters, and congruent number trials with standard error bars (reaction time)

Further, a significant math achievement by hand position by stimuli type interaction was found, $F(2, 170) = 3.29, p < .05, \eta_p^2 = .04$ (see *Figure 13*). Pairwise comparisons revealed that the low math achievement group showed a significant difference in reaction time ($p < .01$) between the dots condition (mean = 679 ms) compared to the letters condition (mean = 699 ms) with their hands on the screen. This appears to indicate that the low math achievement group was more affected by the trials containing letters than those with high math achievement who showed no significant differences between the dots (mean = 662 ms) and letter conditions (mean = 674 ms). While there was no particular difference predicted between these two stimulus types for those with low-achievement, it does further demonstrate how the mere presence of semantic information while subitizing can hinder those with potentially lower math fluency under the added load of nearby-hands.

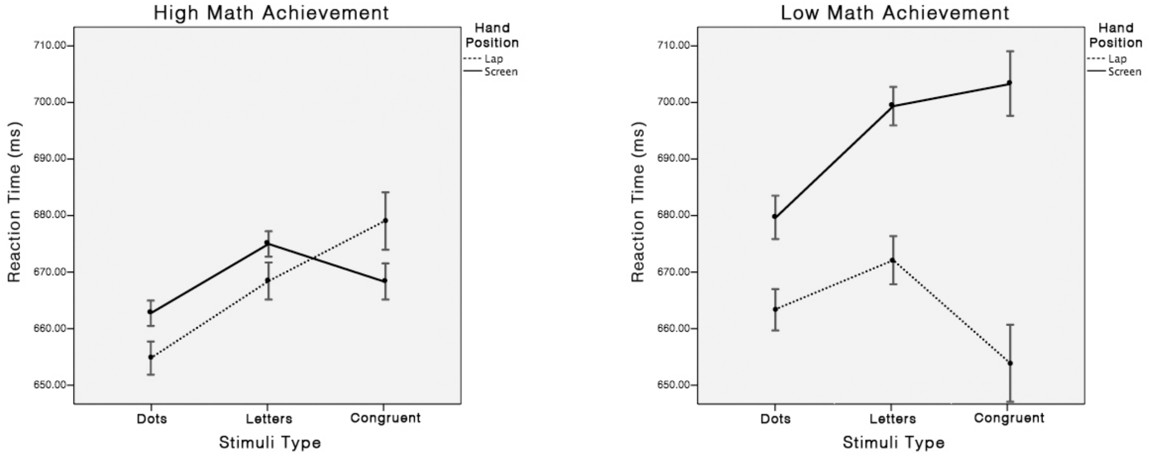


Figure 13. Significant interaction of stimulus type, hand position, and math achievement within the subitizing range for dots, letters, and congruent number trials with standard error bars (reaction time)

To examine participants' incorrect responses on these trials, the same 2 (hand position: near/far) x 2 (math achievement: high/low determined by median split) x 3 (stimulus type: (dots, letters, or congruent Arabic numeral trials) x 3 (number of items: 1-3) mixed ANOVA was conducted using the percentage of errors made as the dependent variable. Errors committed across hand position, the three stimulus types, and quantity was 0%, thus not yielding any interesting findings within the error data of this range. Again, this is not entirely surprising, as subitizing is quite simple. (Although, it is this researcher's opinion that this is an anecdotally miraculous finding given the wildly inconsistent behavior of undergraduate student samples!)

Entire Range (quantities 1-6) Arabic Numeral Trials

To examine the response times within the entire counting range of Arabic numeral trials, a 2 (hand position: near/far) x 2 (math achievement: high/low determined by median split) x 3 (stimulus type: (congruent, 1-away, and 4-away trials) x 6 (number of items: 1-6) mixed ANOVA was conducted. No main effect for hand position was found, which is not surprising, given the fact that the effect size for nearby-hand manipulations can sometimes be rather small (21 ms; Davoli & Brockmole, 2012), while the variability of reaction times particularly within the counting range of our sample was considerably higher (e.g., congruent trials with hands far-away hands for quantity 1 had a standard deviation of 134 ms, whereas congruent trials with hands far-away hands for quantity 6 had a standard deviation of 518 ms). Again a significant main effect for stimulus type was found, $F(2, 170) = 4.79, p < .01, \eta_p^2 = .05$ (see *Figure 14*), with 1-away trials taking longer to count (mean = 972 ms) than both congruent (mean = 942 ms) and 4-away trials (mean = 950 ms). Pairwise comparisons revealed there was no significant difference between congruent trials and 4-away trials. The expected significant main effect of the number of items to be counted was also found ($F(5, 425) = 467.63, p < .001, \eta_p^2 = .85$), wherein we find the expected dogleg like pattern across the range. That is, for quantities within the subitizing range, we find that the reaction times are relatively flat, yet as the quantity increases to four and above there is an increase in reaction time of several hundred milliseconds per item.

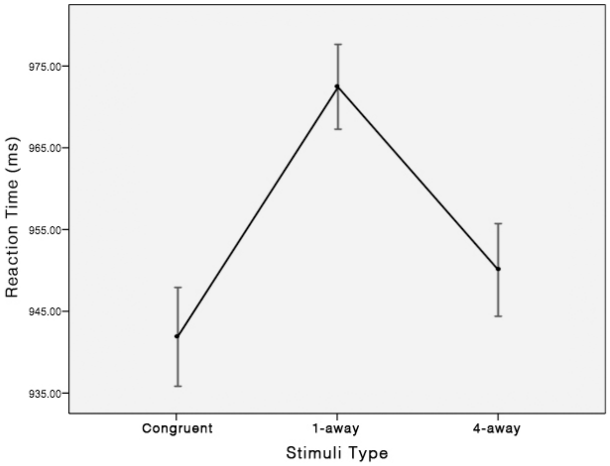


Figure 14. Significant main effect of stimulus type within the entire counting range (1-6) for Arabic numeral trials with standard error bars (reaction time)

No main effect for math achievement was found ($p = .104$) despite high math achievement participants performing faster (mean = 924 ms) than those with low math achievement (mean = 985 ms). An interaction between hand position and math achievement was trending but failed to reach significance $F(1, 85) = 3.4, p = .06, \eta_p^2 = .04$, wherein with nearby-hands the high math achievement participants showed a larger contrast in speed (mean = 917 ms) than their low math achievement peers (mean = 996 ms) across the entire counting range compared to the far-away hands condition (high achievement mean = 932, low achievement mean = 973 ms). This does not confirm our hypothesis that low math achievement individuals would perform more slowly with nearby-hands across the entire counting range, but the results were trending in the expected direction.

A significant interaction between hand position, math achievement group, and stimulus type was found, $F(2, 170) = 3.21, p < .05, \eta_p^2 = .04$, wherein low math achievement participants showed no overall difference between stimulus types regardless of hand position (see *Figure 15*). High math achievement participants however showed significant differences between 1-away (mean = 951 ms) and congruent conditions (mean = 894 ms, $p < .01$). Further, the high math achievement group was faster across particular stimulus types, with significant pairwise differences found within the nearby-hands condition for congruent number (high math achievement mean = 894 ms, low math achievement mean = 983 ms, $p < .05$) and 4-away trials (high math achievement mean = 908 ms, low math achievement mean = 1002 ms, $p < .05$). The 1-away trials showed no significant difference in the nearby-hand condition, but were trending in the expected direction (high math achievement mean = 951 ms, low math achievement mean = 1004 ms, $p = .19$). The fact that there was no difference between trial types for the low math achievement group, coupled with overall faster responding by the high math achievement group in the nearby-hand condition, suggests that the low math achievement participants were performing somewhere near ceiling regardless of stimulus type due to the presence of nearby-hands, consistent with our hypothesis.

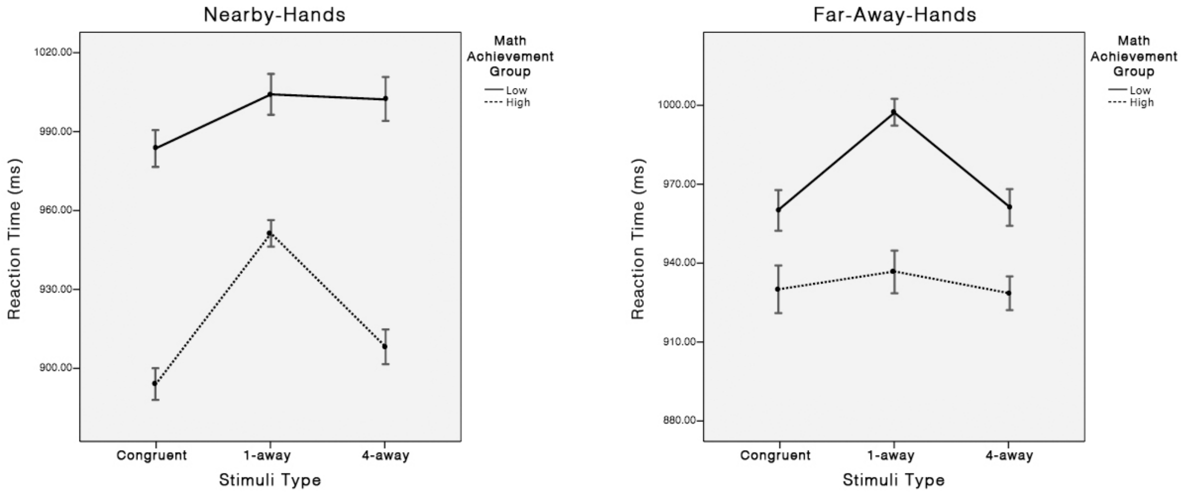


Figure 15. Significant interaction of stimulus type, hand position, and math achievement within the entire counting range (1-6) for Arabic numeral trials with standard error bars (reaction time) 35

To examine participants' accuracy during Arabic numeral trials within the full counting range, the same 2 (hand position: near/far) x 2 (math achievement: high/low determined by median split) x 3 (stimulus type: (congruent, 1-away, and 4-away trials) x 6 (number of items: 1-6) mixed ANOVA was conducted using the percentage of errors made as the dependent variable. No significant main effect for hand position was found, with participants committing errors in 2.1% of trials with their hands far-away and 2.0% of the time in trials with their hands nearby. Similarly to what was found within the subitizing range, a main effect of stimulus type was found, $F(2, 160) = 4.66, p < .05, \eta_p^2 = .05$, with participants committing fewer errors in the congruent condition (1.1%), compared to the 1-away (2.8%), and 4-away (2.1%) conditions (see *Figure 16*). While a main effect of math achievement failed to reach significance, $F(1, 80) =$

3.12, $p = .08$, $\eta_p^2 = .03$, those with lower math achievement did commit more errors (2.6%) than their high achieving peers (1.5%). Further, an interaction between stimulus type and math achievement was found, $F(2, 160) = 4.82$, $p < .01$, $\eta_p^2 = .06$, wherein those with low math achievement were more error prone on the 1-away (3.7%) and 4-away (3.4%) conditions compared to those with high math achievement (committing 2.0% and 0.9% error on those trials respectively; see *Figure 17*).

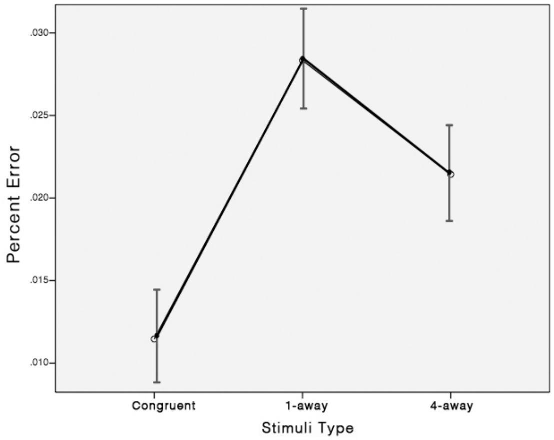


Figure 16. Significant main effect of stimulus type within the entire counting range (1-6) for Arabic numeral trials with standard error bars (accuracy)

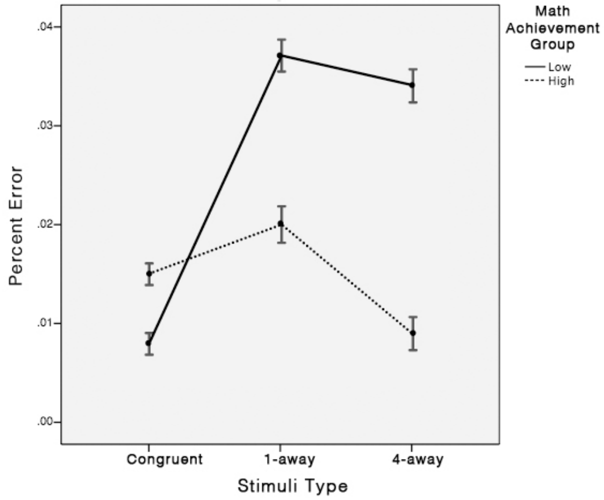


Figure 17. Significant interaction of stimulus type and math achievement within the entire counting range (1-6) for Arabic numeral trials with standard error bars (accuracy)

Another interaction was found between hand position, stimulus type, and math achievement, $F(2, 160) = 3.2, p < .05$, $\eta_p^2 = .04$, wherein with hands in the far-away condition, high math achievement participants commit nearly equivalent errors across conditions (congruent mean = 1.3%, 1-away = 1.1%, 4-away = 1.1%), however in the nearby-hands condition, their accuracy (congruent = 1.8%, 1-away = 2.9%, 4-away = 0.7%) begins to exhibit patterns similar to their low math achievement peers in the far-away hands condition (congruent mean = 1.5%, 1-away = 4.7%, 4-away = 2.8%). This seems to be indicative of the nearby-hand effect causing some detriment even to high achievement participants' accuracy, particularly when utilizing distracting stimuli, as in the 1-away condition. No other main effects or interactions reached significance for the analysis of accuracy.

Entire Range (quantities 1-6), Dots, Letters, and Congruent Trials

To examine the response times of the entire counting range of dot trials, letter trials, and congruent Arabic numeral trials, a 2 (hand position: near/far) x 2 (math achievement: high/low determined by median split) x 3 (stimulus type: (dots, letters, congruent Arabic numeral trials) x 6 (number of items: 1-6) mixed ANOVA was conducted. Like the analysis examining Arabic numeral trials only across the entire range, no main effect of hand position was found. Similarly to the analysis of the subitizing range, a significant main effect of stimulus type was found, $F(2, 170) = 10.6, p < .001$, $\eta_p^2 = .11$, wherein participants were faster to respond to trials containing dots (mean = 910 ms across all 6 quantities) and letters (mean = 911 ms) compared to the congruent numerical trials (mean = 943 ms), indicating the inclusion of the numerical stimuli caused some delay in counting (see *Figure 18*).

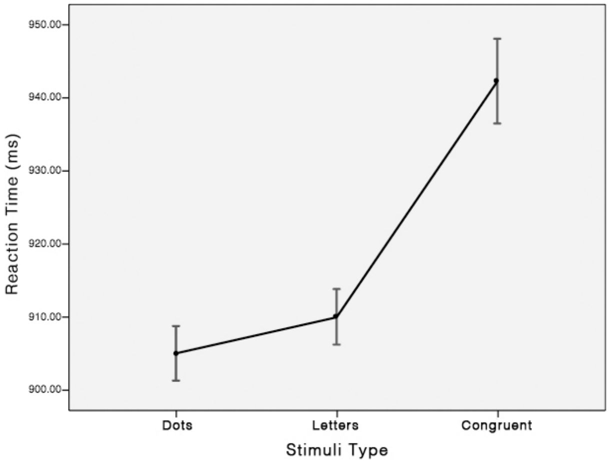


Figure 18. Significant main effect of stimulus type within the entire counting range (1-6) for dots, letters, and congruent number trials with standard error bars (reaction time)

A significant interaction between hand position and the type of stimuli displayed was found, $F(2, 170) = 3.2, p < .05,\ \eta_p^2 = .036$. Pairwise comparisons here revealed that dots were counted significantly faster (p < .05) with hands far-away (mean = 894 ms) compared to nearby (mean = 916 ms). These same differences were not observed in the congruent number (far-away-hands mean = 945 ms, nearby-hands mean = 938 ms) or letter (far-away-hands mean = 909 ms, nearby-hands mean = 911 ms) conditions. Further, with hands far-away, there are significant differences (p < .05) between the dots (mean = 894 ms), letter (mean = 909 ms), and congruent number conditions (mean = 945 ms). Yet, in the nearby-hand condition these differences become muddled, wherein the only significant difference (p < .05) between stimulus types is the comparison of letters (mean = 911 ms) and congruent numbers (mean = 938 ms). An interaction between the number of items presented and hand position was trending but failed to reach significance, $F(5, 425) = 2.16, p = .058,\ \eta_p^2 = .025$. These interactions with hand position seem to be indicative of the hypothesis that nearby-hands hinder serialized counting ability. Despite the lack of main effect for hand position within the full counting range for the analyses either set of stimuli, the fact that interactions are found with nearby-hands seems to indicate that even with variability in reaction time washing out the main effect across the range of one to six dots, nearby-hands still causes a slow down between particular stimulus types.

A significant interaction was found between math achievement group and the number of items presented, $F(5, 425) = 3.849, p < .01$, $\eta_p^2 = .043$, indicating that as the number of items to be enumerated increased, participants with lower math achievement took longer to count than their high math achievement peers. This was driven particularly by significant differences between low and high achievement participants for the quantity of 5 ($p < .05$) (low achievement mean = 1260 ms, high achievement mean = 1111 ms), whereas 6 items was trending toward significance ($p = .09$) (low achievement mean = 1489 ms, high achievement mean = 1375 ms). While no prediction was explicitly made about low math achievement participants demonstrating slower counting ability as the number of items increases, this could be indicative of attentional deficits in these individuals causing decreased counting performance, a relationship that was hypothesized.

An interaction between hand position and math achievement failed to reach significance, $F(1, 85) = 3.537, p = .063$, $\eta_p^2 = .04$, wherein those with low math achievement showed some detriment in counting speed between with nearby hands (mean = 939 ms) compared to far away hands (mean = 962 ms), yet their high math achievement peers showed less difference between conditions and in fact the trend reversed (nearby-hands mean = 884 ms, far-way hands mean = 899 ms). A significant main effect of math achievement was not found, despite low math achievement participants taking longer amounts of time to count (mean = 951 ms) compared to those with high math achievement (mean = 892 ms).

To examine participants' accuracy in dot trials, letter trials, and congruent Arabic numeral trials, the same 2 (hand position: near/far) x 2 (math achievement: high/low determined by median split) x 3 (stimulus type: dots, letters, congruent Arabic numeral trials) x 6 (number of items: 1-6) mixed ANOVA was conducted using the percentage of errors made as the dependent variable. Similarly to the previous error analyses conducted above, no main effect of hand position was found, nor was a main effect for stimulus type. While there was no significant main effect of math achievement, a stimulus type by math achievement interaction was found, wherein those with low math achievement committed significantly ($p < .05$) more errors in the letter condition (mean = 1.9%) compared to dots (mean = 1.1%). No other main effects or interactions reached significance.

Counting Range (quantities 4-6) Arabic Numeral Trials

To determine whether some of our effects and interactions within the entire quantity range were driven largely by the trials containing quantities within the subitizing range, it seemed necessary examine trials containing only quantities of 4 to 6 in a separate analysis. To this end, a 2 (hand position: near/far) x 2 (math achievement: high/low determined by median split) x 3 (stimulus type: (congruent, 1-away, and 4-away trials) x 3 (number of items: 4-6) mixed ANOVA was conducted. Like the analysis of the entire counting range, no significant main effect of hand position was found. Unlike the analysis of the entire counting range however, no significant main effect of stimulus type was found either ($p = .622$), seeming to suggest that it was indeed the quantities within the subitizing range driving the significant main effect found within the entire quantity range for stimulus type. This could be the result of two factors; 1) the variability in counting time between participants in the upper range (4-6) is washing out the effect, or 2) the distracting quality of the incongruent numerical stimuli is more effective within the subitizing range. Further, none of the interactions with hand position or math achievement were significant within this range for reaction time. However, a significant between subjects effect was found for math achievement $F(1, 85) = 4.43, p < .05, \eta_p^2 = .05$, wherein those with high math achievement were faster to count (mean = 1157 ms) compared to those with low achievement (mean = 1269 ms). This finding is interesting, as counting is typically not a task we find differences math achievement differences in, however one study has found a similar difference across participants' level of math anxiety (Maloney, Risko, Ansari, & Fugelsang, 2010), a finding we will explore in greater detail within the discussion.

Examining percent error using the same mixed ANOVA as above, the between subjects effect of math achievement is no longer significant ($p = .13$). However a significant stimuli x math achievement interaction did emerge, $F(2, 164) = 5.262, p < .01, \eta_p^2 = .06$, wherein the low math achievement participants committed more errors in the 1-away (mean = 5%) and 4-away (mean = 5.4%) conditions compared to high math achievement participants (1-away mean = 2.1%, 4-away mean = 1.3%). Again, as with previous error analyses, no main effect of hand position was found for errors.

Counting Range (quantities 4-6), Dots, Letters, and Congruent Trials

Similarly to the analysis of the Arabic numeral trials, we examined quantities of 4 through 6 in a 2 (hand position: near/far) x 2 (math achievement: high/low determined by median split) x 3 (stimulus type: (dots, letters, congruent Arabic numeral trials) x 3 (number of items: 4-6) mixed ANOVA. Again, no main effect was observed for hand position for quantities of 4 to 6. A between subjects effect of math achievement was trending but failed to reach significance

(p = .056), despite high math achievement participants counting faster (mean = 1114 ms) than those with low math achievement (mean = 1215 ms). Interestingly, a main effect of stimulus type was found, $F(2, 170) = 12.76, p < .001, \eta_p^2 = .13$, wherein congruent numerical conditions were counted slower (mean = 1208 ms) compared to both dots (mean = 1145 ms) and letters (mean = 1141 ms) conditions. Again, no significant interactions with math achievement within this range were found, indicating that many of our findings across the entire counting range of one to six items were driven by differences within the subitizing range. Given that the hypothesized effects and interactions for the nearby-hand manipulation were found within the subitizing range, but not within the four to six item range, it seems that large amounts of variability across participants (as in the upper counting range) severely limits our ability to detect differences between hand positions.

The analysis of errors for this range yielded no significant main effects and no significant interactions. This is not surprising, given the dearth of main effects and interactions for accuracy across the entire counting range for these stimulus types. Error rates for stimulus types in this analysis were relatively similar across stimulus types, with participants committing errors 1.9% of the time for dots, 2.8% for letters, and 2.2% for congruent number trials.

Antisaccade

To determine the effect of nearby-hands on the antisaccade task, a 2 (hand position: near/far) x 6 (time delay: 200, 600, 1000, 1400, 1800, or 2200 ms) factorial ANOVA was conducted. Curiously, no main effect was found for hand position in the initial analysis, $F(1, 89) = 0.251, p = .61$. This was a befuddling finding, given the fact that the antisaccade is one of the simplest of attentional tasks, and nearby-hand effects have been found in an array of seemingly more complex designs. Recall that participants completed this task twice, once with their hands on the screen and once with hands in their laps, with the order of completion was counterbalanced across participants. Given the simplicity of the task, and the fact that participants completed the task with hands either nearby or far-away first, it seemed necessary to determine if the lack of main effect was due to a practice effect that washed out any differences between the hand conditions.

To determine this, an additional between subjects variable was added to the ANOVA; whether participants completed the task with hands on screen first or with hands in their lap first. When a 2 (hand position: near/far) x 6 (time delay: 200, 600, 1000, 1400, 1800, or 2200 ms) x 2 (starting hand position: near/far) mixed ANOVA was conducted, we find an interaction between starting position and hand position that explains the lack of main effect in the first analysis, $F(1, 88) = 44.95$, $p < .001$, $\eta_p^2 = .338$, such that when participants complete the task with hands in their laps first, we see a speed up in reaction time from the first (lap mean = 350 ms) to second (screen mean = 302 ms) administration of the task. When participants complete the task with their hands on the screen first, we again see a similar speed up in reaction time (screen mean = 396 ms, lap mean = 336 ms) (See *Figure 19*). Note the more marked practice effect within the screen condition, 396 ms first administration to 302 ms in the second, compared to 350 ms in the first and 336 ms in the second for the lap condition. Examining block order in a 2 (Block administered: first/second) x 6 (time delay: 200, 600, 1000, 1400, 1800, or 2200 ms) factorial ANOVA revealed a significant main effect, $F(1, 89) = 44.962$, $p < .001$, $\eta_p^2 = .336$, indicating that participants became faster the second time they completed the task (first block mean = 373 ms, second block mean = 319 ms; see *Figures 20*, *21*, and *22* for additional graphs). The finding of a practice effect rendered it inappropriate to use participants'' antisaccade speed as a covariate in the analyses of our counting task, but these results do raise some interesting questions that will be explored in the discussion.

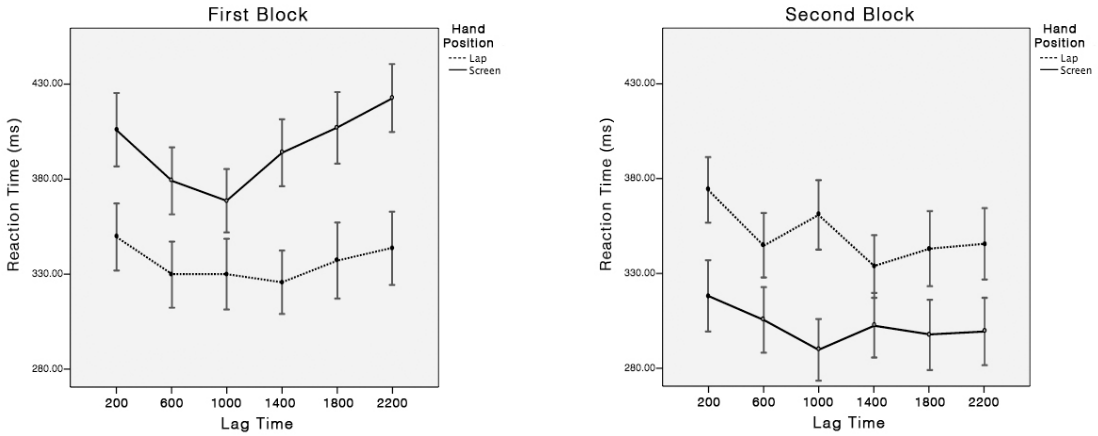


Figure 19. Antisaccade performance by hand position by block. Note that the participants who completed the task with their hands in their laps in the first block had their hands on the screen during the second, and vice-versa

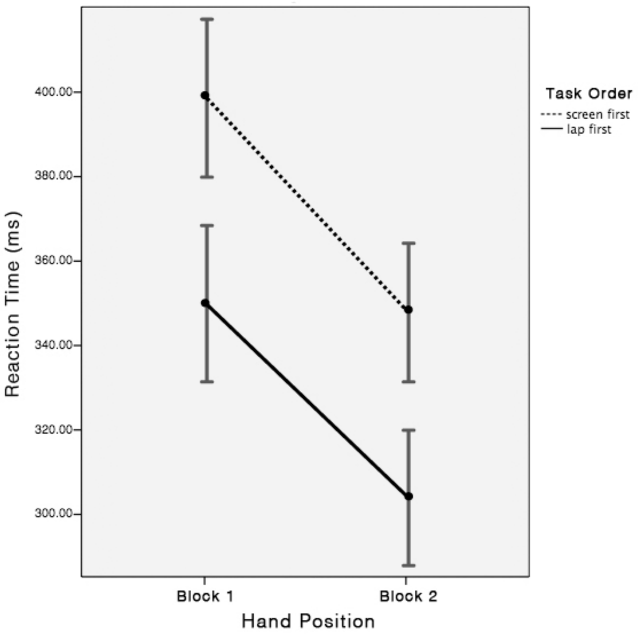


Figure 20. Antisaccade performance by block with standard error bars

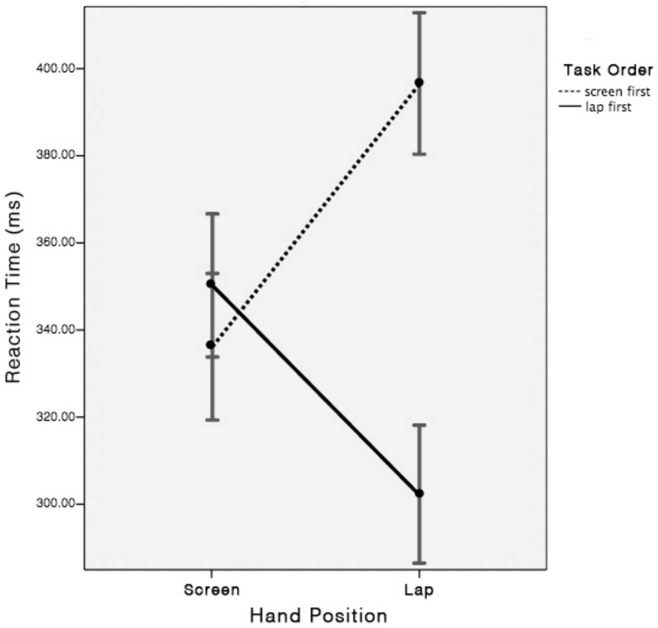


Figure 21. Antisaccade performance by task order group with standard error bars

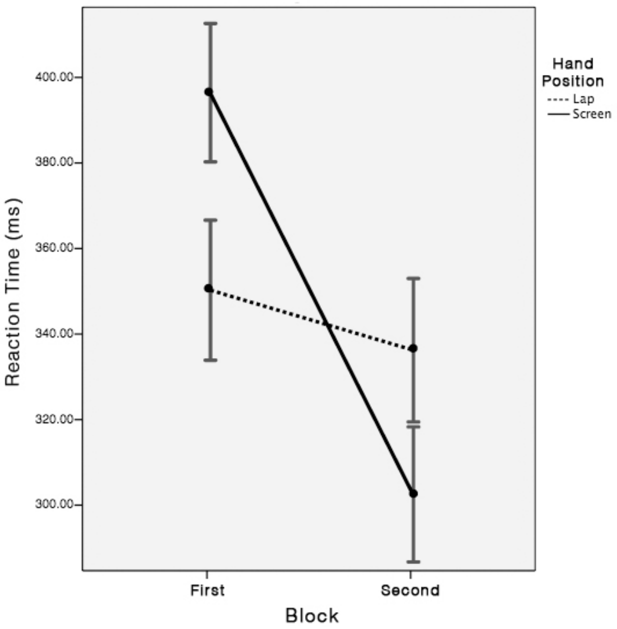


Figure 22. Antisaccade performance by hand position with standard error bars. Note that for each line, the points represent different sets of participants due to the design of the experiment.

Of further note is the finding that participants' average reaction time across both blocks of antisaccade trials correlated negatively with their WRAT scores, $r = -.343$, $p < .01$. This indicated that as participants' WRAT performance increased, reaction times in the antisaccade task decreased.

CHAPTER 5

DISCUSSION

Before discussing the deeper implications the data, let us reiterate the general aims of the present study. The first aim was to examine the underlying cognitive mechanism of the nearby-hand effect using a new and novel method, and particularly, whether nearby-hands cause a delayed or hindered disengagement of attention. Second, the study served to provide further evidence that subitizing (i.e., counting quantities of items three or less) does require attentional resources and is not preattentional as once previously theorized (Trick & Pylyshyn, 1993, 1994), and to do so in a more ecologically valid manner. Lastly, the study aimed to examine whether adults with lower math achievement would show performance deficits in a task where attentional resources may be altered due to the involvement of nearby-hands, thus shedding additional light on the relationship between math achievement and attention, of which there is little evidence using adult research samples.

Regarding the first aim of examining the cognitive mechanism underlying the nearby-hand effect, our findings from the counting task generally support the hypothesis that nearby-hands have an effect on attentional disengagement. Specifically, when nearby-hands are present, participants are slower to disengage from a set of stimuli requiring a serial search. This is evidenced by the findings that within the subitizing range (quantities of 1 to 3) and across stimulus types (Arabic digits, letters, or dots), nearby-hands caused a significant decrease in reaction time when counting. Further, when the stimuli to be counted caused further distraction like in the incongruent Arabic numeral conditions, participants' speed was hindered even further, as the distractor caused an increased attentional draw from which they had difficulty disengaging. This same effect was found when comparing dots, letters, and congruent Arabic numeral trials with nearby-hands, wherein even the presence of any semantic information (whether letters or numbers) caused a distraction resulting in slower reaction times within the subitizing range compared to the trials containing dots only. Further, the finding that nearby-hands hinders subitizing within our modified counting Stroop task is consistent with previous research demonstrating that nearby-hands further hinders reaction time for incongruent trials within the classic Stroop paradigm (Davoli, Du, Montana, Garverick, & Abrams, 2010). As both Stroop tasks utilize the relative automaticity with which adults read to distract participants from a non-semantically driven goal, it is not surprising that nearby-hands affect both paradigms.

Remember that within the full counting range (quantities 1-6) as well as the upper range (quantities 4-6), a significant main effect was not found between nearby and far-away hands, presumably due to the practically small nature of the nearby-hand effect (i.e., 10-20 ms in most tasks) and the amount of variability in reaction time within the higher end of the counting range. Importantly however, in the nearby-hands condition, participants with high math achievement showed differences across stimulus types, with congruent numerical trials eliciting faster responding than incongruent numerical trials. The low math achievement group on the other hand showed no such differences, and performed overall more slowly than their high math achievement peers. Here it seems reasonable to interpret that the low math achievement group, when counting the upper end of the range with nearby-hands were in fact already counting at the ceiling of their performance, thus not demonstrating differences in RT with nearby-hands across congruent or incongruent stimulus types. This further supports the notions discussed in greater detail below relating attention to math achievement.

Within the counting range, particularly with numerical trials, the low math achievement group showed slower responding with nearby-hands, a finding that was trending toward significance when comparing congruent numerical trials to trials containing non-numerical stimuli. Recall that the low math achievement participants showed the slowest performance on the antisaccade task, typically eliciting slower response times than their high math achievement peers. Yet, we cannot fully disentangle the causal nature of this relationship within our task; was it lower math fluency driving some of our differences between the high and low math achievement groups or an overall attentional deficit? Despite this, there are a couple of possibilities. First, individuals with lower attentional resources are more greatly affected by the nearby-hand manipulation. In some cases these individuals are operating at such a poor level of performance that the potential differences between stimulus types (e.g., 1-away trials compared to congruent) were not found within the upper counting range due to their poor attentional resources already severely limiting performance. Alternatively, the poor performance found for the low math achievement group with nearby-hands could be been driven by deficiencies in mathematical fluency resulting in slower counting times overall.

Previous studies have demonstrated that math anxiety, a negative affective response to mathematics that interferes with performance in math tasks (Richardson & Woolfolk, 1980), can hinder counting performance (Maloney, Risko, Ansari, & Fugelsang, 2010). Critically, an inverse relationship has been repeatedly found between math anxiety and math achievement (see Hembree, 1990; Ma, 1999). It is likely that we would have found this inverse relationship within our sample between math achievement and math anxiety, had math anxiety data had been collected. Curiously, Maloney et al.'s 2010 study did not collect data on their participants' math achievement or fluency, so the relationship between achievement and counting ability could not be explored within their sample. Working memory span however, examined via a backwards letter span task was found to be significantly higher in their sample's low math anxiety group.

Given the wealth of data relating the constructs of working memory and attention within the literature (for review see Engle & Kane, 2004), it is not inconceivable that the findings of our present study, as well as Maloney et al. (2010) are reliant on fundamental differences in cognitive control (e.g., working memory or executive attention) rather than their potential byproducts (i.e., math ability or math anxiety). Of further note, is the fact that Maloney et al. found differences within the counting range only, and did not see differences of math anxiety within the subitizing range, much like our present lack of main effect for math achievement when subitizing.

It is useful to point out here that the causal nature of the relationship between math achievement and math anxiety has yet to be fully elucidated by the present literature. That is, we still have not solved the question of whether math anxiety gives rise to a developmental trajectory that results in lower mathematical fluency, or rather that lower mathematics fluency causes increased negative arousal during arithmetic problem solving resulting in the later development of math anxiety. Or further, whether a third larger underlying factor, like an attentional deficit, mediates both trajectories.

Regarding the erroneous notion that subitizing is a preattentional ability, the present study adds further evidence to the prevailing theory that subitizing is not preattentional, and has demonstrated this in a manner that is ecologically germane to real world counting. Previous studies to this end have used roundabout methods of addressing this issue including masking paradigms (Poiese, et al., 2008) and attentional blink tasks (Egeth, et al., 2008; Olivers & Watson, 2008; Xu & Liu, 2008). Despite numerous studies concluding that subitizing requires the engagement of attention, and the journal of *Visual Cognition* devoting an entire issue in 2008 to articles focused on this conclusion, many researchers still refer to subitizing as automatic or preattentional in nature (Just a few examples: Cleland & Bull, 2015; Pincham & Szűcs, 2012; Starkey & McCandliss, 2014). By using a method that simply required participants to count with their hands in different positions, the present study demonstrated that through the manipulation of participants' ability to attentionally disengage, subitizing could be hindered, further demonstrating it is not a preattentional ability.

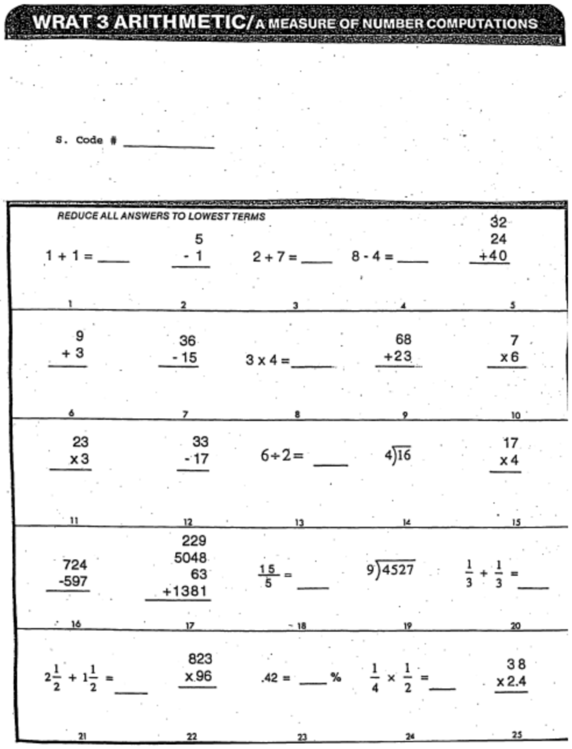
Despite a lack of consensus as to the precise and nuanced attentional mechanism underlying the nearby-hand effect, most previous research has focused on nearby-hands interaction with some aspect of attention. As such, it would seem that by causing a change in participants' attentional abilities via nearby or far-away hands, we have demonstrated directly that subitizing requires the engagement of visual attention which if hindered can slow subitizng performance. With that in mind, Davoli and Tseng (2015), two of the pioneers in nearby-hand research recently teamed together publishing a short editorial discussing the notion that nearby-hands (or what they are now calling "hand altered vision") causes individuals to disengage more slowly from locations near the hands. The findings of the present study are indicative of this "disengagement effect."

The finding that nearby-hands caused overall slower performance in the antisaccade task compared to far-away hands within the first block too seems to be indicative of this disengagement effect. However, with practice it seems that this effect reverses, and participants completing the task for a second time in the inverse hand condition saw an enhanced practice effect if completing the task with their hands on their laps first. The antisaccade task with a nearby-hand manipulation needs to be conducted again using a between subjects design, with the same hand position across multiple blocks to look at this effect further. Also in their review, Davoli and Tseng (2015) address the idea that nearby-hands also cause a "prioritization effect" wherein visual information is prioritized near the hands. It could also be that with practice and greater familiarity with a task, nearby-hands may facilitate performance, causing faster responding after sufficient exposure and overlearning. The antisaccade task is arguably one of the easier experiments to learn, thus a practice effect, and perhaps subsequent facilitation for nearby-hands while completing block two may be a possibility.

Lastly, the results demonstrated a relationship between performance on the attentionally driven antisaccade task and math achievement. Specifically, as participants' math achievement increases, reaction times on the antisaccade task become faster. Previous work within the domain of mathematical cognition and educational psychology have only demonstrated this relationship in childhood or early adolescence (Anobile, et al., 2013; Hassinger-Das, et al., 2014; Steele, et al., 2012). While the design of the present study does not allow for the inference of causality in the relationship between math achievement and attention, it does demonstrate that the correlation between math achievement and attention persists into adulthood. Particularly, those with lower math achievement also perform more poorly on tasks requiring attentional resources.

More research is clearly needed to flesh out whether later deficiencies in mathematics can be attributed to poor attentional control, and what the joint influence of attentional ability and math achievement contribute to overall mathematical fluency in adulthood. The fact that differences were found between math achievement groups for counting is a finding not typically seen within the field of mathematical cognition, given the relative ease with which adults can count. While researchers should expect to find math achievement differences in more laborious arithmetic tasks requiring the engagement of greater cognitive resources, it is curious when differences in basic counting are found. It could be that early attentional deficits give rise to poorer math fluency, and in turn weaker numerical representation in these individuals, thus resulting in potentially slower counting performance that persists into adulthood. More research is needed to further explore the matter.

APPENDIX I: WIDE RANGE ACHIEVEMENT TEST

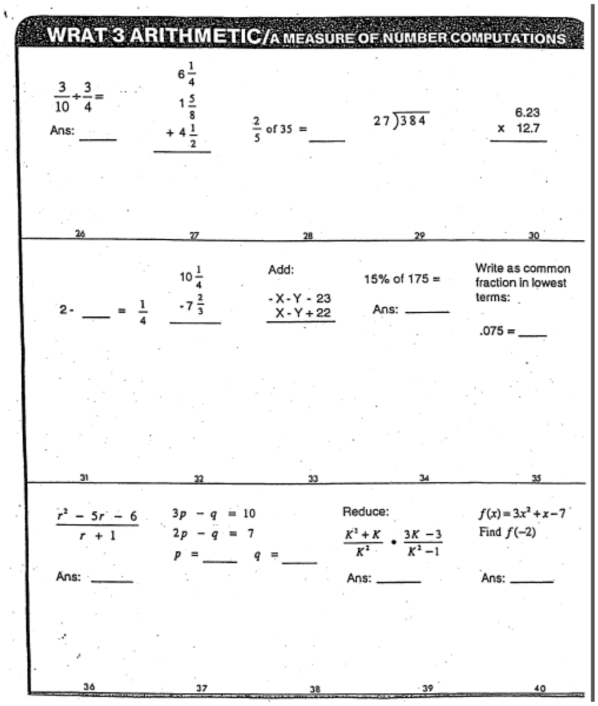


WRAT 3 ARITHMETIC/A MEASURE OF NUMBER COMPUTATIONS

S. Code # ____________

REDUCE ALL ANSWERS TO LOWEST TERMS

1 + 1 = ____	$\begin{array}{r}5\\-1\\\hline\end{array}$	2 + 7 = ____	8 - 4 = ____	$\begin{array}{r}32\\24\\+40\\\hline\end{array}$
1	2	3	4	5
$\begin{array}{r}9\\+3\\\hline\end{array}$	$\begin{array}{r}36\\-15\\\hline\end{array}$	3 x 4 = ____	$\begin{array}{r}68\\+23\\\hline\end{array}$	$\begin{array}{r}7\\\times 6\\\hline\end{array}$
6	7	8	9	10
$\begin{array}{r}23\\\times 3\\\hline\end{array}$	$\begin{array}{r}33\\-17\\\hline\end{array}$	6÷2= ____	$4\overline{)16}$	$\begin{array}{r}17\\\times 4\\\hline\end{array}$
11	12	13	14	15
$\begin{array}{r}724\\-597\\\hline\end{array}$	$\begin{array}{r}229\\5048\\63\\+1381\\\hline\end{array}$	$\frac{15}{5}$ = ____	$9\overline{)4527}$	$\frac{1}{3}+\frac{1}{3}$ = ____
16	17	18	19	20
$2\frac{1}{2}+1\frac{1}{2}$ = ____	$\begin{array}{r}823\\\times 96\\\hline\end{array}$	.42 = ____ %	$\frac{1}{4}\times\frac{1}{2}$ = ____	$\begin{array}{r}38\\\times 2.4\\\hline\end{array}$
21	22	23	24	25



WRAT 3 ARITHMETIC/A MEASURE OF NUMBER COMPUTATIONS

$\frac{3}{10}\div\frac{3}{4}=$ Ans: ____	$\begin{array}{r}6\frac{1}{4}\\1\frac{5}{8}\\+4\frac{1}{2}\\\hline\end{array}$	$\frac{2}{5}$ of 35 = ____	$27\overline{)384}$	$\begin{array}{r}6.23\\\times\ 12.7\\\hline\end{array}$
26	27	28	29	30
2 - ____ = $\frac{1}{4}$	$\begin{array}{r}10\frac{1}{4}\\-7\frac{2}{3}\\\hline\end{array}$	Add: $\begin{array}{r}-X-Y-23\\X-Y+22\\\hline\end{array}$	15% of 175 = Ans: ____	Write as common fraction in lowest terms: .075 = ____
31	32	33	34	35
$\frac{r^2-5r-6}{r+1}$ Ans: ____	$3p-q=10$ $2p-q=7$ $p=$ ____ $q=$ ____		Reduce: $\frac{K^2+K}{K^2}\bullet\frac{3K-3}{K^2-1}$ Ans: ____	$f(x)=3x^2+x-7$ Find $f(-2)$ Ans: ____
36	37	38	39	40

APPENDIX II: IRB APPROVAL

UNLV

1 of 2

INFORMED CONSENT (A)
Department of Psychology

Title of Study: Advanced Mathematical Thinking, Expertise, and Math Anxiety
Investigators: Mark H. Ashcraft, Alex Moore, Gabriel Allred, AmyJane McAuley, David Copeland, Sarah Salas, Wei An, Krystal Kamekona
Contact Phone Number: 895-0175 or 895-3168 or 895-1278

Purpose of the Study

You are invited to participate in a research study on the relationships among math skills, attitudes, and memory, conducted for Dr. Ashcraft in the Psychology Department. The purpose of the study is to understand better how attitudes and math skills influence performance on various measures of math performance.

Participants

You are being invited to participate in this study because you are a student in psychology, math, or mathematics education.

Procedures

In our studies, subjects complete several different tests, some paper and pencil, some on the computer; the tests are listed below. The entire testing session never lasts more than 90 minutes, but usually averages about 45 min to 1 hour. We tape record the tasks that ask you to speak out loud, just so we can check our data records for accuracy after the session; after checking the accuracy, these tapes are then erased.
We will be administering the following tests today: a math anxiety test, a working memory test, a pencil-and-paper math test, a computer-based math test, and a short reading test.

Benefits and Risks of Participation

Although there are no direct benefits of this testing to you, most students find it interesting to see what a real psychology experiment is like. You may ask the experimenter any questions you might have about these procedures, at any time during the experiment. At the end of the session, the experimenter will provide you with a full explanation of the reasons for this research; you may also ask questions then, or you may call Dr. Ashcraft at 895-0175.

There are no risks beyond those of everyday life associated with this testing.

Costs/Compensation

There are no costs to you for participating in this study. You will not be compensated for participating, although your participation will be reported in order for you to fulfill the research participation requirement of the Psychology Department Subject Pool.

Contact Information

If you have any questions or concerns about the study, you may contact Dr. Ashcraft at 895-0175. For questions regarding your rights as a research subject, or for any complaints or comments regarding the manner in which the study is being conducted, you may contact the UNLV Office for the Protection of Research Subjects at 702-895-2794.

Voluntary Participation

Your participation is entirely voluntary, of course; you may withdraw your participation at any time, if you wish, and there will be no penalty.

Confidentiality

Your results will be recorded confidentially, and only Dr. Ashcraft will have access to the list that links your name to your i.d. number. Dr. Ashcraft will keep this list so that a future follow-up study might be possible; if you are contacted for such a follow-up, you of course would again be free to participate or not, as you wish at that time. All results of the experiment are reported anonymously, so your name will never be part of any report on these results. All records will be stored in a locked facility at UNLV for at least 3 years after completion of the study. After the storage time, the information gathered will be added to an anonymous archive, for future reference in continuing research projects on this topic.

Participant Consent: I have read the above information and agree to participate in this study. I am at least 18 years of age.

_____ Yes, I agree to participate.

_____ No, I choose not to participate.

_____ Yes, I agree to having the session tape recorded so that the data can be checked for accuracy.

_____ No, I do not agree to having the session tape recorded so that the data can be checked for accuracy.

_____ Yes, you may contact me for a follow-up study.

_____ No, do not contact me for a follow-up study.

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