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Effects of Practice Type and Task Difficulty on Visuospatial Performance

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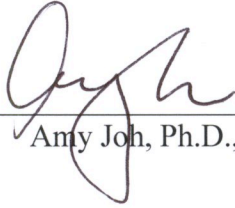
Effects of Practice Type and Task Difficulty on Visuospatial Performance
by
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Bachelor of Arts, The College of New Jersey, 2011

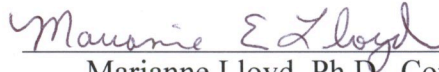
A Thesis Submitted in Partial Fulfillment of the Requirements for the
Master of Science in Experimental Psychology
with a Concentration in Behavioral Neuroscience
In
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Seton Hall University
April, 2014

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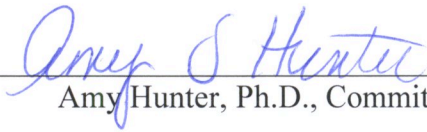
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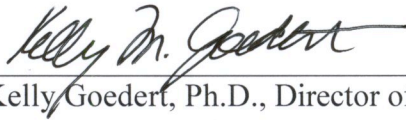
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Kelly Goedert, Ph.D., Director of Graduate Studies

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Abstract

The importance of visuospatial skills for every day survival is highly evident. Practice is a mechanism by which visuospatial skills can be enhanced. The current study examined how general practice, different types of practice, and levels of task difficulty affect visuospatial performance. Seventy-eight undergraduate students participated in the Block Design Task (extracted from the Wechsler Adult Intelligence Scale) in which they had to construct a design with the blocks based on a printed image. Prior to completing 40 test trials, participants received opportunities for motor (physical), mental (visualization), or modeling (observational) practice. Half of the trials contained easy designs, and the other half of trials contained difficult designs. Results indicate that participants benefitted from general practice across trials and that performance was dependent on task difficulty. However, there were no differences in performance due to type of practice. Overall, the results of this study implicate that practice aids in visuospatial performance, and that task difficulty may be a mediating factor.

Introduction

What mechanisms allow humans to understand and interact with the world? How do we accurately reach for a glass on a table, navigate roads while driving, arrange pieces of furniture in a small room, or visualize a scene in our minds? We do so by utilizing visuospatial skills, which is the ability to visually perceive spatial relationships between objects (Kane, Hambrick, Tuholski, Wilhelm, Payne, & Engle, 2004; Miyake, Friedman, Rettinger, Shah, & Hegarty, 2001). Our visual systems are designed to detect objects in the visual field (Kubovy, Epstein, & Gepshtein, 2013) and make sense of incoming information relative to various object properties such as location, size, and color (Marr, 1982; Nordfang, Dyrholm, & Bundesen, 2012). Together, processing visual and spatial information allows us to complete numerous activities from those necessary for survival to those for leisure.

Various factors can impact performance in a visuospatial task including biological factors (genetic makeup, hormones, brain activation), experience (familiarity with visuospatial skills), and practice (techniques designed to improve performance). Practice is especially crucial for visuospatial skills because it allows individuals a chance to improve independently from biological factors or past experiences. For example, it has been shown that the effects of practice can be adapted to similar tasks based on the knowledge and training acquired on one task (Hughes et al., 2013). Research has also shown that practice leads to decreased errors on a decision-making and motor task (Barch & Lewis, 1954). Researchers have also found that practice on a visuospatial task leads to decreased reaction times, whether participants had to identify a target based on visual and locational properties of a cue (Wright & Richard, 1999) or participants performed a stimulus-hand correspondence task similar to 'Simon Says' in which they conducted an instructed movement such as raising an arm (Roswarski & Proctor, 2003). The

latter authors suggested that more practice periods should be tested to identify the amount of practice necessary to obtain a change, emphasizing that identifying the ideal amount of practice is imperative to positively impact learning. Additional research has shown how practice enhances performance on a visual-perceptual task especially when differences in performance occurred based on stimulus complexity (Pellegrino, Doane, Fischer, & Alderton, 1991). In this study, practice was able to mitigate the effects of stimulus complexity so that with difficult stimuli, practice was able to even out level of performance between the difficult and easier stimuli. Taken together, prior research indicates that practice can improve numerous factors related to enhancing performance, such as increasing accuracy and decreasing latency. Research has also shown that practice is adaptive and can potentially mitigate effects of task difficulty.

We practice problems naturally even without instruction. In testing visuospatial performance on a task in which participants were required to repeat a dot sequence in order, researchers found practice occurred via eye movements (Tremblay, Saint-Aubin, & Jalbert, 2006). By using an eye-tracker, the experimenters found that when participants were able to actively rehearse the sequence via eye movements, performance was significantly greater than when individuals were not able to rehearse the sequence. Practice of eye movements in this case signifies an automatic response in attempts to accurately complete the task. Thus, it seems that practice is a technique we conduct even when not explicitly instructed.

Types of Practice

There are several different types of practice and each one provides different benefits that may be relevant for different tasks. The current study focuses on three of the most prominent types of practice associated with visuospatial skills: motor, mental, and modeling practice.

Motor Practice. Motor practice refers to producing movements involved in a specific action sequence or task (Cumming & Ramsey, 2011; Debarnot, Clerget, & Olivier, 2011; Laguna, 2008). Motor practice is helpful because it allows learners to determine the movements and strategies required to complete an action, physically conduct them, and observe the consequences of completing them. Learners obtain visual, haptic, and proprioceptive information during motor practice, all of which are necessary for completing movements (Endo, Wing, & Bracewell, 2011; Lackner & DiZio, 2005; Slotnick, 2010). For example, reaching to grasp an object provides visual information about the location of the object and the individual's body relative to the object. It also provides information about additional characteristics of the object (e.g. size, shape, color), which aids visuospatial skills by providing information that is necessary to process the object. Touching the object provides haptic information (e.g., weight, texture, rigidity) and proprioceptive information about the movement of the hand and arm from muscle feedback, which also aids visuospatial skills by providing additional information about the location of the object and the movement of the individual. The effectiveness of motor practice has been shown in a number of different domains of research including golf putting (Kavussanu, Morris, & Ring, 2009), sequence completion following a pattern of lights on a screen (Georgopoulos, Kalaska, & Massey, 1981), throwing balls into a target (Moreno-Briseno, Diaz, Campos-Romo, & Fernandez-Ruiz, 2010), and recognizing and choosing disparities in computer designs (Shea, Wright, Wulf, & Whitacre, 2000). It has also been shown to be effective for cognitive tasks adapted from the Wechsler Adult Intelligence Scale testing visuospatial skills such as the Digit Symbol Substitution test which measures perceptual speed and the Reverse Digit Span subtest which measures working memory (Voelcker-Rehage & Alberts, 2007).

Mental Practice. Mental practice refers to the visualization of a sequence of actions. Learners think about how to complete a task without physical practice by mentally representing the components of a task and devising strategies through critical thinking (Cumming & Ramsey, 2011; Debarnot et al., 2011). Although learners may receive visual sensory, in contrast to motor practice, there is no feedback through haptic or proprioceptive information. However, similar to motor practice, mental practice has been shown to be effective for a number of different tasks, including mental rotation tasks (Shepard & Metzler, 1988), detecting differences in two sets of navigation instructions (Gyselinck, Beni, Pazzaglia, Meneghetti, & Mondoloni, 2007), remembering locations of objects (Jahn, Knauff, & Johnson-Laird, 2007), and solving math problems (van Garderen, 2006). Mental practice has even been implemented as a tool for helping individuals with neurological damage in a spatial memory task (Grilli & McFarland, 2011). Furthermore, mental practice has been shown to be beneficial for anticipations of movements based on visual information while processing spatial location and object angles (Finke & Shepard, 1986).

Modeling Practice. A third type of practice can be from observing another person who demonstrates how to complete a task, referred to as modeling practice in this study (Hoover, Giambatista & Belkin, 2012; Laguna, 2008; Larssen, Ong, & Hodges, 2012). As such, modeling practice is analogous to observational learning. Observing a model is helpful because it allows learners to see effective strategies being used, as well as the outcome of such strategies while avoiding trial-and-error learning. Modeling provides learners with visual information from the model's actions and thus the sequence of actions required to complete the task. Indeed, the model may be an expert problem-solver who can provide highly valuable visual information and strategies. However, like mental practice, modeling does not provide learners haptic or

proprioceptive feedback since learners do not practice movements themselves. The effectiveness of modeling practice has been shown in a number of studies, including visual perception in sequences of body movements (Bandura & Jeffery, 1973), mathematical problem solving (Wouters, Paas, & van Merriënboer, 2000), detecting errors in drawings (Blandin & Proteau, 2000), reiterating patterns on a computer (Maslovat, Hodges, Krigolson, & Handy, 2010), and improvements in negotiating and working out school problems (Hoover et al., 2012). Additional research has shown that observers tend to mimic the choices and strategies used by the modeler especially when effective practice methods are used (Berger, 1966). Furthermore, in another study, observing a model was found to aid patients with Alzheimer's disease on a pattern learning task (van Tilborg, Kessels, & Hulstijn, 2011).

Comparing the Three Types of Practice

Although it is clear that each type of practice can aid visuospatial skills, the effectiveness of motor, mental, and modeling practice in comparison to each other remains unclear. Inconsistent findings in prior research make it difficult to determine which type of practice yields the best visuospatial performance. This lack of clear finding from previous experiments appears to be based on differences between multiple factors.

Experimental Task. Past experiments have relied on different tasks, ranging from those requiring small, confined movements to those requiring large, full body movements to assess the effect of practice type. For example, the effects of motor and mental practice were examined on a balancing task, which is a gross motor task requiring movements of the entire body and a spatial task requiring participants to understand their relative location based on rotations of the board on which they were standing (Cumming & Ramsey, 2011). Participants were assigned into groups of physical (motor practice), imagination (mental practice), or no practice (control). The results

indicated that participants with motor practice showed better performance than participants with mental practice or no practice. In contrast, another study tested motor versus mental practice by using a finger tapping task, which is an isolated fine motor task requiring movements of constrained areas of the body and requiring visuospatial skills by presenting participants with a pattern on a screen (Debarnot et al., 2011). Participants received motor practice, mental practice, or no practice (control). The results indicated that although it was better to have practice, there were no differences between motor and mental practice.

There are similar disparities in studies comparing motor and modeling practice. One study compared the use of motor practice and observation (modeling) for novel movements such as extending the arm away from body (Capa, Marshall, Shipley, Salesse, & Bouquet, 2011). One group of participants received motor practice, another group observed actions being conducted by an actor, and the last group received no practice. The results indicated that the motor practice group had the best outcome, implicating that the processes involved in movements led to better improvements in participants' performance than observation. Another study also aimed to compare the efficacy of modeling and motor practice in a virtual reality task in which participants selected the location of a target based on previous visual information, such as size and color (Larssen et al., 2012). Participants completed actions on a screen by moving a computer mouse and received observational practice (modeling), physical (motor) practice, or no practice (control). Those who received modeling practice performed significantly better than those who received physical practice, signifying that observing effective strategies was the most helpful. Receiving any type of practice resulted in higher results than the control group.

Overall, these studies represent discrepant results regarding the three types of practice. It is likely that these variations are due to the task presented during test. The results of these studies

also suggest that all three practice types should be compared in a single visuospatial task that controls for a lot of movements since that may distract from the purpose of identifying the best practice method on a visuospatial task.

Task Difficulty. A second factor that contributes to inconsistencies in the results comparing different types of practice is the level of difficulty within tasks. Laguna (2008) tested modeling versus motor practice by asking participants to knock down barriers on a computer screen with a mouse. The task had two versions: a simple version and a complicated version. Participants received modeling practice alone, motor practice alone, modeling and motor practice together, or no practice (control). Laguna found that for the simple version of the computer task, any type of practice was better than the control, but there were no differences amongst the types of practice. In contrast, for the complicated version, the group that received the combination of modeling and motor practice had significantly better performance than both practice conditions, which had better results compared to the control group. It should be noted that in this study, there were no differences between modeling practice alone and motor practice alone. Thus, it appears that the efficacy of different types of practice may depend on not only of the type of task, but also on the level of task difficulty.

As previously mentioned, research has shown that practice may be able to mitigate the effects of task difficulty (Pellegrino et al., 1999). At different levels of difficulty, latency to complete a task varied drastically showcasing the effect of task difficulty. Other research has indicated that at baseline performance, there are vast differences based on task difficulty, but that with practice, performance between levels of difficulty may become comparable (Barch & Lewis, 1954). Additionally, studies have shown that practice is most beneficial for difficult tasks because participants receive the benefits of positive consequences due to their effort and

dedication (Linsenmeier & Brickman, 1976). Not only did these researchers find that performance greatly improved after practice, participants' satisfaction ratings of task completion were higher on difficult tasks compared to easier tasks.

To summarize, it appears that there is a mediating relationship between task difficulty and different types of practice. Consequently, task difficulty should be considered when examining the effects of practice in a visuospatial context.

Gender. Another variable that may play a part in the inconsistent findings of the effect of practice on visuospatial performance is the gender of the participant. On mental rotation tasks, there are consistent gender-related differences with males showing an advantage over females (Awh et al., 1999; Kass, Ahlers & Dugger, 1998). A meta-analysis confirmed gender differences across different types of spatial abilities (Voyer, Voyer, & Bryden, 1995) but also showed that the largest difference (the strongest effect size, $d = 0.66$) was found in mental rotation tasks for participants aged 18 years and older. Further analysis revealed that gender differences that occurred in spatial visualization tasks generally had a mental rotation component. Gender differences in visuospatial skills may arise from a variety of factors such as maturation rates, cerebral lateralization, exposure to different sex hormones, or experience and social factors.

Whether gender differences are due to biological or environmental factors is debatable and may be related to opportunities for practice. For example, Kass and colleagues (1998) argue that being pushed toward training and career opportunities in STEM (science, technology, engineering, and mathematics) fields provides males with additional experiences that aid in spatial tasks. They conducted a mental rotation task with male and female participants and found that with practice, the difference in errors in performance between genders was eliminated. However, they continued to find gender-related differences in a control condition in which

participants did not receive practice. In a different study, Spence, Yu, Feng, and Marsman (2009) assessed spatial abilities of both genders with a novel video game task. Compared to the control group (no practice), both males and females who received practice showed improved performance. These findings suggest that when males and females are provided with the same opportunities for practice, gender-related differences in spatial abilities may disappear.

In summary, since gender differences occur in some assessments of visuospatial ability, it is important to analyze whether gender will impact the results of the current study. However, based on prior research, practice may be able to mitigate gender differences that could potentially occur.

Current Study

Together, previous findings provide compelling evidence for the importance of practice for visuospatial skills. However, due to inconsistencies in the literature, it is difficult to determine how variations in a task influence the effectiveness of practice type. Thus, the current study compared motor, mental, and modeling practice within a single task while also accounting for task difficulty. The goals of the current study were to (1) determine the general effects of practice in a visuospatial task, (2) investigate which type of practice leads to the best performance, and (3) assess the role of task difficulty on the effects of practice.

Block Design Task. Participants were tested with the Block Design Task (BDT), which was extracted from the Wechsler Adult Intelligence Scale (WAIS). The WAIS is a set of various tasks commonly used in over two thousand studies to assess cognitive ability (Wechsler, 1955). The BDT is one of the best-known measures of a visuospatial task in which individual components are used to construct a 3-D design based on a 2-D image (Caplan & Caffery, 1992; Schorr et al., 1982). The BDT includes nine individual blocks that have two sides of solid white,

two sides of solid red, and two sides of half red/half white (crossed diagonally), and participants must recreate a design with blocks while a design image is visible. The BDT has been established as a reliable and valid measure of visuospatial ability, psychomotor skills, perception, and problem solving skills in various populations including college-aged adults (Bolte, Hubl, Dierks, Holtmann, & Poustka, 2008; Ronnlund & Nilsson, 2006; Shea et al., 2000; Toraldo & Shallice, 2004; Verstappen, Weijden, Riet, Grimshaw, Winkens, & Grol, 2004; Wechsler, 1955). Thus, in order to succeed in this task, participants must have good analytic skills, psychomotor functioning, planning abilities, and problem-solving skills. Those that have difficulty with the visuospatial or analytic component of the task still need to be able to rotate and fit the blocks while checking the product with the design and adjusting as necessary (Caplan & Caffery, 1992). The BDT is particularly appropriate for the current study because it is a visuospatial task that can be used with different types of practice and levels of difficulty, it is less likely to induce gender-related differences in performance, and peak performance on this task is typical in college-aged students (Caplan & Caffery, 1992; Rozencwajg et al., 2005; Ryan, Kreiner, & Tree, 2008; Schorr, Bower, & Keirnan, 1982, Voyer et al., 1995).

Strategies for Solving the BDT. Researchers have established three types of strategies used to complete the BDT: global, analytic, and synthetic. When using a global strategy, individuals take a holistic approach to solving the BDT. Participants view the design as a whole and do not break down the design into units such as discrete blocks. Thus, participants who use the global strategy construct the blocks to match the overall shape of a design based on perceptual similarity, typically through trial and error (Rozencwajg & Corroyer, 2001; Rozencwajg et al., 2005). When using an analytic strategy, individuals mentally segment the design into units and attempt to match each block to the design. With this strategy, whether

edges share the same color is an important component. Participants who use the analytic strategy tend to complete the design in either columns or rows (Rozenchwajg & Corroyer, 2001; Rozenchwajg et al., 2005; Schorr et al., 1982). Finally, when using a synthetic strategy, individuals complete designs based on ‘gestalts’ that are perceived. These gestalts generally mimic a shape such as a triangle or diamond. Thus, similar to global strategy, participants rotate blocks to fit the shape. However, similar to analytic strategy, participants focus on one area at a time (Rozenchwajg et al., 2005; Schorr et al., 1982). The global strategy is assumed to be the least effective because participants spend more time rotating blocks to fit the design and assessing the design as a whole. With synthetic and analytic approaches, however, participants are able to focus on smaller units at a time in order to perform faster and more successfully.

Prior research suggests that there are age-related differences in participants’ use of the different strategies. There is some indication that adolescents (around age 17) (Rozenchwajg & Corroyer, 2001) and young adults (around age 25) (Rozenchwajg et al., 2005) tend to use a synthetic approach to solving the BDT. However, other research has shown that college-aged students tend to use an analytic strategy (Schorr et al., 1982). Children around age 12 (Rozenchwajg & Corroyer, 2001) and adults over 50 (Rozenchwajg et al., 2005) tend to use the global strategy. Thus, it is not surprising that peak performance on this task occurs around age 18 (Rozenchwajg et al., 2005) since participants are more likely to use synthetic or analytic strategies—the strategies presumed to be more effective—during this time.

Task Difficulty and the BDT. Performance on the BDT also depends on the difficulty level of a design, contributing to individual differences (Royer & Weitzel, 1977). A number of factors are implicated in increased difficulty, including designs that are less fragmented and depict more coherent (holistic) shapes (Miller & Skillman, 2008), edges that share the same color

(Caplan & Caffery, 1992; Schorr et al., 1982), indistinguishable interior edges (Caplan & Caffery, 1992), designs with stripes due to overlapping edges (Rozenchwajg & Corroyer, 2001), and designs with both colors crossed diagonally (Royer & Weitzel, 1977; Schorr et al., 1982).

Based on these findings, Miller and his colleagues determined level of difficulty based on two factors. The first factor has to do with edges that share the same color. Designs with two adjacent blocks that share the same colored edge make it harder for participants to perceive that the blocks are separate. The second factor is the number of options possible to a surface of a block. If a block from the design is a solid color, then there are only two options because it can only be solid red or solid white. However, if the block is half red/half white, then there are four options because of the four rotations that can occur. Thus, a design with solid colored blocks and edges that have different colors would be considered easier than a design with half red/half white blocks with edges that share the same color (Miller, Ruthig, Bradley, Wise, Pedersen, & Ellison, 2009).

Using Miller and colleagues' (2009) principles, the current study identified easy designs as having no same-colored edges and few half red/half white blocks and difficult designs as having all same-colored edges and all half red/half white blocks. Additionally, a medium difficulty design using principles of easy and difficult designs was created for the practice phase consisting of few same-colored edges and few half red/half white blocks (Figure 1). Participants received 40 test trials after motor, mental, or modeling practice. Regardless of practice condition, participants received both easy and difficult block designs.

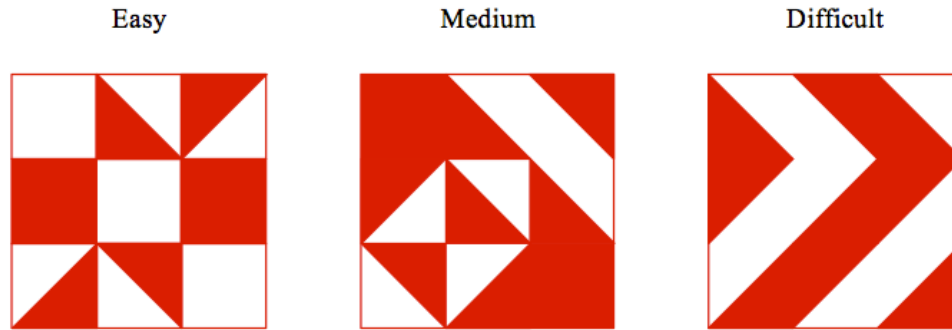


Figure 1. Examples of the BDT experimental designs. Easy and difficult designs were used during the test phase. Medium designs were used during the practice phase. In this example, the easy design has 5 solid colored blocks and no edges that share the same color. The medium design example has 2 solid colored blocks and 6 edges that share the same color. The difficult design example has 0 solid colored blocks and all edges that share the same color.

Performance was assessed by accuracy, operationalized as the number of blocks that matched the design, and latency, operationalized as the amount of time required to complete the design. If general practice is helpful then it is expected that participants' performance will improve across trials, meaning accuracy would increase and latency would decrease. This result would be consistent with prior research that has shown practice is useful (Barch & Lewis, 1954; Hughes et al., 2013; Pellegrino et al., 1991; Roswarski & Proctor, 2003; Wright & Richard, 1999). In terms of comparing practice type, if physically conducting movements during practice, which allows participants to acquire visual, haptic, and proprioceptive information, is the most beneficial for visuospatial problem solving, then participants should show the best performance. If visualizing a series of actions and critically thinking of problem-solving strategies while acquiring visual information is most helpful, then participants should perform best after mental practice. If observing a model demonstrating expert solutions while acquiring visual information is the most beneficial, then participants should perform best after modeling practice. Based on prior research it is unclear as to which practice type would yield the best performance (Capa et al., 2011; Cumming & Ramsey, 2011; Debarnot et al., 2011; Larssen et al., 2012). Finally, if

performance is influenced by level of task difficulty, then participants should show different outcomes for easy and difficult designs trials. This result would be consistent with research showing that performance can vary between levels of task difficulty (Barch & Lewis, 1954; Laguna, 2008; Linsenmeier & Brickman, 1976; Pellegrino et al., 1999).

Method

Participants

Seventy-eight undergraduate students (56 females) were recruited from Seton Hall University's psychology department research participant pool. Participants received one credit for their participation in the study. The mean age of participants was 19.26 years ($SD = 1.49$). Participants' race was identified as Caucasian/White (56.4%), African American/Black (16.7%), Asian (12.8%), Native American or Pacifica Islander (1.3%), or undisclosed (12.8%). For ethnicity, 14.1% of participants identified as Hispanic.

Materials

For the BDT, nine individual blocks and 44 cards printed with a custom two-dimensional design on a solid white index card were used. Each block was 2.54 cm^3 and thus a completed design with all nine blocks was 7.62 cm^3 . Each design was printed in red and white to reflect the color schemes of the blocks (Figure 1) and measured 3.81 cm^2 in total (representation of each block = 1.27 cm^3).

Experimental Design

Each participant was randomly assigned into one of three practice method conditions. For *motor practice*, participants engaged in physical practice by independently completing the BDT according to the presented design. For *mental practice*, participants were instructed to visualize completing the presented design without actually doing so. For *modeling practice*, participants observed an experimenter completing the task according to a presented design. Participants did not handle the blocks during the mental and modeling practice trials. Regardless of practice method condition, all participants were presented with both easy and difficult designs during test.

Thus, practice method was a between-subjects variable and difficulty level was a within-subjects variable.

Procedure

Each session took place at a small table with the experimenter and participant sitting across from each other. The session was filmed for reliability coding. At the start of each session, the experimenter explained that the goal of the BDT is to recreate the design on the card with the blocks in front of them. It was also explained that there are nine identical blocks with six sides of different colors, which can be arranged to create a design. Each participant received a practice phase and test phase, and completed a questionnaire at the end of the session.

Practice phase. Participants received a total of four practice trials. A card with a design of medium difficulty was presented to the participant next to the blocks and participants were given 30 seconds to practice the design. In the motor practice condition, participants were instructed to use the blocks to recreate the design. They were encouraged to keep working until time was over, even if they had already completed the design. In the mental practice condition, participants were instructed to visualize using the blocks to recreate the design on the card for 30 seconds. However, they were prohibited from handling the blocks. Finally, in the modeling practice condition, participants were instructed to observe the experimenter as she recreated the design on the card. The experimenter spent entire 30 seconds completing the design. The same experimenter served as the model for all modeling condition participants. Participants in the modeling condition also did not handle the blocks during the practice trials.

Test phase. Following the practice phase, participants completed 40 test trials. A semi-randomized order of designs with 20 easy and 20 difficult designs was presented. For each trial, a design was presented next to the blocks and participants were instructed to recreate the design.

Each trial ended when participants indicated they had finished creating the design, or when 20 seconds had passed, whichever occurred first. This trial duration was determined from pilot data suggesting that most participants were able to complete an easy design within 20 seconds.

Questionnaire. After completing the practice and test trials, participants filled out a brief questionnaire to provide their demographic information (gender, age, class year, major, GPA, ethnicity, and race), and information about previous exposure to the BDT. This information was collected as a way to potentially explain individual differences in visuospatial performance.

Data Coding and Analysis

Each trial was coded for accuracy and latency. Accuracy was scored by the number of blocks (out of 9) that matched the original design. For example, a score of 9 indicated that the design the participant recreated matched the design that was presented during the practice phase completely. A score of 7, on the other hand, indicated that two of the blocks were arranged incorrectly. Latency was scored by the amount of time (in seconds) required to complete the design. Latency was considered to be independent from accuracy, in that participants may indicate that they are done with the design even with low accuracy. Additionally, if participants were unable or unwilling to recreate a design, then they stopped and were scored for what had been completed up until that point.

Secondary coders scored 20% of all trials for reliability. Coders agreed on 89% of trials for accuracy ($\kappa = .86$). The correlation between coders on latency was $r = .84$. If the two coders disagreed on a measure, then the coders discussed the trial until an agreement was reached.

Results

Accuracy and latency were assessed to examine the impact of general practice across trials, practice type, and task difficulty on visuospatial performance. Recall that easy and difficult designs were presented in a randomized order so that each participant received 20 trials of each difficulty level, but within a given number of trials (e.g., the first 8 trials), the number of easy-difficult combinations could vary (e.g., 4 and 4, 3 and 5, or 2 and 6). Therefore, the data was analyzed by separating each level of difficulty and within each difficulty level, creating 5 blocks of 4 trials. For example, for the easy design trials, trial block 1 included the first, second, third, and fourth easy design trials regardless of how many difficult design trials occurred before or between these trials. Likewise, for the difficult design trials, trial block 1 included the first, second, third, and fourth difficult design trials presented regardless of how many easy trials were presented before or between these difficult design trials. This method allowed for separate 5 (trial block) x 3 (practice type) x 2 (difficulty level) x 2 (gender) mixed measures ANOVAs to be conducted for the two dependent variables. Gender was included to determine whether there were differences in performance between males and females. Trial block and difficulty level were within-subjects variables, and practice type and gender were between-subjects variables. A significance level of $\alpha = .05$ was used for the cut off of p -values. Effect sizes were assessed using Cohen's interpretation in which 0.2 was considered a small effect size, 0.5 was considered a medium effect size, and 0.8 was considered a large effect size (Cohen, 1988).

Effects of Practice, Practice Type, Task Difficulty, and Gender on Accuracy

The analysis on accuracy revealed a main effect of trial block [$F(4, 576) = 32.472, p < .001, \eta_p^2 = .184$] indicating that practice across trials led to improvements in accuracy (trial block 1: $M = 6.02, SD = 2.81$; trial block 2: $M = 6.40, SD = 2.61$; trial block 3: $M = 6.72, SD =$

2.45; trial block 4: $M = 6.75$, $SD = 2.53$; trial block 5: $M = 6.92$, $SD = 2.39$). There was also a main effect of task difficulty [$F(1, 144) = 228.521$, $p < .001$, $\eta_p^2 = .613$] indicating that accuracy was higher on easy design trials ($M = 8.55$, $SD = 1.63$) than on difficult design trials ($M = 4.61$, $SD = 1.63$). There was a significant interaction between trial block and task difficulty [$F(4, 576) = 8.422$, $p < .001$, $\eta_p^2 = .055$]. Practice type and gender were not significant ($ps > .848$).

To further investigate the interaction between trial block and task difficulty, separate ANOVAs were conducted for easy and difficult design trials. The results revealed a significant effect of trial block for easy designs [$F(4, 288) = 8.826$, $p < .001$, $\eta_p^2 = .109$] (Table 1A) and difficult designs [$F(4, 288) = 24.623$, $p < .001$, $\eta_p^2 = .255$] (Table 1B), reiterating that for both levels of difficulty, accuracy increased with practice across trials. Table 1B shows that there was more variance in participants' performance on the difficult design trials compared to the easy design trials. The small variance for the easy design trials is most likely due to ceiling effects. Additionally, the point at which accuracy improved and the amount of improvement varied by difficulty level (Figure 2). For easy design trials, pairwise comparisons revealed that trial block 1 was significantly different than all other groups ($ps < .018$, $ds > .31$). However, other trial blocks did not significantly differ from each other. The small effect size indicates slight improvement after trial block 1 however performance was so close to ceiling that there was no room for improvement. These differences have small effect sizes indicating that the magnitude of improvement across trial blocks for easy design trials is quite trivial, likely due to the fact that participants started with high accuracy in trial block 1. In contrast, for difficult design trials, pairwise comparisons showed that accuracy for trial block 1 significantly differed from all other groups ($ps < .04$, $ds > .45$). Trial block 2 was also significantly different from all other groups ($ps < .04$, $ds > .26$). Trial blocks 3, 4, and 5 did not significantly differ from each other. The

results indicate that performance on the difficult trials improved fairly continuously across trials but that after block 3, improvement slows down. But compared to improvements in the easy design trials, participants showed greater improvement across trial blocks. Medium effect sizes were found for differences in accuracy between trial block 1 and other trial blocks. Differences between trial block 2 and other blocks had small effect sizes.

Table 1A. Mean accuracy scores on easy design trials. Standard deviations are shown in parentheses.

Trial Block	Motor Practice	Mental Practice	Modeling Practice	Overall
1	8.21 (1.32)	8.38 (0.93)	8.35 (1.58)	8.31 (1.29)
2	8.56 (0.69)	8.70 (0.52)	8.46 (1.11)	8.57 (0.81)
3	8.69 (0.57)	8.69 (0.43)	8.70 (0.64)	8.69 (0.55)
4	8.80 (0.48)	8.72 (0.47)	8.71 (0.57)	8.74 (0.50)
5	8.70 (0.64)	8.76 (0.75)	8.69 (0.65)	8.72 (0.67)
Overall:	8.58 (0.69)	8.62 (0.86)	8.47 (0.76)	

Table 1B. Mean accuracy score on difficult design trials. Standard deviations are shown in parentheses.

Trial Block	Motor Practice	Mental Practice	Modeling Practice	Overall
1	3.61 (1.98)	3.77 (2.03)	3.83 (1.74)	3.74 (1.90)
2	4.28 (1.86)	4.11 (2.15)	4.31 (1.61)	4.23 (1.86)
3	4.71 (1.84)	4.63 (2.32)	4.90 (1.77)	4.75 (1.97)
4	4.67 (2.25)	4.60 (2.42)	5.02 (1.77)	4.76 (2.14)
5	4.93 (2.21)	5.35 (2.30)	5.07 (1.86)	5.12 (2.11)
Overall:	4.45 (1.95)	4.76 (2.40)	4.61 (2.14)	

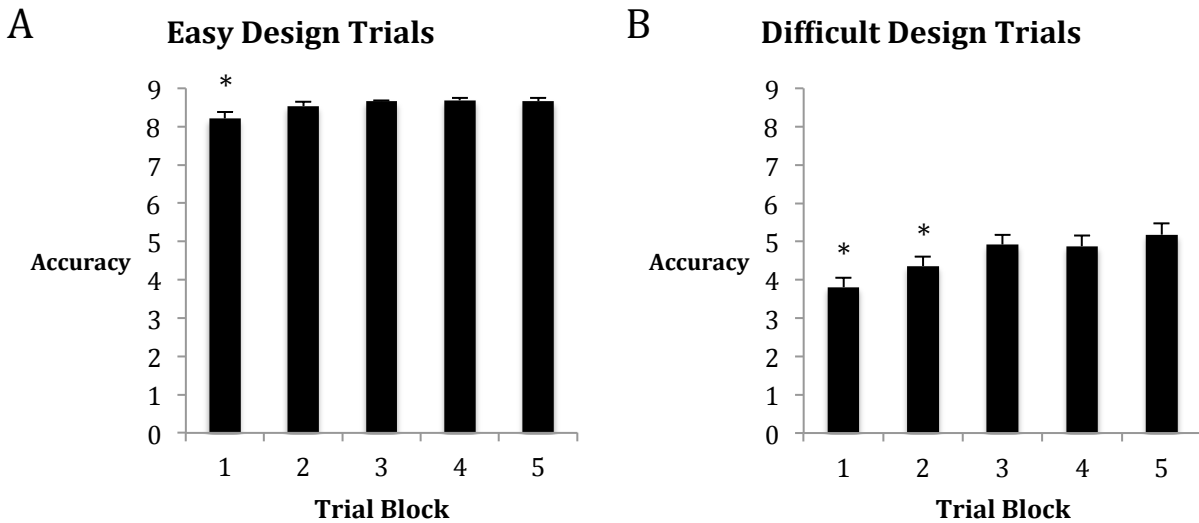


Figure 2. Mean accuracy separated by trial block. Accuracy scores ranged from 0 to 9 blocks that matched the original design. Trial block 1: 1st – 4th trial, trial block 2: 5th – 8th trial, trial block 3: 9th – 12th trial, trial block 4: 13th – 16th trial, and trial block 5: 16th – 20th trial. Error bars represent mean standard errors. A: results for easy design trials; B: results for difficult design trials. * denotes significance from all other trial blocks.

Additionally, to determine participants’ responses to the practice method received during the practice phase without the effects of general practice, accuracy for trial 1 was analyzed using a 3 (practice type) x 2 (difficulty level) x 2 (gender) ANOVA. The results revealed a significant effect of task difficulty [$F(1, 77) = 37.897, p < .001, \eta_p^2 = .365$]. However once again, there was no significant effect of practice type or gender ($ps > .670$). These results suggest that ceiling level performance for easy design trials occurred immediately following the practice phase (Table 2), with participants showing high accuracy even on the first trial.

Table 2. Mean accuracy scores on trial 1. Standard deviations are shown in parentheses.

Difficulty Level	Motor Practice	Mental Practice	Modeling Practice	Overall
Easy	8.25 (1.39)	8.33 (1.32)	8.29 (1.11)	8.29 (1.23)
Difficult	3.56 (3.07)	3.06 (2.56)	3.10 (1.85)	3.24 (2.49)
Overall:	5.00 (3.44)	4.88 (3.36)	4.50 (2.87)	

Effects of Practice, Practice Type, Task Difficulty, and Gender on Latency

Latency was assessed in several ways to reflect the finding that participants did not complete all trials during the allotted time limit. Although medians are typically used to assess missing data, in this study, means were used for analyses since unfinished trials were not equivalent to missing data. Those trials reflect a prolonged attempt to reproduce a design and also produce accuracy scores. Participants continued working until they believed they were finished or until the time limit was over. However, if the trial was unfinished, participants were aware that they had not completed the design since the image is available for them. Thus, latency was first examined by assigning a value of 20 seconds for the unfinished trials because 20 seconds was the maximum time limit for each trial. Second, latency was also examined by removing the trials in which participants did not complete the trial. Third, as with accuracy, only the first trial was examined to assess the immediate effect of practice type. Finally, latency was analyzed by taking into account the first trial completed by a participant to assess any effect of practice type on latency to complete a trial.

Using the first method showed that findings for latency—when 20 seconds was assigned to incomplete trials—mimicked the findings for accuracy. The overall ANOVA revealed a main effect of trial block [$F(4, 576) = 31.104, p < .001, \eta_p^2 = .178$] indicating that practice across trials helped participants complete the designs more quickly (trial block 1: $M = 18.76$ seconds, $SD = 1.88$; trial block 2: $M = 18.45$ seconds, $SD = 2.15$; trial block 3: $M = 18.21$ seconds, $SD = 2.25$; trial block 4: $M = 17.97$ seconds, $SD = 2.52$; trial block 5: $M = 17.92$ seconds, $SD = 2.65$). There was also a main effect of task difficulty [$F(1, 144) = 107.049, p < .001, \eta_p^2 = .426$] indicating that latency was lower on the easy design trials ($M = 16.73$ seconds, $SD = 1.83$) compared to the difficult design trials ($M = 19.76$ seconds, $SD = 1.83$). There was an interaction

between trial block and task difficulty [$F(4, 576) = 16.796, p < .001, \eta_p^2 = .104$], which is explained below. As with accuracy, practice type and gender were not significant ($ps > .508$).

To further explore the interaction between trial block and task difficulty, separate ANOVAs were conducted for easy and difficult design trials. Again, trial block was significant for both easy designs [$F(4, 288) = 26.401, p > .001, \eta_p^2 = .268$] (Table 3A) and difficult designs [$F(4, 288) = 5.397, p = .001, \eta_p^2 = .070$] (Table 3B). From the tables, it is evident that based on the larger standard deviations for easy design trials, there was much more variability. In contrast, variance was lower for difficult design trials, most likely due to floor effects. However, as with accuracy, the point at which performance increased (in this case, latency decreased) and the amount of change differed depending on task difficulty (Figure 3). For easy design trials, pairwise comparisons revealed that trial block 1 was significantly different from all other blocks ($ps < .001, ds > .43$). Trial block 2 was also significantly different from all other groups ($ps < .001, ds > .19$). Trial blocks 3, 4, and 5 did not significantly differ from each other. These results indicate that performance steadily become faster across trials for easy designs with close to medium effect sizes, however that it likely pans off after trial block 3. Note that latency was decreasing steadily even as accuracy showed small sporadic improvements on the easy design trials. In contrast, for difficult design trials, pairwise comparisons showed that trial blocks 1 and 2 significantly differed from trial block 5 ($ps < .048, ds > .31$) indicating that the improvement in latency did not occur until between trial blocks 4 and 5 for difficult designs. For difficult design trials, latency was close to floor effects so any significant decrease does not reflect a substantial improvement in performance, since the difference from trial block 1 and 5 was within one second and because results yielded small effect sizes. Overall, there were larger improvements in latency for easy designs and delayed and smaller improvements in latency for difficult designs.

Again, this pattern is in contrast to accuracy, for which performance steadily improved on trials with difficult designs. These discrepancies suggest that accuracy and latency measure different components of visuospatial performance and differ based on task difficulty.

Table 3A. Mean latency (in seconds) on easy design trials. Standard deviations are shown in parentheses.

Trial Block	Motor Practice	Mental Practice	Modeling Practice	Overall
1	17.34 (2.36)	17.79 (2.03)	17.71 (1.79)	17.61 (2.05)
2	16.67 (2.77)	17.10 (1.87)	17.26 (1.96)	17.01 (2.22)
3	16.32 (2.64)	16.69 (1.68)	16.82 (2.03)	16.61 (2.14)
4	15.95 (2.87)	16.16 (2.28)	15.50 (2.23)	16.21 (2.46)
5	15.71 (2.94)	16.22 (2.39)	16.45 (2.52)	16.13 (2.61)
Overall:	16.34 (2.25)	16.78 (2.78)	17.05 (2.47)	

Table 3B. Mean latency (in seconds) on difficult design trials. Standard deviations are shown in parentheses.

Trial Block	Motor Practice	Mental Practice	Modeling Practice	Overall
1	19.87 (0.69)	19.89 (0.40)	19.98 (0.10)	19.91 (0.46)
2	19.89 (0.41)	19.84 (0.53)	19.92 (0.27)	19.88 (0.42)
3	19.85 (0.60)	19.73 (0.72)	19.84 (0.69)	19.80 (0.66)
4	19.74 (0.84)	19.78 (0.40)	19.70 (0.70)	19.74 (0.66)
5	19.76 (0.93)	19.60 (0.91)	19.78 (0.83)	19.71 (0.88)
Overall:	19.78 (0.57)	19.62 (0.70)	19.86 (0.62)	

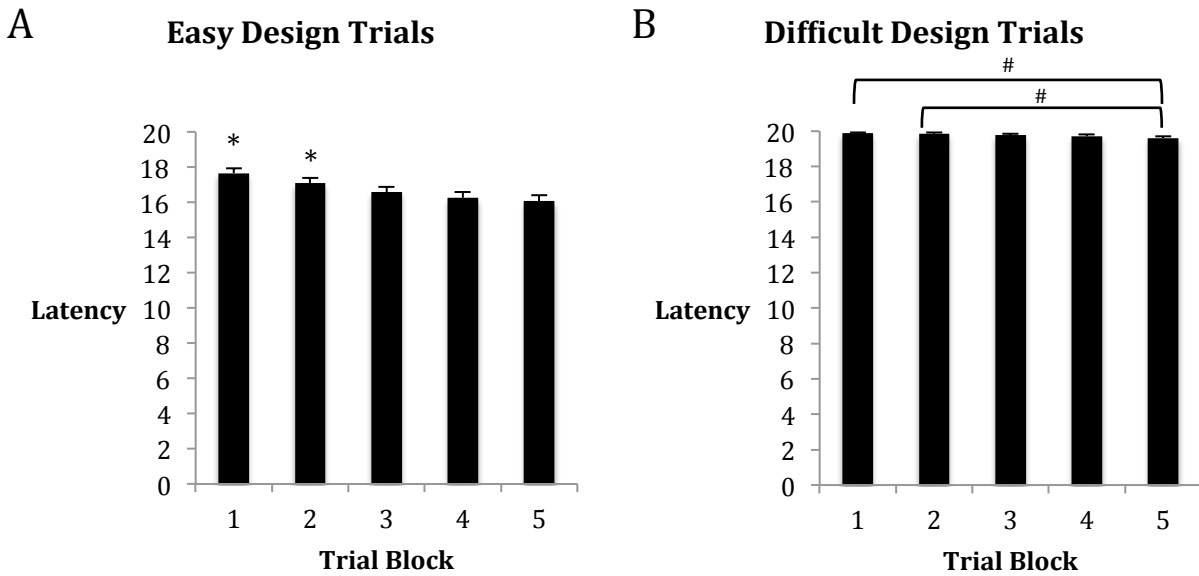


Figure 3. Mean latency separated by trial block. Latency ranged from 0 to 20 seconds and reflected the amount of time required for participants to complete a design. Trial block 1: 1st – 4th trial, trial block 2: 5th – 8th trial, trial block 3: 9th – 12th trial, trial block 4: 13th – 16th trial, and trial block 5: 16th – 20th trial. Error bars represent mean standard errors. A: results for easy design trials; B: results for difficult design trials. * denotes significance from all other trial blocks. # denotes a significant difference between two specified trial blocks only.

The second method of analyzing latency removed the unfinished trials from the analysis. The same analysis was conducted using trial blocks. The results revealed a significant effect of trial block [$F(4, 264) = 6.262, p < .001, \eta_p^2 = .087$], indicating that latency decreased across trials. However, there was no effect of task difficulty ($p = .304$). This result is not surprising considering only 10.1% of difficult design trials were completed compared to 86.6% of easy design trials that were completed. There was also no effect of practice type or gender ($ps > .399$).

Third, to determine participants' responses to practice without the effects of general practice, latency for trial 1 was analyzed using a 3 (practice type) x 2 (difficulty level) x 2 (gender) ANOVA. Results revealed a significant effect of task difficulty [$F(1, 77) = 23.550, p < .001, \eta_p^2 = .263$]. Once again, there was no significant effect of practice type or gender ($ps >$

.380). These results indicate that floor level performance for difficult design trials occurred immediately following the practice phase (Table 4).

Table 4. Mean latency scores on trial 1. Standard deviations are shown in parentheses.

Difficulty Level	Motor Practice	Mental Practice	Modeling Practice	Overall
Easy	16.62 (2.50)	17.89 (2.26)	18.14 (1.95)	17.54 (2.26)
Difficult	19.67 (1.41)	20.00 (0.00)	20.00 (0.00)	19.89 (0.82)
Overall:	18.73 (2.27)	19.27 (1.64)	19.50 (1.27)	

The final analysis of latency assessed individual differences to complete trials, the first trial completed for each participant was analyzed. Results revealed no effect of practice method ($p = .772$), task difficulty ($p = .496$), or gender ($p = .234$). Descriptive results revealed that 26.9% of individuals completed trial 1 and 47.4% of participants completed trial 2. In addition, 20.5% of participants' first trial completed ranged from trial 3 to 8. One participant's first completed trial was trial 14 and two participants' first completed trial was trial 18. One individual did not complete any trials. These results indicate that practice type did not have an effect even for the initial trials completed.

Proportion of Trials Completed

In order to account for a large portion of unfinished trials, the proportion of trials completed within 20 seconds was analyzed. Overall, participants completed 48.8% of all trials. The ANOVA yielded a main effect of trial block [$F(4, 576) = 10.522, p < .001, \eta_p^2 = .068$] indicating that practice across trials lead to participants being able to complete more trials within 20 seconds (trial block 1: $M = 43.3\%$, $SD = .541$; trial block 2: $M = 45.3\%$, $SD = .455$; trial block 3: $M = 49.4\%$, $SD = .456$; trial block 4: $M = 50.8\%$, $SD = .454$; trial block 5: $M = 53.4\%$, $SD = .460$) (Figure 4). There was also a main effect of task difficulty [$F(1, 144) = 350.219, p < .001, \eta_p^2 = .709$] indicating that participants completed the easy design trials more frequently ($M =$

85.3%, $SD = .25$) compared to the difficult design trials ($M = 11.5\%$, $SD = .25$). However, there was no interaction between trial block and task difficulty ($p = .946$), likely due to the large number of difficult design trials that were not finished within the time limit and thus assigned a value of 20 seconds, which reduced variability in the data. Practice method was not a significant variable ($p = .466$) (Table 5). Gender was once again not a significant variable ($p = .963$).

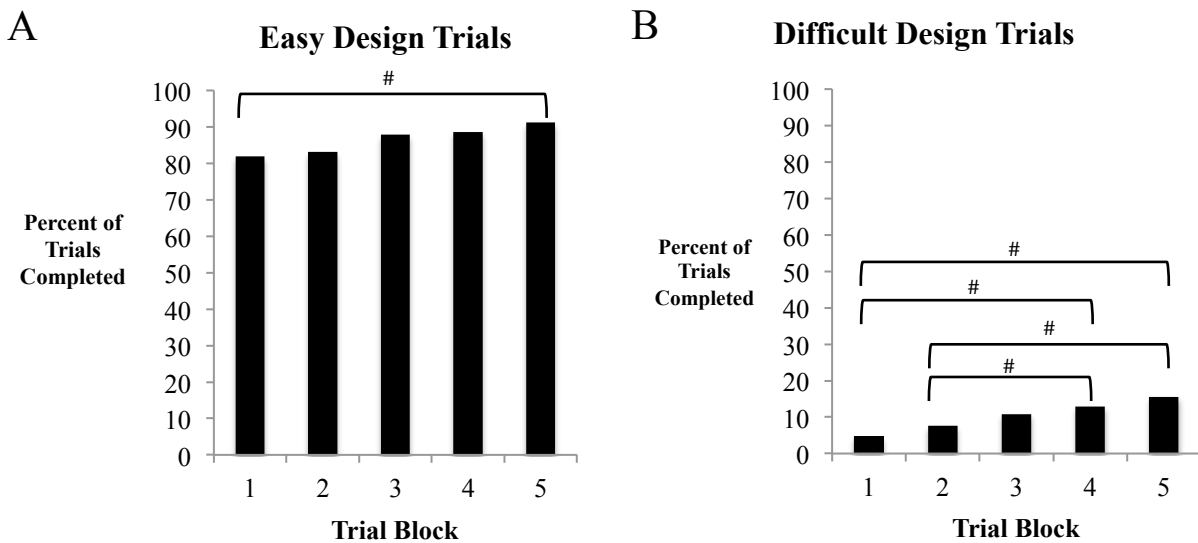


Figure 4. Percent of trials completed separated by trial block and task difficulty. Trial block 1: 1st – 4th trial, trial block 2: 5th – 8th trial, trial block 3: 9th – 12th trial, trial block 4: 13th – 16th trial, and trial block 5: 16th – 20th trial. Error bars represent mean standard errors. A: results for easy design trials; B: results for difficult design trials. # denotes a significant difference between 2 specified trial blocks only.

Table 5A. Percent of trials completed on easy design trials. Standard deviations are shown in parentheses.

Trial Block	Motor Practice	Mental Practice	Modeling Practice	Overall
1: Trials 1 – 8	76.54 (0.35)	81.92 (0.28)	87.12 (0.24)	81.86 (0.29)
2: Trials 9 – 16	78.27 (0.34)	88.81 (0.25)	82.12 (0.31)	83.06 (0.30)
3: Trials 17 – 24	86.12 (0.31)	87.88 (0.19)	89.62 (0.21)	87.90 (0.24)
4: Trials 25 – 32	90.31 (0.24)	90.58 (0.22)	85.15 (0.27)	88.67 (0.24)
5: Trials 33 – 40	90.38 (0.25)	93.23 (0.22)	90.19 (0.25)	91.28 (0.24)
Overall:	84.34 (0.30)	88.49 (0.23)	86.83 (0.26)	

Table 5B. Percent of trials completed on difficult design trials. Standard deviations are shown in parentheses.

Trial Block	Motor Practice	Mental Practice	Modeling Practice	Overall
1: Trials 1 – 8	2.88 (0.15)	6.15 (0.17)	5.19 (0.133)	4.74 (0.15)
2: Trials 9 – 16	8.00 (0.21)	10.88 (0.23)	3.85 (0.12)	7.58 (0.19)
3: Trials 17 – 24	8.27 (0.17)	14.23 (0.29)	10.00 (0.25)	10.83 (0.24)
4: Trials 25 – 32	10.65 (0.24)	19.54 (0.31)	8.65 (0.22)	12.95 (0.26)
5: Trials 33 – 40	17.61 (0.30)	18.58 (0.30)	10.58 (0.24)	15.59 (0.28)
Overall:	9.48 (0.22)	13.88 (0.26)	7.65 (0.19)	

Additional Variables

Separate ANOVAs for accuracy and latency were conducted to examine whether other variables impacted performance. Results from each ANOVA indicated that none of the following variables influenced participants' performance in the current study: age ($p = .993$), class status ($p = .920$), GPA ($p = .990$), race ($p = .922$), ethnicity ($p = .319$), and college major ($p = .999$).

Furthermore, 91% of participants had little to no exposure to the BDT.

Discussion

The goal of this study was to explore how general practice, practice type, and task difficulty influence male and female participants' performance on a visuospatial task. Participants received one practice type for both levels of task difficulty and 40 test trials to assess improvements in performance. The results suggest that general practice does matter. Across practice types and difficulty levels, accuracy increased and latency decreased across trials. Additionally, the results indicate that task difficulty is important. For easy design trials, participants reached high levels of accuracy earlier on, compared to difficult designs and thus had little room to improve. However, for latency on easy design trials, there was a steady decrease across trials, whereas for difficult design trials, participants were not able to complete numerous trials.

Why Practice Type Did Not Influence Performance

Surprisingly, the type of practice method did not affect participants' performance. What factors are responsible for why participants benefited equally from motor, mental and modeling practice? One possibility is that four practice trials were not sufficient to elicit performance specific to practice types. Four practice trials were chosen in this experiment based on pilot data suggesting that performance may be improved after four trials. However, trial block related findings showed that gains in performance continued throughout the session, whether continuously or in spurts. Regardless, participants showed improvements in both accuracy and latency well beyond the fourth test trial, which suggests that perhaps more practice trials would be necessary for participants to benefit from a specific practice type.

A second possibility is that the difference between the two levels of difficulty was too robust and masked improvements in performance between practice types. There were clear

ceiling and floor effects. For easy design trials, participants' accuracy scores were at ceiling level performance and although there were some improvements, the effect sizes were small. However, latency of easy design trials showed a steady decrease across trials and had medium effect sizes. For difficult design trials, accuracy scores had a steady increase across trials with medium effect sizes, whereas latency was near to floor performance with small effect sizes. Furthermore, a majority of participants were unable to complete difficult level designs (89.8% of difficult trials), indicating that perhaps the difficult trials were too challenging. This large discrepancy between the two levels of difficulty could have masked the benefits of practice type. Perhaps if different gradations of difficulty levels were used during the test trials (e.g., medium), then effects of practice type would be more obvious. This possibility is further supported by the findings from studies that have shown that task difficulty has a mediating effect on practice (Barch & Lewis, 1954; Laguna, 2008; Linsenmeier & Brickman, 1976; Pellegrino et al., 1999), but this relationship has not been thoroughly studied.

A third possibility is that participants benefitted equally from different types of practice because of their age. As previously mentioned, research has indicated that peak performance on the BDT occurs around age 18 (Rozenchwajg et al., 2005). The participants in this study ranged from 18 to 27 years of age and according to prior research, these individuals should be using effective strategies to complete the BDT resulting in high performance (Rozenchwajg & Corroyer, 2001; Rozenchwajg et al., 2005). Furthermore, a study tested four types of spatial abilities across the ages of 20 to 91 and found that for spatial visualization, a severe decline occurred after the age of 70 (Borella, Meneghetti, Ronconi, & De Beni, 2014). According to previous research, performance on the BDT is not likely to decline due to aging until after the age of 49 (Royer, Gilmore, & Gruhn, 1984). Thus, because participants in the current study were at peak

visuospatial performance, they may not have been readily influenced by practice methods especially after only four practice trials. Put another way, participants at this age may have performed well regardless of practice type.

A fourth possibility is that participants may have used different strategies regardless of the practice type they received during the practice phase. As previously mentioned, participants in this age range tend to use either the synthetic or analytic strategy to complete the BDT (Rozencwajg & Corroyer, 2001; Rozencwajg et al., 2005; Schorr et al., 1982). The practice methods may not have been set up to improve performance for individuals using the analytic strategy. In the mental practice condition, participants have to visualize creating the design without actually doing so. Thus, participants do not have the opportunity to break down the design block by block. It is possible that in visualizing the construction, participants focused on the overall, or global, shapes in the design. In modeling practice, although the experimenter completed the design block by block, it is unknown as to whether the participants focused on each block placement or on the overall design. Finally, in motor practice, it was possible for individuals using the analytic strategy to reap the benefits of it. Since analytic and synthetic strategies generally lead to best performance on this task, it is possible that any lack of effect due to practice type may be dependent on not experiencing the benefits of those strategies during the practice phase.

Fifth, although the current study was designed to assess differences between practice types, the results may simply reflect the inconsistent nature of practice effects on visuospatial skills. As mentioned previously, some studies have found differences between the practice types that are inconsistent with each other in that one type of practice was found to be a better method than another or vice versa (Capa et al., 2011; Larssen et al., 2012), Whereas some studies have

found no differences between different practice types (Debarnot et al., 2011; Laguna, 2008).

Thus, it is possible that effects of practice are exaggerated under certain conditions and concealed under other circumstances not tested explicitly here or in previous research.

Practice Types and Brain Regions

In addition, the lack of observable differences related to practice methods may be related to the brain regions that are activated during motor, mental, and modeling practice. Generally, visuospatial skills during the process of learning activate various regions of the brain associated with learning, memory, and higher-level processing. The ventromedial prefrontal cortex (VMPFC) and the dorsolateral prefrontal cortex (DLPFC) are activated during visuospatial tasks such as finding a target amongst directional cues (Li, Chen, Han, Chui, & Wu, 2012).

Additionally, the hippocampus and primary visual cortex specifically correspond to visuospatial processes such as navigating through mazes and recognizing an object and its location (Baddeley, Jarrold, & Vargha-Khadem, 2011; Muzzio et al., 2009). Activation of the hippocampus is correlated with spatial learning and memory, which are both necessary in order to conduct a visuospatial task accurately (Pilly & Grossberg, 2012).

Motor practice generates activation in areas involved in motor perception including the supplementary motor area, inferior parietal lobe, and the occipito-temporal area (Engel, Burke, Fiehler, Bien, & Rosler, 2008). These regions are not generally highly activated during visuospatial performance. Thus, motor practice could lead to a disadvantage on visuospatial performance since similar brain regions are not being activated in conjunction. However, since there is no competition of neural processing, it is also a possibility that this could be an advantage. In contrast, mental practice leads to higher activation of the hippocampus compared to no practice (Maguire & Hassabis, 2011). Since the hippocampus is activated during mental

practice and while visuospatial skills are being used, it seems likely that mental practice would lead to improved performance. However, one could argue that perhaps this leads to an over-activation of regions that hinders the potential benefits of mental practice. An over-activation of a specific brain region likely leads to increases in neuronal firing rates, which with repeated stimulation is likely to become fatigued. Modeling practice is unique in that the concept is related to the existence of mirror neurons, which are dedicated to detecting and executing imitative actions (Gleissner, Meltzoff, & Bekkering, 2000; Rizzolatti & Craighero, 2004). The presence of mirror neurons in humans, including during early infancy, suggests that learning from modeling practice is a skill to which humans are predisposed. During modeling practice, there are high levels of activation in the DLPFC and VMPFC (Burke, Tobler, Baddeley, & Schultz, 2010), two regions also activated with the use of visuospatial skills. Thus, similar to mental practice, it is likely that an over-activation of the same brain regions impedes the benefits of modeling practice. Since participants benefitted from practice in general, which in this study consists of a motor component, it is likely that any lack of difference between practice types that occurred is likely to be due to overlapped activation in areas related to visuospatial ability.

Gender Differences

The results of the study showed no differences in accuracy or latency based on participants' gender. There were also no gender-related differences based on practice type or task difficulty. This finding was expected since performance on the BDT is suggested to be equivalent for males and females (Caplan & Caffery, 1992; Ryan et al., 2008; Schorr et al., 1982, Voyer et al., 1995). Furthermore, since only 28.2% of participants were male it was difficult to compare performance between genders. Any significant finding would have had to be taken with caution since it is difficult to compare between discrepant sample sizes. Future studies can

further assess the effect of gender by collecting data from an equal number of male and female participants.

Limitations and Future Directions

In addition to the factors discussed above, there are possible limitations of the current study that could have impacted the results. One major possible limitation is individual differences in visuospatial ability. Since there were no baseline measures on general visuospatial skills, it is difficult to assess whether performance on initial trials were due to the effect of practice from the practice phase or due to natural visuospatial ability. Analyses of trial 1 did not reveal an effect of practice type, thus if a baseline assessment was conducted, performance on trial 1 could have been compared with visuospatial ability before the practice phase.

Additionally, as previously mentioned, it is very likely that four practice trials were not enough practice to elicit changes based on the different practice types. Furthermore, participants' accuracy during practice phase was not assessed. Although this is only applicable to the motor practice condition, it is possible that incorrect completions during practice could have hindered later performance.

In addition, the measure of latency in this study was difficult to assess. Because a large amount of trials were unfinished, it is possible that this variable did not measure true latency. If there was no time limit to complete the design, participants' latency would measure the amount of time it took to complete a design, or to give up. In this study, latency measures the amount of time to complete the design within the time limit, or if participants were not able to complete the design. Thus, results obtained from analyses of latency should be interpreted with caution.

Future research should implement more practice trials in order to attempt to achieve the effects of practice method. Researchers should consider targeting a different age group to seek

differences among practice methods, since participants in this study were likely performing at their peak age. Performance on the BDT by young adults can be compared to older adults to examine how age affects the influence of different practice types. Additionally, neuroimaging techniques can be utilized in order to measure levels of activation in the brain regions discussed.

Conclusion

Practice can be beneficial for learning and improving performance. This concept relates to almost any type of activity, including visuospatial performance. The results from the current study show that general practice was able to enhance performance when there was room to improve. It is important to note that although no effect of practice type was found in the current study, previous research has shown that different techniques of practice are involved in improving performance but a myriad of factors may have contributed to that lack of effect in this study. Furthermore, the results of this study indicate that task difficulty needs to be taken into consideration when assessing performance on any task. As shown, accuracy and latency change differently depending on the level of task difficulty. The implications of this study are applicable to everyday life. With the use of practice, individuals can strengthen their visuospatial skills in mastering difficult tasks including to aid in activities such as throwing and catching a ball, solving puzzles, and navigating through a busy street. However, it is possible that if a task is too easy and performance is already high, practice may not be able to develop further improvement. Additionally depending on the situation, practice type may not matter, but rather practice at all in general. The importance of practice should also be emphasized in education systems to improve students' visuospatial skills, but also for general cognitive abilities.

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