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Age-Related Changes in Visual Spatial Performance

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Age-Related Changes in Visual Spatial Performance

by

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Abstract

Visual spatial skills allow individuals to understand the relationship between objects, people, and the environment for their everyday activities. Visual spatial abilities incorporate visual, motor, and cognitive components, each of which changes across the lifespan. The current study examined the effects of age-related changes and practice type on visual spatial performance. Participants between 40 and 79 years of age were asked to complete the Block Design Task (BDT) by using nine blocks to recreate various designs. Both accuracy and latency were measured to examine these changes. Task difficulty and practice type were varied and cognitive abilities were measured via MMSE (Mini Mental State Examination) to examine which variables contribute to age-related changes in visual spatial skills. The results showed age-related changes in both accuracy and latency. Age-related changes in accuracy were influenced by task difficulty and time constraints. Meanwhile, age-related changes in latency were only influenced by task difficulty. On easy trials, younger and older participants performed similarly. However, on difficult trials, older participants required significantly longer durations with slightly lower accuracy scores. In contrast, practice type and MMSE did not influence accuracy or latency. However, because our sample was made up of individuals with high education levels, such as Seton Hall professors, we saw maintained cognitive abilities and increased visual spatial performance compared to prior research. Together, these findings suggest that most age-related changes were related to task difficulty, however, participants' occupation and education level may aid maintain cognitive and visual spatial abilities.

Introduction

In the United States, the average life expectancy is approximately 78 years of age (Centers for Disease Control and Prevention, 2015), which means we spend about 60 years of our lives as adults. During this long period of adulthood, we experience changes in cognitive, perceptual, and motor skills. Of particular importance are declines in visual spatial skills, which allow us to obtain, retain, represent, and manipulate objects or information (Nguyen, Mulla, Nelson, & Wilson, 2014). Visual spatial skills are necessary for understanding the relationships between objects, a skill that supports many of our everyday tasks such as driving, moving furniture, packing a suitcase, playing sports such as golf, and using a map for directions (Boonen, Schoot, Wesel, Vries, & Jolles, 2013; Nguyen et al., 2014; Notarnicola, Maccagnano, Pesce, Tafuri, Novielli, & Moretti, 2014). An everyday example of a visual spatial problem that is relevant for most adults is deciding where to park. One must consider the location of a certain parking space, recall the intended destination, and compare the distance between the two. By doing so, visual spatial knowledge is being used about where the parking spot is in relation to the world, particularly the destination. Thus, age-related changes in visual spatial skills have the potential to affect the quality of adults' daily lives. This study examined age-related changes and the effects of practice on visual spatial performance in adults between 40 and 79 years of age.

Visual Spatial Performance across the Lifespan

Visual, cognitive, and motor abilities work together in the performance of a visual spatial task (Pazzaglia & De Beni, 2010). Thus, as these abilities change with age, so do visual spatial skills. For example, age-related declines in vision mean it can become more difficult to distinguish relevant shapes, colors, locations, or size—information necessary to manipulate and interact with objects (Larssen, Ong, & Hodges, 2012). Age-related declines in cognition mean it can become more difficult to process information and distinguish relevant information from irrelevant information—making it more difficult for people to understand the relationships between objects (van Gerven, Paas, Van Merriënboer, & Schmidt, 2000). Lastly, age-related declines in motor abilities mean it can become more difficult to react to and orient oneself accurately towards objects—making it more difficult to physically manipulate the objects needed in the performance of a visual spatial task (Ren, Wu, Chan, & Yan, 2013).

In experimental settings, one way in which these separate skills combine to support visual spatial ability is by asking participants to use blocks to create specific designs (Ronnlund & Nilsson, 2006; Wechsler, 1955). This task, called the Block Design Task (BDT), has been used with participants between the ages of 16 and 90, in both healthy and clinical populations (Wechsler, 1955; Zelinski, Dalton, & Hindin, 2011). Participants are presented with nine blocks they could use to recreate a design shown in a picture (Figure 1). The difficulty level of each design can be varied by the number of solidly colored or split-colored blocks as well as the distinguishability of each edge determines design difficulty. Easy designs primarily consist of solid color blocks with adjacent blocks having different color edges (Figure 1). However, difficult designs primarily consist of split-colored blocks with adjacent blocks having same color edges (Figure 1). Medium designs consist of features from both easy and difficult designs, such that they have both solid colored, split-colored blocks, adjacent edges that share the same color edges, and have different color adjacent edges (Figure 1;Miller, Ruthig, Bradley, Wise, Pedersen, & Ellison, 2009). To succeed in this task, participants must obtain relevant visual information, integrate the information about the blocks with the picture, problem solve to figure out how they fit together, and move the blocks and place them accurately in a timely manner to complete the puzzle.

Figure 1. Examples of easy, medium, and difficult designs in the BDT.

Schorr, Bower, and Kiernan (1982) examined BDT performance in college-aged students and found that young adults could solve easy designs faster and more accurately compared to more difficult designs. For example, they showed 100% to 88% accuracy rates per subject corresponding to the easy and difficult trials, respectively. In contrast, Paulo and colleagues (2011) found that accuracy scores were generally low for older adults between 60 and 90 years of age, ranging between 0% and 35%. They also found that performance declined at a steady rate in older participants such that errors increased by 1% for each year of age. For example, a typical 80-year-old participant would make 10% more errors compared to a 70-year-old participant. Regardless of age, participants typically have some trouble when completing a difficult design compared to an easy design during the BDT (Goldhammer et al., 2014).

Other measures of visual spatial skills have shown similar age-related changes. For instance, visual spatial skills can also be assessed using the short Object Perspective-Taking Task (sOPT), which allows researchers to assess a participants' understanding of where objects are in relation to the world (Borella, Meneghetti, Ronconi, and De Beni, 2014). Participants were asked to imagine they were at a certain point in the scene and to identify the center of the scene, based on their location. To succeed in this task, participants needed an understanding of where the center of a visual scene was in relation to three other object locations, which was made possible through visual spatial abilities. Vision allowed the participants to see the three objects and their hypothetical location within the scene. Cognition allowed the participants to assess the relationship between the three objects to find the middle of the scene. Borella and colleagues (2014) found that participants between 20 to 40 years of age perform well on the task (mean *z*-score of .50). At 40 years of age visual spatial skills begin to decline. These declines become even more drastic between 60 and 80 years of age (mean *z*-score of -1.00 for 60 to 80-year-olds).

Lastly, visual spatial skills can be assessed with a more applied task, such as driving through a visual scene, called the Money Road-Map test (Hatta et al., 2015). Participants determined whether to turn left or right to accurately move through a visual scene that contained bends in the road. To succeed in this task, participants needed an understanding of the road conditions within the visual scene as well as how to manipulate the steering wheel correctly based on the turns. Vision allowed the participants to see the bends while motor abilities allowed them to enact the correct maneuver. Using this task, Hatta and colleagues (2015) found similar age-related changes in spatial abilities as in other research. The mean *z*-score for 50-year-olds was .47, whereas, for 80-year-olds, it was -.18.

Role of Practice in Visual Spatial Performance

Although changes in visual spatial skills are a part of normal and healthy aging, Paulo and colleagues (2011) found that age-related declines in Block Design Task could occur at a slower rate as a function of education. Particularly, at the same chronological age, participants with higher education levels (college or graduate school) performed better than those with lower education levels (elementary or high-school). The results regarding education suggest that spatial skills do not have to decline just because someone is aging. More specifically, cognitive reserve could be aiding participants in their visual spatial performance. Cognitive reserve refers to the brain's ability to tolerate age-related, or even disease-related changes within the brain, without displaying any symptoms (Tucker & Stern, 2011). Cognitive reserve allows the brain cope with these changes by using alternative strategies to optimize performance on cognitively demanding tasks (Tucker & Stern, 2011). Reed and colleagues (2010) suggest that the ability to cope with these changes is built through engaging in cognitively demanding tasks. Therefore, cognitive reserve varies person to person. By continuously engaging in cognitively demanding tasks, individuals are essentially practicing them. Therefore, participants with higher levels of education may have performed better on the BDT because they had different, or possibly more, opportunities to practice cognitively demanding tasks, as well as more opportunities to build up alternative processing strategies in the face of age-related changes.

Despite age or education level, practice can be beneficial to all. Practice involves the repetition of a task with the goal of improvement (Hughes et al., 2013). Generally, practice of a visual spatial task has been linked to increased accuracy and decreased completion time (Barch & Lewis, 1954; Hughes et al., 2013; Wright & Richard, 1999). Practice is believed to enhance visual spatial performance because over time practice decreases resource demands (Reisberg, 2013). For instance, when a task is fairly new, each component of a task requires more attention. With practice, the individual can focus on the components of the task that need improvement (Chi, Feltovich, & Glaser, 1981; Reisberg, 2013).

There is evidence that short-term practice can improve some forms of visual spatial performance in older adults, with the improvement lasting at least several weeks. Kass, Ahlers, and Dugger (1998) tested participants from 21 to 57 years of age with a mental rotation task in which participants were shown two images of a ship on a computer screen. The participants estimated the degree in which the ship was rotated from the original position. Participants were assigned to one of three conditions: practice with feedback, practice while using an instruction manual, or no practice (control condition). The feedback group was told whether they were right or wrong after each trial. The instruction manual group was provided with visual illustrations of possible ship rotations in order to guide their estimations. Participants in the practice with feedback condition made fewer errors than those in the control condition, but participants in the instruction manual condition made slightly more errors than the control group. When tested again three weeks later, the feedback group made more errors than they made during the initial session, but still had lower error rates than the other two groups.

In addition to highlighting the importance of practice, the findings from Kass and colleagues' (1998) demonstrated the importance of practice type. Long-term changes in performance occurred only when short-term practice was paired with feedback. Meanwhile, short-term practice with an instruction manual did not have any significant long-term changes in performance compared to the control group (Kass et al., 1998). These findings are similar to the general findings in the literature, which show that practice can be categorized broadly into three categories—motor practice, modeling practice, and motor-modeling practice—and that each type can influence visual spatial performance. These three practice types are discussed separately below, including their effectiveness and examples of how they could be implicated in the BDT, previewing the current study.

Motor practice. Motor practice involves an interaction between the participants and the task in which the participants physically attempt to solve the problem (Cumming & Ramsey, 2011). In the BDT, motor practice would involve participants practicing moving the blocks physically to create different configurations as they learn to solve the puzzle. Motor practice has been found to be most beneficial for enhancing performance on physical tasks, such as accurately following and pointing at a moving object or throwing a ball at a target (Hird, Landers, Thomas, & Horan 1991; Kohl, Ellis, & Roenker, 1992; Shea, Wulf, Wright, & Whitacre, 2000). Motor practice was beneficial because participants were physically solving the problem, allowing them to go through trial and error, using sensory feedback to learn from mistakes to better understand which actions will help them to obtain their goal (Shea et al., 2000).

Modeling practice. Modeling practice involves an interaction between the experimenter and the task, while the participants observe the experimenter physically try to solve it (Hoover, Giambatista, & Belkin, 2012). In the BDT, participants would watch the experimenter physically manipulate the blocks in order to solve the puzzle that the participants will later need to solve. Modeling practice has been found to be beneficial to learning explicit strategies, employable to physical tasks such as kicking a soccer ball accurately into a goal (Larssen et al., 2012). Unlike motor practice, modeling practice does not provide sensory feedback and opportunities for evaluating one's actions (Shea et al., 2000). However, modeling practice was beneficial to participants because they were able to see the correct procedures that must be taken to complete the task, although they may not have found the solution themselves (Larssen et al., 2012).

Combination practice. Combination practice involves participants using more than one type of practice, such as motor paired with mental practice or motor practice paired with modeling. Mental practice involves mentally interacting with the problem through obtaining and retaining visual features of an object, while producing mental representations and rotations of the objects, allowing the participants to work through a problem and determine how they should fix it (Cumming & Ramsey, 2011). Although mental practice has been studied by itself (Cumming & Ramsey, 2011; Driskell, Copper, & Moran, 1994), it appears that a combination of motor and mental practice was just as effective as motor practice alone during physical tasks (Hird, Landers, Thomas, & Horan, 1991; Kohl, Ellis, & Roenker, 1992). Thus, MacKay's (1981) claim, that mental practice takes place during motor and modeling practices, could explain why the combination of motor and mental practice has been found to be as effective as motor practice alone and not more effective. Therefore, mental practice was not explored independently in the current study.

Contrary to the combination of motor and mental practice, the motor and modeling combination practice has been found to be particularly beneficial to improving visual spatial performance (Peretti, Danion, Gierski, & Grange, 2002). The motor-modeling combination involves the participants watching the experimenter physically interact with the problem, while the participants also actively interact with the problem themselves in order to accurately solve the problem. In Peretti and colleagues' (2002) study, participants between 60 and 75 years of age solved the Tower of Toronto (TT) puzzle in which they rearranged colored disks in a particular order on pegs while following certain rules. Particularly for older adults between 60 and 75 years of age, a combination of motor and modeling practice was necessary for enhanced performance; in comparison, motor or modeling practice alone were not as beneficial.

Although these types of practice have been found to beneficial across the literature, we do not know how practice would influence age-related changes in visual spatial abilities outside of mental rotation tasks, for instance, the BDT. The BDT differs from a mental rotation task because participants need to physically and mentally interact with the blocks opposed to just mentally rotating them. The BDT requires participants to visually process the blocks within the designs, cognitively process how the blocks are used to recreate the design, as well as physically rotate the blocks in order to successfully solve the problem. Thus, it would be helpful to broaden our knowledge on how practice can influence visual spatial skills generally. By broadening our knowledge, we may be able to identify a practice that best helps our long-term spatial abilities.

Current Study

The current study explored age-related changes in visual spatial performance. Participants were healthy adults between 40 and 79 years of age because Borella and colleagues (2014) found that significant declines in visual spatial abilities begin around 40 years of age. As in previous research (Goldhammer et al., 2014; Paulo et al., 2011; Zelinski et al., 2011), the current study used the Block Design Task (BDT) to assess participants' visual spatial performance. The BDT was beneficial to studying the effects of short-term practice because the BDT allows for immediate feedback. More specifically, participants can see whether their placement of a block was correct or not by comparing their blocks to the design card.

In the current study, we measured accuracy (the number of blocks out of nine that were placed correctly) and latency (time required to complete the trial) to determine whether visual spatial performance changed with age. Because older participants may require more time to process and solve each trial, and because the time to complete a trial may reveal age-related changes, participants could take as long as they needed to complete each trial.

Using the guidelines of Miller and colleagues (2009), we determined task difficulty of each design. Participants completed 10 trials with easy designs and 10 trials with difficult designs so that we could examine whether task difficulty influenced performance. We also examined easy and difficult trials in terms of trial blocks (the first five trials vs. the last five trials) to assess whether general practice influenced performance. Additionally, participants received 12 practice trials in a motor, modeling, or motor-modeling combination condition prior to the test trials, so that we could examine whether practice type influenced performance.

Finally, we assessed each participant with the Mini-Mental State Examination (MMSE). We administered the MMSE to ensure that the participants were cognitively capable of performing the task, but also to see if cognitive abilities influenced visual spatial performance. The MMSE is a brief, easily administered, and widely used test of cognitive abilities (Stein et al., 2015). Possible scores range from 0 to 30; any score below 25 was considered below average for a healthy individual.

The first aim of the current study explored whether there are any age-related changes in visual spatial performance. As part of the first aim, we also explored whether variables such as task difficulty, practice type, and MMSE scores—variables found to be significant in previous research—influenced age-related differences in BDT performance. The second aim of the study was to determine whether general practice could influence age-related differences in BDT performance using trial block as a proxy for practice. As part of the second aim, we only included the variables that appeared to moderate changes in visual spatial performance, from the first set of analyses, to further explore the possible relationship between practice and age-related changes. The third aim of the study was to determine whether time constraints affected age-related changes in visual spatial performance.

Method

Participants

A prior power analysis was conducted for an ANCOVA with three variables (practice type, difficulty level, and age group), which suggested approximately one hundred participants for the current study. Participants were recruited through emails, announcements in newspapers, and by word of mouth. The inclusion criteria for the current study was for participants to be between 40 and 80 years of age, have full use of both hands, and to be able to read, write, and understand English. For practical reasons, the current study only recruited forty-eight participants (24 male, 24 female). Twenty-four (12 male, 12 female) of the participants were between the ages of 40 and 59, thus in the younger age group, and the other twenty-four participants (12 male, 12 female) were between the ages of 60 and 79, thus in the older age group. Demographics are displayed in Table 1.

Table 1

Mean age, mean MMSE, and demographic information for participants.

	Younger	Older	Overall
Mean Age	49.83 (*SD* = 5.78)	67.13(*SD* = 5.04)	58.48 (*SD* = 10.30)
Mean MMSE	29.50 (*SD* = 1.18)	29.13 (*SD* = 1.15)	29.31 (*SD* = 1.17)
Race			
Caucasian	87.50%	95.80%	91.70%
Asian	12.50%	4.20%	8.30%
Ethnicity			
Hispanic	12.50%	0%	6.30%
Not Hispanic	87.50%	100%	93.70%
Education			
Elementary	0%	4.20%	2.10%
High-school	8%	0.00%	4.20%
College	17%	12.50%	14.60%
Graduate	75%	83.30%	79.20%
Retirement			
Retired	0%	29.2	14.60%
Not retired	100%	70.80%	85.40%

Materials

The BDT was completed using nine red and white blocks (each 2.54 cm^3). The six surfaces of the blocks were colored such that two surfaces were completely white, two were completely red, and two were half white and half red. The blocks were used to create a design depicted on one of 24 two-dimensional design cards (each 3.81 cm^2). Four cards contained designs of medium difficulty (for practice trials), 10 cards contained designs of low difficulty (for easy test trials), and 10 cards contained designs of high difficulty (for difficult test trials). Following the standards set by Miller et al. (2009), easy designs incorporated more solid colored blocks and adjacent block edges were distinguishable by different colors as seen in Figure 1. Difficult designs incorporated more split-colored blocks and adjacent block edges share the same colors. Medium designs incorporated a mixture of solid and split-colored blocks with some adjacent block edges sharing and others not sharing the same color edges.

The standard MMSE was used to determine participants' cognitive status. Scoring was done by adding up the number of points received for each correctly answered question with a maximum possible score of 30.

Experimental Design

We manipulated the between-subjects variable, practice condition, by randomly assigning participants into one of three practice conditions: motor, modeling, or combination. We also manipulated the within-subjects variable, task difficulty, by presenting participants with one of four trial orders. The four trial orders were different randomizations of the 10 easy and 10 difficult designs throughout the test trials so that participants received easy and difficult designs in different orders. We randomly assigned participants to a practice condition and trial order based on their age group, young or old, and gender, male or female. Across all four trial orders, there were 16 participants per practice condition, 8 participants in each age group for each practice condition, and 4 male and 4 female participants in each age group for each practice condition, as shown in Table 2.

Table 2

Number of participants in each cell of the experimental design.

Practice Condition	Motor		Modeling		Combination	
Age Group	Younger	Older	Younger	Older	Younger	Older
Total Participants	8	8	8	8	8	8
Male	4	4	4	4	4	4
Female	4	4	4	4	4	4

Procedure

All sessions were recorded on video for offline reliability coding. After obtaining informed consent, the experimenter explained that the goal of the task was to recreate the design displayed on the card using all nine blocks. The experimenter demonstrated how each block was identical, consisting of two solid white sides, two solid red sides, and two split-colored sides. The experimenter explained that participants could rotate the blocks as they deemed necessary to recreate the design.

Practice trials. Participants received 12 practice trials with medium designs as seen in Figure 1. On each practice trial, participants spent 30 seconds using motor, modeling, or combination practice depending on their condition assignment. Participants in the motor practice condition were instructed to physically recreate the design presented to them. If participants finished recreating the design before the end of the 30-second practice period, then the experimenter mixed up the blocks again so that participants could spend the rest of the time practicing. This procedure ensured that all participants spent the same amount of time practicing. Participants in the modeling practice condition watched the experimenter create the designs. The experimenter spent the entire 30 seconds recreating the design once. Lastly, participants in the combination practice condition watched the experimenter recreate the designs while also practicing on their own simultaneously for the full 30 seconds.

Test trials. Immediately following the practice trials, participants received 20 test trials. Half of the trials consisted of easy designs and the other half consisted of difficult designs. The two difficulty levels were presented to the participant in a random trial order. As before, participants were asked to recreate the design using the nine blocks. However, there was no time limit for each trial. When participants finished each trial, they verbally informed the experimenter. Then, the experimenter mixed up the blocks and presented a new design for them to complete.

MMSE and Demographics Questionnaire. After completing the practice and test trials, the experimenter asked the participants 11 short questions from the MMSE. Following the MMSE, participants filled out a brief questionnaire to provide demographic information (gender, age, education level, retirement status, ethnicity, and race) and information about previous exposure to the BDT.

Data Coding and Analysis

A primary coder scored both practice and test trials. Accuracy was scored as the number of correctly placed blocks for each design. While latency was scored by the amount of time the participant spent on each design in seconds. Practice trials were scored for accuracy, except for the modeling practice trials, as the participants were not the ones recreating the designs and thus did not provide any accuracy scores. During practice trials, participants had the opportunity to score higher than nine blocks correct, due to having the full 30 seconds to complete the designs. Practice trials were not scored for latency as all participants were given 30 seconds to recreate the designs. During test trials, the primary coder scored both accuracy and latency. However, during the test trials, they were instructed to tell the experimenter once they had successfully completed the design, allowing them to score up to nine correct blocks. Latency was scored out of unlimited time.

Secondary coders scored 25% of all trials for reliability. The primary and secondary coders agreed on 96.82% of the trials for accuracy. The correlation between coders on latency was $r = .99$. If the coders disagreed on a measure, then they reviewed the relevant trial on video and resolved the discrepancy through discussion.

Results

Age-Related Differences in Performance

The main question of interest was exploratory, examining whether visual spatial performance changes with age and whether such changes were related to practice type, task difficulty, and cognitive status. Therefore, separate 3 (practice type: motor, modeling, or combination) x 2 (task difficulty: easy or difficult) x 2 (age group: younger or older) repeated measures ANCOVAs were conducted on accuracy and latency. Gender and MMSE scores were entered as covariates. Covariate adjusted means were reported for any analysis that contained covariates. A significance level of $\alpha = .05$ was used for the cut-off of *p*-values. Effect sizes were examined using Cohen's interpretation for partial eta squared (η_p^2) such that .1 was small, .3 was medium, and .5 was a large effect size.

Accuracy. Initially, the ANCOVA revealed a main effect of task difficulty, $F(1, 40) = 4.73$, $p < .05$, $\eta_p^2 = .11$, and an interaction between task difficulty and MMSE, $F(1, 40) = 4.34$, $p < .05$, $\eta_p^2 = .09$. There were no other main effects or interactions (ps > .15, $\eta_p^2 < .09$).

Because the MMSE produced continuous scores, the interaction between task difficulty and MMSE was examined with separate correlations for easy and difficult trials. On easy trials, accuracy was not related to MMSE scores ($r = .27$, $p = .07$, $n = 48$), However, on difficult trials, accuracy appeared to be correlated positively with MMSE scores ($r = .29$, $p = .04$, $n = 48$) (Figure 2).

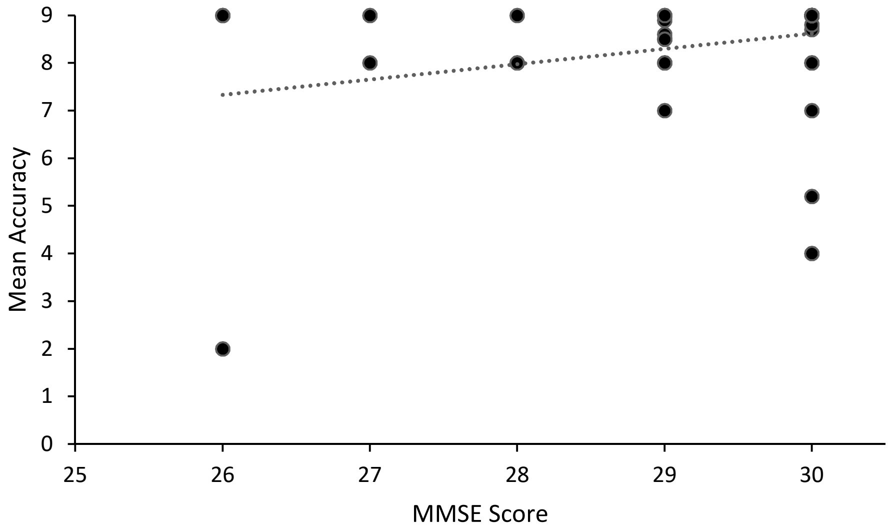

Figure 2. Correlation between MMSE scores and accuracy on difficult designs. MMSE scores for the current study began at 26, but the lowest possible score was a 0 and the highest score was 30.

After, examining Figure 2 it was evident that an outlier may have driven the positive correlation. *SDFBeta* measures the amount of influence each case has on a regression line, thus it allows researchers to identify potential outliers in a dataset (Hair, Black, Babin, & Anderson, 2009). Therefore, *SDFBeta* was calculated for each case to determine whether an outlier was driving the correlation. Any case with *SDFBeta* > 2 was considered to be an outlier and excluded. After removing an outlier and re-running the analysis, the ANCOVA revealed a main effect of task difficulty $F(1, 39) = 4.73$, $p < .05$, $\eta_p^2 = .10$, and an interaction between task difficulty and age group $F(1, 39) = 4.96$, $p < .05$, $\eta_p^2 = .11$. However, the interaction between task difficulty and MMSE was no longer significant ($p = .79$, $\eta_p^2 = .01$), therefore the outlier in the data set drove its significance. Additionally, there were no other main effects of interactions (ps $> .21$, $\eta_p^2 < .08$).

To examine the interaction between task difficulty and age group two separate *t*-tests were conducted on easy and difficult trials. On easy trials, the younger participants (*M* = 8.89, *SD* = .21) and the older participants (*M* = 8.92, *SD* = .18) completed the designs with similar accuracy levels, $t(45) = .53$, $p = .69$, $d = .15$. However, on difficult trials, younger participants were more accurate (*M* = 8.86, *SD* = .32) compared to older participants (*M* = 8.32, *SD* = 1.20), $t(45) = 2.05$, $p < .05$, $d = .62$. However, both groups were performing near ceiling level on both easy and difficult designs

Latency. The ANCOVA revealed a main effect of task difficulty, $F(1, 40) = 6.64$, $p < .01$, $\eta_p^2 = .15$, and an interaction between task difficulty and age group**,** $F(1, 40) = 26.63$, $p < .01$, $\eta_p^2 = .40$. There were no other main effects or interactions (*p*s > .26, $\eta_p^2 < .66$).

To examine the interaction between task difficulty and age group, separate *t*-tests were conducted for easy and difficult trials. On easy trials, the younger participants (*M* = 24.30, *SD* = .81) and the older participants (*M* = 27.73, *SD* = 6.85) completed the designs with similar latencies, $t(46) = 1.50$, $p = .14$, $d = .70$. However, on difficult trials, older participants required twice as long (*M* = 111.39, *SD* = 43.39) to complete the designs than did the younger participants (*M* = 54.76, *SD* = 26.63), $t(46) = 5.45$, $p < .01$, $d = 1.57$ (Figure 3).

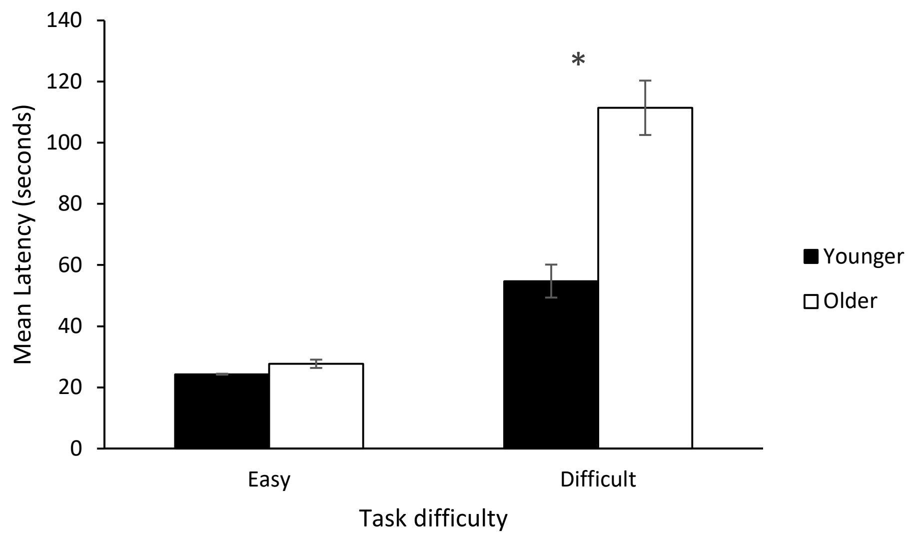

Figure 3. Mean latency separated by age group for easy and difficult trials. $^{*}p < .01$.

Trial-Related Changes in Performance

After identifying the variables that influence age-related changes in BDT performance, the next question of interest was whether participants showed improvement during the test session. That is, do participants benefit from short-term practice unrelated to the type of practice they received? Therefore, the test trials for the two difficulty levels (10 easy trials and 10 difficult trials) were separated into 2 blocks (first 5 vs. last 5 trials) to examine trial-related changes in performance.

Accuracy. The variables that were not significant from the initial analysis (practice type, MMSE, and gender) were omitted to create a 2 (task difficulty: easy or difficult) x 2(age group: younger or older) x 2 (trial block: first 5 trials or last 5 trials) repeated measures ANOVA. The analysis only yield a main effect of task difficulty, $F(1, 46) = 6.04$, $p < .01$, $\eta_p^2 = .12$. The main effect of task difficulty reflected that participants performed better on easy trials ($M = 8.90$, $SD = .19$) in comparison to difficult trials ($M = 8.45$, $SD = 1.35$). Therefore, participants did not benefit from general practice in the current study. There were also no other main effects or interactions (ps > .09, $\eta_p^2 < .06$).

Latency. The variables that were not significant from the initial analysis (practice type, gender, and MMSE) were omitted to create a 2 (task difficulty: easy or difficult) x 2 (age group: younger or older) x 2 (trial block: first 5 trials or last 5 trials) repeated measures ANOVA. As expected, there was a main effect of task difficulty, $F(1, 46) = 126.11$, $p < .01$, $\eta_p^2 = .73$, and an interaction between task difficulty and age group, $F(1, 46) = 27.41$, $p < .01$, $\eta_p^2 = .37$. The analysis also revealed a main effect of trial block, $F(1, 46) = 12.05$, $p < .01$, $\eta_p^2 = .21$, and an interaction between task difficulty and trial block, $F(1, 46) = 8.18$, $p < .01$, $\eta_p^2 = .15$. There were no other main effects of interactions for accuracy (ps > .15, η_p^2s < .05).

The interaction between task difficulty and trial block was examined with separate *t*-tests for easy and difficult trials. On easy trials, participants completed the designs more quickly during the second trial block ($M = 25.39$, $SD = 7.56$) than they did during the first trial block ($M = 26.64$, $SD = 8.67$), $t(47) = 2.88$, $p < .01$, $d = .15$. Although the difference was significant, the difference was small: less than 1.5 seconds, on average. On difficult trials, participants also completed the designs more quickly during the second trial block ($M = 77.94$, $SD = 45.97$) compared to the first trial block ($M = 88.21$, $SD = 48.09$), $t(47) = 3.16$, $p < .01$, $d = 0.22$. However, the improvement was greater: about 10 seconds, on average (Figure 4).

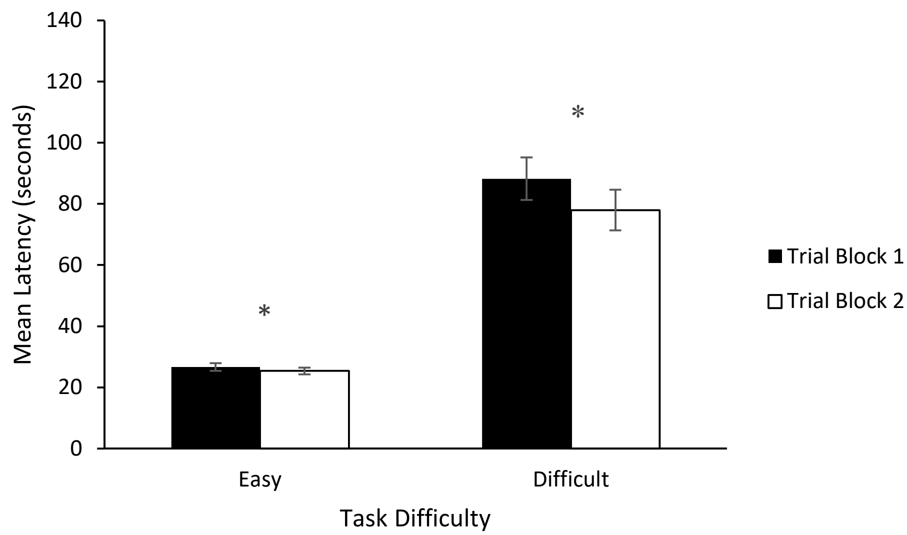

Figure 4. Mean latency separated by trial block for easy and difficult trials. *$p < .01$.

Effects of Time Constraints on Performance

As reported above, without time constraints, participants in both age groups showed high accuracy levels, particularly on the easy trials. However, were there age-related changes in performance when there was a time constraint? To examine this question, 2 (practice type: motor or combination) x 2 (age group: younger or older) ANOVA was conducted on accuracy during practice trials, which were the only portion of the study with a time limit (30 seconds per practice trial). Only the motor and combination practice condition were included in this analysis. The modeling condition did not yield any accuracy scores from participants because participants simply observed the experimenter during practice.

This ANOVA revealed a main effect of age group, $F(1, 28) = 6.44$, $p < .01$, $\eta_p^2 = .19$. Younger participants ($M = 8.09$ correct out of 9, $SD = 1.73$) showed higher accuracy during practice trials than the older participants ($M = 6.36$, $SD = 2.09$). In other words, older adults fared worse with a time limit (Figure 5). There was no main effect of practice type. Participants performed equally in the two conditions (Motor: $M = 7.39$, $SD = 2.23$; Combination $M = 7.06$,

SD = 1.98; p = .63, η_p^2 = .01). There was also no interaction between the two variables (p = .23, η_p^2 = .05).

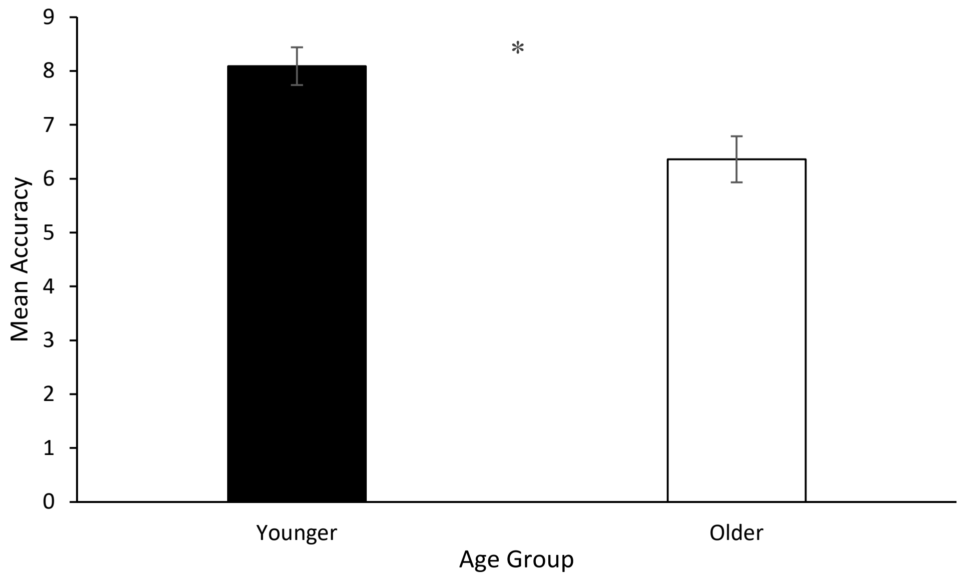

Figure 5. Mean accuracy for practice trials separated by age group. $^{*}p < .01$.

Discussion

The goal of the current study was to examine age-related changes and the effects of practice on visual spatial performance in adults between 40 and 79 years old. Performance was examined using both accuracy and latency, and several variables were examined as possible influencers of BDT performance. In the current study, age-related changes were found in accuracy and these changes were influenced by task difficulty and time constraints. However, these effect sizes were relatively small. There were also age-related changes in latency and these changes were influenced by task difficulty. However, latency was also influenced by trial block, independent of age group. Task difficulty and age group had larger effect sizes in comparison to accuracy, meanwhile, trial block only produced small effect sizes for latency. Overall, practice type and MMSE were not related to accuracy or latency.

Age and Visual Spatial Performance

Age-related changes in visual spatial abilities were evident when comparing accuracy between the two age groups on difficult designs, such that younger participants outperformed older participants. Even though there were age-related changes in accuracy, the differences were much smaller compared to prior research. Despite being older, participants were still performing near ceiling level in the current study. Ceiling level performance was likely due to the unlimited time allotted to participants during test trials. For instance, when examining timed trials, older participants performed worse, but still not to the same degree as prior research. However, prior research by Paulo and colleagues (2011) examined a more diverse group of older participants and did not provide them with prior practice. For example, compared to the participants in the current study, Paulo and colleagues' participants were slightly older participants (60 to 90 years of age) with more diverse education levels (elementary school to graduate school), which may have resulted in the lower accuracy scores.

Age-related changes in visual spatial abilities became even more evident when looking at the amount of time it took each group to recreate the designs, particularly on difficult designs. The older participants required more time to complete difficult designs compared to younger participants. The age-related changes in latency were likely due to visual, cognitive, and motor declines because all three skills play an essential role in visual spatial performance (Pazzaglia & De Beni, 2010). For instance, difficult designs could have been more cognitively demanding, due to the fact these designs contained split-colored blocks, instead of solid blocks, and adjacent blocks shared the same color edges. Thus, the older participants may have required more time to distinguish blocks from one another, process how to recreate the designs, and then correctly manipulate the blocks into place, resulting in increased latencies (Larssen et al., 2012; van Gerven et al., 2000). Meanwhile, easy designs may have been less cognitively demanding, due to the fact these designs contained solid colored blocks and adjacent blocks with different color edges, thus allowing individual blocks to be easily distinguished from one another. Therefore both groups of participants could process and complete easy designs at similar speeds.

Practice and Visual Spatial Performance

When we practice a visual spatial task, accuracy increases and completion time decreases, allowing us to perform the task more effectively (Barch et al., 1954; Hughes et al., 2013; Wright et al., 1999). In the current study, accuracy scores were not influenced by general practice, such that participants performed about the same between the first set and the second set of designs, likely due to unlimited time they were given while completing these designs. However, participants did benefit from practice from in terms of completion time, such that participants were faster during the second half of trials compared to the first half. Particularly on the difficult trials, performance became noticeably faster. Therefore, practice appears to benefit visual spatial performance on the BDT.

However, contrary to previous studies, practice type did not appear to influence accuracy or latency. One possibility for this discrepant finding could be sample size: The current study tested only 48 participants, with 16 participants per practice condition. Meanwhile, the power analysis suggested 100 participants. Thus, a larger sample may be required to detect the effects of practice. The second possibility for this discrepancy was the amount of practice: Perhaps, 12 practice trials were insufficient to facilitate changes in performance specific to practice type. Or, perhaps 12 practice trials was more than enough such that all participants benefited from practice and washed out the potential differences between the conditions. A third possibility for the discrepancy was trial duration: Participants had unlimited time to complete the designs, allowing them to perform at ceiling level. Note that even on the difficult trials, both age groups averaged 8.4 correct blocks of 9. On average, participants made less than 1 error.

Based on motor evoked potential (MEP) and mirror neuron research, it is also possible that participants benefitted equally from all three types of practice because the same motor commands are being engaged in the brain across all three practice types. MEPs are electronically recorded responses to stimulation of motor cortex, which governs movement (Sakamoto et al., 2012). Therefore, as an individual actively practices a task MEPs increase. However, even during modeling practice MEPs of the individual observing an action increased. The MEPs corresponded to specific muscles necessary to perform the observed task (Sakamoto et al., 2012). Moreover, mirror neurons are visuomotor neurons that fire when we watch an action be performed, but also while we perform the action ourselves (Van Gog, Paas, Marcus, Ayres, &

Sweller, 2009). Mirror neurons allow the observer to learn new motor patterns based on the visual information and transform these observations into motor commands to imitate the actions of the experimenter (Van Gog et al., 2009). Therefore, because the same areas may be active under motor and modeling practice, which would also be active in the combination, this may be why there were no effects of practice type observed in the current study.

Importance of Cognitive Abilities on the BDT

As van Gerven et al. (2000) stated, when cognitive abilities decline it becomes harder to understand relationships between objects, thus affecting visual spatial performance. In the current study, two measures were used as a proxy for cognitive skills: MMSE and education level. However, education was omitted from the analyses because we could not obtain sufficient diversity in education. Approximately 80% of participants had completed graduate school. Moreover, 75% of younger participants and 83% of older participants had graduated from a graduate school. Therefore, the current study was lacking variability in education across the two age groups, which in turn could make the results unrepresentative.

In the current study, all participants performed well on the MMSE, scoring above 26. On average, both younger and older participants scored about 29. MMSE scores were not found to be significantly associated with performance once outliers were removed from the dataset. However, it was likely that MMSE scores did not have any influence on age-related changes in visual spatial skills for the current study due to cognitive reserve. The sample was mainly made up of Seton Hall professors with high education levels, who performed well on the BDT. Salthouse (2006) found that individuals that have stimulating occupations, such as professors, maintain higher cognitive abilities despite aging. Additionally, Salthouse (2006) found these occupations to be correlated with higher performance on measures, such as cognitive and visual spatial measures. Therefore, the discrepancies between the current study and prior research in age-related differences in accuracy may have also been because our sample had higher, or possibly even unrepresentative, cognitive abilities.

Despite having no significant findings for MMSE scores, our results were consistent with the importance of maintaining cognitive abilities, as they may influence visual spatial performance on everyday activities. The current study found that our participants performed better on the BDT compared to prior research. More specifically, all participants, despite age, performed near ceiling level on easy and difficult designs, which was likely due to the unlimited time they were given, but it could also be due to their cognitive reserve. As we've previously seen, about eighty participant of our participants had graduate level educations and sixty-six percent were Seton Hall professors. High education levels and cognitively stimulating jobs have been linked to individuals' brains having a higher tolerance to age-related changes within the literature on cognitive reserve. More specifically, participants with high IQs, education levels, and stimulating occupations have been found to display fewer signs of aging (Tucker et al. 2011). Reed and colleagues (2010) suggest that stimulating occupations and education are opportunities for individuals to build up coping mechanisms to age-related changes, such that they can find alternative ways of processing. Therefore, due to having higher education levels and stimulating occupations, participants may have had more experience with cognitively demanding tasks, as well as more opportunities to build coping mechanisms. Thus, these alternative processing methods, or neural networks, may have aided participants in their performance. It seems likely that cognitive reserve played a role in the current study because even when participants faced a time limit, older individuals still performed better on the BDT compared to prior studies. Another instance, which supports the idea of cognitive reserve aiding participants, was found when examining MMSE scores. Despite aging, older participants also performed about the same on the MMSE compared to younger participants. Therefore, cognitive reserve may have allowed our participants to tolerate and show fewer signs of aging.

Limitations and Future Directions

One major limitation of the current study was the sample and sampling technique. A convenience sample was used in which Seton Hall University professors made up a large majority of the sample (66.67%). While it was necessary to use a convenience sample to reach a non-college age population and examine age-related changes in older adults, this sampling technique yielded an unrepresentative sample that was problematic for several reasons, including the lack of diversity in participants' race, ethnicity, education level, and retirement status. Therefore, the results may not be generalizable to the typical aging population. Another limitation may be the range of the older participants. Although the older group included participants between 60 and 79 years of age, the median age in this group was 67.50. There were 20 participants between 60 and 70 years of age, but only 4 participants between 71 and 79 years of age. Additionally, eighty-three percent of the older participants had graduated from a graduate school and only twenty-nine percent were retired. Therefore, the sample was lacking participants of older ages in addition to lacking diversity within their education levels and retirement status. Overall, if the current study contained a more representative sample, the results may have been different (e.g., larger differences between the two age groups, a stronger effect of task difficulty, or possibly an effect of practice type or MMSE).

Future research should strive to examine visual spatial skills across the lifespan, but in a way that allows for more diversity and representativeness in the sample. Researchers should put an emphasis on what occupations individuals have and how that may aid their performance despite age-related changes, via cognitive reserve. As the current study suggests high education levels, stimulating jobs, and staying engaged may benefit us while we age, particularly in our visual spatial abilities.

It may be helpful to examine age-related changes in visual spatial skills in situations that are more similar to what we encounter in our everyday activities. The current study suggests that as we age, tasks that incorporate visual spatial skills might become increasingly difficult. However, prior research has also found practicing a task to be beneficial. Future research should study whether age-related changes affect tasks we perform, or practice, every day. More importantly, these changes should be studied in everyday situations that have real-world consequences. Even though many people may play with puzzles as a hobby, not being able to complete a design quickly or accurately does not have any real-world consequences. However, visual spatial situations, such as driving do have real-world consequences. Future research should continue to examine driving with a simulator as Roenker, Cissell, Ball, Wadley, and Edwards (2003) have done. Roenker et al. (2003) have found that by using a driving simulator, older adults improved in making turns and signaling while driving. By using a driving simulator to study age-related changes in visual spatial abilities, future research can explore whether driving habits are a result of age-related changes. For instance, do older drivers drive more cautiously, so they have enough time to detect, process, and use relevant information from their surroundings? Future research could also explore whether cognitive abilities or training on a visual spatial measure, such as the BDT, could be linked to driving abilities. More specifically, what role do cognitive abilities play in driving? Is performance on the BDT an extension of our performance on everyday activities? Expanding upon research conducted by Roenker (2003) is an important way to study visual spatial abilities because it directly relates to our everyday activities and in turn, we could assess if and how we could maintain such abilities, despite age-related changes.

Overall, the current study has shown that age-related changes do occur in visual spatial performance as a function of task difficulty. Despite age-related changes, our results show that general practice, as well as maintained cognitive abilities, can allow us to solve visual spatial problems more effectively. Therefore, the importance of practice and cognitive abilities should be studied further in an attempt to improve our understanding of age-related changes in visual spatial performance, as they influence our everyday lives.

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