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Impact of Sequence and Cognitive Aging on Spatial Learning from Ground Level and Aerial Perspectives

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IMPACT OF SEQUENCE AND COGNITIVE AGING ON SPATIAL LEARNING FROM GROUND LEVEL AND AERIAL PERSPECTIVES

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ABSTRACT

This study examined the impact of healthy aging on two important factors that are common in spatial learning. The first is the perspective a person views an environment from. The second is the sequence that the items are encountered in the environment. In order to test the effects of these factors on spatial learning, participants watched four videos in which they learned two environments from the ground-level perspective and another two from an aerial perspective. One video of each perspective presented each side of the rectangular layout sequentially and the other presented the layout in a random order. After each video, participants created a map of the environment to determine how well they learned the layout. This study compared performance between healthy young adults and healthy senior citizens. It was anticipated that healthy senior citizens would show a similar pattern of learning to healthy young adults with the exception of having a higher level of error. Overall, the present study demonstrated that people tend to learn a layout better from an aerial perspective than from a ground-level perspective, that participants were able to learn a layout better when presented in a sequential order than a random order, and that while there was not a significant difference between senior citizens and young adults on the aerial perspective conditions, seniors performed significantly worse than young adults on the conditions presented from the ground-level perspective.

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CHAPTER I

INTRODUCTION

One of the skills that plays a major role in our lives is the ability to navigate from Point A to Point B successfully. Traveling from Point A to Point B involves several factors, such as complexity of route, number of potential and available routes, distance between two routes, etc. As we repeatedly navigate or study this path, we will eventually learn these factors. While we are learning a route or map, we acquire knowledge about the different objects and landmarks and how they relate to one another, which increases our spatial knowledge. This type of learning can fall under spatial learning. Thorndyke (1981) pointed out that spatial knowledge includes landmarks, margins of the area, various courses a person can take, and if the area can be broken down into sub-areas. With practice, we also learn the proper sequence of steps to take in order to successfully complete each step within the particular route we chose, which falls under sequential learning. The main purpose of this study was to examine how cognitive aging impacts the interaction between spatial learning and sequential learning.

In order to fulfill that goal, this study used a 2x2 within-subjects design to compare and contrast how well participants learned an environment. It was intended to compare and contrast how well participants could learn a layout from different perspectives that the environment was viewed from and when the layout was presented in either a sequential order or a random order.

1.1 *Brain areas influencing learning and memory*

Within the brain, there are several structures that play a role in learning. One such structure is the hippocampus. The hippocampus is involved with the formation of explicit memories. The hippocampus is also responsible for converting short-term memory into long-term memory. A second area of the brain that influences learning and memory is the caudate nucleus. The caudate nucleus has been linked to instrumental learning and response learning.

There has been some debate as to what role the hippocampus and the caudate nucleus plays in place and response learning. For spatial learning, place learning is defined as being able to learn the location of an object, such as Cleveland, OH is located north of Columbus, OH. On the other hand, response learning is the ability to learn the set of responses needed to get from one location to another (for example, turning left on Street X, going straight for a particular distance, and then turning right on Street Y).

Packard and McGaugh (1996) explored this debate by deactivating the caudate nucleus in one group of rats and the hippocampus in another group of rats and had both groups of rats go through a probe trial in which the rats were placed in one chamber and the chamber on the left was baited with food. On the eighth and sixteenth days, the rats received an injection of lidocaine in the area of the brain that was supposed to be deactivated and placed in the north arm. The rats were placed in the opposite chamber and they were marked as response learning if they turned left and place learners if they turned right. What Packard and McGaugh found was that on Day eight, the control rats were place learners, the rats that had their caudate nucleus deactivated were place learners and the rats that had their hippocampus disabled did not show a trend toward response learning or place learning. On Day 16, the control rats were response learners, the rats with the deactivated caudate nucleus tended to be place learners, and the rats with the deactivated hippocampus tended to be response learners. These results demonstrate that both types of learning occur at the same time, place learning is independent of response learning, that the hippocampus is involved with place learning, and the caudate nucleus is involved with response learning (Packard & McGaugh 1996). Since the rats with the deactivated hippocampi had trouble with place learning, it is suggested that people who do not have a hippocampus that is working to its full potential, such as senior citizens (Golomb et al., 1993), will have trouble with place learning. Response learning is based on following a particular sequence of steps. Based on these notions, this study intended to examine how participants would respond when they were presented with a series of landmarks and were asked to recreate a map with each landmark in its proper place.

DaCunha et al. (2003) performed a similar study to Packard and McGaugh (1996). In DaCunha et al.'s study, they compared the inactivation of the hippocampus to the inactivation of the substantia nigra within cued and spatial learning. Cued learning is when a person sees an item; it causes him or her to recall another item. This is related to spatial learning in that when a person sees one landmark, it could cue them that another landmark is next or that they had already past a landmark. For both the spatial task and the cued task, DaCunha et al. used the Morris Water Maze. Based on their findings, DaCunha et al. concluded that the substantia nigra plays a significant role in cue learning while the hippocampus plays a role in recalling a location and that the substantia nigra is independent from the hippocampus in some forms of memory. Since DaCunha et al.'s study demonstrates that rats have trouble navigating through an environment when they have an impaired hippocampus, it can be speculated that humans with an impaired hippocampus could potentially have trouble recalling how to navigate through an environment as well.

1.2 *Spatial learning and Memory*

Hartley, Maguire, Spiers, and Burgess (2003) examined response learning and place learning in relation to spatial navigation and how they are represented in memory. Within their study, they used way-finding and route navigation to examine these types of learning. Hartley et al. defined way-finding as being able to figure out a unique path when traveling from one point to another. Hartley et al. define route following as being able to follow a learned route. Both of these paradigms occurred on the ground level (as opposed to aerial learning, which involves an aerial or map view). One item to note is that Hartley et al.'s definition of route following differs from Shelton and Gabrieli's (2002) definition of ground-level learning. Shelton and Gabrieli stated that ground-level learning is learning a layout from the ground-level. Within this study, we used Shelton and Gabrieli's definition and we will address their research later.

In order to test these paradigms, Hartley et al. (2003) used a computer to create two virtual towns. In the first town, participants used the way-finding paradigm and each time they navigated through the town, they had to take a different route. In the second town, participants had to repeatedly follow the same route. During the course of the study, participants were being scanned by a MRI machine.

Hartley et al. (2003) found that the right hippocampus was activated during the way-finding task and the caudate nucleus was activated during the route following task. They also found that the more accurate people were with the way-finding task, the greater the activation in the hippocampus, and Hartley et al. stated that these results demonstrate that the hippocampus is responsible for the processes that are involved with navigating correctly. This statement would support the idea that there should be a difference between young adults and senior citizens when it comes to spatial navigation because the hippocampus changes as we age.

Hartley et al.'s study is related to several points that Burgess, Maguire, and O'Keefe (2002) brought up in their literature review. One item that Burgess et al. noted was that the right hippocampus is activated in recalling where objects are located when navigating through an environment. They also noted that the posterior hippocampus is involved with object location that is not related to navigation. In contrast to the right hemisphere, Burgess et al. stated that the left hippocampus is represented in episodic memory. In relation to the current study, if a person has damage or a severe decline in the functioning to the right hippocampus, he or she will have struggled more than a healthy person to learn the layout of an environment. This would apply regardless of whether the environment is presented in sequential order or whether it is presented in a non-sequential order.

1.3 *Types of perspective*

Memories of landmarks are not the only items in spatial learning that has multiple formats. Perspective is one area that the environment can be presented in different formats. As mentioned before, this study used the perspectives discussed by Shelton and

Gabrieli (2002). The first perspective is spatial learning from a ground-level perspective, which provides a first-person perspective of the environment by traveling through an environment on the ground level (Shelton and Gabrieli, 2002). The second perspective is spatial learning from an aerial perspective, which is learning a layout from a map view and provides a global view of the layout (Shelton and Gabrieli, 2002). Within their study, participants learned two environments: one from a ground-level perspective and a second environment from an aerial perspective. During the learning part of the procedure, the participants' brains were scanned by using a MRI. After the participants saw all of the environments in both perspectives, they were tested for object recognition. Finally, participants were asked to draw a map of each environment in order to test how well they remembered each one.

Shelton and Gabrieli (2002) found that when it came to drawing a map of the environment, the participants used a sequential method (drawing the items in the order they were presented) to draw the map they learned from a ground-level perspective. For the environment learned from the aerial perspective, participants drew the map by quadrant/section. Shelton and Gabrieli (2002) found that several parts of the brain were activated in the ground-level perspective, including the parahippocampal cortex and the posterior hippocampus. These results relate to the current study in that since many regions of the hippocampus are activated during ground-level learning activities, it is expected that senior citizens with lower functioning hippocampi will struggle more on the ground-level learning tasks than healthy age-matched controls.

1.4 *Sequential learning and its impact on spatial learning*

Another aspect that influences spatial learning is sequence. Shelton, Fields, Spence, and Yamamoto (2006) examined the impact of sequence on spatial learning and the parts of the brain that were activated. The procedure for this study was very similar to Shelton and Gabrieli (2002). Half of the participants watched one sequential order movie and one random order movie. Both movies were from the ground-level perspective. The other half of the participants watched a sequential movie and a random order movie that were shown from the aerial perspective. Shelton et al. found that the participants were significantly less accurate when they viewed the random order ground-level perspective compared to when they viewed the sequential ground-level perspective. When it came to the aerial perspective, there was not a significant difference in accuracy between the sequential-order movie and the random order movie.

In the course of three experiments, Shelton et al. (2006) examined how sequence impacts on ground-level learning and aerial learning. During Experiment 1, Shelton et al. examined the sequence that people reconstructed the environment they had learned. In order to test the participants' learning, the experimenters had the participants build a model of the environments. The models were classified as having been completed in a sequential order (the model was built based on the order the objects appeared), spatially-driven (non-sequential schematic order), or random order. Half of the participants had learned and were tested in the ground-level perspective and the other half in the aerial perspective. Shelton et al. found that when reconstructing the environment learned from the ground-level perspective, participants used a sequential method to build the model.

When participants reconstructed the environment learned from the aerial perspective, they rebuilt it in a spatially-driven order.

During the Experiment 2, Shelton et al. (2006) examined how sequence impacted the learning of an environment from a ground-level perspective and from an aerial perspective. In order to do this, Shelton et al. divided each movie into four legs and played them in a random order. Participants learned two environments from either the aerial perspective or the ground-level perspective. Participants were shown one environment in a sequential order and the other environment random order. The results were similar to Shelton et al. in that participants performed similarly on the sequential aerial task, random order aerial task, and sequential ground-level task and performed significantly worse on the random order ground-level task.

For Experiment 3, Shelton et al. (2006) examined the length of time it would take people to learn an environment in a ground-level perspective and aerial perspective when the sequence was disrupted. The learning procedure was similar to Experiment 2 and the testing procedure was similar to Experiment 1. Shelton et al. found that participants did better at building the model they had learned from the aerial perspective than the one they had learned form the ground-level perspective. They also found that participants were more accurate in reconstructing sequential models. It was also found that participants felt that they needed to view the random order ground-level video more than the other three videos. Shelton et al. pointed out that there was an interaction between sequence and perspective and that even though participants viewed the non-sequential ground-level learning video more than the others, they still performed worse on the reconstruction task than on the other three models. In summary, Shelton et al. found that sequence plays a larger role on ground-level learning than aerial learning. Since these results were found with healthy young adults, it poses the question of how the performance of people with decreased hippocampal functioning would compare to the performance of people with normal hippocamal functioning.

1.5 *Cognitive Aging*

One area that cognitive aging plays a role in is sequential learning, as demonstrated in Gaillard, Destrebecqz, Michiels, and Cleermans (2009). One item that they point out in their literature review was that there is a debate in the research when it comes to whether or not age impacts implicit learning and if so, how age impacts learning. Based on this debate, Gaillard et al. conducted a study in which they examined the interaction of age and practice on sequential learning. In order to conduct the study, they gathered three groups of people young adults, middle-age adults, and senior citizens.

All of the participants went through three tests. The first test was a serial reaction time test that had an underlying sequence that participants were not told about. Next, participants had to complete a generation task in which they were shown a dot in one of the boxes and then for 108 trials, they had to try to predict where the dot would go next. Finally, participants took part in a recognition task. Gaillard et al. (2009) found that the response time decreased with practice and that the older the participant was, the longer it took for him or her to respond. Participants who had more trials were found to be quicker than those who had less. Gaillard et al. also found that participants were able to pick up on the sequence regardless of age and length of practice, though the participants who had more practice learned the sequence better. There was no difference in recall due to age, and young adults performed significantly better than the middle-age adults and senior citizens on the recognition task (Gaillard et al., 2009). This study supported the findings of Aizenstein et al.'s (2006) study in which participants had a greater reaction time and lower accuracy when it came to the trials that did not have a pattern and that senior citizens had a higher reaction time than young adults.

One item that is related to reaction time is the complexity of the task. Bo and Seidler (2010) examined the impact that task complexity and aging play on spatial learning and showed that senior citizens became increasingly impaired in their sequential learning ability as the complexity increased. In the current study, since the non-sequential ground-level environment is the most complex and had given participants the most trouble in Shelton et al.'s (2006) study, it was anticipated that senior citizens would be most dissimilar from young adults for this environment.

Golomb et al. (1993) examined how people are impacted by hippocampal atrophy and if it was related to difficulty with memory. The participants were at least 55 years old and did not show any signs of dementia. Participants went through an MRI, took a recall test that examined their working memory, and performed tasks that examined long-term memory: two verbal tasks and one non-verbal task. Golomb et al. found that age had a significant impact on hippocampal atrophy. Out of the 50 people who were found with an atrophied hippocampus: 12.8% were 55-65 years old, 32.9% were 66-76 years old, and 56.8% were 77-88 years old. Golomb et al. also found that those with an atrophied hippocampus performed worse on the long-term memory task and that there was no statistically significant difference between the two groups on the working memory task. Since the majority of participants were over 60 years old, the criterion for recruiting senior citizens for the present study was that they were over 60 years old and did not show signs of dementia.

In addition to the atrophy in the hippocampus (Golomb et al., 1993), Aizenstein et al. (2006) found that senior citizens' prefrontal cortex and striatum were smaller than those found in young adults and that senior citizens had a lower level of activation in their right putamen (a part of the striatum) than young adults. This signifies that the striatum begins to decay as people age. In the current study, it was anticipated that the atrophy of the hippocampus and the lower level of activation in the striatum, and prefrontal cortex in senior citizens would have a negative impact on their learning.

Besides examining how aging impacts recall tasks, there has also been research on how cognitive aging impacts the learning of a map. One such study that examined learning a layout had been performed by Iachini, Poderico, Ruggiero, and Iavarone (2005) in which participants had to perform a mental scanning task of a layout they learned. There were two groups of participants: young adults and senior citizens. First, participants went through a series of tests that examined their memory capabilities and visuo-spatial abilities. Then participants had to attempt to learn a perimeter that had colors at different points. Participants had to try to learn the location of each color and the distance between each one. Iachini et al. found that there was not a difference between young adults and senior citizens when it came to memorizing the sequence of colors. But the senior citizens were significantly less accurate than the young adults in learning the distances between each point. In relation to the current study, what this means is that it is anticipated that senior citizens should have a higher rate of error in placing the landmarks on a map than young adults do.

Jansen, Schmelter, and Heil (2010) also examined the impact that age has on spatial learning, except that they used a virtual environment instead of a physical layout. Within Jansen et al.'s study, there were three groups of participants: young adults, middle-age adults, and senior citizens. Participants went through two learning trials, two testing trials, and one map-drawing trial. During the first learning trial, there were not any landmarks (represented by toys). Participants had to use a joystick to successfully navigate through a maze four consecutive times without making a mistake. During the first testing trial, participants had to navigate through the environment (that still did not have the landmarks in place) and the researchers kept track of the number of mistakes and the distance the participant had to navigate before they made it to the finish line. Next, participants had to go through the second learning phase in which they navigated through the environment with all the landmarks in it and had to successfully complete the task without error twice in a row. Afterwards, the participants had to navigate around the maze, which had the landmarks removed again, and walk to each position where a landmark had been and indicate which landmark had been in that position. Finally, participants had to draw a map of the maze that included detail such as dead ends, corners, etc.

Overall, Jansen et al. (2010) found that there was a negative correlation between age and spatial learning ability: young adults generally outperformed older adults in all of the tasks. Since the current study is using a paradigm that is similar to Jansen et al., it was anticipated that the results from the current study would be similar to their results. One limitation to Jansen et al.'s study is that not every participant has the same capability of using a joystick. For example, it is anticipated that there could be generational differences and that it could be more likely that young adults would have more experience navigating around a virtual environment using a joystick or controller than older adults, especially senior citizens. In order to eliminate this potential confound, the current study showed the participants movie clips that took the participant around the layout instead of having them navigate around the environment themselves.

1.6 *Summary*

It has been demonstrated thus far that the basal ganglia and the hippocampus play a significant role in learning and memory and that the functioning of both these areas declines with age. A significant decline in functioning, outside of healthy aging, is linked to dementia and Alzheimer's disease. Both of these diseases involve a level of memory loss.

Based on the prior research, the primary objective of this project was to test the ability of healthy young adults and healthy senior citizens to learn environments from both the ground-level perspective and aerial perspective and how sequence impacts the ability of both groups to learn a layout from each perspective. It was hypothesized that the young adults would demonstrates similar pattern of learning that was found in Shelton et al. (2006) in that young adults perform significantly worse on the non-sequential ground-level test and that the senior citizens would show a similar pattern as the young adults with the exception of having a higher margin of error.

CHAPTER II

METHOD

2.1 *Participants*

Two groups of participants were recruited (n = 24 each). The first group consisted of young adults that were undergraduate students at Cleveland State University. Within this group, there were 9 males and 15 females. The average age of this group was 21.54 years old and the range of ages was 18-33. The second group consisted of healthy senior citizens who were above 60 years old. There were 13 males and 11 females within this group. It was assumed that they did not show signs of dementia since they were taking college courses. These participants were recruited from Cleveland State University's Project 60 program. The average age of the senior citizen group was 69.05 years old and the range of ages was 60-80 years old. To test to see whether there was a significant difference between the two groups in terms of age, a between-subjects t-test was performed. It was found that the average age was significantly different between the two groups, $t(46) = -31.95$, $p < .001$. The number of males to females within each group was not significantly different, $t(46) = 1.15$, $p = .23$. All participants had either normal or corrected-to-normal vision. They either received partial course credit for a psychology course or a monetary amount ($10) in compensation for their participation.

2.2 *Materials*

There were eight movies: four environments with two movies per environment. The environments were a zoo, a convention center, a park, and a market. For each environment, one movie displayed the ground-level perspective and the other movie displayed the aerial perspective. Each movie was broken down into four clips with each clip showing a particular leg of the environment. Figure 1 shows an example of the rectangular shape of the layout and the side that each leg was assigned to. All four legs were viewed. The variation was that for the environments that were learned sequentially, participants viewed Leg 1, then Leg 2, Leg 3, and finally Leg 4. For the environments that were learned non-sequentially, the order in which the legs were viewed was randomized. To inform participants which leg they were about to view, a text display came onto the screen that stated which leg was about to be shown. Then the screen changed to the environment and began displaying the particular leg. All movies were shown using Psyscope (Cohen, MacWhinney, Flatt, & Provost, 1993).

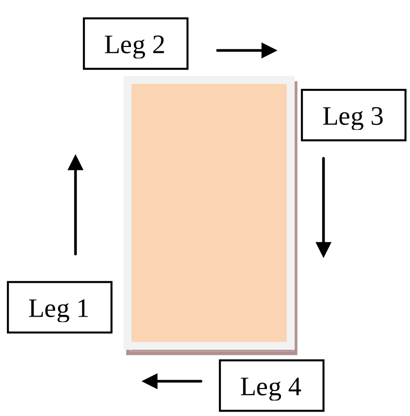

Figure 1. Visualization of leg location

2.3 *Procedure*

2.3.1 *Conditions*. There were four conditions. One condition was that the participants learned the environment from a ground-level perspective and the legs were presented sequentially. A second condition was that participants learned a new environment from a ground-level perspective and the legs were presented in a non-sequential order. A third condition was that participants learned a third environment from an aerial perspective with the legs shown in sequential order. The fourth condition was that participants learned a fourth environment from an aerial perspective with the legs presented in a non-sequential order. Participants learned all four conditions. This means that there were 24 potential orders in which the conditions could be presented. The order in which the conditions were presented in had been counterbalanced across participants.

2.3.2 *Learning Phase*. For each condition, participants first viewed instructions stating that they would be viewing a layout that has been divided into four legs. Next, the experimenter pressed the "spacebar" key to start the trial. During the first trial, the experimenter pointed out the 10 landmarks. After the fourth leg was shown, a new set of instructions had appeared on the screen. This set of instructions told the participant that he or she would view the layout six more times and that he or she should pay close attention to the landmarks that were pointed out in the trial run and what the location of the objects were in relation to the rest of the landmarks. After the participant was done reading this set of instructions, he or she pressed the spacebar for the set of trials to begin. After viewing all six trials, the participant then performed the task described below in order to measure how well they learned the layouts.

2.3.3 *Measurement of learning*. In order to establish how well the participants learned each environment, after the participants viewed a condition seven times, they were asked to create a map of the layout that they have just learned, including landmarks. The method that they followed was that they were presented with a piece of paper taped to a magnetized dry erase board. On the paper, an image similar to Figure 1 was drawn and participants were asked to recreate the map they had viewed by placing magnetized strips with the names of the landmarks onto the proper location within the diagram.

After creating the map, the participants then viewed the next condition. This procedure was repeated until the participant had learned one environment from the aerial perspective in sequential order, one environment from the aerial perspective in non-sequential order, one environment from the ground-level perspective in sequential order, and one environment from the ground-level perspective in non-sequential order. In order to measure accuracy, the experimenter computed a distortion index (DI) that quantifies the spatial distortion of the map created by the participant. The equations and procedure used to compute DI are described by Waterman and Gordon (1984). To calculate DI, the experimenter took into account how much of a shift in the X and Y coordinates existed between the participant’s map and the answer key as well as any change in the scaling factor and any rotation that occurred. For the DI, it is a score that ranges between 0 and 100. A DI of 0 means that the participant has drawn the map perfectly and a score of 100 means that the participant has placed all of the landmarks in the same location.

CHAPTER III

RESULTS

A 2 (young adult group vs. senior citizen group) x 2 (aerial perspective vs. ground-level perspective) x 2 (sequential order vs. random order) repeated-measures ANOVA was used to analyze the data. In terms of outliers, there was only one data point for one of the seniors that fell outside of the range of 3 standard deviations from the mean. When this outlier was removed, it did not change the results, so the outlier was kept in the final analysis.

It was found that all three variables had a significant main effect on the DI. For the two groups, it was found that the overall performance of the young adults (40.67, S.E. = 2.96) was significantly better than the performance of the senior citizens (50.48, S.E.= 2.96), $F(1, 46) = 5.49$, $p=.024$. It was also found that participants created more accurate maps of environments that were presented in the aerial perspective (34.86, S.E.= 2.06) than of the ground-level perspective (56.29, S.E.= 3.07), $F(1, 46) = 46.56$, $p<.001$. For order, it was found that the maps of the sequential order environments (42.94, S.E.= 2.19) were significantly more accurate than the random order maps (48.21, S.E.=2.46), $F(1, 46) = 6.52$, $p = .014$.

In terms of the interactions between variables, the Perspective * Group interaction was the only one that was significant, $F(1, 46)=7.5$, $p=.0090$. An independent samples t-test was run to see what way this interaction was significant, with the results being displayed in Figure 2. For the ground-level perspective, it was found that the DI of the young adults' maps (47.07, S.E. = 4.093) was significantly lower than that of the senior citizens' maps (65.51, S.E. = 4.59), $t(46) = -3.00$, $p=.0040$. For the aerial perspective, it can be suggested that young adults and senior citizens learned the environments equally well because there was not a significant difference between the young adults' maps (DI = 34.27, S.E. = 2.85) and senior citizens' maps (DI = 35.46, S.E. = 2.98), $t(46) = -0.29$, p=0.77).

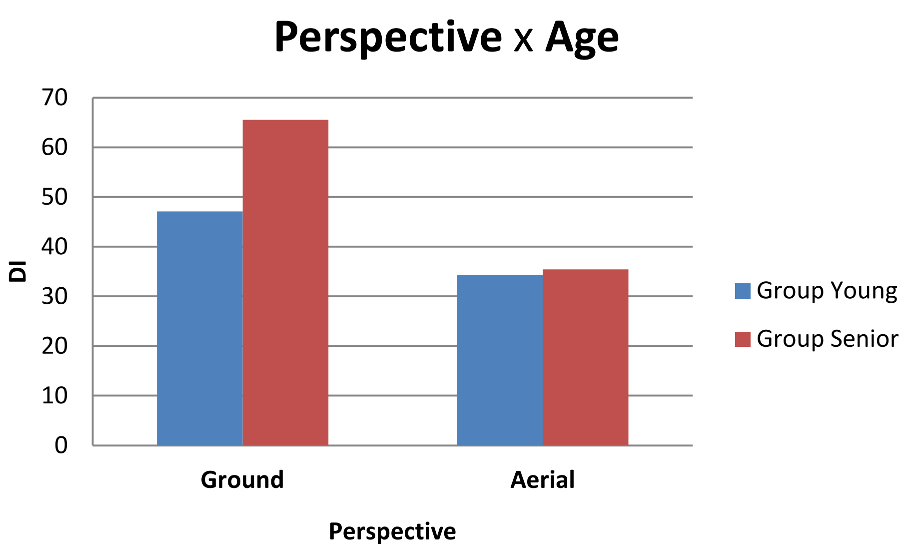

Figure 2. There was a significant interaction between perspective condition and age. Seniors performed significantly worse on the ground-level condition than the young adults and there was no significant difference on the aerial condition

The Order x Group interaction was not significant, $F(1, 46) = 2.197$, $p=.145$. For the young adult group's performance, the average DI on the sequential order conditions was 36.50 (S.E.=3.01) and the average DI on the random order conditions was 44.84 (S.E.=3.35). For the senior citizen group, the average DI on the sequential order conditions was 49.38 (S.E.=3.21) and the average DI on the random order conditions was 51.59 (S.E.=3.62).

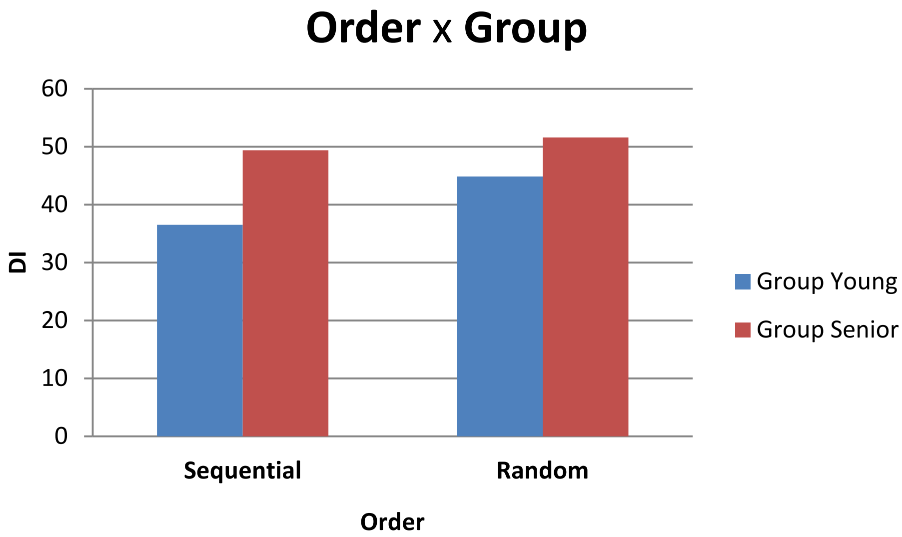

Figure 3. While there was not a significant interaction between order and group, there was a significant difference between groups on the sequential order condition

There was not a significant interaction between Perspective and Order, $F(1, 46) = .14$, $p = 0.71$. Because there was a priori hypothesis that the random presentation order would affect spatial learning from the ground-level perspective, paired-samples t-tests were also run to see if there were significant differences in performance between conditions. The data are presented in Figure 3. There was not a significant difference between the sequential ground-level and random ground-level conditions, $t(47) = -1.71$, $p=.094$, and between the sequential aerial and random aerial conditions, $t(47) = -1.69$, $p=.097$.

Figure 4. While there was not a significant interaction between perspective and order, people performed worse on the sequential ground-level condition than the sequential aerial condition, significantly worse on the random ground-level condition than on the random aerial condition, significantly worse on the sequential ground-level than random aerial conditions, and significantly worse on the random ground-level than the sequential aerial condition

There was not a significant Group x Perspective x Order interaction $F(1, 46) = 0.077$, p=.78, as shown in Figure 4.

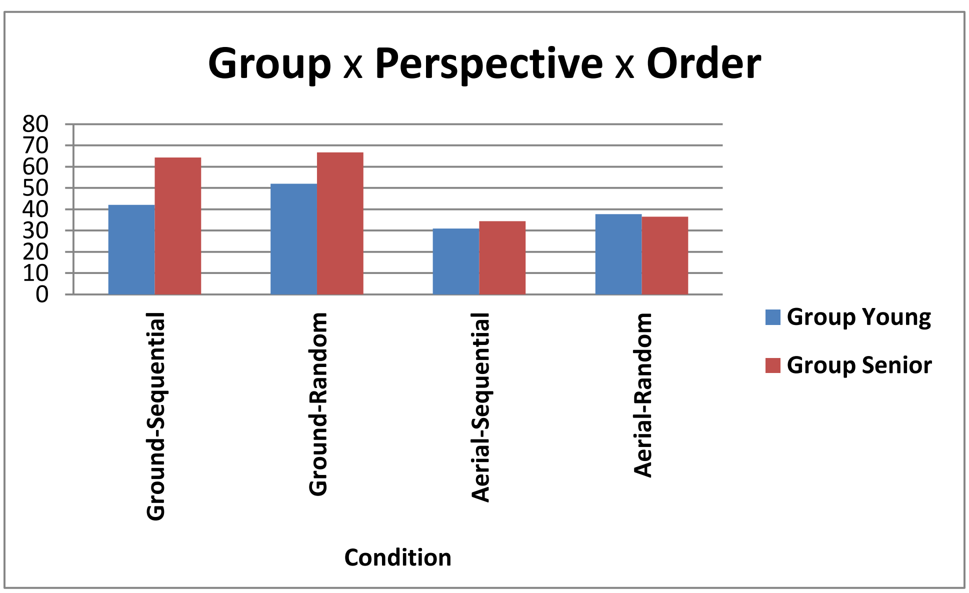

Figure 5. While there was not a significant 3-way interaction, there was a significant difference between groups on the ground-level sequential condition. There was not a significant difference between groups on any other condition.

CHAPTER IV

DISCUSSION

The results demonstrate that age impacts a person's learning ability on a spatial learning task and that the young adults were able to more accurately recreate maps of the environments presented in the ground-level perspective. There was not a significant difference between groups on the aerial perspective. Since the results demonstrated that the ground-level perspective was harder than the aerial perspective, it should not be a surprise that the seniors performed worse on this task, based on the results of Bo and Seidler (2010). This can be attributed to the atrophying of the hippocampus as we age (Golomb et al., 1993). As the hippocampus atrophies with age, people are able to store less information in their memory as the task's complexity increases, which would explain the senior group's higher average distortion index. It was also found that learning is influenced by the perspective that the environment is presented for both young adults and seniors. Participants had an easier time learning environments that were presented in an aerial perspective than in a ground-level perspective. What this would mean is that ground-level learning is more complicated than aerial learning.

Outside of this study's paradigm, if someone makes a mistake on a ground-level task, then that person runs a high risk of getting lost because he or she does not have a perspective of where the target location is in relation to the current location. On the other hand, the aerial view allows people to see the relationship between items (such as the distance between Object A and Object B and what direction one would need to go in to get from Object A to Object B). For aerial learning, a person can more easily compensate for a mistake by either examining the map to examine where the target location is in relation to the person's current location and the person can better discern an alternate route or how to get back on track. Within this paradigm, while participants could better see the spatial relationship between two objects, they could not see all aerial view at once. A future research project would need to see how different our aerial paradigm is from viewing the entire aerial layout at once.

The learning ability of participants was also significantly influenced by whether the legs of the environment were presented in a sequential order or a random order. Participants were more accurate when it came to creating maps of environments that were presented in a sequential order than environments that were presented in a random order. One possible explanation for this main effect is that the sequential order perspectives allow participants to easily construct a mental map because during each run of the movie, all four legs are presented in the same order and all of the landmarks are presented in the same order. On the other hand, in the random order conditions, the landmarks are presented in a different order each time the movie plays, which makes it more difficult for the participant to form a mental map of the environment. As mentioned before, there was not a difference between groups on the order conditions. One possible explanation is that while there was a main effect of order was large enough that participants performed significantly worse on the random order conditions, it can be suggested that the random order conditions were not complex enough for the senior citizens to perform significantly worse than the young adults on the random order conditions.

The focus of this study was to build upon Shelton et al.'s (2006) study. What was unique about the current study was that while Shelton et al. only tested young adults, this study tested both young adults and seniors. Some of Shelton et al.'s results were replicated in the current study. One portion that was replicated was that participants were better at creating the maps they learned from the aerial perspectives than those learned from the ground-level perspectives. They also were better at re-creating those layouts learned from the sequential order conditions than the random-order conditions. Another portion that was replicated was that participants had significantly more trouble re-creating the random ground-level condition than the two aerial conditions. One major portion that was not replicated was that while Shelton et al. did not find a significant difference in performance on the two aerial conditions and the sequential ground-level condition, this study found that participants performed significantly worse on the sequential ground-level condition than on the sequential aerial condition and the random aerial condition. It is difficult to pinpoint a specific reason for the different results, outside of potential population differences between the present study and Shelton et al's study. This does demonstrate the need for further research to better explain how perspective and sequence impact learning.

Overall, this study supports the finding of prior research that the ability to learn and recall information declines with age. Specifically, what the results imply for everyday life is that since participants have trouble learning a new environment through the ground-level perspective but not the through aerial perspective, it would be to a person’s advantage to bring a map with them when they are going somewhere new. This would be particularly true for senior citizens. The reason behind this claim is that since senior citizens performed significantly worse than young adults on the conditions presented in the ground-level perspective, they would be more likely to get lost in a new environment than young adults would. But if the senior citizens bring a map, they would be just as likely to find their way to their destination as a young adult who is using a map.

One potential confound in terms of age could be the type of senior citizens I had recruited. Since the seniors that I had recruited were taking courses at Cleveland State University, they could be more cognitively active than an average senior citizen. A potential side effect of this is that seniors who take college courses and have an extremely high level of cognitive activity could possibly be that they have better cognitive performance than the general population. In order to test to see if this is true, one possible future study could test a group of seniors who are not taking courses in order to compare and contrast the results to see if taking courses did have an impact on this study. Another issue is that senior participants were not screened for symptoms of dementia and other neurodegenerative disorders. It was assumed that since these seniors were taking college courses, their cognitive ability would be healthy for someone their age. Having a screening would make this study methodologically stronger and help demonstrate that the results are not due a neurodegenerative disease.

Another manner in which this study could be methodologically improved would be to include a measure that examines implicit learning. While re-creating the map had relied on implicit learning to a certain degree, it can be considered more of an explicit learning paradigm. In order to fully test learning, future studies could include a second test that would test implicit memory.

Another item to consider is how complexity impacts memory in the short time frame compared to a longer span of time. This study tests participants immediately after they viewed the condition. But what if the participants had time to process the information? If participants have more time to process the information, would the performance on the ground-level conditions and the random order conditions be different? One potential way to test how the amount of time to process the information impacts performance would be to test some of the participants immediately after they view the condition, a second group could be tested later in the day, and a third group could be tested significantly later (such as a week). A future study could use this paradigm to test a prediction of whether or not greater lengths of processing time would lead to a significant improvement on the difficult conditions. Another potential study could test to see how repeated testing impacts performance as complexity increases. For example, in the real world, it would make sense that people would struggle to learn and navigate around a novel environment from the ground-level. But one potential prediction that future study could examine is that as people are repeatedly tested within an environment, would their performance improve to the point that there is not a significant difference between the performance on the ground-level condition and the aerial condition?

Besides the potential future research projects mentioned, another possibility is examining how well patients with Parkinson's disease perform in the current paradigm. Research has shown that the basal ganglia are responsible for processing multiple sequential orders at the same time (Shin & Ivry, 2003). Based on this fact, it is not surprising that patients with Parkinson's disease struggle with sequential and procedural learning (Jackson, Jackson, Harrison, Henderson, & Kennard, 1995; Sarazin et al., 2002). It has also been found that participants who had Parkinson's disease had more trouble learning and navigating around an environment from a route-based perspective than age-matched controls (Uc et al, 2007). Ultimately, this study intended to lay the foundation for the comparison of the roles of the hippocampus and basal ganglia in spatial learning and how aging and deterioration of these structures impacts spatial learning.

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