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Effects of Orientation Change on Spatial Learning of Novel Environments on Younger and Older Adults

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EFFECTS OF ORIENTATION CHANGE ON SPATIAL LEARNING OF NOVEL ENVIRONMENTS ON YOUNGER AND OLDER ADULTS

MICHAEL J. FOX

ABSTRACT

Yamamoto and DeGirolamo (2012) found that increasing age has unequal effects of impairment on spatial learning dependent on the perspective in which an environment is learned. Further, the learned condition of ground-level perspective (first-person exploratory) showed greater decline in elderly participants than was found in aerial (map reading) conditions. These results supported previous research involving fMRI scans implicating the medial temporal lobe (MTL) role in exploratory navigation of novel environments and MRI scans indicating MTL atrophy with age. However, Yamamoto and DeGirolamo (2012) did not consider the effects of conducting the experiment with one condition being presented with changing orientation (ground-level) and the other condition having fixed orientation (aerial). Utilizing new research revealing the MTL's role in orientation processing, the present study reexamined Yamamoto and DeGirolamo (2012) findings with the introduction of the condition aerial-with-turns (map reading with changing orientation). The findings of this experiment suggest changing orientation in the learning condition has greater impact on elderly participants' performance of spatial learning tasks than that of the perspective in which the learning condition is in.

Keywords: aging, spatial learning, navigation, map, ground-level, aerial, route, survey, orientation, aerial with turns

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CHAPTER I

INTRODUCTION

The adverse effects of normal and pathological aging on spatial learning have now been well documented in the scientific literature (Moffat, 2009; Vlcek,2011). Spatial learning is the successful recording and recalling of information about the environment that allows one to learn locations within that environment. Spatial learning allows us to navigate from one point in space to another with minimal error. This area of research is still in its infancy and further experimental exploration is needed into the phenomenon of aging on spatial learning if it is to become a fundamental understanding of lifetime cognitive development. At this time, the discrepancy between elderly and the younger adults are well noted (Iachini, Iavarone, Senese, Ruotolo, and Ruggiero, 2009; Moffat, 2009; Vlcek, 2011) but only recently has the psychological mechanism behind age correlated decline in spatial learning been examined. The present study seeks to expand previous work done by identifying the basis in discrepancy between the performance of aerial and ground-level navigation learning in younger adult and elderly adult populations in the experiment conducted by Yamamoto and DeGirolamo (2012). Specifically this study sought to address the role of orientation in perspective on spatial learning and age to compare and contrast learning ability on perspective differences and orientation change between younger and older adults.

1.1 Defining Perspectives

A few factors of spatial learning include complexity of route (Thorndyke, 1981), number of alternative routes (Thorndyke, 1981), landmarks (Siegal and White, 1975), as well as the perspective and orientation in which the route is learned (Shelton and McNamara, 2004). The focus of this study is on these last two factors, perspective and orientation. Due to this focus of perspective and orientation it is important to control for these other aspects of spatial learning. As with all areas and fields of research, it is necessary to establish definitions of the language used in these studies. *Ground-level* perspective refers to exploratory navigation in the first person or ground level observer, this perspective is also commonly referred to as *route* perspective. In this perspective, orientation is constantly changing in reference to the local environment. Turns in space re-orient the perspective in regards to environmental landmarks and thus are constantly updated within exploratory navigation learning conditions. It is analogous to navigation in the "real" world. *Aerial* perspective refers to an aerial view of an environment and typically has a fixed orientation of an environment (i.e., North as up) and is also commonly referred to as *survey* perspective. This perspective is analogous to map reading as it often provides a global view of the layout (Shelton and Gabrieli, 2002).

Initial research into spatial memory and the influence of ground-level and aerial on orientation specific learning conditions was conducted by Shelton and McNamara (2004). In these experiments it was determined (using measures of accuracy and latency) that participants were best at recognizing scenes that were used in the initial learning condition. Those who learned ground-level perspective were faster on ground-level recognition than aerial information and vice versa. This experiment also initially implicated the role of orientation. For the purpose of the present thesis, the vital contribution presented from the Shelton and McNamara (2004) studies are the Methods and Procedure used to examine the role of orientation change in spatial memory. Ultimately this experiment revealed a cognitive cost to perspective change from study to test, that memory recall is faster when there is the same orientation and same perspective as the learning condition, and a strong learning preference in initial orientation in recall of landmarks within an environment.

1.2 Orientation during Navigation

Further research on navigation and aging has shown that orientation of a learned environment does affect spatial processing, and has identified the medial temporal lobe as a central brain structure in processing orientation changes of spatial learning (Shelton and Pippitt,2007). Ground level (route) and aerial (survey) encoding are processed differently when learning novel environments, however it is not entirely clear which dimensions of these account for the difference between these two modes of environment learning. Shelton and Pippitt (2007) examined two of these dimensions using virtual space and fMRI technology to study brain activation in learning and retrieval of novel environments. It is required to isolate the dimensions of spatial learning when seeking to discover the functional neural model that differentiates aerial and ground-level learning. It is particularly necessary to separate perspective (aerial vs ground level) and orientation. One difficulty is that ground-level constantly incorporates orientation change as one moves through an environment, it is almost vital to the experience of first person perspective while navigating any environment, novel or known. In order to account and counter for this Shelton and Pippitt (2007) used a third variable called "aerial-with-turns" which was also used in the present study. The aerial-with-turns condition is the perspective of the aerial (map-like) condition with dynamic orientation at each turn of navigation through the environment. It was predicted and confirmed that learning an environment from a perspective with aerial-with-turns would create greater facilitation for aerial perspective recognition over ground level, and that aerial-with-turns would show preference for multiple preferred orientations for recognition based on the changing orientation of each leg of the path. The second experiment then utilized fMRI scans to determine which level of activation occurred when presented aerial-with-turns encoding compared to ground level and aerial encoding. If the activation of the aerial-with-turns condition matched that of aerial condition activation it would indicate that those areas are related to perspective encoding information of novel environments. If, however, the activation shown by the fMRI more closely resembled the activation seen in the ground-level encoding, this would indicate areas of encoding for orientation change in the brain. Results revealed that the aerial-with-turns condition had closer activation patterns with the ground-level condition in the hippocampus/parahippocampal cortex and poseterior cingulate cortex. This suggests that not only are these areas within the medial temporal lobe vital for ground level condition, but they also are responsible for encoding orientation changes during learning of novel environments. It was found that activation of the aerial-with-turns condition resembled fixed aerial encoding condition in the anterior superior parietal cortex and the posterior superior parietal cortex, as well as the fusiform gyrus, and the right cuneus. This similarity indicates areas of the brain related to perspective encoding in novel spatial environment (Shelton and Pippett, 2007). The results of this experiment indicate that orientation factors and perspective factors are encoded differently in different brain regions; this also provides explanatory value to previous results. Previous experiments have demonstrated that there is greatest facilitation of recall when testing conditions match both orientation and perspective of the learned condition which can now be accounted for by these two brain regions matching in retrieval with encoding conditions (Shelton and McNamara, 2004). The greater the match in the test condition stimulus to the initial encoding stimulus the greater the facilitation in recognition.

1.3 Neurophysiological effects of Aging

Research on the neurophysiological basis for the proposed experiments and effects of aging must also be examined to develop a secure understanding of the presented hypothesis. Attempts to identify the neural basis of spatial navigation and the effect of aging - both normal and pathological - have implicated an extensive network with in the brain. This network includes the hippocampus, parahippocampal gyrus, medial and right inferior parietal cortex, cerebellum, and parts of the basal ganglia (Vleck, 2011). The hippocampus is identified as the neural basis for cognitive maps as originally outlined by O'Keefe and Nadel in 1978.

A number of studies have shown that there is decreased volume of the hippocampus in older adults (Jack, Jr., Petersen, Xu, Waring, O'Brien, Tangalos, Smith, Ivnik, and Kokmen, 1997) but other studies reveal conflicting results (Van, Plante, Davidson, Kuo, Bajuscak, and Glisky, 2004). One study examining the effects of non-pathological hippocampal atrophy on working and long term memory in those older than

55, found that those with atrophied hippocampi performed worse on long-term memory tasks but that there was no difference in working memory tasks (Golomb,Kluger,George, Tarshsih, and Ferris, 1993). There is decreased activation in the MTL between younger and older adults during the encoding process (Grady, McIntosh, Horwitz, Maisog, Ungerleider, Mentis, Pietrini, Schapiro, and Haxby, 1995). It has less to do with actual volume of the medial temporal lobe and more with activation levels while learning and recalling. Of particular research interest in this area is that of the effects of pathological aging on the MTL and what that means for navigation.

1.4 Current Examination

Yamamoto and DeGirolamo (2012) successfully demonstrated the discrepancy between younger and older adults ability to learn landmark locations in which landmarks were presented in the first person perspective. The experiment examined differences between aerial perspective versus ground-level perspective learning on older and younger adults. Yamamoto and DeGirolamo (2012) combined information revealed by Shelton and Gabrieli (2002) in regards to the medial temporal lobe's role in ground-level perspective encoding, with research indicating medial temporal lobe atrophy as a natural phenomenon of normal, healthy aging. This experiment predicted that elderly participants would show less accuracy than younger participants in the ground level encoding condition. The results of the experiment confirmed this prediction and also indicated that there was no difference between experimental groups in the aerial perspective encoding condition. Yamamoto and DeGirolamo (2012) were the first to look at the effects of aging on aerial and ground-level perspective side by side, and they concluded that learning through map reading is better maintained through the aging process than first person perspective navigation. However, learning through map reading may still be susceptible to age related decline.

The major issue, and the focus of the present thesis, is that it remains unclear from the previous work presented by Yamamoto and DeGirolamo (2012) what role orientation change plays in the processing of novel spatial environments. The influence of orientation on encoding and recall with aging has yet to be determined. In this previous experiment, ground-level perspective had varying orientation while the aerial perspective remained at a constant, unchanging orientation (north as up), possibly confounding perspective (ground-level/aerial) and orientation (variable/fixed). Yamamoto and DeGirolamo (2012) ultimately attributed the findings to differences in perspective. However, results from Shelton and Pippitt (2007) suggest that orientation may carry stronger explanatory value in explaining the difference between younger and older adults in these tasks.

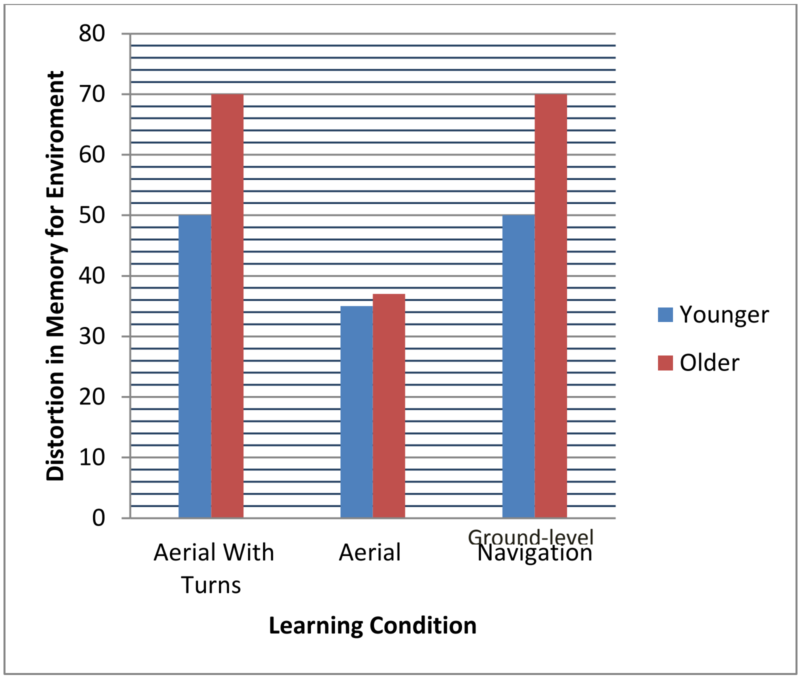

Figure 1 Predicted Results The expected results for implicating orientation as the stronger effect on spatial learning decline in older adults. Higher distortion values indicate poorer reconstruction of environment.

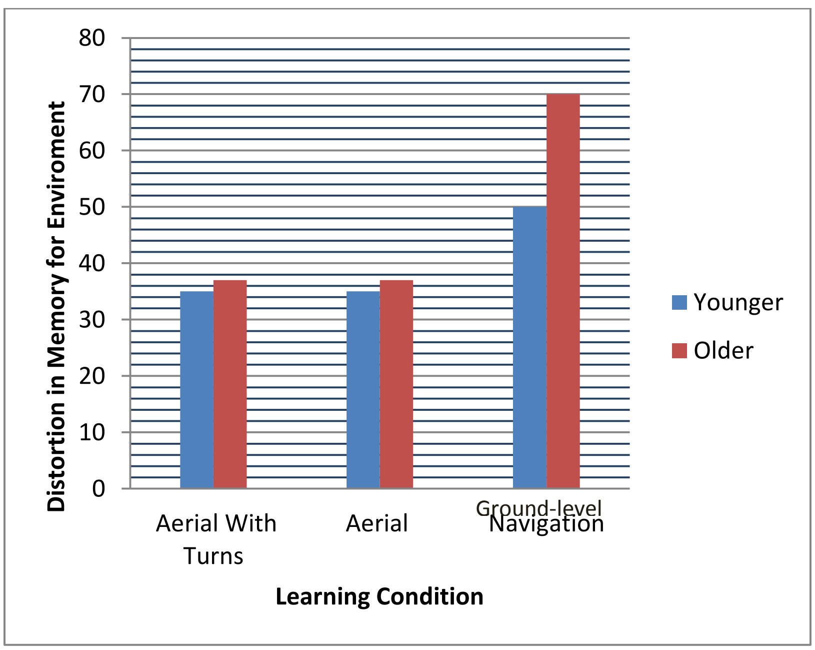

Figure 2 Possible Alternative Results The expected results for implicating perspective as the stronger effect on spatial learning decline in older adults. Higher distortion values indicate poorer reconstruction of environment.

Adapting the methods and procedure of Yamamoto and DeGirolamo (2012) to include the aerial-with-turns condition experienced in Shelton and Pippitt (2007), the hypothesis of the present experiment, shown in Figure 1, suggests that orientation change would account for the greatest amount of variability rather than perspective (shown in Figure 2) between older and younger adults during the reporting of learned, novel, virtual environments. More specifically, it was expected that learning an environment in the aerial-with-turns condition would show similar results as that when learning in the ground-level condition because of the role of dynamic orientation within both conditions. This prediction is supported by Shelton and Pippitt (2007), in which fMRI scans revealed similar patterns of activation in the MTL during aerial-with-turns and ground-level conditions.

However, in aiming to distinguish the roles of perspective and orientation, by introducing the aerial-with-turns condition experienced in Shelton and Pippitt (2007), it would be possible that the aerial-with-turns condition's dynamic orientation would not be affected by spatial learning decline. Resultantly, the alternative hypothesis, shown in Figure 2, expects that learning an environment in the aerial-with-turns condition would show similar results in older adults as that when learning in the aerial condition because of the role of perspective within both conditions. This result would indicate that it is not the changes in orientation while an environment is learned that affects the non-pathological aging population's ability to reconstruct learned environments, but, rather, it is the decline in ability to encode ground-level perspective.

1.5 Utilization of Virtual Environments

Finally, in order to understand the research methodology and the proposed experiment's validity it is crucial to first examine the role of Virtual environments (VE) in previous navigation studies. Virtual environments' testing has been shown to be a valid way of evaluating navigational skills. For example, Cushman, Stein, and Duffy (2008) examined results from real world and computer generated environments in younger, normal aged elderly, and pathological aged elderly who specifically were suffering from dementia. It was found that there is an identical pattern of results with strong correlation between real and VE tests across all groups.

The greatest strength in utilizing VE is that of the regulation it affords; environments can be precisely controlled, objects specifically manipulated, and results of experiments precisely recorded. Studies before Cushman et al. (2008) also suggested that despite lack of actual movement through an environment, spatial knowledge acquired through navigating transfers to real world application (Kalova,Vlcek, Jarolimova, and Bures, 2005). Furthermore Ruddle, Payne, and Jones (1997) examined the formation of cognitive maps from VE compared to real world environments and found throughout the formation process the cognitive maps were close to identical.

Despite its apparent validity, researchers must be mindful of utilizing this type of technology with older adults. As a result, adequate practice to help reduce discrepancies in familiarity with technology between experimental groups must be provided. Additionally, various visual and motor impairments in the elderly must be controlled for as well as possible.

1.6 Summary

Utilizing the research presented above, this experiment was conducted under the prediction that orientation change will present itself as accounting for the greatest amount of variability in reporting of learned, novel, virtual environments between older and younger adults. This prediction is supported by the fMRI scans conducted by Shelton and Pippett (2007) showing similar patterns in activation of the MTL in aerial with turns condition as were found in ground-level conditions. Combining this research along with the work of Yamamoto and DeGirolamo (2012) this experiment seeks to provide greater insight into the effects of aging and the role of orientation change on spatial learning.

CHAPTER II

METHODS

The present study examined the effects of orientation change on spatial recall in both younger and elderly participants using virtual environments and simple recall tasks. It was expected that older adults would be less accurate on recall tasks when the learning condition includes environments with changing orientation than their younger counterparts. It was also predicted that older and younger adults would show equal or close to equal accuracy when recall is of non-orientation changing learned condition. The reasoning and research supporting this prediction is as discussed above.

2.1 Participants

Two groups of participants were recruited (n=18 in each). The first group was comprised of enrolled undergraduate students at Cleveland State University. Within this group there were four males and fourteen females. The average age for this group was 19.7 and the range of ages were from eighteen to twenty-five.

The second group consisted of healthy senior citizens who were above the age of 60 years old. These participants were recruited from Cleveland State University's Project 60 enrollment and from the Cleveland Heights Community Center. In this group there were twelve males and six females. The mean age for this group [68.4] had a range of sixty to eighty-four. Participants from each group were screened for dementia using the St. Louis University Mental Status (SLUMS) exam (Tariq, Tumosa, Chibnall, Perry, & Morley, 2006; the exam is available online at http://aging.slu.edu/index.php?page=saint-louis-university-mental-status-slums-exam). Young and older participants showed similar scores overall, with older adults scoring higher than younger adults (younger: M = 25.5, SE = .648; older: M = 28.5, SE = .364). Following the assumption that younger adults were all cognitively healthy undergraduate students, this suggests that all participants were cognitively healthy. Mean scores for these SLUMS did reliably differ between groups $t(34) = -4.037$, $p < .001$. Average age was significantly different between the two groups, $t(34) = -30.95$, $p < .001$. The number of females to males within each group was also significantly different, $\chi^2(1) = 7.2$, $p = .007$. Gender effects were not examined for this experiment. Participants received either monetary compensation or partial credit in a psychology course for their participation. Also all participants were either native or fluent English speakers and had normal or corrected to normal vision.

2.2 Materials

The experiment utilized three virtual environments used in previous research, each of the same size measuring 110 x 130 ft in virtual space. These environments were displayed on a desktop computer using the PsychoPy program (Peirce, 2009). Each environment was visually distinct from each other, and each contained 10 large landmarks and seven small objects in a unique location. These environments included a convention center, a park, and a market along with respective relevant landmarks. Each environment was presented in either a ground-level, aerial, or aerial-with-turns condition.

Each environment controlled for complexity of route, the number of alternative routes, and the length of routes which allowed for the isolation of the specific role that perspective and orientation play in spatial learning. All environments were viewed sequentially from the starting point.

2.3 Procedure

2.3.1 Conditions. Each participant viewed three environments, one in each of the three conditions. In the ground-level condition, participants viewed the environment from the perspective of a six-foot- tall observer walking through it. In the aerial condition, participants viewed the environment from the perspective of an observer 70 feet above the ground looking straight down without changing orientation (aerial-without-turns). In the aerial-with-turns condition, participants viewed the environment with changing orientations (aerial-with-turns). In all conditions, approximately 2-3 landmarks were visible in their entirety at any one scene. The walk-through of the environment began at the southwest corner and proceeded clockwise along the perimeter of the environment. At each corner of the ground-level or the aerial-with-turns environment the observer made a 90 degree turn to face the new direction of travel. There was no orientation change for the aerial condition's corners. Figure 3 provides an example of the turns. It needs to be noted that in aerial-without-turns the observer maintains the initial orientation within each environment. However, aerial-with-turns follows a similar orientation as changes seen in the ground-level navigation condition. The addition of the aerial-with-turns condition allows for the isolation of orientation change in spatial learning from perspective.

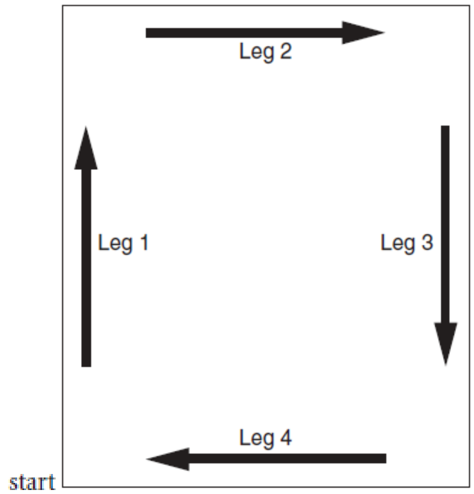

Figure 3 Visualization of Procession Directional procession of the environments started in the bottom left corner of each environment and preceded clockwise.

2.3.2 Design. The primary independent variable was the two participant age groups, younger adults and older adults. The other major independent variable was the type of spatial condition; aerial, aerial-with-turns, and ground-level conditions. These spatial learning conditions were within subject factors, while the ages of the two groups were between subject factors. The dependent variable was the Distortion Index (DI) based on the recall of landmark locations from the three different environment conditions.

2.3.3 Learning Trials. Participants were instructed to learn the locations of the 10 landmarks for memory test that would take place later on. As part of the instruction, participants were shown a diagram of the overall shape of the environments indicating the four legs of the virtual space taken in clockwise direction. The participants were also given instructions about the three possible conditions the environments might appear in: ground-level navigation, aerial condition, and aerial-with-turns condition. These instructions were presented visually and participants initiated the trial by hitting the spacebar. On the first run of each environment the 10 landmarks to be learned were identified by the experimenter. The screen grayed and participants were instructed to hit the spacebar to initiate the experiment. Participants then viewed 6 runs of the environment. Each run of the environment took approximately 40 seconds. After learning the environment, participants were presented a magnetic dry erase board with paper clipped to it, on which a rectangle representing the perimeter of the environment had been drawn to scale (17.92 x 21.18 cm). It also indicated the southwest corner of the environment as the starting point for navigation in each of the environments. Participants were asked to recreate the environments layout within the rectangle using magnetic disks and labels. Participants were free to turn the board and were provided with 10 identical magnetic disks each 2 cm in diameter to mark the landmarks within the rectangle. Each landmark's name was also provided to show which disk corresponds to which landmark. The participants were given unlimited time to complete the task and may place landmarks in any order. No error feedback was provided. Following the completion of these tasks participants were presented with a new environment and they repeated the procedure until all three environments were completed. The orders of the three conditions were completely counterbalanced over participants. Three environments were randomly assigned to each condition with the constraint that (a) each environment appeared in each position of the sequence with equal frequency and (b) a given environment would be preceded and followed by two other environments with equal frequency. This was achieved by using the Latin square technique (Williams, 1949). It is important to note that the three test environments were designed to be equivalent in both difficulty and structure so that only the themes varied between each environment, thus there was only need to partially counterbalance the order of the environments shown.

2.4 Measures

The dependent measure for this experiment was an evaluation of accuracy of participants' reconstruction of the landmark layout within the environment. The accuracy was measured using a Distortion Index (DI), in which the reconstructed layouts were translated, rotated, and linearly scaled so that the reported layout matches the actual layout as much as possible. The best-fit layout can be uniquely determined by using the least square method. The regression coefficients associated with this transformation are then used to generate a DI value. The DI value is a measurement of the overall accuracy of the reconstructed layout after the translation, rotation, and scaling is accounted for. This quantifies the spatial distortion of the created map from the original. The DI is a value ranging from 100 to 0 with 0 being accurate reconstruction and 100 being the case in which all landmarks are placed on one point on top of each other (Tobler, 1994; Waterman & Gordon, 1984).

CHAPTER III

RESULTS

Distortion Indices were taken for each participant along with means and standard deviations for each age group and each learning condition. DIs were then evaluated with a mixed ANOVA with group (younger vs older adult) as a between-subject factor and learning condition (aerial vs. aerial-with-turns vs ground-level conditions) as a within-subject factor.

There were a total of four outliers that fell outside the range of two standard deviations from the computed mean DI values of each age group for each condition; however the exclusion of these participants' data did not change the finding, thus they were left in for the final analysis.

For the young adult group the average DI for ground-level condition was 40.57 (S.E. = 5.657), for aerial the average DI was 24.78 (S.E.=2.035), and for aerial-with-turns the average DI was 34.69 (S.E. = 4.599). For the older adult group the average DI for ground-level condition was 52.73 (S.E.= 6.685), for aerial the average DI was 39.56 (S.E. = 5.523), and for aerial-with-turns the average DI was 53.33 (S.E. = 5.97). These means are shown in Figure 2.

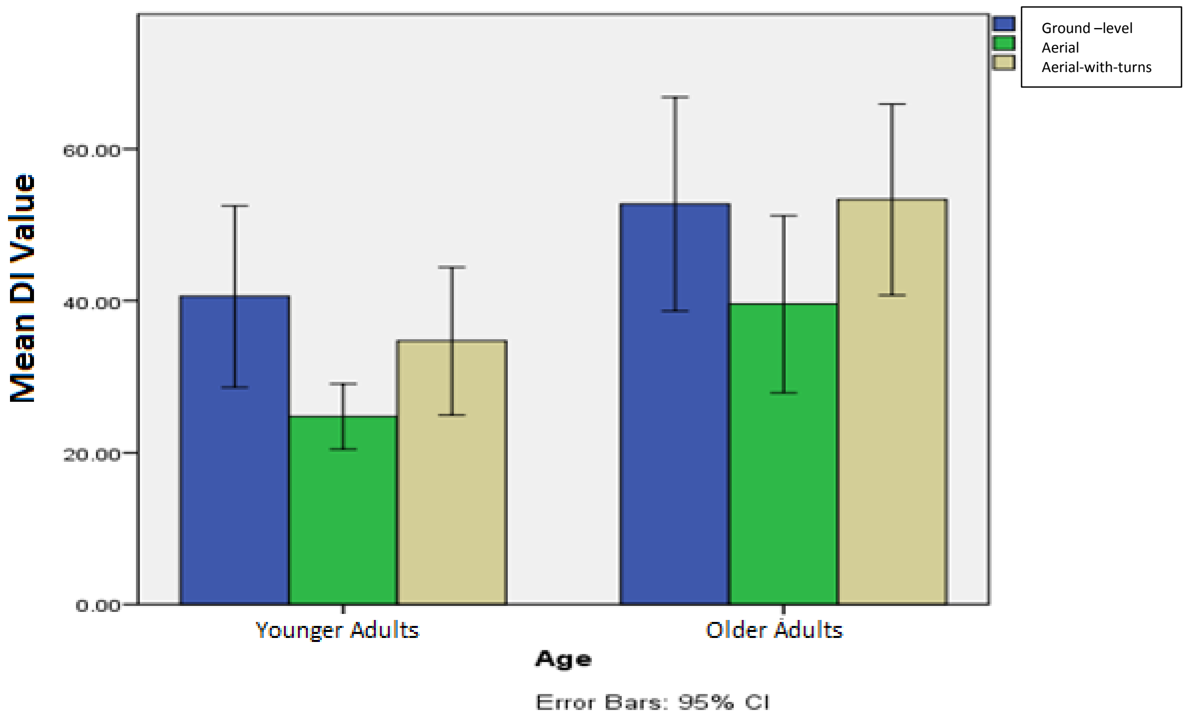

Figure 4 Mean DIs of Age Groups Mean DI values for each condition are shown for each age group to show comparison between group performance on environment reconstruction. Error bars show the 95% confidence interval of performance for each condition.

Overall performance of young adults (33.4, S.E.=3.18) was significantly better than older adults (48.5, S.E.= 3.18) $F(1,34) = 11.4$, $p = .002$, $\eta_p = .25$. It was also found that DIs were significantly different in the three conditions $F(2,34) = 4.43$, $p = .016$, $\eta_p = .12$; mean DIs shown in Figure 4 suggest that there was a similar performance for ground-level condition and aerial-with-turns condition but that environments in these conditions were both less accurately recalled than environments presented in the aerial condition.

There was no significant interaction between Perspective and Age $F(1,34) = .198$, $p = .821$, $\eta_p = .006$, suggesting that performance of younger and older adults was varied by the three learning conditions in the same way.

CHAPTER IV

DISCUSSION

The expected result that elderly adults would show similar patterns in accuracy for the aerial-with-turns condition and the ground-level condition was confirmed. This implicates that it is not perspective as previously thought, but rather orientation change processing that declines with natural (non- pathological) aging. This is supported by the findings in the experiments conducted by Shelton and Pippitt (2007). The fMRI scans conducted revealed similar activation levels for environments involving aerial-with-turns and ground-level conditions in the MTL, suggesting that it is orientation change that is processed by the MTL and not the perspective an environment is learned in. The alternative hypothesis predicted that aerial-with- turns would show results similar to those found with aerial-without-turns, which would confirm previous research conducted by Yamamoto and DeGirolamo (2012) in that it is perspective processing that declines with age. The present findings demonstrate that this alternative hypothesis is most likely incorrect.

The results of this experiment also show that although both main effects of age and perspective are significant, there is no significant interaction between age and perspective. This suggests that although age and the learning perspective affect spatial learning, there is not a significant decline in learning one perspective over another with age. However, the results of this experiment are supportive of the hypothesis based off Shelton and Pippitt (2007) that the aerial-with-turns condition would be more similar to the ground-level condition as opposed to aerial condition.

The main effect of age having significance suggests and corroborates previous findings that as humans age some cognitive abilities decline, specifically learning of novel environments. The main effect of perspective having significance also suggests and corroborates previous findings that learning of an environment is influenced by the perspective it is learned in. Although there was no significant interaction between Age and Perspective, comparative means suggest that aerial-with-turns condition is most similar to ground-level condition.

For both groups of participants aerial was the most accurately reported condition. This finding of aerial condition being the easiest (lowest DI value) has been found in past studies (Yamamoto & DeGirolamo, 2012). The significance of perspective main effect indicates that participants were better at learning the presented environment in the aerial condition than the other conditions, suggesting that ground level and aerial-with-turns are more complex. Also replicated from previous studies is the generally higher DI values of older adults compared to younger adults, which may be accounted for by normal aging causing atrophy and weaker activation of the hippocampus. The present research, however, does conflict with previously conducted experiments, mainly Yamamoto and DeGirolamo (2012) which found significant interaction between age and perspective learning conditions. The largest discrepancy between the present study and Yamamoto and DeGirolamo (2012) were that in previous research younger adults did worse overall on the aerial condition compared to the present study and that older adults from the previous research performed worse overall on the ground-level condition than older adults in the present study. This may be accounted for by a number of reasons. Though difficult to isolate the exact cause of discrepancies between this study and previous studies, it is most likely to be unique sample differences between the present study and previous research. Specifically, finding marginal significance that elderly performance for the aerial condition was worse than younger adults points to unique differences to this study's sample. One explanation may come from studies indicating loss of proficiency of map reading ability in elderly adults when compared to younger adults (Meneghetti, Fiore, Borella, & De Beni, 2011). Another major limitation of this study was that the male/female ratio was significantly different between two age groups. As a result of this limitation it may be advantageous to re-examine this study with a larger sample size to eliminate any possible gender confounds. Ultimately, further research is needed to resolve these discrepancies between studies.

It was predicted that the experiment would demonstrate older and younger adults would perform equally well on the aerial condition, further corroborating the findings of Yamamoto and DeGirolamo (2012). However, this was not the finding of the present study. This makes it difficult to confirm that these differences in performance between the elderly and younger adults are not the result of slower processing or less technological familiarity. Presentation and procedure were held constant between groups to control this aspect of concern.

This study sought to investigate whether or not the effects of aging on spatial learning as reported by Yamamoto and DeGirolamo (2012) are the result of perspective differences (ground level vs. aerial) or orientation changes (aerial vs. aerial-with-turns) during encoding. Building from extensive previous research it was predicted that fixed orientation vs. changing orientation are more likely to account for the results found in Yamamoto and DeGirolamo (2012) than the ground-level vs. aerial perspectives. On the basis of research which has shown high levels of MTL activation during first-person perspective encoding as well as during aerial-with-turns condition encoding , it is likely that the MTL is responsible for incorporating orientation change into encoding. Further noting that the MTL is particularly susceptible to age related atrophy, it was hypothesized that elderly adults would perform worse on both the first-person ground-level condition and aerial-with-turns condition then their younger counterparts. Despite not finding significant interaction, a trend of similar results found between ground-level condition and aerial-with-turns rather than between aerial and aerial-with-turns suggests that though different types of spatial learning may not be affected differently by aging, the mechanism for incorporating orientation change may be affected by MTL atrophy and decreased activation associated with non-pathological aging.

This understanding of the effect of aging on orientation change processing provides new insight on caring for a growing aging population in the United States and abroad. The implication of this research suggests a new evaluation of minimizing disorientation in new environments and the risk that comes with that disorientation. With stronger supporting research, medical professionals may need to advise patients of this phenomenon and make recommendations on how to minimize this risk, such as choosing paths with the fewest number of orientation changes and planning the trip out on a physical map before embarking to a new area (and then following the plotted path exactly). This also may have architectural implications for everything from shopping malls to nursing homes, which should minimize the number of orientation changes needed to navigate through them in order to minimize the risk of confusion, disorientation, and the emotional and cognitive strain that arises when one is found in that situation.

What remains to be determined from this study is the role of transforming perspectives when reporting learned environments. In this experiment, participants reported landmarks from the learned environment on white boards that resemble a map grid, as they did in Yamamoto and DeGirolamo (2012). Thus, regardless of whether or not the learned condition was ground level or aerial, reporting was conducted in an aerial-esque fashion. It is possible that this transformation of perspectives had an impact for the older adults and is not simply related to a difference in perspective encoding, though the results suggest orientation change as a major factor. Although similar results from ground-level and aerial-with-turns conditions indicate that perspective difference between learning condition and reporting is not likely to be a factor in the present paradigm, further experiments are needed to confirm this conclusion.

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