WAYFINDING STUDY IN VIRTUAL ENVIRONMENTS: THE ELDERLY VS. THE YOUNGER-AGED GROUPS.

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Abstract
This study aims to examine the impact of architectural wayfinding aids on wayfinding performances in comparison of the elderly group and the younger-aged group. An ambulatory healthcare facility was simulated using Virtual Reality (VR) to develop two levels of wayfinding aids for the same environments. The base model included minimal wayfinding aids, and the design model included more wayfinding aids. The VR environment was presented in the form of video in order to test wayfinding performances at three different wayfinding decision points. Results showed that age and wayfinding aids impacted wayfinding performances. The younger-aged group performed wayfinding better compared to the elderly group. Participants who were tested in the design model were more successful in wayfinding compared to the elderly group. The elderly group reported that more salient wayfinding aids such as a big logo and paint colors helped their wayfinding while the younger-aged group reported less salient aids such as door designs as helpful wayfinding aids. When there were minimal wayfinding aids, the elderly participants needed to rely mostly on memory recall by remembering turns or paying close attention. When participants felt that the wayfinding test was difficult, their performances were less successful. Findings in this study suggest that wayfinding design for the elderly should consider the limited ability of recall and therefore, design wayfinding aids more frequently with more salient aids to avoid confusion. The elderly group needed to rely on their limited cognitive ability when there were not enough wayfinding aids, which make them experience difficulties in wayfinding.

Keywords
Elderly; healthcare; virtual reality; wayfinding.

Introduction
As technology in Virtual Reality (VR) advances, it has been used in various areas of architectural design and research (Lee, 2009). One of the areas that researchers have utilized VR vigorously is wayfinding studies. Wayfinding is spatial problem solving that is comprised of three processes: decision making, decision executing, and information processing (Arthur & Passini, 1992). As Arthur and Passini (1992) pointed out, designers should understand how users perceive, interpret, and process the space and information in wayfinding decision-making and execution. It is not likely that building users would be able to experience and evaluate architectural design before it is designed and built. The sequential activities in a building such as wayfinding are especially difficult
to experience prior to building construction. Studies using VR have helped researchers and designers understand the issue of wayfinding as it enables people to experience the design before the construction.

Wayfinding in healthcare facilities is particularly important and requires more attention because navigating through healthcare facilities can be a frustrating and stressful experience for patients and their families who arrive at facilities already distressed or physically weak. It becomes a more critical issue for the elderly, who tend to have limited mobility and vision compared to younger people. As the baby boomer generation ages, it will steadily join the senior population, which needs more medical care. It is estimated that the senior population (65 and older) will be more than doubled to 86.7 million in 2050 (U.S. Census Bureau, 2008). Considering this trend, it is important for healthcare designers and administrators to understand the needs of this particular group. However, there is very limited information available for healthcare designers to plan in order to satisfy this user group.

Another trend in the healthcare industry is the increase in ambulatory healthcare facilities. For the last 50 years, the healthcare industry in the U.S. has gone through many changes, including constant expansion. Recently, the transformation of the healthcare industry is primarily internal reconstruction rather than building new facilities and additions, with the exception of ambulatory healthcare (Verderber & Fine, 2000). Now, outpatient surgery, diagnostic and testing centers, and free-standing urgent care centers offer services that were previously provided only at larger hospitals (Carpman & Grant, 2001). The statistics from the U.S. Department of Labor’s Bureau of Statistics support this trend. The ambulatory healthcare service establishments in the U.S. reached 87.3 percent in 2008 (Bureau of Statistics, U.S. Department of Labor, 2010). Building codes have adopted this growth in ambulatory healthcare as well. The International Building Codes (IBC) 2009 has added sections for “ambulatory health care” occupancy to improve occupant safety. Although the growth in ambulatory healthcare facilities is reflected in many areas, research in this area is still limited in number (ICC, 2009).

The primary purpose of this study is to explore the impact of architectural wayfinding aids in wayfinding performances in comparison of the elderly group and the younger-aged group using simulated VR environments. This study has several specific objectives. First, this study is to examine how physical environmental factors affect wayfinding decisions when people determine directions at various choice points while wayfinding. Secondly, this study is to compare wayfinding behaviors between the elderly group and the younger-aged group in order to find the elderly people’s unique wayfinding characteristics. This study used VR to test subjects’ wayfinding performances in different physical environmental conditions.

**Wayfinding for the Elderly**

Wayfinding, the ability to find one’s way without getting lost (Passini, Rainville, & Marchand, 1998) is an important part of everyday living. Wayfinding requires a wide range of cognitive abilities (Spiers & Maguire, 2008). The ability to make use of long-term spatial memory is most critical in guiding wayfinding. The formulation
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of a cognitive map allows the user to store and recall information about his/her environment. The advancement of age is associated with the deterioration of cognitive abilities, directly affecting the user's ability to find their way in an environment. This aging process includes physical, psychological, and social changes (Satariano, 2005). Changes in the brain that are caused by aging occur in areas primarily involved with spatial abilities (Salthouse, Mitchell, Skovronek, & Babcock, 1989). In addition, there are changes in sensory systems while people age, such as decreased visual acuity and contrast sensitivity which directly affect how the environment is perceived (Faubert, 2002). Senior citizens are more likely to experience fatigue, slower reaction time, memory loss, and confusion (Satariano, 2005). Older individuals' capabilities to distinguish change in an environment are no longer an ordinary task, but it becomes, rather, a challenge. As studies on wayfinding and the elderly suggest, changes from the aging process make the elderly people have more difficulties in wayfinding.

Head and Isom (2010) examined age effects on spatial navigation abilities considering the multiple cognitive and neural factors that contribute to successful navigation. Results showed that aging was associated with lower ability in recall of landmarks that were encountered in the environment as well as difficulty with identifying landmarks that were marked on the map. This study suggests that older individuals have deficiencies in their cognitive map formation and recall. Older adults who have more severe cognitive impairments, such as dementia, may experience more difficulties in recognizing their surroundings and navigating throughout their environments (Rainville, Passini, & Marchand, 2001). Patients with Dementia of the Alzheimer's Type (DAT) have more difficulties in wayfinding as wayfinding disorders are associated with cognitive deterioration and they have a significant degree of impairment in their decision making and information processing (Rainville, Passini, & Marchand, 2001). Another study on DAT developed design criteria for easier wayfinding (Passini, Pigot, Rainville, & Tetreault, 2000) through interviews with a nursing home staff and experiments with residents. Results from this study suggested that environmental aids should be accessible at every decision point and architectural design should avoid monotonous design and the lack of reference point.

Wayfinding in an environment is dependent on many different factors. As individuals make their way throughout the environment, they are either helped or hindered by the availability of a variety of environmental aids. In a successful wayfinding system, specific orientation aids such as signs, maps, directories, landmarks, lighting, and site and building layouts combine to help guide people to their destinations. Supporting aids and design elements are critical in providing users with a helpful environment (Carpman & Grant, 2001). Studies have shown that environmental aids affect wayfinding performances. For older adults whose cognitive and physical abilities are limited, wayfinding aids such as environmental aids are important physical elements to improve wayfinding and eventually their independent living. Davis, Therrien, and West (2009) examined place learning with simple and complex environmental aids in older and younger women. Their study aimed to solve the connection between salient aids, the contribution of color, and the
complexity of the aids. In addition, they tried to clarify the contribution of working memory in place learning and cue salience. Results demonstrated that older women needed more salient, complex cues in order for them to perform well compared to the younger group. This result suggests that there is a need for more specialized wayfinding methods for those individuals with below average cognitive function. Scialfa, Spadafora, Klein, Lesnik, Dial, and Heinrich (2008) examined iconic sign comprehension in older adults. This study sought to determine whether iconic sign comprehension suffers in healthy aging and in the presence of cognitive impairment. Results showed that moderately impaired older adults comprehended fewer than 25% of all signs.

**Virtual Reality for Wayfinding**

Virtual reality (VR) has been defined in various ways. It is defined as extending objects into an environment that does not physically exist (Slater & Usoh, 1994), a direct experience of a computational environment (Bricken, 1990), or a technological presence (Steuer, 1992). These definitions, although different, still include the notion that digital simulation of a real world environment has occurred in the environment. The development of virtual environment technology has provided researchers with a myriad of options for experimenting in numerous fields. Virtual environments have been used in the medical (John, 2007), psychotherapy (Rothbaum & Hodges, 1999), educational (Pan, Cheok, Yang, Zhu, & Shi, 2006), and design fields (Wu, Zhang, & Zhang, 2009). Within the design field, virtual environments have become an active means of experimentation.

VR has also been suggested to be beneficial to researchers who are interested in examining spatial abilities, wayfinding, and cognitive mapping (Richardson, Montello, & Hegarty, 1999; Sharlin, Watson,lutphen, Liu, Lederer, & Frazer, 2008; Wu, et al, 2009). Witmer, Bailey, Knerr, and Parsons (1996) suggested that exposure to VR is effective in training individuals to find a specific route in a real world situation. In studies that have demonstrated VR to be beneficial for wayfinding research, it was very important to understand the usability and effectiveness of various navigational tools. Wu et al. (2009) conducted usability tests of three wayfinding aids in an environment such as a view-in-view map, an animation guide, and a human system collaboration. Burigat and Chittaro (2007) measured navigational performance through a series of tests to compare various navigational aids and found 3D arrows to be the most salient cue available and most effective for both experienced and inexperienced users. The study also found a 3D desktop virtual environment to be an acceptable testing medium for their study.

Another topic that has been studied vigorously in VR research is active and passive participation in virtual environment navigation. An active participant navigates in a virtual environment using navigational tools such as a keyboard and mouse while passive participants follow a predefined virtual route passively. Results from studies that examined differences in wayfinding performance effectiveness among active and passive participations are contradictory. A study that compared wayfinding performances in real environments after training in virtual environment showed that active participants' performances differed from participants with
no training. However, comparison with passive participants and participants with no training could not be concluded due to a lack of statistical significance (Farrell, Amold, Pettifer, Adams, Graham, & MacManamon, 2003). Studies that were conducted in the virtual environment only showed that active wayfinding performances did not demonstrate superior results compared to passive performances (Wilson, Foreman, Gillet, & Stanton, 1997; Wilson, 1999). There are possible limitations in using an active participation method for certain groups of people, specifically with older adults. However, a recent study investigating early-onset Alzheimer’s Disease (AD) patients’ learning in new and familiar environments found that active participation in VR can assist those patients in studying cognitive maps in familiar surroundings (Jheng & Pai, 2009).

**Methods**

**Participants**
A total of 101 subjects participated in the wayfinding tests. There were two participant groups in this study: the elderly group and the younger-aged group. The elderly group’s participants were recruited from a local church’s senior citizen fellowship group and the Veteran’s Home of Indiana residence. There were 38 elderly participants: 20 females and 18 males. Their ages ranged between 66 and 82 years. The younger-aged group’s participants were 63 college students at a Midwestern university. Among them, there were 50 female and 13 male students. Their ages ranged from 18 to 24 years. Data from 6 additional participants were excluded from the data analysis due to incomplete data.

**Apparatus**
Autodesk 3ds Max Design 2010 was used to generate healthcare environments. Previous wayfinding studies have used virtual models that have been too abstract or simplified and therefore lacking in realistic quality (Wu, et al., 2009). In an abstract virtual environment that lacks real world quality, users cannot be as efficient and successful in remembering locations and configuring accurate directions. In this study, the Mental Ray rendering engine was used to create a photorealistic representation of the environments.

The simulated videos were projected on screens with rear-projection systems. The same type of projection system was used in test settings for both participant groups. The elderly group’s tests took place in recreational rooms, and the younger-aged group’s tests were conducted in classrooms.

**Test Videos**
Test videos simulated a healthcare facility in order to test a participant’s wayfinding performance. The scenario of the simulation is that a participant who visits a healthcare facility is escorted from the radiology waiting lounge to the radiology department. After the participant receives the services, the person walks out of the radiology department and is instructed to find the correct way back to the radiology waiting room. Although the same scenario was used for all participants, there were two different types of test models: the base model and the design model. Among the elderly group participants, 24 individuals participated in the base model test and 14 in the design model test. Among the younger-aged group participants, 33 individuals participated in the base model test.
and 30 individuals in the design model test. The two models differ from each other by unique architectural features. See Figure 1.

The base model was created with minimal architectural aids for wayfinding. It had one paint color on all walls and plain designs throughout the space. On the other hand, the design model was created with several architectural aids for wayfinding, featuring a unique design located on the radiology waiting lounge door that leads to the hallway connected to the radiology department. In addition, the design model exhibits various paint colors and a salient hospital logo on the wall supplemented with accent lighting. Both models have a double door at the end of the main hallway with a metal kick plate. The building layout was designed and modified with the help of a healthcare design firm.

The models were animated with a wide-angle lens following the wayfinding route. The wide-angle lens was used to provide a 65 degree field of view and a more immersive virtual environment. The camera traveled at a walking speed of 1.143 m/sec, which is similar to previous studies' speeds in interior virtual environment navigation such as 1.0668 m/sec in North and Miller (2002) and 1 m/sec in Haq, Hill, and Pramanik (2005). The camera was positioned at a height of 1.5 meters from the floor and maintained throughout the animation. The animated videos had the same camera route positioning and angle in both models. Each test type included four videos. The scenario of the test was introduced to participants before the test started. Participants were also informed before the test that they would watch a set of videos and that they were supposed to find their way back on their own later. The first video starts from the radiology waiting room and arrives to its destination, the radiology department. The route from the starting point to the destination measures approximately 18 meters. The run time for the first video was about 16 seconds. Refer to the YouTube link here for the base model video: http://www.youtube.com/watch?v=HQbu_MIY8i8. Refer to the YouTube link here for the design model: http://www.youtube.com/watch?v=8tQqfG35NeA. A 10 minute break was implemented after participants had finished the first video. After the break, participants watched three videos that led them from the radiology lab back to the radiology waiting room.

Those three videos ended with decision points, at which the participants would be asked to pick the correct direction to find their way back. See Figure 2 for the three decision points. Figure 3 illustrates the first decision making point. The first
video showed the wayfinding test route from the radiology department to the first decision point. There were two direction estimates they could choose from: left or right. Participants indicated their direction estimates by circling either “left” or “right” on the questionnaire. The correct answer was “left.” The second video started from the first decision point and went to the second decision point. See Figure 4. There were three direction estimate choices: left, straight, and right. Participants indicated their direction estimates by circling “left,” “straight,” or “right” on the questionnaire. The correct answer was “straight.” See the YouTube link here for the base model’s decision point 2 video: http://www.youtube.com/watch?v=IGVa3_Kg780. The third video started from the second decision point to the third decision point. See Figure 5. The third decision point had two direction estimate options to choose from: left or right. Participants indicated their direction estimates by circling “left” or “right” on the questionnaire. The correct answer was “left.” See the YouTube link here for the design model’s decision point 3 video: http://www.youtube.com/watch?v=1MIN3_ciifjo.

**Procedure**

The testing was conducted in groups. The investigator visited different facilities such as university classrooms, a recreational room, and a church conference room to collect data from different groups. Passive participation was used in this study. Previous studies have shown that passive participation does not yield inferior results compared to active participation (Wilson, Foreman, Gillet, & Stanton, 1997; Wilson, 1999). Each participant sat in front of a...
projector screen to see the video. It was made sure that each participant was able to view the video without interruption. A questionnaire was handed out to each participant before the video viewing, and the test scenario was explained.

Further instruction for the test was verbally given to each participant: the video that simulated the route from the radiology waiting room to the radiology department would be shown. Next, it was explained that a series of three videos that show the route from the radiology department back to the radiology waiting room would be shown after a ten-minute break. The participants were informed that their wayfinding performance would be tested. After participants viewed each testing video, they were asked to answer which direction to take in order to make their way back. This answer was circled on the provided questionnaire. The questionnaire included three additional questions. The first question asked about the participants’ perceived wayfinding ability in general. A question about the perceived difficulty level of the wayfinding testing they just finished was asked next. The last question asked about what was most helpful for successful wayfinding.

**Results**

The main purpose of this study was to examine the relationship between age, architectural wayfinding aids, and wayfinding performances. It was predicted that participants in the younger-aged group and participants tested in the VR environment with various architectural wayfinding aids would perform the wayfinding better with less error. It was also predicted that participants who perceived their general wayfinding ability to be higher and participants who perceived wayfinding tests in this study to be easier would perform wayfinding better. In addition, this study explored various wayfinding aids to examine how each wayfinding aid is related to wayfinding performances.

**Wayfinding Performances at Each Decision Point**

In order to examine how age and wayfinding aids are related to wayfinding performances, cross tabulations of wayfinding performance data were developed for each wayfinding decision point. See Figure 6. Overall, results showed that the younger-aged group performed better compared to the elderly group. Participants in the VR test environment with more architectural wayfinding aids (the design model) performed better compared to the participants in the VR test environment with minimum architectural wayfinding aids (the base model). When the younger-aged group and the elderly group were tested in the base model, participants in the younger-aged group performed better at every decision point. The interesting thing to note is that 50% or fewer participants from both the elderly and the younger-aged groups were successful in choosing the correct direction for the third decision point. In the design model, participants in the younger-aged group performed better than participants in the elderly group overall. In addition, participants in the younger-aged group in the design model performed better than participants in the younger-aged group in the base model.

Every participant in the younger-aged group who was tested in the design model was
successful with the wayfinding decision making at the third decision point. On the other hand, less than 50% of the elderly group was successful in choosing the right direction at the third decision point.

Wayfinding Aids and Performances

The question that asked what was most helpful for successful wayfinding was an open-ended question, and multiple answers from each participant were allowed. The answering rate was lower for the base model compared to the design model. There were 20 answers and 57 participants in the base model while there were 36 answers and 44 participants in the design model. The results demonstrate that architectural aids helped participants in wayfinding in the design model. Participants in the base model had to depend on their own abilities to recall information from memory and to pay attention to find their way. This may have been more difficult for elderly participants who have limited cognitive abilities. Salient architectural aids such as the hospital logo and paint color seem to assist elderly participants more, whereas there were higher percentages of younger participants who mentioned more subtle aids such as the door design and artwork as helpful wayfinding aids. These results support Davis et al. (2009), who suggested that older women were more successful in wayfinding with salient aids than younger women.

It is interesting to note that younger participants in the base model acknowledged the door design as a helpful wayfinding aid. Not a single elderly participant mentioned the door design to be a wayfinding aid in the base model. The unique door design in the base model is located at the double doors at the end of the main corridor. See Figure 7.

Correlations between Variables

Relationships between variables were examined through correlational analyses. There was a significant positive correlation between general wayfinding ability and overall wayfinding performance ($r = .552$, $N = 101$, $p < .0005$, two-tailed). Participants who felt they were good
at wayfinding in general performed better on the test. There was also a significant positive correlation between perceived wayfinding difficulty and overall wayfinding performance \((r = .670, N = 101, p < .0005, \text{two-tailed})\). The perceived general ability of wayfinding explains 45% of the variation in wayfinding performance. That is, participants who perceived the wayfinding test to be more difficult performed less successfully. Age and perceived difficulty of wayfinding were also related \((r = .494, N = 101, p < .0005, \text{two-tailed})\). The elderly group found the wayfinding of this study to be more difficult compared to what the younger-aged group did. In addition, the elderly group perceived their wayfinding ability to be worse compared to the younger-aged group \((r = .533, N = 101, p < .0005, \text{two-tailed})\).

**Effects of Age and Wayfinding Aids on Overall Wayfinding Performance**

A two-way mixed design Analysis of Variance (ANOVA) was conducted to examine age and wayfinding aids’ effects on overall wayfinding performance. The overall wayfinding performance was measured to be the total number of successes at three wayfinding decision points. In this analysis, age (the younger-aged vs. the elderly) and the existence of architectural wayfinding aids (the base model vs. the design model) were the independent variables. The overall wayfinding performance was the dependent variable. This analysis yielded a significant main effect of age, \(F (1, 97) = 8.44, p = .005, \text{partial eta squared} = .08\). Participants exhibited significantly more success in the younger-aged group \((M = 2.52, SE = .67)\) than the elderly group \((M = 2.03, SE = .82)\). In addition, the analysis yielded a significant main effect from the existence of wayfinding aids, \(F (1, 97) = 11.6, p = .001, \text{partial eta squared} = .14\). Participants exhibited significantly more successes in a VR environment with more wayfinding aids \((M = 2.64, SE = .61)\) than with minimal wayfinding aids \((M = 2.11, SE = .80)\). See Figure 8. There was no significant interaction between the factor of age and the factor of wayfinding aids because VR environments were given by the investigator and participants did not choose them.

![Figure 8: Age and wayfinding aids' effects on performance. (Source: Authors).](image)

**Age and Wayfinding Aids’ Effects on Perceived Wayfinding Difficulties**

The ANOVA revealed a significant effect of age on participants’ perceptions with their general wayfinding abilities. A two-way mixed design Analysis of Variance (ANOVA) was conducted.
to examine age and wayfinding aids’ effects on perceived difficulties in wayfinding in this test. This analysis yielded a significant main effect of age, F (1, 101) = 28.58, p < .0005, partial eta squared = .228. Participants exhibited significantly more perceived wayfinding difficulty in the elderly group (M = 3.92, SE = 1.13) than in the younger-aged group (M = 2.66, SE = 1.02). There was a significant main effect of wayfinding aids on the perceived wayfinding difficulty, F (1, 101) = 5.05, p = .027, partial eta squared = .05. Participants who were tested in the VR environment with more wayfinding aids felt the wayfinding task to be easier compared to the group tested in the VR environment with minimal wayfinding aids. Participants exhibited significantly more perceived wayfinding difficulty in the VR environment with minimal wayfinding aids (M = 3.18, SE = 1.26) than in the VR environment with more wayfinding aids (M = 3.80, SE = 1.53). See Figure 9.

Figure 9: Age and wayfinding aids’ effects on perceived difficulty. (Source: Authors).

There was no significant interaction between the factor of age and the factor of wayfinding aids in this study because VR environments were given by the investigator and participants did not choose them.

**Conclusion**

This study aimed to examine how physical environmental factors affect people’s wayfinding in ambulatory healthcare facilities. It implemented research methodology that tested building users’ wayfinding performances in two different VR environments that simulated an ambulatory healthcare facility. The base model VR environment included minimum wayfinding aids, while the design model VR environment included more salient wayfinding aids. In addition, this study compared the elderly group and the younger-aged group to discover unique challenges that elderly people would have in wayfinding.

Results showed that the younger-aged group performed better than the elderly group. Participants tested in the design model were significantly more successful compared to those tested in the base model. The results for the three decision points in this wayfinding study were also conclusive. More than half of the participants in the elderly group, for both the base model and the design model, were not able to answer correctly for the third decision point. It is interpreted that the elderly individuals have lower abilities in recalling landmarks (Head & Isom, 2010) and need more salient aids for better wayfinding (Davis et al., 2009). For the current study, the wayfinding aids located at the third decision point were less salient. The elderly group ranked more salient aids such as a big logo in the hallway or paint colors as better wayfinding aids that helped their wayfinding.
In relationships between age, wayfinding aids, and wayfinding performances, the ANOVA revealed that age and wayfinding aids affected wayfinding significantly. In addition, age and wayfinding aids impacted perceived difficulties of wayfinding. The perceived difficulties of wayfinding were strongly correlated with wayfinding performances, and this demonstrates that perceptions are strongly related to performances in wayfinding.

This study suggests that VR can be used in wayfinding studies for the elderly and showed results that support previous studies. It also suggests that wayfinding design for the elderly should consider the limited cognitive abilities of the elderly; the elderly have to rely on these when there are limited wayfinding aids, creating more difficulties in wayfinding. Therefore, designers need to plan wayfinding aids more frequently with more salient aids to avoid confusion for the elderly.

References


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