COLOUR AS AN AID FOR ELDERLY DURING VISUOSPATIAL NAVIGATION IN A VIRTUAL POLYCLINIC ENVIRONMENT

A Ph.D. Dissertation

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The Graduate School of Economics and Social Sciences
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THE DEPARTMENT OF
INTERIOR ARCHITECTURE AND ENVIRONMENTAL DESIGN
İHSAN DOĞRAMACI BİLKENT UNIVERSITY
ANKARA

September 2018

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Doctor of Philosophy in Interior Architecture and Environmental Design.

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ABSTRACT

COLOUR AS AN AID FOR ELDERLY DURING VISUOSPATIAL NAVIGATION IN A VIRTUAL POLYCLINIC ENVIRONMENT

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It is well documented that elderly people often have difficulties in finding their way in unfamiliar environments. In this study, it is aimed to explore the usage of colour as visuospatial navigation tool for elderly people with tests in a virtually simulated polyclinic environment. Neutral, warm and cool colour experiment settings were compared to find out the effect of different colours on elderly people's visuospatial navigation performances by using a head mounted display. The experiment was conducted with 90 participants in three phases; eligibility questionnaires, testing on computer, and presence questionnaire. The findings showed that neutral coloured setting affected participants' visuospatial navigation performances negatively compared to warm and cool coloured settings. However, there was no significant performance difference between warm and cool coloured environments. In addition to that, when they were asked to reach to the destination point, male participants spent shorter time, did fewer wrong turns, experienced fewer hesitations and travelled shorter distances compared to female participants. Currently, due to the increase in the elderly population, designing well-functioning interior spaces for the elderly has become a more pressing matter. The findings of this study will provide important clues for both interior designers and environmental psychologists.

Keywords: Colour, Elderly, Visuospatial Navigation, Virtual Reality, Wayfinding.

ÖZET

SANAL BİR POLİKLİNİK ORTAMINDA RENK KULLANIMININ YAŞLILARIN GÖRSEL UZAYSAL NAVİGASYONLARINA YARDIMI

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Yaşlı insanların tanıdık olmayan çevrelerde yol bulmakta güçlük çektiği açık bir şekilde belgelenmiştir. Bu çalışmadaki amaç, renk kullanımının yaşlıların sanal bir poliklinik simulasyonu ortamında görsel uzaysal navigasyonlarına etkisini araştırmaktır. Deneyde yaşlıların görsel uzaysal navigasyon performansları, sanal gerçeklik gözlüğü kullanılarak nötr, sıcak ve soğuk renkli ortamlarda ölçülüp kıyaslanmıştır. Deney, 90 katılımcı ile üç aşamada; uygunluk anketleri, bilgisayar ortaminda test, ve sanal ortamda buradalık testi ile gerçekleştirilmiştir. Sonuçta nötr renkli ortamın görsel uzaysal navigasyon performansı sıcak ve soğuk ortamlara kıyasla olumsuz yönde etkilediği ortaya çıkmıştır. Ancak sıcak ve soğuk renkli ortamlarda anlamlı bir performans farkı gözlemlenmemiştir. Ek olarak, katılımcıların varış noktasına ulaşmaları istendiğinde, erkek katılımcıların kadın katılımcılara kıyasla daha az zaman harcadığı, daha az sayıda yanlış yola saptığı, daha az tereddüt yaşadığı ve daha az yol kat ettiği sonucu gözlemlenmiştir. Günümüzde yaşlı nüfusun artması sonucunda, yaşlılar için iyi tasarlanmış iç mekanların tasarımının önemi her geçen gün artmaktadır. Bu çalışmanın sonuçlarının hem tasarımcılar hem de çevre psikologları için önemli doğurguları olacaktır.

Anahtar Kelimeler: Görsel Uzaysal Navigasyon, Renk, Sanal Gerçeklik, Yaşlılar, Yol Bulma.

ACKNOWLEDGEMENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER - 1

INTRODUCTION

Wayfinding systems can be supported by the usage of appropriate environmental design elements such as signage, layout and landmarks in order to overcome the difficulties of navigating in unfamiliar environments. The use of colour is an additional tool for navigation. It may be helpful in developing a mental map of the architectural environment (Dalke, Little, Niemann, Camgöz, Steadman & Hill, 2006). Navigating and orientation in both real and virtual environment can be enhanced by cues. Cues can be summarized as any form of information available within the environment, such as verbal, graphic, architectural and spatial cues (Sun & de Vries, 2009).

Previous research indicated that in various age participant groups (among children, adults or elders), colour improves peoples' wayfinding and cognitive mapping performances (Dalke et al., 2006; Davis & Therrien, 2012; Farran, Courbois, Van

Herwegen, Cruickshank & Blades, 2012; Helvacıoğlu & Olguntürk, 2011; Hidayetoğlu, Yıldırım & Akalın, 2012; Holscher, Meilinger, Vrachliotis, Brosamle & Knauff, 2006; Read, 2003).

Previous research comparing wayfinding and cognitive mapping abilities and performances of elders and younger-aged people, reported that elders have more difficulties than younger-aged people in terms of memorizing maps, navigating, route learning, map learning and place learning because of cognitive decline such as; changes in learning, short term memory, attention and response times (Allain, Nicoleau, Pinon, Etcharry-Bouyx, Barre, Berrut, et al., 2005; Barrash, 1994; Iaria, Palermo, Committeri & Barton, 2009; Jansen, Schmelter & Heil, 2010; Lipman & Caplan, 1992; Mahmood, Adamo, Briceno & Moffat, 2009; Moffat & Resnick, 2002; Rodgers, Sindone & Moffat, 2012; Salthouse & Siedlecki, 2007; Sjölinder, Höök, Nilsson & Andersson, 2005; Wilkniss, Jones, Korol, Gold & Manning, 1997). Moffat, Kennedy, Rodrigue and Raz, (2006) reported that changes related to age in the areas of the brain which support cognitive mapping might be partially responsible for the deterioration of the wayfinding ability that goes parallel to aging.

Hospitals are public facilities for all ages of people. There might be an increased number of visits to a hospital along with growing age due to the addition of various health risks and potential accidents (DeFrances, Lucas, Buie & Golosinskiy, 2008). Hospitals might resemble a maze of separated, confusing spaces, because of their complex functions and various programs. Hospitals are particularly challenging to navigate because of the complex medical terminology. Due to the visitors' health concerns as well as stress levels, the navigation process becomes even more challenging (Cooper, 2010). Yoo (1992) pointed out that when people get lost and are unable to orientate themselves, they experience increased blood pressure, headaches, desperate feelings and tiredness. Moreover, there are other potential wayfinding issues in hospitals as a result of these facilities being extremely large and quite overwhelming with the many departments with medical names. "This issue may further degrade the wayfinding experience of visitors and patients even more than the impact of their current health and/or vision conditions. "All of these factors make healthcare facilities unique and possibly troublesome (especially to older populations)" (Rousek & Hallbeck, 2011:449). Elders need more support than the younger-aged people for navigating by themselves in an unfamiliar environment. For elderly whose cognitive and physical abilities being restricted, navigational aids are essential factors which enhance their wayfinding and eventually living conditions as a whole.

As a result of social, economic, scientific, technological and health-care developments populations have been living longer and the number of elderly has been increasing. United Nations (2013) stated that in the report "World Population Ageing", "The global share of older persons (aged 60 years or over) increased from 9.2 per cent in 1990 to 11.7 per cent in 2013 and will continue to grow as a proportion of the world population, reaching 21.1 per cent by 2050" (75). Because of the increasing elderly population, designing interiors for elderly becomes an important issue.

1.1 Aim of the Study

The primary aim of this study is to explore the effects of colour as a visuospatial cue on spatial navigation and to develop a cognitive map in elderly people, in a simulated virtual polyclinic environment. Previous research showed that the aid of visual cues on spatial perception and wayfinding is essential. However, it is still unclear how the colour scheme of an environment affects the visuospatial navigation performances of elderly people and if it is possible to create easier to navigate indoors for elderly people by using specific colour schemes. The aim of our study is to fill in the gap in the literature regarding the effects of colour on visuospatial navigation of elderly people in a virtually simulated polyclinic environment by comparing three different colour schemes: neutral, warm and cool.

1.2 General Structure of the Thesis

This thesis is comprised of six chapters. After an introductory first chapter, the following three chapters review related literature. In the second chapter, definitions and concepts related to wayfinding and spatial navigation are elaborated on; including the literature review on measuring methods and tasks of spatial navigation performance in virtual environments. Besides, individual differences affecting spatial navigation are explained. Additionally, this chapter also explores virtual reality and spatial cognition research using virtual reality devices. In addition, the third chapter also includes a literature review on measuring methods and tasks of spatial navigation performance in virtual environments.

The third chapter gives the basic definition and concepts of colour and explains the three most widely used colour order systems. Moreover, the third chapter also presents colour as a part of interior design element, its function in wayfinding within previous literature and usage in healthcare environments.

The fourth chapter describes the experiment with its scope, aim, research questions, hypotheses, and methodology. The methodology of the experiment, a detailed selection procedure of the participant group, the used instruments and creation phase of the virtual environment is provided.

In the fifth chapter, the results of the experiment are statistically analysed and the discussion of the results is given with related previous studies in the literature. In the sixth chapter, the major conclusions of the study, limitations, and suggestions for future research are explained.

CHAPTER - 2

WAYFINDING AND SPATIAL NAVIGATION

2.1. Understanding Wayfinding and Spatial Navigation

Kevin Lynch (1960) firstly explored the characteristics of an urban space affecting people and how well people remembered physical features. He introduced the term of wayfinding to the literature. After then, different researchers gave many definitions of wayfinding, and contributed to the knowledge on wayfinding over the years.

Wayfinding is the "consistent use and organization of definite sensory cues from the external environment in order to reach a desired destination" (Lynch, 1960:3). Arthur and Passini (1992) maintained that wayfinding is a spatial problem solving activity with three specific yet connected processes: *decision making, decision execution*, and *information processing*. According to Arthur and Passini (1992), both perception and cognition are essential parts of information processing. Making and executing decisions are both built on information processing. Wayfinding is also defined as the ability to situate oneself in a location and reach intended destinations or to cognitively and behaviourally navigate within spatial environments (Passini, 1984; Rovine & Weisman, 1989). Additionally, Lovs (1998) explained the process of with steps in which people first select their goal, and then a destination is selected finally to be completed by selecting a route to follow. According to Golledge (1999), wayfinding is a persuasive, motivated and directed activity; a process in which decisions are made to follow a path or route between the original position and the desired destination.

Arthur and Passini (1992) explained cognitive mapping as a segment of perceiving the environment in which cognition is the origin of information to make and execute a decision. Perception is the mechanism of gathering information by the use of senses, while cognition is the understanding as well as the manipulation of information (Arthur & Passini, 1992). The gathering of information is not sufficient for wayfinding, as the information also has to be understood and manipulated, considering these two steps are essential segments of the wayfinding process. Lynch (1960) maintained that cognitive maps are introduced for tasks of wayfinding. Garling, Book and Lindberg (1984b) suggested that cognitive maps are used when considering "people's behaviour in social and physical environments is determined by action plans, and, if the execution of such action plans requires travelling, plans for how to travel, termed travel plans are formed and executed"(3). Arthur and Passini (1992) explained cognitive map as "an overall mental image or representation of the spaces and the layout of a setting” (23) and cognitive mapping is described as “the mental structuring process leading to the creation of a cognitive map” (23). Kitchin (1994) suggested that cognitive maps could be used to solve spatial problems such as wayfinding and navigation.

Chen and Stanney (1999) suggested a more elaborated version of Arthur and Passini's (1992) theoretical model of wayfinding process as dividing into three sub-processes: *cognitive mapping*, *decision making* (wayfinding plan development), and *decision executing* (the final and actual physical movement guided by navigation within the environment) (see Figure 1). Earlier suggestions of subdivisions are inferior to the current model, which defines the wayfinding process, including some precise influences of spatial information, orientation and knowledge.

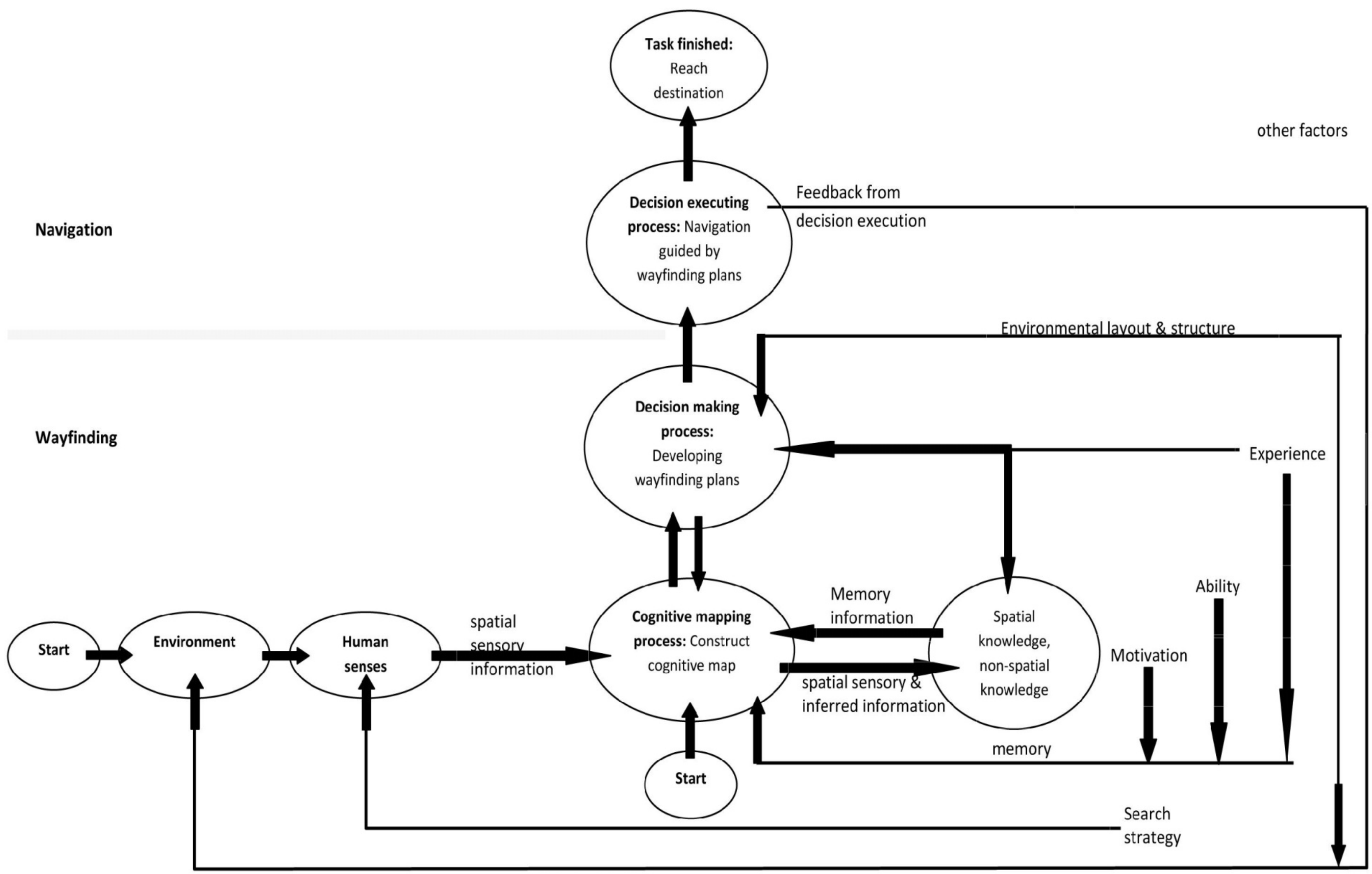

Figure 1: Theoretical model of wayfinding (retrieved from Chen & Stanney; 1999:681)

In the literature, the terms wayfinding and navigation can often be substituted with each other (in some studies, navigation is used as a synonym for wayfinding). Although these terms overlap semantically, there is a significant but subtle difference between them. Montello and Sas (2006) stated that wayfinding is the efficient and goal-directed planning section of navigation. Navigation is the coordinated and goal-oriented form of movement through an environment. It requires first the planning and then the execution of each movement. Montello (2005) explained that navigation might be explained as having two components of locomotion (travel) and wayfinding (see Figure 2). Locomotion is defined as the body's movement according to the local surrounds;

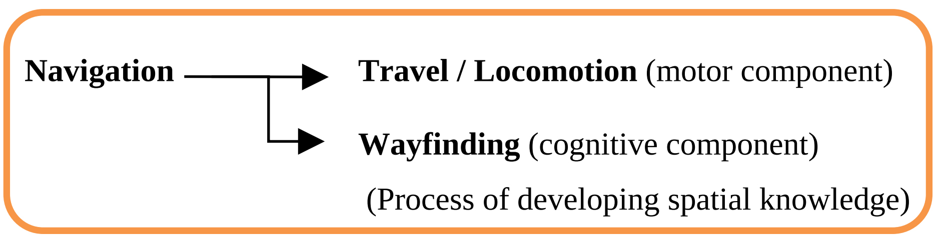

Figure 2. Understanding spatial navigation

wayfinding is planning and decision making step that takes the distal and local surrounds into consideration. Finally, travel is the final motion in which the current location is changed after the altering of position to the new position from a view point (Zhang, 2008). It can be referred to as "the perceptual-motor coordination to the local surrounds and includes activities such as moving towards visible targets and avoiding obstacles" (Montello & Freundschuh, 2005:69). The second element of navigation is wayfinding and it is the “cognitive coordination to the distant environment, beyond direct sensorimotor access, and includes activities such as trip planning and route choice” (Montello & Freundschuh, 2005:69) where the navigational path is decided by the knowledge of an environment, the visual cues as well as navigational aids. There are several sensory systems which supply information for navigating and a diversity of cognitive systems is concerned in modifying information from the senses and the memory. (Montello, 2005). Shah and Miyake (2005) suggest that the visual and structural characteristics of physical environments might have a positive or negative effect on the performance of various navigation tasks.

2.2. Cognitive Maps and Three Levels of Spatial Knowledge Acquisition

According to the Chen and Stanney's (1999) wayfinding model, wayfinders usually generally start out by perceiving the environment in a direct way, or from the use of a cognitive map.

> “After a cognitive map has been generated, the second main step in the wayfinding process is decision-making. This generally involves using the cognitive map information generated in the first step to guide the development of wayfinding plans. This is followed by a decision-execution process, in which navigation commences, guided by the wayfinding plans developed in the second step” (Chen & Stanney,1999:676).

The wayfinding process can be concluded with the sufficient repetition of these steps until the target destination is reached. To elaborate, cognitive mapping, as defined by Downs and Stea (1973) and Golledge (1987), is the procedure of acquiring, forming, and preserving spatial information and spatial knowledge. A cognitive map is the total sum of environmental information accumulated in the memory. According to the definitions of most researchers, cognitive maps are mental devices that store for simplifying, coding, and ordering the infinitely complex world of human-environment interactions (Arthur & Passini, 1992; Chen & Stanney, 1999; Downs & Stea, 1973; Golledge, 1987; Karimi, 2015; Kitchin, 1994; Montello & Freundschuh, 2005; Montello & Sas, 2006; Passini, 1984). According to Chen and Stanney's (1999) explanation, during the cognitive mapping process, in which individuals cultivate an understanding of the world that surrounds them, spatial information is gathered by individual sensors and are amalgamated with the accumulated spatial knowledge in order to create a cognitive map which help performing the wayfinding and navigation tasks.

Passini (1984) stated that there are already many existing cues within the environment, and if those cues can be related to the wayfinding task, they are defined as *spatial information*. In addition to spatial information, sufficient general information on the spatial settings is required to complete wayfinding tasks. Passini (1984) defined three major types of information; sensory, memory and inferred. Sensory information is obtained by an individual’s use of five senses, memory information is the recall from one’s memory and lastly inferred information is gained through inference as in a combination of the two other information types. Chen and Stanney (1999) explained that spatial knowledge is the result of integrated spatial information. Most researchers agreed on dividing spatial knowledge into three separate levels; *landmark knowledge*, *route (procedure) knowledge*, and *survey knowledge* (Darken, 1996; Evans, Fellows, Zorn & Doty, 1980; Garling, Book & Ergenzen, 1982; Jul & Furnas, 1997; Siegel & White, 1975; Thorndyke, 1980).

As stated earlier, a cognitive map is considered the first process of wayfinding. Once a cognitive map is created, the second step of wayfinding process is the decision making step. According to Chen and Stanney's (1999) explanation in the decision making process, "individuals plan actions and structure them into an overall wayfinding plan" (673) which has its roots on the previously created cognitive map. "The result is an action plan that includes information of selected routes and proper actions to move through the routes. The generated action plans are fed back to memory as spatial knowledge" (Chen & Stanney, 1999:676). Garling et al. (1984a, 1984b, 1984c, 1986) stated that action plans are used to link the internal information processing to real behaviour. Travel plans are a part of the action plan and these travel plans are previously created ways of action utilized to reach the desired destination with the minimum effort required. According to this theory, a hierarchical procedure which incorporates information from as well as about the environment shapes the travel plans. Therefore, travel plans usually lead to deductions and acquisition of knowledge, which are stored in cognitive maps. These travel plans and the related action plans are often improved and corrected. During this revision process, newer information is gathered which can be used to change and enhance cognitive maps.

Spatial navigation and knowledge acquisition has difficulties in measurement, because navigating in a virtual environment (VE) is not easy for a human who is accustomed to navigation in the real world. Thus, navigation in virtual environments has a high probability of the user becoming lost, compared to the real world. (Grant, 1997; Witmer et al., 1996). Peponis et al. (1990) claimed that the landmark knowledge is about the use of salient objects in order to help one's orientation in remembering information. Route knowledge is obtained when landmarks and other relevant visual features are functional in terms of triggering direction based decisions as one navigates from one point to another in a preset path. In this specific type of knowledge, the context of routes are contained which have been travelled previously. Additionally, in the case of many routes and landmarks within a single cognitive map of the environment, survey knowledge is gained thereafter (Edwards et al., 1998). Peponis et al., (1990) attributed survey knowledge to be the ultimate stage of knowledge acquisition. Survey knowledge uses increasingly abstract terms regarding reference and is based on world-centered form of frame of reference. An individual with complete survey knowledge is a person that has obtained navigational awareness. Determining and classifying unique behaviours associated with each and every level of knowledge mentioned paves the way for the surfacing of observable values that are specific to each one. There are major metrics listed in the Table 1 (retrieved from Nash et al., 2000), used for the assessment of the three levels of spatial knowledge acquisition. Under each type of navigational knowledge, the metrics are explained within the knowledge according to the literature.

Table 1. Major metrics used for the assessment of three levels of spatial knowledge acquisition (Retrieved from Nash et al., 2000).

The three levels of spatial knowledge acquisition	Metric	Value Measured
1. Landmark knowledge	Landmark recognition	Number of objects correctly identified as appearing
	Landmark recall	Number of objects correctly recalled
	Location recognition	Number of correct recognitions and false alarms
2. Route knowledge	Directional pointing task	Angular error
	Route distance estimation task	Absolution deviation from the real distance of the path (estimate within less than 5ft an exact match)
	Route replication task	Number of wrong turns; route traversal times; distance travelled
	Location sequencing	Correct location sequencing for near and far trials
	Orientation performance	Turning angle; error; average speed; ranking of difficulty (1=easiest; 5=most difficult)
3. Survey knowledge	Pointing task	Angular disparity (disparity less than 5° an exact match; disparity in excess of 90° a complete navigation disorientation)
	Euclidean distance estimation task	Absolute deviation from the real distance of the path (estimate within less than 5ft an exact match)
	Search effectiveness	Time, distance, errors, ratio of the percentage of space searched; time between checkpoints; path accuracy (number of wrong turns)
	Alternate route selection	Time, distance, errors
	Object placement task	Total number of objects placed in the correct rooms; total angular deviation and total distance error
	Map drawings	Map goodness, object classes, relative object position scores; directional accuracy, relative distance estimation, and land form (shape, placement, and relative scale)

2.2.1. Landmark Knowledge

Landmark knowledge is the accumulated information of the visual details of certain locations within an environment. This level of knowledge is acquired by directly observing objects within an environment, or simply viewing indirect representations of the environment, such as photographs or videos. Landmark knowledge is the essential component that builds towards survey and route knowledge (Darken, 1996; Goldin & Thorndyke, 1981).

Landmark knowledge takes a specific landmark in an environment into consideration when measuring navigational learning and knowledge assessment. Recognition of these specific landmarks makes the navigation process easier in VEs, as these landmarks create a sense of immersion in the VE. The landmarks in studies conducted in VEs consist of three dimensional objects to simple differentiating landscapes, or wall markings, as these objects all have distinct differences from the landscape, creating a certain sense of recognition in the participants of navigational exercises.

Landmark knowledge was measured by McCreary and Williges (1998) on the experiment where the participants navigated through a six room VE. In this VE, random sequences of pictures of objects were shown to the participants and the number of correct identification of objects in the participant responses correlated to the landmark knowledge of the individual participants.

In addition to such a study, these landmark objects are also asked to be written down by the participants in order to determine which ones are remembered and recognized without any time constraints in the experiment (Edwards et al., 1998, Gunther, 1997). This method was called the landmark recall which is based on the number of objects correctly recalled.

The last metric in the landmark knowledge area is the location recognition, which is in the study by Goldin and Thorndyke (1982); Witmer et al., (1995), where the number of correct recognitions and false alarms of the participants were noted and measured to determine the navigational performance. Alawadhi et al. (2011) also mentions the studies of Craik (1968) and Cohen (1980). Craik (1968) measured the spatial knowledge of a subject via place recognition tests and questionnaires regarding landmark and location. Cohen (1980)'s subjects were exposed to a tour of a museum, and afterwards he measured the ability of the participants of recalling sequential progression and recognition of elements. This was another cued recall task, just like the study by Witmer et al. (1995).

2.2.2. Route Knowledge

Route knowledge is defined as the information that relates to the sequence of actions needed to follow a route in a precise manner. It is also known as procedure knowledge. This name is a result of a represented procedure, which describes the movement starting from a point, having certain checkpoints in anchor points, landmarks and several points of stopping in the route, and having the goal or final destination in the end (Gale, Golledge, Pellegrino & Doherty, 1990). In VEs, route knowledge is used as the assessment method, measuring the navigating person's ability to point certain landmarks in a given route. There are several metrics on the route knowledge assessment category within the aforementioned directional pointing task. In this task, the navigator points towards certain locations while navigating between a start point and a destination, stopping at landmarks to assess whether they were explored earlier or not (Boyd et al., 1997; Goerger et al., 1997). If the navigator is successful in memorizing the landmarks within a given route correctly, this translates into properly gained route knowledge. In the opposite case where the navigator does not adequately memorize the route, this leads to difficulties in wayfinding.

In addition to the directional pointing task, Goldin and Thorndyke (1982); Satalich (1995) developed the route distance estimation task. The participants were asked to navigate between two points in a pre-determined route, to evaluate and estimate the distance of the path travelled, comparing it to the real distance. The values measured in this study are the absolution deviation according to the real distance of the route which is considered within equal or less than 1.5 meters of an exact match.

Another study was conducted by Witmer et al. (1996) under the name of the route replication task. In this task, the participants were involved in a VE route several times, in which they used a form of study aid such as coloured photographs, maps or step by step instructions to measure the accuracy of navigating through the route in the real world. In this study, the values measured were the number of wrong turns, route traversal times and finally the total distance travelled. These were compared to the navigation of the real world route, to assess the navigational performance of the participants in the route within the VE.

Bakker et al., (1998), created the study of orientation performance, which is also under the category of route knowledge metrics. This study considered and assessed the route knowledge by measuring the participants' orientation, in terms of their ability to orient themselves in the measurement of degrees, in relation to the features and landmarks in the given environment. In this study, the turning angle of participants, errors, average speed of participants, ranking of difficulty from 1 being the easiest and 5 being the most difficult were the values measured.

Goldin and Thorndyke (1982) also studied the route knowledge metrics, in the study of a location sequencing task, where researchers observe the sequence of actions which are performed at certain locations in the route by the participants, to measure the sequencing of location in terms of trials that are either near or far away. Slides were shown to the participants depicting objects in pairs, where they were asked to determine which occurred first, and which occurred later in the virtual experimental route. Edwards et al. (1998) along with Gunther (1997) assessed route knowledge in timing metric where the participant's locating ability for an object in the VE was measured compared with the timing of a previous identification in a guiding tour session.

There is much research in the literature, studied the route knowledge metrics such as Cohen and Schuepfer (1980), Farran et al. (2012), Jansen-Osmann and Wiedenbauer (2004), Tang et al. (2009), Tlauka et al. (2005). Tang et al. (2009) conducted a VE experiment in which three scenarios were created, in a game that took place in an emergency escape situation to determine whether various emergency signs aid wayfinding in these particular situations, and if so, to what extent. The time spent and the number of errors was the measurements for this study. It was concluded that the lack of signs leads to a considerably slower escape than either older signs or new signs. Additionally, males had a better wayfinding performance compared to females.

Jansen-Osmann and Wiedenbauer (2004) studied the role of landmarks on navigation by comparing children and adults in a VE experiment. The number of errors and decision points (walking distance) were measurements for the evaluation of this study. No difference has been found between older children and adults in terms of the number of errors and decision points. Moreover, female participants conducted more errors when exploring the maze without the landmarks present, therefore showing that females rely on the existence of landmarks significantly more than males.

Tlauka et al. (2005) investigated the effects of sex differences in spatial knowledge which has been gathered through a virtual shopping center’s simulated exploration experiment. The wayfinding task took note of the time spent and the number of errors to evaluate the results, which prevailed that females took a longer time to travel from the starting location to the final destination while following a route in the VE that is the shopping center. In addition, females made more frequent erroneous turns and directions.

Farran et al. (2012) investigated the influences of focal (easy to verbalise) and non-focal (difficult to verbalise) colours as an environmental cue when learning and memorizing a route in a VE. The number of errors was one of the measurements for the evaluation of route task. It is found that adults with Williams's syndrome made significantly more errors than the typically developing 9-year-olds, but not the 6-year-olds. It was also found that among all three participant groups, fewer errors were reported and more colours were memorized in the focal coloured setting compared to the non-focal coloured setting.

Cohen and Schuepfer (1980) explored how landmarks and routes were perceived by children and adults in a VE. The number of errors and the number of decisions were measurements for the evaluation of route task. The findings showed that six graders made significantly less incorrect turn choices compared to second graders. Additionally, sixth graders made more errors than adults, creating an age-based correlation. To elaborate, children relied more on the position as well as the sequence of landmarks compared to adults, who made less mistakes due to landmarks.

2.2.3. Survey Knowledge

Survey knowledge shows the configuration relations between routes and locations in an environment. It converts the topographic characteristics of the space, such as the object locations relative to an anchored extensive coordinate system, the inter-object Euclidean distances and the shape of large spatial objects which are unidentifiable from any viewpoint alone (Thorndyke & Hayes-Roth, 1982). The other names for survey knowledge are configurational knowledge and secondary spatial (Chen & Stanney, 1999). Thorndyke and Hayes-Roth (1982:586) suggested that “Acquiring survey knowledge solely through navigation entails both costs and benefits. Our data indicate that the principal advantage of such learning is the ultimate superiority of the acquired cognitive map”.

Survey knowledge is conducted in the form of a cognitive map; therefore the metrics under this category assess the participants' internal ideas following exposure to a VE in the corresponding studies. The first of survey knowledge metrics is the pointing task conducted by Satalich (1995). Koh (1997) and Satalich (1995) used the exposure to VE to record the accuracy of performance of the participants as they pointed to the locations of objects placed in the VE. In these measurements, the angular disparity was the main value measured which was the disparity less than 5 degrees considered an exact match and the difference above 90 degrees to be considered a complete navigation disorientation. Another study was conducted by Koh (1997), Satalich (1995) under the metric of Euclidean distance estimation task. The “birds-eye” distance travelled was estimated by individual participants considering the objects in the environment as well as notable locations. An estimate within less than 1.5 meters was considered an exact match in both these studies.

Darken and Sibert (1996a)'s study on survey knowledge was called the search effectiveness metric and it recorded the distance travelled and the ratio of space searched compared to the total virtual environment space spanned while the individual participants practiced primed searches without any prior information given to them. The studies of Satalich (1995), Goerger et al. (1997) and Boyd et al. (1997) also used the search effectiveness metric. Satalich (1995), for example, asked the participants to locate a distinct room in the VE of the study. In this case, the most efficient routes to the room were blocked by a fire in the building. In this study, the participants were asked to estimate the Euclidean distance between the objects and their current location. The results showed that males had a significantly better spatial ability in estimating the distance compared to females.

Maps were another important metric subject to measure survey knowledge. For example, Edwards et al. (1998) and Gunther (1997) asked the participants to recall and place the important objects recalled on a paper map after the VE exposure session. In the study by Gunther (1997), 3D sound was implemented into the virtual environment to help the participants find certain exact locations within the environment or enhance the rate at which spatial knowledge is gained by the participants. The results of the study showed that the implementation of the 3D sound did not help the participants gain spatial knowledge in an increased rate, while having a positive effect on the time spent in locating objects within the environment. Another metric regarding mapping methods were used by Boyd et al. (1997) and Goerger et al. (1997), where participants were asked to place magnets on a white board, in distance regarding relations to each other, as if the board was a top-down view of the VE, in the format of a map. The arrangement of magnets was later used to measure relative object position scores and directional accuracies of the participants. Goldin and Thorndyke (1982) conducted an experiment to measure survey knowledge comparing simulated and actual navigation. The results showed that the participants in the simulated navigation showed better or equal survey knowledge compared to the participants in the actual navigation. Billinghurst and Weghorst (1995), Darken and Sibert (1996b) also measured the spatial knowledge by requesting the participants to draw a map of the VE after the exposure to that particular environment.

2.3. Individual Differences Affecting Spatial Navigation

There are certain individual differences that affect spatial navigation in a crucial way. Several sides of individual differences were identified previously in the literature, such as; spatial familiarity, motivation, sense of direction, learning style, handedness of users, occupation, education level, memory, and experience, however with respect to this study age and sex differences of individuals are considered major factors which affect an individual's spatial navigation performance.

2.3.1. Age Differences

Age has a significant effect on user's ability in wayfinding. There have been numerous studies over the years focusing on the difference in wayfinding behaviour and mental processes that take place during this activity caused by age differences (Cornell, Heth, & Skoczylas, 1999; Lawton, 1994; Passini et al., 1995; 1998; 2000; Weisman, 1987). Elders are more likely to suffer memory loss and become disoriented, which restrains their wayfinding ability. Studies indicated that “wayfinding behaviour and accuracy are affected by the outcomes of aging such as lack of concentration and memory disorders as in dementia of Alzheimer type” (Passini et al., 1998:2000). Previous research comparing elders and younger-aged group wayfinding and cognitive mapping abilities and performances, reported that elders have more difficulties than the younger-aged group in terms of memorizing maps, navigating, route learning, map learning, and place learning because of cognitive decline such as; changes in learning, short-term memory, attention and response times (Allain et al., 2005; Barrash, 1994; Iaria et al., 2009; Jansen et al., 2010; Lipman & Caplan, 1992; Mahmood et al., 2009; Moffat & Resnick, 2002; Rodgers et al., 2012; Salthouse & Siedlecki, 2007; Sjölinder et al., 2005; Wilkniss et al., 1997).

Moffat, Zonderman and Resnick (2001) explored age differences of spatial memory in a virtual environment (VE) navigation task, comparing 133 young, middle and old aged participants. The completion time, the number of errors and distance number of errors were the measurements for this study. It is found that elder volunteers took a longer time to solve the trials, travelled longer distances and made significantly more spatial memory errors compared to younger participants of the study.

Lee and Kline (2011) examined the influence of architectural wayfinding aids on wayfinding performance by comparing an elderly group (38 elders between the ages of 66 to 82) and a younger-aged group (63 young adults between the ages of 18 to 24) in a virtual ambulatory healthcare facility. In this study, participants directed the researcher verbally; in each decision point, participants answer open-ended questions about architectural aids and their errors are measured. It is found that the younger-aged group had a better wayfinding performance compared to the elderly group. The elderly group of participants often relied on their limited ability of recalling from memory when insufficient wayfinding aids were present, thus leading to them experiencing further difficulties in wayfinding.

Barrash (1994) explored the impact of aging on route learning ability comparing five different age groups (80 individuals -divided regarding age intervals- between the ages of 18 and 78). It is found that the elderly participants had more difficulty in learning the route in terms of making errors.

Iaria et al. (2009) explored the effects of aging on developing and using cognitive maps in a VE, comparing 30 young (19-30 years) and 25 older (50-69 years) participants. It is seen that elderly participants needed more time to create and develop a cognitive map of the environment compared to the younger participants while needing more time as well as making more frequent errors when using the cognitive map for purposes of orientation.

Jansen et al. (2010) examined the process of the acquisition of spatial knowledge in 20 younger adults (20–30 years), 20 middle-aged adults (40–50 years), and 20 elderly (60–70 years) in a desktop based VE, in which the participants were taught a way within a virtual maze environment with landmarks and were asked to recall the landmarks while drawing an overview of the maze. “The results revealed a general decline in spatial memory of the elderly, that is, in the time needed to learn a new route, in the retrieval of landmarks from memory (landmark knowledge), and in the ability to draw a map (configurational knowledge)”(Jansen et al., 2010:54).

Moffat and Resnick (2002) investigated how navigational behaviour was affected by age differences in a virtual Morris water maze. The research also explored the ability of the elderly to cultivate cognitive maps after concluding the navigation experience. It was found that compared to the younger participants, elderly volunteers covered longer linear distances to locate the hidden platform.

Sjölinder et al. (2005) examined the acquisition of spatial knowledge in a virtual grocery shop environment, comparing 24 young-aged adults (20-31 years) and 24 elders (61-77 years). The findings revealed that the elderly participants required more time to solve the tasks; and while performed similar navigation performance in the physical world, the elderly participants were less likely to generate survey/configurational knowledge.

Wilkniss et al. (1997) explored the spatial learning abilities in 25 younger adults (18-21 years) and 25 healthy older adults (59-81 years) evaluating two different tasks; recalling the route and drawing a 2-dimensional map. It is found that the elderly participants had significant difficulty retracing the route, ordering landmarks and memorizing the route.

Moffat et al. (2006) examined how age differences effect functional brain activation during VE navigation task comparing 30 young (21-39 years) and 21 older (60-78 years) participants. It is reported that the changes in the brain areas that support cognitive mapping affected by aging are responsible to a degree for the deterioration in wayfinding ability.

2.3.2 Sex Differences

The sex difference is still a debated issue in the literature, not only in wayfinding but also in spatial ability in general (Voyer, Voyer, & Bryden, 1995). Although sex differences are not uniformly found to be significant, when they are found they often favour males (Allen & Hogeland, 1978; Linn & Petersen, 1985; McGee, 1979).

Lawton (1996) maintained that the origin of sex differences lie in different strategies that are used to overcome orientation issues. It is also shown that males use an orientation strategy whereas females use a routing strategy. To elaborate, it was found that females show that they rely on landmark-based route information more than males while males simply adjust to global reference points such as the directions of north, west, south or east, or even sun’s current position (Lawton, 1994; 1996). Architectural differentiations and anomalies are the environmental cues used by females in their routing strategies. Environmental cues are critical constituents of wayfinding that increase the awareness of individuals regarding their environment while facilitating a wayfinding task.

Jansen-Osmann and Wiedenbauer (2004) conducted research on how the use of landmarks affects wayfinding. In the experiment, participants were taught a route by using a slide presentation. After the presentation, participants were asked to remember and point out the inherent landmarks in order to find their way in a VE. The findings prevailed that male participants relied on landmarks less than female participants. Sandstrom, Kaufman and Huettel (1998) explored the incorporation of disparate distal cues comparing males and females in a VE Morris Water Maze task. The results showed that males use both landmark and geometric information while females solely rely on the former. Additionally, males and females use different strategies while focusing on different attributes of the environment. Finally, it was presented that in the cases where landmark and geometric information was available at ready, males were faster at reaching a hidden target compared to females.

Tlauka et al. (2005) studied the acquisition of spatial knowledge within a virtual shopping centre comparing males and females. A series of tasks comprised of wayfinding, directional estimates and distance estimates as well as a map placement tasks was given to the participants. It was found that there was significant difference favouring male participants. Sex difference was prevalent in even measures such as pointing accuracy and the number of errors in the navigation task (Bryant, 1982; Devlin & Bernstein, 1995; Lawton, Charleston, & Zieles, 1996). Devlin and Bernstein (1995) found that the errors of males were significantly less in number compared to females in a computer simulated wayfinding exercise. Galea and Kimura (1993) and Devlin and Bernstein (1995) concluded their studies with consistent results on sex differences. The average time of completion was longer for females in wayfinding tasks. The results were also less accurate in the wayfinding performance of females when compared to male participants. The pointing task measured the amount of control over the information necessary to successfully navigate within an environment. Lawton (1994) also showed that females reported more errors in pointing tasks with lower confidence than males. The significant advantage of male participants was recorded in spatial route learning in an unfamiliar environment as well as certain tasks that need survey knowledge such as drawing maps and estimating distances travelled (Castelli, Corazzini, Geminiani 2008; Coluccia, 2007; Çubukçu & Nasar, 2005; Devlin & Bernstein, 1995; Lawton & Morrin, 1999; Moffat et al., 1998; O'Laughlin & Brubaker, 1998; Tlauka, Brolese, Pomeroy, Hobbs, 2005).

Results were inconclusive in the broad spectrum regarding sex differences and the sense of direction. Bryant (1982) found that males had a higher rating of their own sense of direction compared to females in a self-reported study. On the other hand both Kozlowski and Bryant (1977) and Vanderberg, Kuse and Vogler (1985) found no significant sex related difference in the sense of direction. Pedersen (1999) conducted a self-rating environmental competency test. The results showed that males were more successful and competent according to their reported results compared to females. The same bias was seen in the wayfinding abilities of both sexes, leaning towards a more confident reporting from men. This shows that there is a difference in terms of confidence levels between male and females. The higher level of anxiety reported by females on performing spatial tasks combined with less confidence values reported while drawing the map of a floor plan as well as the feeling of uncertainty reported while navigating in a building also support these findings (Lawton & Kallai, 2002; Lawton et al., 1996; O'Laughlin & Brubaker, 1998). A high portion of the studies revealed that sex differences were present in wayfinding strategies as well as accuracy. These findings presented that males had a better performance in most of the cases. (Lawton, 1996; McGuiness & Sparks, 1983; Miller & Santoni, 1986; Ward, Newcombe, & Overton, 1986).

2.3.3 Other Individual Differences

Apart from the individual differences affecting spatial navigation such as age and sex; handedness, familiarity, experience, visuospatial abilities, education level and occupation are also the other factors. People navigate and behave differently in environments while the information they use is different for a range of reasons. There are many individual factors and wayfinding styles affect how people structure the environment cognitively.

One of the factors that influence wayfinding performance is the handedness of users. Some users have a right hemisphere dominance which is seen in left-handers, and this attribute is reported to be connected to making significantly fewer errors compared to right-handers or left-hemisphere dominant individuals in the computer kiosk wayfinding task in Delvin and Berstein's study (1997). Right hemisphere dominance was been associated with higher levels of creativity as well as more developed mental rotation skills (Burke et al., 1989; Coren, 1993; Newland, 1981; Porac & Coren, 1981; Stewart & Clayson, 1980). Spatial familiarity is depicted as merely 'how well a place is known' (Chalmers & Knight, 1985). Most of the studies have agreed on that familiarity has a positive impact on the experience of spatial orientation and wayfinding behaviour. Golledge (1991) explained that as familiarity within an environment is increased, a cognitive map can be developed. Ruddle, Payne and Jones (1998) found that the increased familiarity provided more accurate spatial knowledge in a simulated environment.

Doğu and Erkip (2000) examined spatial factors affecting wayfinding behaviour of individuals in a shopping mall. They found that familiarity is the most critical factor that affects wayfinding behaviour in interior spaces. O'Neill (1992) reported that the increase of familiarity within a space increases the wayfinding performance as well as spatial orientation and wayfinding tasks in terms of both lower reported latency values and higher values of accuracy. Also, the degree of complexity of the layout of the environment becomes less significant. According to O'Neill's (1992) study, familiarity is a more essential factor which directly influences the wayfinding performance of individuals compared to the spatial factors.

Background of the individuals also affects wayfinding. People are socialised differently, as their upbringing is influenced by different geographical and social environments. Their way of perceiving and using the environment differ in regards to their different cultural backgrounds. Doğu and Erkip (2000) stated that wayfinding behaviour is different in individuals because of factors such as education, profession and past experiences/backgrounds with different settings. It is even affected by different modes of travel. For example, a taxi driver is a professional who is constantly engaged with travelling distances. Due to his route changing on a daily basis, he has a higher level of knowledge regarding streets and roads as well as neighbourhood locations compared to people with different professional pursuits (i.e. housewife, teacher, etc.).

Experience, visuospatial abilities, education level and occupation of the individual are also some interacting factors affecting wayfinding and navigation performance. Saku (1992) presented that in contour map reading and route planning tasks, geography students performed significantly better than psychology students. Students comprised of each department were divided into two groups, and these groups were separated by the variable of one group receiving 20 minutes of training in geographical lexemes. This trained group had a better performance compared to the groups that were not trained. Tkacz (1998) presented that map-reading can be taught alongside with navigational techniques to improve navigation skills.

Bogue and Marra (2003) stated that visuospatial skills are the abilities to first recognize and then organize information when a person sees something and then interprets it. Visuospatial skills can be exemplified by the activities of reading, shape recognition, finding objects within an image or following a map. Besides, Voyer et al. (1995) explained that visuospatial ability might not be a unitary construct, and instead could be an amalgamation of certain skills. Visual-spatial skills are therefore essential for success in many engineering courses and all technical professions (His, Linn, & Bell, 1997; Miller & Bertoline, 1991; Sorby & Baartmans, 2000). Peters, Chisholm and Laeng (1995) have come up in a sample where students of engineering had a better performance on the Mental Rotations Test compared to students who pursued Bachelor of Arts degrees. Additionally, male engineering students had a better performance compared to female engineering students, thus showing a sex difference.

Visuospatial ability is defined as the ability to process information that involves spatial relations (Yang, Conners, & Merrill, 2014). Linn and Petersen (1986), explained the four common types of spatial abilities that are; visuospatial perception, spatial visualization, mental folding and mental rotation. Visuospatial perception is the ability to perceive spatial relationships in regards to the orientation of one's body without taking the distracting information into consideration (Linn & Petersen, 1986). On the other hand, the mental ability to manipulate and rotate objects in space quickly as well as accurately is called the mental rotation. Spatial visualization is explained as a complicated and multiple step manipulation of spatially recognized information. These abilities are interceded and supported by an additional fourth spatial cognitive element which is the spatial working memory (Shelton, Elliott, Hill, Calamia & Gouvier, 2009).

Visuospatial working memory (Baddeley, 1986) is the aptitude to collect visual-spatial memories under attentional control temporarily, to be able to accomplish a given task. Baddeley (2000) suggests that this particular cognitive aptitude may have certain individual differences for higher level spatial abilities, exemplified with mental rotation. This Spatial working memory also stands for storing large data in terms of short-term spatial memories "This memory is used in the temporary storage as well as manipulation of visual-spatial information including memorizing shapes, colours, location and motion of objects in space. It is also present in tasks that include the planning of spatial movements such as planning a route within and through a complex building" (Baddeley, 2000:423).

2.4. Virtual Reality and Its Use in Spatial Navigation Research

Virtual Environments (VEs), the platforms that allow the simulation of 3D environments on a computer, are an increasingly used method for wayfinding and spatial navigation studies (Blackman, Mitchell, Burton, Jenks, Parsons, Raman, et al., 2003; Cohen &

Schuepfer, 1980; Cubukcu & Nasar, 2005a, 2005b; Devlin & Bernstein, 1995; Farran et al., 2012; Jansen-Osmann & Wiedenbauer, 2004; Moffat et al., 1998, 2001, Morganti, Carassa & Geminiani, 2007; Omer & Goldblatt, 2007; Ruddle et al., 1998; Ruddle & Peruch, 2004; Sandstorm et al., 1998; Tang, Wu & Lin, 2009; Tlauka et al., 2005; Umemura, Watanabe & Matsuoka, 2005). VEs are now able to closely approximate real world conditions due to the advancements in computer graphics (Hardiess, Mallot, Meilinger, 2015).

In the real world, there are many variables and it is impossible to control all of them in an experiment setting. In order to examine a specific condition's relationship with a factor, one must control all the variables within a setting. In these cases, a simulated environment provides a more isolated experiment setting in which the variables can be controlled. Hardiess et al. (2015) stated that the term *virtual reality* (VR) was initially introduced by Jaron Lanier in 1989. His definition states that, VR is an amalgam of technologies created to generate a human-computer interface which makes it possible for users to interact with, immerse in, and feel the presence within a computerized 3D environment, while also using their natural senses and motor skills in conjunction. According to the encyclopaedic definition, VR is "the use of computer modelling and simulation that enables a person to interact with an artificial three-dimensional visual or other sensory environment" (Lowood, 2018:1). Vilar and Rebelo (2010) explained that VR uses a computerized technology in which an illusion of reality is created where the user can interact with the environment. The main objective is to create a realistic environment for the user.

Rebelo, Duarte, Noriega and Soares (2011) explained that the concepts of immersion, presence, interaction, and involvement are crucial to understand both the physical and psychological experience of VR users. Rebelo et al. (2011) introduced presence as “a subjective concept associated with psychological aspects of the user relationship to the sense of being in the VE” (383). They also indicated that presence refers to experiencing the VE without being aware of one's own actual physical existence. Presence is defined as the sense of embodiment felt in the virtual environment, without noticing the physical space where the user’s body resides in. VR is also suggested to researchers due to its benefits in fields such as spatial cognition, wayfinding and cognitive mapping (Richardson, Montello & Hegarty, 1999; Sharlin, Watson, Sutphen, Liu, Lederer & Frazer, 2009; Wu, Zhang & Zhang, 2009). Involvement and immersion are presented as required conditions for experiencing presence. According to Witmer & Singer (1998), involvement is “the psychological state experienced as result of focusing one's energy and attention on a coherent set of stimuli or meaningfully related activities and events” (227). Witmer and Singer (1998) also defined immersion as “the psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli” (227). Rebelo et al. (2011) explained that video games, for example, include a high level of involvement when played on a non-immersive standard home television. Thus, involvement is directly related to the level of concentration on the VE, which means that any factor that distracts the user can affect the involvement. Moreover, as Rebelo et al. (2011) clarified that “the immersion provided by a virtual environment is directly related to the isolation from the real world and the quality of interaction involved within tasks and the environment in the VR system" (383). In the context of VR, an interaction is established through the communication which is between the user and the system VR is run on. User motions can be detected as well as the actions while refreshing the VE, which results in a defined interaction with the inputs of users. According to Witmer and Singer (1998), there are certainly factors in involvement and immersion that are different; however the levels they are experienced in the VE are not dependent on each other. Therefore, if the level of involvement is increased, the users do experience a greater depth of immersion within an immersive environment. This statement goes both ways. Presence experience is a complex structure of factors and variables that affect both involvement and immersion.

Previous research presents the fact that using VEs in spatial cognition related research has many advantages compared to the usage of real environments due to the controllability of the VE compared to a real environment, as well as its ease of change. Vilar and Rebelo (2010) showed that one of the major advantages of VR is its flexibility. When VR is used, the researchers may manipulate the environment's layout at will, which leads to different interactions that can be designed to facilitate suitable experiment conditions. In VR, monitoring as well as recording of behaviours is quite easy to conduct, therefore paving way for the researchers to gain spatial knowledge on the subjects for further evaluation (Morganti et al., 2007). Participants may operate completely self-determined. Any environment can be simulated and navigation can be measured through a computer network (Jansen-Osmann & Wiedenbauer, 2004). Furthermore, participants may gain knowledge of directions as well as distances (Albert et al., 1999; Willemsen & Gooch, 2002), gain route and survey knowledge (Gillner &

Mallot, 1998; Osmann, 2002) and effectively navigate in a VE (Darken & Silbert, 1996a, 1996b; Ruddle et al., 1999; Memikoğlu, 2012; Sancaktar & Demirkan, 2008).

According to the classification of Guiterrez, Vexo and Thalmann (2008) in Karwowski, Soares & Stanton (2011:383), there are three kinds of immersion; “the kind of immersion based on the physical configuration of a VR user interface; fully immersive (using head mounted display), semi-immersive (large projection screens), or non-immersive (desktop-based VR)”. Gutierrez et al. (2008) stated that immersion’s physical level is determined by how little the user can perceive the real world while in the VE. As Rebelo et al. (2011) clarified that “the lower the perception (see, hear, touch) of the real world, the greater the classification of immersion in VR” (383).

Todays' most developed VR technology is the head mounted display (HMD) system which is a fully immersive VR system where nothing intrudes upon visual field except a scene in the simulated environment (Vilar & Rebelo, 2010). Satava and Ellis (1994) maintained that the technological advancements leading to advanced cell phones also enable the accessibility of HMD systems to increase by many times. A standard HMD system has two miniature displays and an optical system which projects the images from the screens to the eyes, thus presenting a stereo view of the virtual world to the user. (Vilar & Rebelo, 2010) The users' head's position and orientation is continuously measured by an integrated motion tracker which allows the image generating computer to adjust the representation of the scene from the VE to the current view. Therefore, the user can move around the VE freely, while looking around, which changes the point of view constantly, and the user is presented with a real-world-like experience of observing and interacting with the environment.

One of the major advantages of the HMD systems is the high sense of realism and presence that participants experience. The immersion level is also high, thus naming it as a fully immersive VR, where the user is isolated completely from the real world (Gutiérrez et al., 2008). Another advantage of the HMD is the greater sense of depth it provides to the users with the fully immersive 3D graphics. Vilar and Rebelo (2010) claimed that there is no need for head or eye tracking through extra devices, as the new generation HMDs also include this hardware. In the use of an immersive VR system, where the head position is updated constantly, spatial learning could be ameliorated (Westerman, Cribbin & Wilson, 2001). The HMD devices are also cheaper than the Cave Automatic Virtual Environment (CAVE) systems and require less staff to operate. It is thus easier to prepare a VR in HMDs compared to the CAVE system. The biggest advantage of the HMD compared to the desktop and CAVE systems are related to the field of view (FOV) of the devices. According to Patterson et al., (2006), the natural human FOV is 200 degrees horizontal combined with 130 degrees vertical, where the middle 120 degrees cover the area of binocular overlap. The huge FOV of 200 degrees cannot be covered fully by the monitors or wall projections; however HMDs cover the human eyes completely on a nearer degree, which provides better immersion. According to Geoghegan (2015), HMD systems have a higher FOV value than the desktop and CAVE systems thus providing a more realistic VE for the users.

The disadvantages of the HMDs start off with the physical side effects of fully immersive VEs. Beside the advantage of being fully immersed in the virtual world, participants in VR systems usually experience negative after effects, most common examples being motion sickness, balance disturbance, and drowsiness (Stanney & Salvendy, 1998). Cyber sickness is the concept developed to name the negative health consideration within the HMD systems. The FOV values, while being better than the CAVE and desktop systems, still lack the real human FOV which is 200 degrees. The most advanced HMD systems currently have 120 degrees of FOV like the Oculus Rift. Another disadvantage is shared with all immersive VR systems, where the participants do not have *accurate kinaesthesia*, which is the synchronization of perceived movement in between the virtual environment and the user’s own body parts (Vilar & Rebelo, 2010). There are also specific output devices needed for the users to activate their visual, aural and tactile senses. In addition, lower resolution is another disadvantage of todays' HMD systems. Vilar and Rebelo (2010) claimed that the HMDs have a lower resolution compared to the fully high definition displays in the CAVE and desktop environments. On the other hand, this defect can be overcame with the advancements in technology, as new HMD hardware is manufactured annually with better resolution and refresh rate values.

According to the previous studies comparing traditional desktop and HMDs in old technology, it is seen that the researchers have not arrived to a consensus on the effects of display for assessing navigation task in a VE (Ruddle et al., 1999; Ruddle & Peruch, 2004; Santos et al., 2009). There are many controversial results of studies, comparing traditional desktop system and HMDs in assessing human navigation tasks in VE. Ruddle et al. (1999) found that participants navigated quicker with the HMD; they spent less time stationary, looking around more while moving. In this study, Ruddle et al. (1999) defined the brand of the HMD used as the Virtual Research VR4, the device has a very low resolution of (247x230) and it used a keyboard control rather than real time movement. The immersion in such a device is very low compared to the newer generation HMDs. Ruddle and Peruch (2004) once again used an older technology HMD system and explored that there was no differences between the two systems in the rate of spatial knowledge gained. However, distances comprised of straight lines were estimated in a more accurate way using the desktop. Santos et al. (2009) explored that even though users were most commonly satisfied with the VR system, and found the HMD interaction intuitive as well as natural, most had a better performance on a desktop system. Stereo HMD i-glasses SVGA Pro (1998) was used for this study. Resolution: 800 x 600 pixels, Stereoscopic capabilities, 26° of field of view, frame rate of 60Hz or 120 Hz (corresponding to mono or stereo), an orientation sensor (tracker) InterTrax 2 from Intersense with degrees of freedom (yaw, pitch and roll) and a PC with a Nvidia GeForce FX5950 graphics card. The desktop setup used had a 17`` monitor with a resolution of 800x600pixels. The used system here is a very low-cost one, as the study indicates that a low-cost VR system's performance is evaluated. Comparing this system with newer devices as Oculus Rift is very important, considering the technological advancements in the field of virtual reality over the decade.

Li et al. (2014) used Oculus Rift Development Kit 1 in the experiment regarding a VE. The navigation of the participants was measured in the VE, using the metric of distance judgment. According to the result of the study, Oculus Rift yielded better distance judgments. Li et al. (2014) claimed that the lesser FOV, HMD devices such as the NVIS nVisor SX provided a worse distance judgment compared to the Oculus Rift. In this study, 32 participants were used to navigate the VE with Oculus Rift, and the age of the participants ranged from 18 to 30. All 32 participants completed the experiment without any cybersickness symptoms.

Young et al. (2014) compared the NVIS SX60 with the Oculus Rift DK1, on perception and action tasks in the VE. In the study, the distance estimation as well as the virtual object interaction and complex search tasks were combined with simpler viewing experiments to conclude that Oculus Rift performed better in task completion and immersiveness, while the side effects of HMDs such as cyber sickness did not differ in both devices. This study was conducted in two separate experiments. In the first experiment 24 participants were used with ages ranging from 18 to 23. All 24 participants completed the study without any sickness symptoms. The second experiment was conducted on 13 participants with ages ranging from 18 to 26, and 2 subjects were unable to complete the experiment due to sickness resulting from the use of Oculus Rift.

Lastly, Crehem-Regehr et al. (2015) used the newer device of Oculus, the Oculus Rift DK2 in the study of distance perception. Distance estimation was used as the metric once again. The estimation results showed that Oculus Rift DK2 provided better results for the experiment compared to the NVIS SX60 device. Also, the greater FOV provided by Oculus is noted to be an important factor in this result. The result was obtained through the participation of 22 participants with the mean age of 24.7. One participant was unable to finish the study because of minor motion sickness symptoms.

It is important to note that earlier literature does not provide very clear results (Ruddle et al., 1999; Ruddle & Peruch, 2004; Santos et al., 2009), as the improved VR technologies such as the Oculus Rift or HTC Vive provide a much more realistic and immersive virtual-reality environment. Oculus Rift DK 1, DK 2 and HTC Vive are newer generation HMDs. As Oculus Rift DK1 was created before the HD lens technology, the resolution of DK1 is 1280x800 and DK2's as well as HTC Vive’s resolution is 1920x1080 which is noted as FullHD. This improvement alone projects a better VR experience compared to the older literature, as the resolutions are already many times better. Also, the DK1's Pixel Layout of RGB coloring changed to Pentile Layout in DK2 and later on Vive. Vive also includes an OLED and a smaller screen size of 5.7 inches, however the refresh rate is improved to 75 Hz from 60 Hz. The low persistence technology of Vive combined with the lower latency values create a more responsive and immersive VR experience. The FOV of Oculus Rift DK1 was set to 110 degrees and it was lowered to 100 in DK2 and was followed in HTC Vive, as the value is more suitable to the human eyes (Popa & Popa, 2014).

For this study, conducting an experiment in a VE had the advantage of being able to modify the colours of visuospatial cues in a large-scale generic hospital environment in a constant manner. Within the scope of this study, the use of immersive virtual system, HMD system HTC Vive will be more advantageous in terms of providing users updating the head position and increasing the sense of presence. Availability and testing of this system is being evaluated at the moment. There is not any study comparing the desktop system and the HTC Vive. However, by the use of a newer generation HMD such as Vive, increased level of immersion can provide users better navigation task in VE. The configuration and technical specifications, as well as a comparison between the HTC Vive HMD and the Oculus Rift are given in Table 2.

Table 2. Comparison of technological differences between Oculus Rift and HTC Vive

	Oculus Rift	HTC Vive
Display	OLED	OLED
Resolution	1280x800	1920x1080
Refresh Rate	60 Hz	75 Hz
Field of View	100 Degrees	100 Degrees

Considering the fact that Vive is a new technology, there is not much spatial cognition and wayfinding research. However, according to the results of the recent studies presented in the conferences found in the published proceedings (Crehem-Regehr et al., 2015; Li et al., 2014; Young et al., 2014) show that Oculus Rift as well as any other newer generation HMD has many advantages compared to the other developing HMDs in the field of spatial cognition research.

In the first part of this chapter, spatial cognition research connecting visuospatial cues with navigation performance and wayfinding are summarized and compared by taking the concepts of cognitive maps and three major levels of spatial knowledge acquisition into consideration. The assessment methods of the three levels of spatial knowledge in VEs; landmark, route and survey knowledge are also thoroughly analysed in the secondary part of the chapter, by pointing out various studies measuring these knowledge levels in particularly different ways. After reviewing the existing literature on spatial cognition research measuring navigation performance for various participant groups in different settings, the chapter focuses on the subject of VR, and how the use of simulated VEs became increasingly popular in the field of spatial cognition research. The advantages of various VR systems that were developed in the last two decades were compared and summarized, while introducing the latest technology in the field of VR: HMDs. It was also noted that VEs are becoming rapidly common and readily available, thus replacing real environments in spatial cognition research, as seen in the recent literature. To summarize, VEs are a feasible alternative to real environments, and have many advantages discussed thoroughly in this chapter. The technology in the field of VEs has developed rapidly, starting from simple displays to HMDs which simulate a very realistic environment with an improved sense of presence for the users. The aim of this chapter as a whole is to present the justification for the procedure of the study.

CHAPTER - 4

COLOUR AND SPATIAL NAVIGATION

4.1 Basic Colour Terminology

Knowing the three qualities or attributes; which are hue, value (brightness or lightness) and chroma (intensity or saturation) is important to understand the effects of colour on a phenomenon. These three dimensions of colours; hue, value and chroma are able to be individually measured (Munsell, 1988; Fehrman & Fehrman, 2000). Hue, is the attribute which gives a chromatic colour its name such as green, yellow, blue, etc. Human eye can differentiate one colour form another thanks to a colour's hue (Fehrman & Fehrman, 2000). Black, grey and white are the colours which do not have any hue, can be described as achromatic colours (Raskin, 1986). *Value*, also described as brightness and lightness, symbolizes "the lightness or darkness of a colour" (Hunt, 1923:84), indicates the ratio of blackness or whiteness in a colour (Pile, 1997). Thus, thanks to value human eye can separate a lighter colour from a darker one (Munsell, 1988). Shades and tints are also the important terms about the values of colour. Tints, in other words lighter values of a colour can be acquired by increasing white. Additionally, shades which are darker values of a colour can be acquired by increasing the ratio of black. Besides the tints and shades, there are also tones. The attribute of brightness becomes an important aspect in order to make more effective contrast. *Chroma*, also described as saturation, intensity and purity increase the vividness and strength of a colour (Pile, 1997). It basically shows the ratio of pigment in a colour (Fehrman & Fehrman, 2000). In other words, it is also the measurement of a colour in terms of its strength or weakness (Birren, 1969b). A pure colour becomes desaturated, or the chroma may be lowered, when the ratio of white, black, or grey increased. Another option to make a pure colour desaturated is to increase the ratio of a colour away from that specific colour in the spectrum (Pile, 1997).

Colours can also be represented in two types, related to their hue contents such as; *achromatic* and *chromatic* colours. Achromatic colours are white, black and grey and chromatic colours are the ones other than these colours (Raskin, 1986). Colours are categorized as either *cool* or *warm* by their hue contents and positions on the spectrum as well as the perception of their viewers. Cool colours; which are green, blue and violet, are the ones near the violet end of the spectrum and warm colours; which are red, orange and yellow, are the ones near the red end of the spectrum. Related to its blue or red ratio, violet may be perceived as cool or warm (Pile, 1997).

4.2 Colour Order Systems

It is a difficult task to deal with over ten million colours that human eye can distinguish (Hardin, 1992). Most people have difficulties on describing a colour, particularly with regard of its variation from other colours. Many scientists and researchers have been working on the classification of colours and explored several number of colour order systems over the years. The most popularly used colour ordering systems in various field of research, are explained in this chapter such as; Munsell Colour System, Natural Colour System and CIELAB. All those colour ordering systems created to provide a systematic method and easiness in colour classification by using the three attributes of colour.

4.2.1 Munsell Colour System

The Munsell Colour ordering system is the most popularly one, having its name from A.H. Munsell, established in 1905 (Hunt, 1987). Munsell Color Theory is based on a three-dimensional model in which each colour is comprised of three attributes of hue, value and chroma (Munsell Corporation, 1980). Hunt (1987) explains the hues as it is seen in Figure 3. There are 10 major hues of which five are principle hues and five are intermediate hues. The five basic hues are arranged in a clockwise order around the circle such as; red, yellow, green, blue and purple while the colours in between are the intermediate hues (Hunt, 1987). Equally spaced 100 hue radii are generated the hue circle.

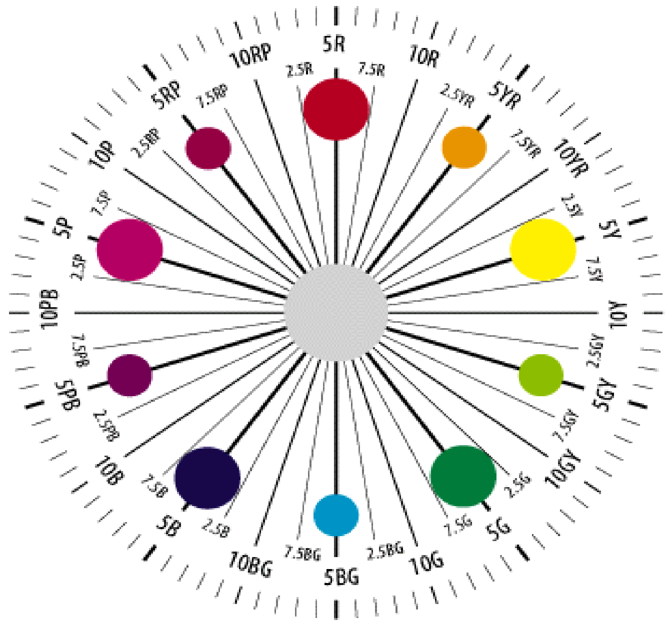

Figure 3. The Munsell hue circle.
(http://dba.med.sc.edu/price/irf/Adobe_tg/models/images/munsell_sphere.gif)

Hunt (1987) suggests that hue ranges change from 0-10, thus making up 11 radii. The principle hues are distributed among each hue range, around the radius 5. The clockwise numbers are given starting from the hue ranges of 0 to 11 (Hunt, 1987). For instance, the segment between 5YR and 10YR are; 6YR, 7YR, 8YR, 9YR, 10YR , 1Y, 2Y, 3Y, 4Y and 5Y. This system is the same along any other hues and between them. The remaining divisions are shown by the usage of decimal points; 3.5 YR is the middle point between the hues of 3YR and 4YR. Hues are situated on the vertical axis (Hunt, 1987). This vertical axis shows the values ranging from light to dark (Feishner, 2000, see Figure 4). In the Munsell Book of Colours notation, chromatic colours are represented by their hues, values and chroma in the exact order. The first variable is the value and is represented by (V). This value is defined from 0 to 10 and refers to the colour’s

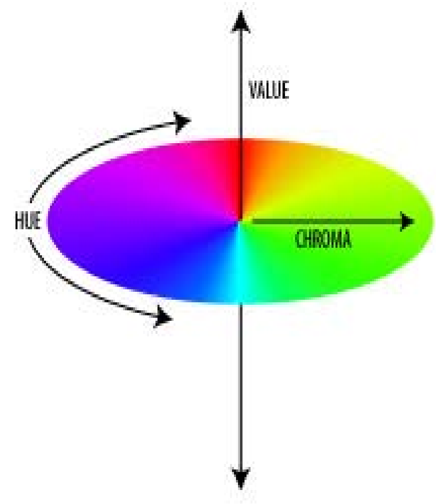

Figure 4. Geometrical framework of Munsell Colour System (http://dba.med.sc.edu/price/irf/Adobe_tg/models/images/3_axes.JPG)

perceived lightness and luminance factor (Agoston, 1987). There are ten main steps in the value as shown in Figure 5 vertically, while white designated 10 at the top and black 0 at the bottom (Hunt, 1987). The value symbol 0/ (at the bottom) shows perfect black whereas; the symbol 10/ (at the top) shows perfect white; the symbol 5/ (in the middle) shows middle grey (Munsell Colour Corporation, 1980). By a geometrical framework of Munsell Order System, dimensions of hue, value, chroma are symbolized in Figure 5. The central vertical axis starts at the bottom from black and moves towards white towards the top. Chroma values have equal steps in between from the neutral axis towards the outside in the colour space (Munsell Colour Corporation, 1980). The perceived saturation is given by the Chroma notation (C). It is defined according to its difference from neutral grey. The chroma scale is open-ended (see Figure 6). The measurements are conducted along a hue-radius which translates into the chroma being zero at the centre (neutral grey) and it increases outward in a progressive manner towards a maximum chroma (Agoston, 1987).

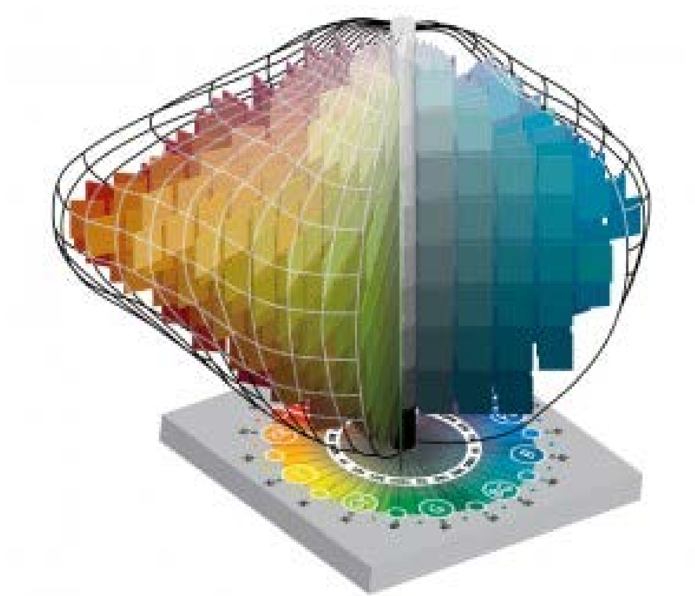

Figure 5. Geometrical framework showing hue, value and chroma in Munsell Colour System. (http://munsell.com/wp-content/uploads/2011/09/Munsell-Color-Solid-Plus-base-color-theory-300x239.jpg)

In the Munsell Book of Colour, every 50 hue chart is presented with a Value/Chroma grid. The hue notations were also labelled in each chart (see Figure 6). In the square grid arrangements, the variations of Munsell values are given vertically and the chroma is given horizontally (Agoston, 1987; Hunt, 1987).

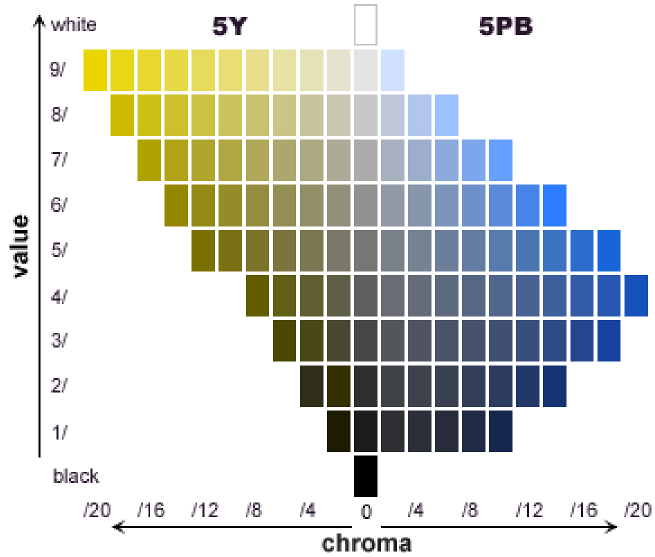

Figure 6. Sample pages from the Munsell Book of Color (1929) (http://www.handprint.com/HP/WCL/IMG/munsell2.gif)

The Munsell Colour System has many applications due to the ease of use, and provides the artist the opportunity to decide the elements of a colour without experimentation and gives precise pigment specifications (Hunt, 1987). On the other hand, colour-scientists use it in many professional fields across the globe in their specific colour designs and the communication of colour information between different departments (Munsell Colour Corporation, 1980).

4.2.2 Natural Colour System (NCS)

The Natural Color System (NCS) is an advised perceptual colour model published by the Scandinavian Colour Institute (Skandinaviska Färginstitutet AB) of Stockholm, Sweden in the nineteenth century (Fehrman & Fehrman, 2000). It is based on the opponent colour system of German physiologist Ewald Hering. It is important to fully comprehend the approach and systematic of Hering colour system, in order to fully comprehendd NCS.

Hering's colour system has four primary hues such as; yellow, blue, red and green due to the inability to describe them in terms of any combination of other colours (Hunt, 1987). These four primary hues are paired twice as green and red, and blue and yellow where the colours in each of these pairs are opponent colours. Along with white and black, there are six basic hues including the previously mentioned primary fours (Hunt, 1987). "This new colour pair is different from the unique-hue pairs in its opponency, in that blackish white or whitish blacks are possible, experienced as the colour gray" (Hunt, 1987:86).

NCS defines six psychological fundamentals, which are also Hering's six basic colours: Yellow, red, blue, green, white and black (Fehrman & Fehrman, 2000). NCS starts judging the colour by first determining its hue. Hues of colours in the 0, 90, 180 and 270 degrees (see Figure 7) are the yellow, red, blue and green in order. NCS hue circle is divided by the four hues into four quadrants. Each quadrant is named by its

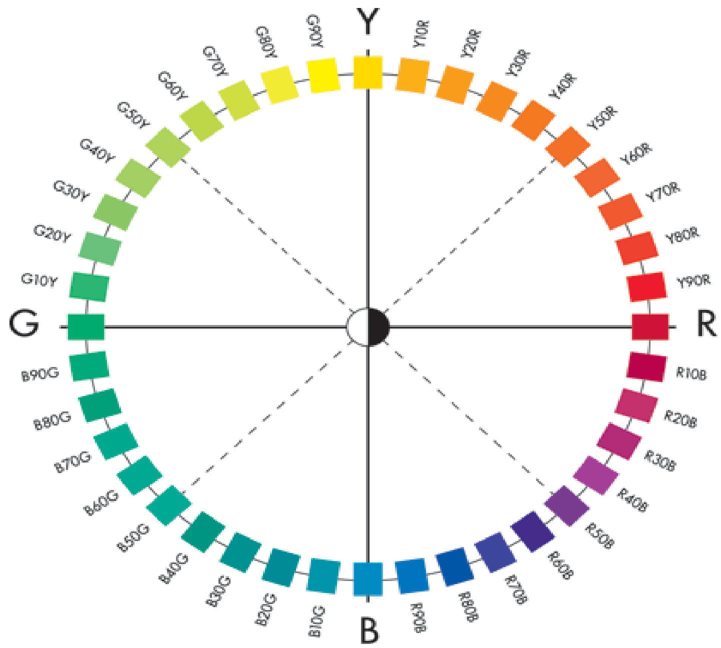

Figure 7. The NCS colour circle.

(http://www.ncscolour.com/PageFiles/615/NCS_Colour_Circle.png)

neighbouring colours. “The scale that is read clockwise shows standard NCS hue designations” (Agoston, 1987:134). The dashed lines in 45, 135, 225 and 315 degrees are the hues that are in the middle of two primary colours, and they divide the circle into two quadrants in which, to exemplify, the arc between G50Y and Y50R represents the yellows. This terminology opens up new terms such as yellowish reds and bluish reds, which stand for the hues of red which are closer to other primary colour values within the circle (Agoston, 1987). Colours are defined by the relative amounts of basic colours in them according to NCS. These are presented by percentages (Hunt, 1987). For example, the notation of Y50R in the colour circle represents a 50/50 mixture of the unitary yellow and the unitary red. In the hue triangle, by the relative amounts of S, W, and C, the perceived colour can be represented (see Figure 8).

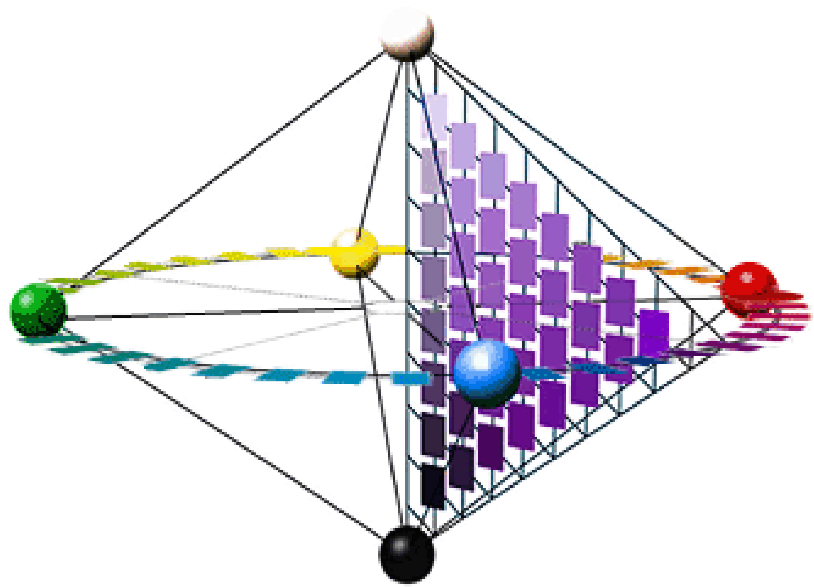

Figure 8. Geometrical framework of the Swedish NCS colour model (http://www.handprint.com/HP/WCL/IMG/ncs.gif)

Rather than mixing colours, the system is often used for matching colours. A colour is determined as an absolute measure based on its perception. The NCS has adopted by the Swedish Standard Institution (SIS) as a Swedish Standard for colour notation and colour atlas (Swedish Standards Institution, 1996). There are 1750 colour samples in the 42 pages (Swedish Standards Institution, 1996). The initial page reveals the NCS colour circle with 40 colour samples of high chromaticness (saturation), presenting the hues selected for the atlas (see Figure 9). The next page consists of colour samples for purely grey or near-grey colours, also known as non-chromatic or slightly-chromatic varieties of colour. The next forty pages show NCS triangles in which there are separate hues and relationships analysed according to black and white colours (see Figure 9). In the NCS colour atlas "the chromatic hues are arranged in a circle with nine intermediate steps

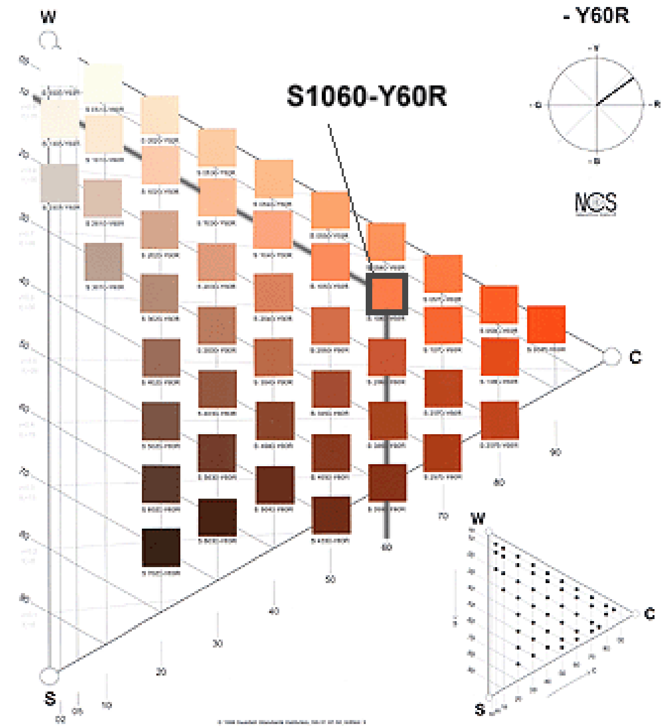

Figure 9. A sample page from the NCS Colour Atlas 96 (http://www.handprint.com/HP/WCL/IMG/ncspage.gif)

between each, totalling to forty hues. Then, for each hue, a triangular chart is developed showing the pure hue and its relationship to white and black" (Fehrman & Fehrman, 2000: 205).

As it is stated, NCS is a system of colour which exists in the domain of psychology, where descriptions of colour are related to their perceptions. Because of this reason, NCS may be useful for any person with either no knowledge regarding colour or the proper background or experience regarding colour specifications and measurement (Agoston, 1987). Verbal descriptions of colours are important for the system, which makes the notation easier to understand when compared to other colour systems. NCS system was intended to help colourists as well as manufacturers to communicate regarding different colours in the sense of colour perceptions (Swedish Standards Institution, 1996).

4.2.3 CIELAB

CIELAB is a model derived from CIE model, developed by Richard Hunter. It defines colours along two polar axes for colour (a and b) and a third for lightness (L). It is important to comprehend the idea behind the CIE in order to fully explain CIELAB. In 1931, the International Lighting Commission or CIE recommended a system of colour measurement (Grandis, 1986). The system is “based on spectrophometric measurements of colour samples illuminated by specific types of lighting and related to the visual response of a standard observer” (Fehrman & Fehrman, 2000:209).

Dimensions of colour (hue, chroma and value) are called the CIE’s tri-stimulus values. The tri-stimulus values are X, Y, Z (red, green and blue) and they can be produced from these letters (Agoston, 1987). CIE has a chromaticity diagram which is a companion with x and y (see Figure 10). This diagram is used to recognize the wavelength and degree of saturation of a given colour. The physically realizable spectral pure colours and non-spectral pure colours are located in the diagram (Grandis, 1986). In the centre, there is white light supplied by the source. The diagram of chromacity is useful when locating the positions of colours that are comprised of two or more of the primary colours. All the three dimensions of colour are specifically given in the CIE triangle (Grandis, 1986).

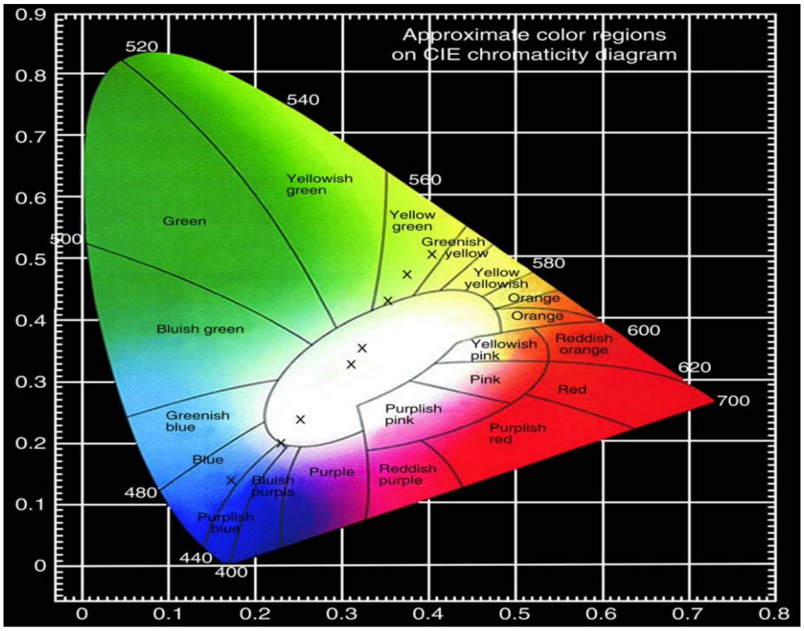

Figure 10. The CIE chromaticity diagram (http://www.nature.com/ncomms/2013/131111/ncomms3717/images/ncomms3717-f4.jpg)

The CIELAB was established to adapt a standard of uniform colour scale for the measurement of colour differences. As previously stated, CIELAB system is suggested for matching standards of material and object production. The industrial usage of colour is emphasized in the difference evaluations within the system (Agoston, 1987). CIELAB has an objective standard, thus eliminating the human interpretation caused differences and issues, while also getting rid of the colour fading related problems (Agoston, 1987). Moreover, it has been used by researchers that conduct scientific experiments via a specified instrument for the measurement (Grandis, 1986). If the tolerance level is low, the manufacturing task becomes proportionately difficult. In industry, “in the production of large amount of paint, fabrics and other coloured materials and objects, colours are usually required to match the standards within a stated tolerance of variation; the smaller the tolerance, the more difficult the task of manufacture” (Agoston, 1987:90).

In order to create certain colour differences by handing out a standard approximately uniform colour scale, CIE recommended CIELAB in 1976 (Agoston, 1987). This gives estimated colour space uniformity for the determination of colour differences through algebraic calculations of tri-stimulus values (Agoston, 1987). “ There is a vertical metric lightness L axis in the basic structures of the CIELAB that passing centrally through evenly spaced horizontal planes that are subdivided into square grids containing coordinates a and b which are the tri-stimulus values” (Agoston, 1987:107; see Figure 11). In the CIELAB uniform three-dimensional colour space, every colour has a unique location in the 3-D cartesian coordinates, with respect to L, a and b axes (see Figure 12). L is the metric-lightness axis, and represents hueless colours starting from 0 in the bottom as black, and raising in value to 100 to reach white. The other two coordinates represent colours, such as a representing red/green coordinate and b representing the yellow/blue coordinate. (Agoston, 1987).

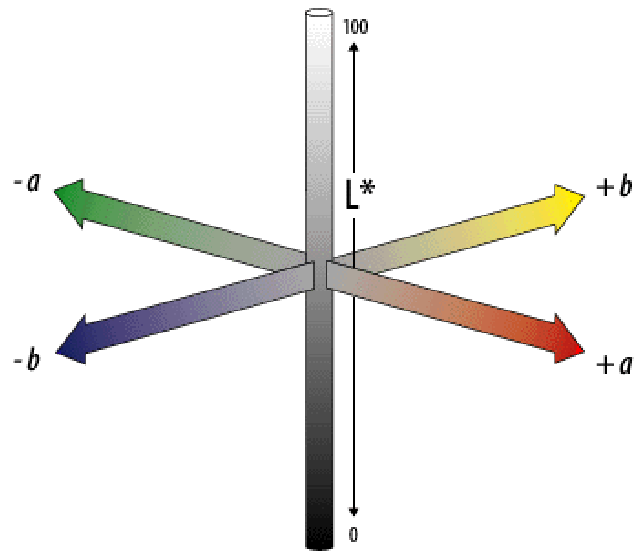

Figure 11. The CIELAB colour space

(http://dba.med.sc.edu/price/irf/Adobe_tg/models/images/CIELAB.gif)

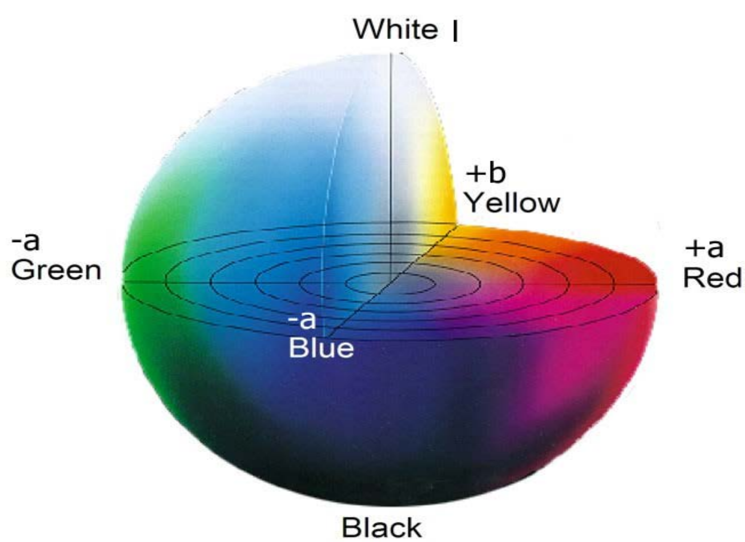

Figure 12. The CIELAB uniform three-dimensional colour space.

(http://www.coatsindustrial.com/en/images/Colour%20difference_tcm35-152855.jpg)

4.3. Colour as an Interior Design Element

Colour is a flexible and powerful element of interior design that provides functional and aesthetic qualities for occupants of the space. Park and Guerin (2002) explored that colour shapes the environment, and its integration in the design process is essential because colour is one of the major influences on how we interpret and discover our environment. Hard and Sivik (2001) explained that colours in an environment serve as tools of communication between people and the objects or surfaces surrounding them.

Thus, colours can be used to give the right idea to people through the built environment. The incorrect use of colour provides undesired message and can impair the user's ability to interact with their environment. Additionally, Shehata claimed (2000) that too much colour can have the effect of making something more difficult, rather than easier to use.

Colour as a visuospatial cue can be used to enhance wayfinding performance in especially unfamiliar environments by emphasizing the architectural layout of the building environment. Environments that are generally difficult to navigate in can be exemplified with buildings that have many long corridors and complex interiors such as schools with many classrooms and hospitals with many departments. The following parts explain the importance of colour usage in wayfinding and spatial navigation, and its implications in healthcare environments.

4.3.1 Colours' Function in Wayfinding and Spatial Navigation

According to Smith (2003), colour is one of the most influential interior design elements, and its effects must be carefully understood to apply it in the right way. Colour has high impact in the environment where we live, work and play, and has a dramatic effect in changing and improving the aesthetic shape of different areas in wayfinding. Dijkstra et al., (2008) explored that wall colour in a built environment might provide a relatively easy, low-cost strategy for promoting increasingly relaxed feelings and effortless wayfinding. Similarly, Kaya and Erkip (2001:37) concluded that “crowding may be reduced by brightening a room with light colours or graphic designs on walls”. Park and Guerin found (2002) that corridors, floors, wards and waiting rooms with colour affect the perception of individuals. The colours chosen in these areas can also have an inspirational and stimulating effect. Wayfinding in settings with colour is easier than in settings without colour (O’Neill, 1991). Abu-Obeid (1998) suggested that designers should use colour codes or colour schemes to provide differentiation in the built environment and facilitate wayfinding. People use different types of environmental cues when wayfinding within buildings. MacKenzie and Krusberg (1996) suggested that to create an effective wayfinding system that uses intrinsic spatial cues as well as being consistent, wayfinding designers should be in the primary process of planning the facilities and developing them in an early stage.

The most commonly studied wayfinding system is colour coding. The results of some studies showed that only certain departments can be colour coded, because most multistorey buildings with complicated floor plans were not built to be colour coded (Carpman & Grant, 1995; Nicoll, 1995). Only a few colours should be used to provide an effective wayfinding system with colour coding (Carpman & Grant, 1995). When choosing the colours, nameable colours should be picked for instance red and blue, instead of colours harder to vocalize such as light blue or bluish red (Nicoll, 1995). The colours should also be highly discernible for colour blind individuals as well (Carpman & Grant, 1995). “Once the colours are chosen, they should be used logically and consistently” (Carpman & Grant, 1995:108). A potential issue that is also present for smaller sized facilities is that the colours could be used for other purposes, such as furnishing or decorations as was also pointed out by Rezenstein and Vaitkus (1981). De Jesus (1994) found that inconsistent use of colour coding may lead to a significant reduction in its effectiveness as a wayfinding guide. Also, colour coding the different levels of the building will enhance the location recognition and individuality. Sharpe and Jagle (2001) suggested that designers should consider providing alternatives to colour coding in wayfinding aids and other visual cues in the built environment to aid individuals who cannot discern between colours.

There is also much research in the literature on using coloured landmarks to improve wayfinding. The general consensus of the studies point towards better results with the use of coloured visuospatial cues however there is no significant difference found in between cool and warm coloured settings. To summarize some of the major studies, Werner and Schindler (2004) studied the spatial structure of a building and how it affected wayfinding performance of its dwellers. Colour was used as a visuospatial cue in this study, where five objects were placed in deadends on each floor plan with different colours. Colour was found to be a significant visual cue in this study, as it helped the participants be directed within the hallways. Helvacıoğlu and Olguntürk (2011) used a similar colour usage in their study, in which a real school environment was used to explore the effects of coloured landmarks on wayfinding performances of children. Grey and coloured landmark usage was compared, and the results showed that colour had a significant effect on the wayfinding performance of children. Coloured landmarks had higher memory scores for the children compared to grey landmarks.

Dalke et al. (2006) used colour and lighting as visuospatial cues in a hospital environment and found out that different colour and lighting usage lifted the monotony in a hospital environment, providing better psychological support for patients, thus helping their healing process. Recovery rates were actually increased with the less monotonous colour usage, which included no grey and beige colours, or in other words, neutral colours.

Davis and Ohman (2016) studied a VR simulation of a senior residential building, and assessed the wayfinding for adults that had Alzheimer's disease and a control group without it. Salient cues within the environment were found to be helpful in increasing the effiicency of wayfinding for the elders with Alzheimer's disease. These salient cues used in the experiment are ten high contrast large and colourful objects laid down in the route, claiming once again that colour is a significant visuospatial cue to enhance wayfinding.

Another study by Farran et al. (2012) focused on the use of colour and its help in learning a route. The study was conducted in a virtual environment, to children of 6 and 9 years old, as well as adults, all with Williams Syndrome. The settings of the experiment were divided into two, the first having focal or easier to verbalize colours, while the second having non-focal colours which are difficult to verbalize. There was a significant positive effect of using focal colours compared to the non-focal colours. These focal colours consisted of the warm colours explained further into the study, and used within the procedure as a setting for this experiment.

Marquardt (2011) studied another disease, dementia, and how lighting, colour and signage could be used in architecture to make it easier for the patients to identify and locate rooms with similar function within a hospital environment. Colour was found to have a positive effect on wayfinding, visual access and the reduction of decision making difficulty. Read (2003) used colour in child care environments, and found that bright and warm colour usage within the classrooms had a positive effect on the mood and learning capabilities of children, thus suggesting colour is a flexible, accessible and important design element for interior designers.

Lawton and Kallai (2002) found that occupants might have different preference for wayfinding strategies (using a map or compass, referring to landmarks, etc.). Preferences for wayfinding aids may vary across cultures and this should be considered by designers. Jansen-Osmann and Wiedenbauer (2004) suggested that designers should place landmarks in buildings next to the correct turns in order to optimize landmark-based wayfinding. The use of landmarks in wayfinding may be successfully examined in VEs. Jung and Gibson (2007) found that physical landmarks also help successful wayfinding performances during emergency situations. To elaborate, certain material or colour changes, as well as notable shapes as landmarks may be used as cues in design and interior architecture of buildings to create easy to perceive exit spots during emergencies. Schmitz (1999) concluded that the relationships of routes and landmarks should be taken into consideration by designers when planning space to facilitate wayfinding. It is important to provide both the route information as well as the landmark information in the built environment and in wayfinding aids when possible.

Use of colour to enhance wayfinding abilities and the significance of a place is very important in the built environment. Designers need to provide recognizable cues (signs, colours, etc.) within spaces for individuals to rely on while trying to find their way (Park & Guerin, 2002). According to Haq and Zimring (2003), when participants directed to search, they have shown a better comprehension of an environment due to completely comprehending the environment around them. When an individual is more familiar to a setting, it is easier to learn more about the overall configuration of that environment (Doğu & Erkip, 2000). Open exploration (searching without direction) was an important factor that made it possible for subjects to become familiar with the setting and therefore establish a cognitive map. The way corridors were connected to each other allowed participants to find their way more easily; this may be a predictor in coloured walls and floors. For a person who is new to an environment, intersections are more important than corridors. Movement within an environment creates an understanding of its configurational attributes, which allows a more accurate environmental cognition and wayfinding. Both the room's shape as well as the layout might impact wayfinding and an easier form of wayfinding may increase both the functional and satisfying qualities of a space. To ease wayfinding, designers should layout spaces and shape rooms so that they relate to major circulation access in a consistent way. Therefore, to ease wayfinding in complex buildings or buildings with irregular plans, designers want to emphasize major circulation axes or provide features visible from points throughout the building (e.g., using colour, views to a landscape or other prominent features). Areas without colour caused slower wayfinding and were less accurate at pointing visitors to designated places in buildings. Non-coloured areas caused difficulty for visitors who had to associate the environment they experienced with a two-dimensional representation (Werner & Schindler, 2004).

4.3.2 Colour in Healthcare Environments

Hospitals are infamous for being labyrinths. Tofle et al. (2004) suggested that hospitals are difficult to navigate in, due to their large floor plans, complexities and harder to comprehend medical names of departments (Tofle et al., 2004). Garling (1984) and Weisman (1981) showed that the primary elements in wayfinding are; degree of differentiation, visual access, signs, and architectural legibility. Kaplan (1982) stated that distinct colours can be used for landmarks aside from graphics, signage, and other visual cues to improve wayfinding.

Park and Mason (1982) found that most people don't find colour coding as effective in wayfinding as a form symbol. Evans et al. (1980) explored that a differentiating colour on accent walls could be useful in a monochromatic environment. Goldstein and Oakley (1986) indicated that colour is an aid more useful than form to guide individuals with head injuries causing learning and memory retention. Malkin (1992) presented the idea that for special demographics such as the elderly or people with dementia as well as Alzheimer's disease, colour-dominance is preferred rather than form-dominance. Hoglund and Ledewitz (1999), the designers of many Special Care Units for patients of dementia maintained that colour coding as well as conventional signage, different finishes, flooring, hardware, and lighting do not provide clearly perceptible cues for many patients of dementia. The elderly cannot differentiate slight changes in colour, and colour coding is too complex for most residents to comprehend. Additionally, they think that landmarks and sight lines have the most potential for wayfinding and cueing. They also suggest that most environmental cueing is too hidden for people with dementia.

Wayfinding and place recognition using colour as a specific aid tool has also been explored by Cooper (1994) and Leibrock (2000). As a direct consequence of the natural process of aging, the visual functions of humans become impaired over time, and several processes associated with vision also slow down. The adaptation in moving from a brightly illuminate area to a darker area also slows the process along with the accommodation, that is the process of focusing on an object or task. Tofle et al. (2004) suggested that other two age-related processes are Presbyopia, which is the inability of the eye to focus on nearby objects or tasks, and the yellowing which is the clouding of the lens. As these two phenomena develop, the images start to become blurred, and the eyes are more sensitive to glare, increasing the amount of light required to conduct daily activities. Steffy (2002) noted that “some colour vision deficiency does occur with age. As the lens clouds, there is less ability to distinguish colour at lower light intensities and/or distinguish between dark colours. Generally, all colours are dulled, but blue is particularly muddied” (14). The elderly may require 4 to 5½ times more illumination to distinguish a figure from the background, compared to a healthy adult (Cooper, 1993; Hiatt, 1991; Hughes & Neer, 1981; Liebrock, 2000; Pastalan, 1982). Christenson (1990) for example pointed out that: “Gradual yellowing [of the lens] impairs the perception of certain colours, particularly greens, blues, and purples. Dark shades of navy, brown, and black are probably not distinguishable except under the most intense lighting conditions” (11). Additionally, the detection of disparities between pastel colours such as blues, beiges, pinks and yellows is usually extremely difficult.

Brawley (1997) indicated that providing high levels of contrast for older adults is crucial to enhance visual function. Cooper, Ward, Gowland, and McIntosh (1991) confirmed that the elderly lose their abilities of distinguishing unsaturated colours. This was emphasized more for cool hues and was found to be more noticeable after age 60. Elders are best able to distinguish highly saturated colours at the warm end of the spectrum and they are less able to differentiate pastel blues on the cool side. Blue/ purple were the most difficult colours to see.

In conclusion, this chapter explains the basic colour terminology and colour order systems which is useful in understanding the aim of this study as a whole. Additionally, the chapter presents the previous literature regarding the use of colour in built environments and its effects on wayfinding.

CHAPTER - 4

THE EXPERIMENT

4.1. Scope of the Study

The main aim of this study is to explore the effects of colour as visuospatial cue on spatial navigation and developing a cognitive map in elders, in a simulated polyclinic environment (Süzer & Olguntürk, 2018). A generic polyclinic floor of a large scale hospital building is selected for this study and three different colour schemes are compared to explain the aid of colours on visuospatial navigation in elders.

The scope of this study explained through four aspects which also give clues about the chapters of the dissertation (see Figure 13). Wayfinding and locomotion are the two components of navigation. Locomotion is the motor component and wayfinding is the cognitive component in which travellers develop spatial knowledge. The two levels of

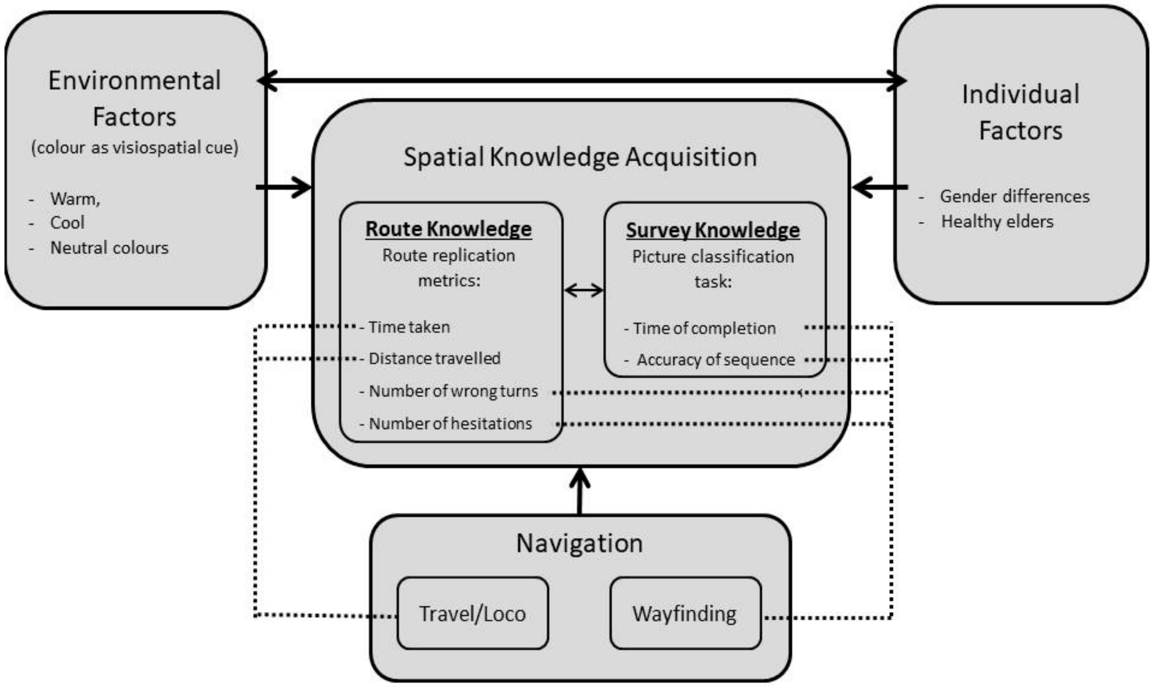

Figure 13. The scope of the study (Retrieved from Süzer & Olguntürk, 2018:4)

spatial knowledge acquisition used in this study that are; route knowledge and survey knowledge. Besides that, the two tasks to measure different levels of spatial knowledge are indicated. First task is given as the route replication task to measure route knowledge and the metrics are; number of wrong turns, time taken, number of experiencing hesitations and distance travelled. The second task is picture classification task to measure survey knowledge, and the metrics are time of completion and sequence. Individual factors may affect spatial knowledge acquisition and then wayfinding and spatial navigation. Wayfinding is a problem solving activity which can be affected by individual factors such as; age, sex, visuospatial abilities, handedness of users, familiarity, education level and occupation. For this study, besides the sex difference, healthy elders' visuospatial navigation and cognitive mapping performances are explored. The three different coloured virtual environment settings that are; neutral, warm and cool settings investigated for this study as an environmental factor. The only difference between the three settings was the colours of visuospatial cues. The dependent and independent variables of this study can be seen in Table 3.

4.1.1 Research Questions

1. Do coloured visuospatial cues ease navigation compared to neutral?
2. Which colour setting improves spatial navigation? / Do warm coloured visuospatial cues improve spatial navigation compared to cool?
3. Is there any difference between males and females' spatial navigation performances? / Do females have difficulties in spatial navigation compared to males?

4.1.2 Hypotheses

1. Coloured visuospatial cues ease navigation compared to neutral by
   a. decreasing the time spent,
   b. reducing the number of wrong turns,
   c. minimizing experiencing hesitations,
   d. reducing the distance travelled.

2. Warm coloured visuospatial cues improve navigation compared to cool by

   a. decreasing the time spent.

   b. reducing the number of wrong turns.

   c. minimizing experiencing hesitations.

   d. reducing the distance travelled.

3. Females; spend more time, have more wrong turns, experience more hesitations, travel longer distances compared to males.

Table 3. Dependent and independent variables of the research

Dependent variables
1. Route replication task: a. the time spent, b. the number of wrong turns, c. the number of experienced hesitations, d. the distance travelled.
2. Picture classification task: a. time of completion, b. sequence accuracy.
Independent variables
1. Colour of cues: a. cool b. warm c. neutral
2. Sex: a. females, b. males.

4.2. Method of the Study

4.2.1 Participants

The selected participant group consists of ninety healthy elders, chosen by snowball sampling according to their age, education level, handedness, and sex (see Table 4, for the distribution of sex in three settings). When a potential participant is identified and s/he asked to recruit his/her friends or neighbours. Those steps are repeated until the required sample size is found. The provision of a participant who has no experience in the field of design and architecture is an important idea, as the information should be supplied to professionals in the field of design may have a different user's perspective. Therefore, an individual who has or had an experience of interior design or architecture is excluded from the study.

The participant group required to be balanced as to sex (45 females and 45 males) to explore sex differences in the aid of colour on visuospatial navigation. The participant group was consisted of 90 volunteers (m=70.42, std. dev. =4.399, n= 90), balanced as to their sex; 45 females (m=70.49, std. dev. =4.324, n= 45) and 45 males (m=70.36, std. dev. =4.422, n= 45). The age of the participant group varies in between 65 and 80. The experiment is conducted with three different participant groups of 15 females and 15 males each, for the neutral, warm and cool coloured experiment settings.

Table 4. The distribution of participants in three experimental settings

Participants (65-80 ages) N=90	Setting 1 (neutral)	Setting 2 (warm colours)	Setting 3 (cool colours)
Females	n=15	n=15	n=15
Males	n=15	n=15	n=15

4.2.2. Instruments

In order to eliminate those results in visuospatial navigation performance may be determined by cognitive and functional impairments, spatial skills and depressive symptoms, several cognitive tests indicated below were conducted.

4.2.2.1. Ishihara Test for Colour Blindness

All of the participants are asked if they have any eye or vision deficiencies. Participants who have any vision deficiencies are asked to take the experiment with their correction equipment such as contact lenses or eyeglasses, which they wear regularly (see Appendix A). Participants are also given *Ishihara's Tests for Colour-Blindness* (Ishihara, 1975) in the very same room with the experimental setup, under the same lighting conditions. It is a series of plates that are designed to provide a quick assessment of colour vision deficiencies. Volunteers with any severe visual difficulties were not admitted to the experiment.

4.2.2.2. Montreal Cognitive Assessment (MoCA)

MoCA is a simple but promising tool for evaluating mild cognitive impairment and early Alzheimer's disease (Nasreddine et al., 2005; Selekler et al., 2010). The MoCA assesses several cognitive domains. Elderly who are validated as cognitively impaired as a result of the Montreal Cognitive Assessment (MoCA) are not eligible for the experiment (see Appendix B). The MoCA was created in 1996 by Nasreddine et al., in Montreal, Quebec. Selekler et al. (2010) stated that the MoCA is "a screening device used to assess attention and concentration, executive functions, memory, language, visuospatial abilities, abstract thinking, calculation, and orientation domains" (166). The MoCA test validation study (Nasreddine et al., 2005) has shown the MoCA to be a promising tool for detecting Mild Cognitive Impairment and Early Alzheimer's disease compared with the well-known Mini-Mental State Examination. Because of this reason MoCA is preferred for this study.

The MoCA is initially designed for North American population therefore; the cut-off score is indicated as 26. The test was later modified specifically for Turkish population and the cut-off score is indicated as 21(Selekler et al., 2010). In this experiment, the volunteers, who had less than 21 points from Turkish version of MoCA were not admitted to participate.

4.2.2.3. Functional Activities Questionnaire (FAQ)

Elderly who are validated to have dependency as a result of the Functional Activities Questionnaire (FAQ) are excluded from the experiment (see Appendix C). The FAQ was created in 1982 by Pfeffer et al. for initial assessment of functional impairment. The Functional Activities Questionnaire (FAQ) measures instrumental activities of daily living (IADLs), such as preparing balanced meals and managing personal finances.

In the original version of FAQ, cut point of 9 (dependent in 3 or more activities) was recommended to indicate impaired function and possible cognitive impairment (Pfeffer et al., 1982). Additionally, FAQ is standardized and adopted for Turkish culture by Selekler et al., 2004. The cut-off score of FAQ for Turkish culture is indicated as 5 (dependent in 2 or more activities) for ages of 50-69 and 9 (dependent in 3 or more activities) for ages of 70 and more, to determine impaired function and possible cognitive impairment (Selekler et al., 2004). Selekler et al. (2004) indicated that the scores of FAQ increase when the age grows and education level decreases. The Turkish version of FAQ is used for this study.

4.2.2.4. Geriatric Depression Scale (GDS)

Elderly who are validated to have depressive symptoms as a result of GDS are excluded from the experiment (see Appendix D). Depression is not a natural part of aging. Depression is often reversible with prompt recognition and appropriate treatment.

However, if left untreated, depression may result in the onset of physical, cognitive, functional, and social impairment, as well as decreased quality of life. While there are many instruments available to measure depression, the GDS, first created by Brink et al. (1982), is one of the most commonly used self-rated depression scales in elderly. Validity and reliability studies of GDS for Turkish culture are investigated by Ertan and Eker in 2000. The Turkish version of GDS is used for this study.

4.2.2.6. Judgement of Line Orientation Test (JLO)

Participants who are validated to have decreased spatial skills as a result of the JLO Test are excluded from the experiment (see Appendix E). The JLO test is a widely used measure of visuospatial judgment that was originally conceptualized by Benton et al. in 1978. JLO is a standardized test of visuospatial skills commonly associated with functioning of the parietal lobe in the right hemisphere. The standardization study of JLO Test is completed for Turkish culture by Karakaş in 2004. It is seen in the Table 5, for 12 and more years of education the normative interval for 55-73 ages is in between 20-26.

Table 5. Mean and standard deviation values of JLO Test according to research conditions (Retrieved from Karakaş, 2004:317)

JLO Test	Education Level											
	5-8 years education				9-11 years education				12+ years education			
	Age											
	20-54 ages		55-74 ages		20-54 ages		55-76 ages		20-54 ages		55-73 ages	
Total score	$\bar{x}$	Ss	$\bar{x}$	Ss	$\bar{x}$	Ss	$\bar{x}$	Ss	$\bar{x}$	Ss	$\bar{x}$	Ss
	20.03	4.58	19.81	4.00	22.46	4.52	21.18	4.82	25.37	3.51	23.04	3.43

4.2.2.6. Presence Questionnaire (PQ)

The PQ is a questionnaire to assess the sense of presence in the VR. The assessment of sense of presence is important because the participants have to feel present in order to orient themselves. The effectiveness of VEs has often been linked to the sense of presence reported by users of those VEs. There are many questionnaires measuring presence. However, Baren and IJsselsteijn (2004) reported that the calculated reliabilities and validities have occurred for only the "Igroup Presence Questionnaire" (IPQ) developed by Schubert et al., 2000 (alpha value = 0.87) and the "Presence Questionnaire" (PQ) developed by Witmer and Singer, 1998 (alpha value = 0.88). The Turkish version of PQ is used for the third phase of this study, which is translated previously in Özdinç's research (2010) (see Appendix F). Witmer and Singer (1998) identified involvement and immersion as conditions for presence. They aimed to develop a measure of presence addressing factors that influence involvement and immersion. By answering the thirty-two items based on such factors; control, sensory, distraction, and realism, the spatial presence of the participants was verified.

4.2.3. Description of the Virtual Environment Settings

VE is preferred for this study because changing the colours of visuospatial cues in a hospital is more efficient with a simulation. For this study, in order to acquire consistent results in VE with the real one, it is crucial to prepare the simulated environment like a real hospital. Polatli Public Hospital's which is a large scale generic public hospital, two dimensional drawings are obtained from Ministry of Health. The modelling phase of generic hospital is created via "Sketch Up" by Autodesk which is a professional 3D computer graphics program for making 3D animations, models, and images. After the virtual hospital environment is generated, the model is imported in to "Iris VR". Iris Vr is an extension which makes the virtual environments viewable and navigable with VR hardware such as Oculus Rift or HTC Vive. The simulated environment supports navigation in it via "Iris VR" which is an extension used for experiencing instant virtual reality for the building industry. Due to its well-designed interface and its open architecture this extension can be widely used by both architects and cognitive scientists. In addition, it is easily combined with the affordable VR HMD "Oculus Rift and HTC Vive", so that the same simulation environment can be used to empirically investigate real human wayfinding behaviour as well.

The virtual experiment is conducted on a polyclinic floor of a large scale hospital. Providing an appropriate route representing a patient's real hospital experience is important for this study. As a typical route for any visitor, starting from the entrance to the selected examination room in a polyclinic floor of a hospital is simulated.

Each participant was told: “Watch the route, written below, in a polyclinic prepared in a computer environment. After learning the route, please wear the head mounted display and replicate the same route”.

Entrance ⇒ Cardiology department ⇒ Examination room 3

“Bilgisayar ortamında hazırlanmış bir poliklinikte aşağıda yazılan rotayı dikkatlice izleyiniz. Rotayı öğrendikten sonra, sanal gerçeklik gözlüğünü takıp, aynı rotayı takip ediniz”.

Giriş ⇒ Kardiyoloji bölümü ⇒ 3 numaralı oda

Specific surfaces on the route were determined to be used as colored spatial cues. Three different settings were created. The only difference between these settings was the colours of visuospatial cues. It is decided to use four different colours for each colour setting; the 1st colour is for the specific walls behind nurses' stations, the 2nd one is for the information desk, the 3rd one is for the furniture’s in the waiting areas, and the 4th one is for other walls (see Figure 14).

Figure 14. Partial plan of the polyclinic showing the route (about 55 meters)

NCS colour system is preferred to give initial decisions on colours because as it is explained in Chapter 3.2.2, it presents a colour system according to an organization of hue, chromaticness and blackness levels, which makes it easier to determine any colour scheme. Colour schemes selected for the experiment are as follows:

1. *Neutral colour setting (control group):* For neutral colour setting, an achromatic colour scheme was determined which includes three different levels of blackness (35-20-

05), and two different hues (Y50R-B50G) without any chromaticness (00-02) (see Figure 15).

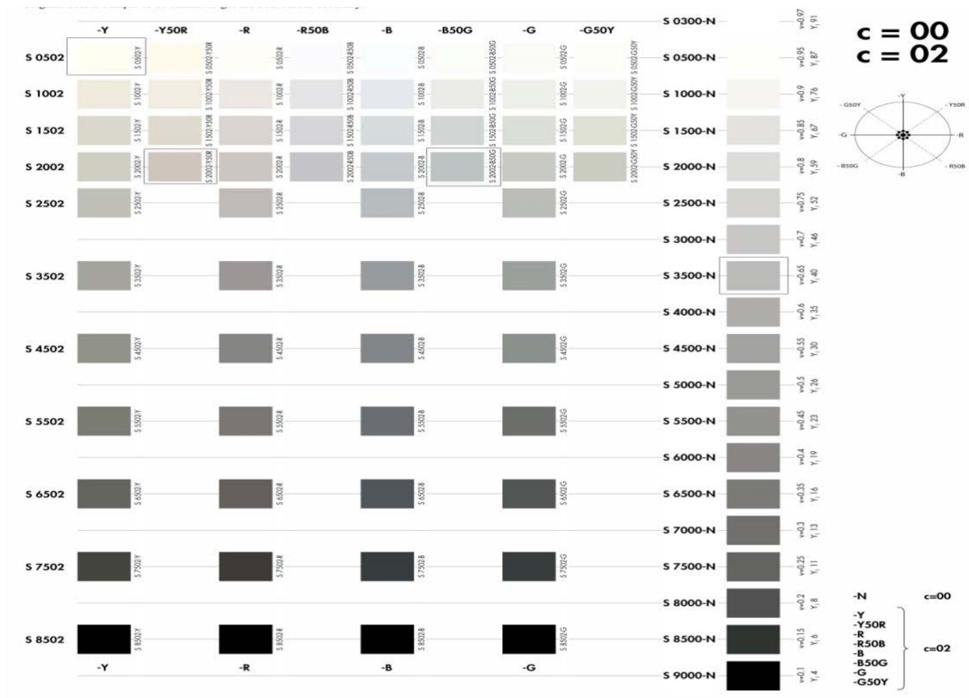

Figure 15. Selected colours (retrieved from NCS catalogue pg: 6)

2.*Warm colour setting:* For warm colour setting, four monochromatic colours were determined, one has higher level of hue (Y90R), other three have lower levels of hue (Y10R); with two different blackness levels (30-05) and two different chromaticness (40-10) (see Figures 16 and 17).

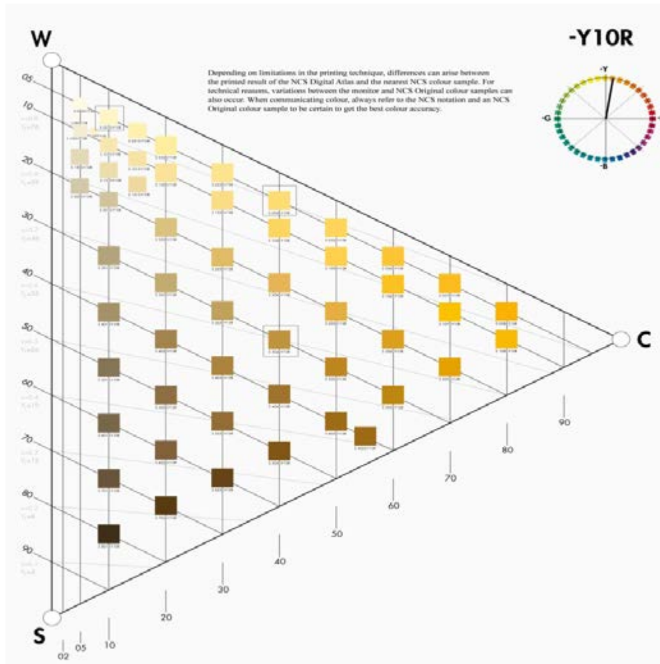

Figure 16. Selected colours (retrieved from NCS catalogue pg:8)

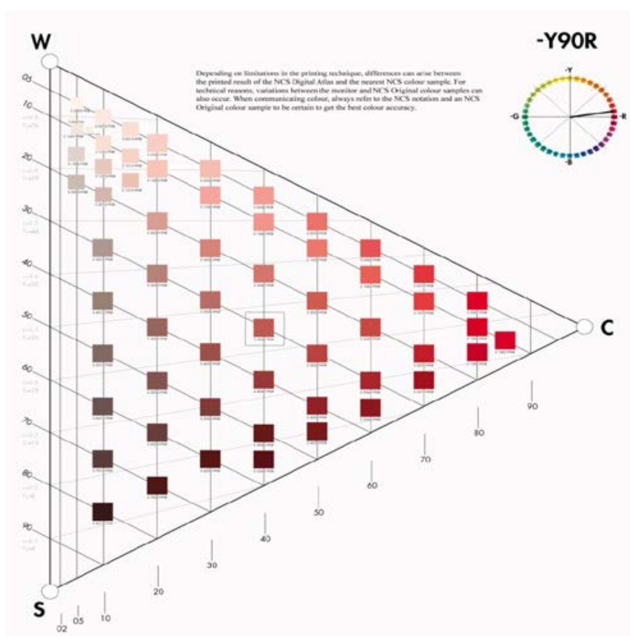

Figure 17. Selected colours (retrieved from NCS catalogue pg:16)

3. *Cool colour setting:* For cool colour setting, four monochromatic colours determined, one has higher level of hue (B90G), other three have lower levels of hue (B10G); with two different blackness levels (30-05) and two different chromaticness (40-10) (see Figures 18 and 19).

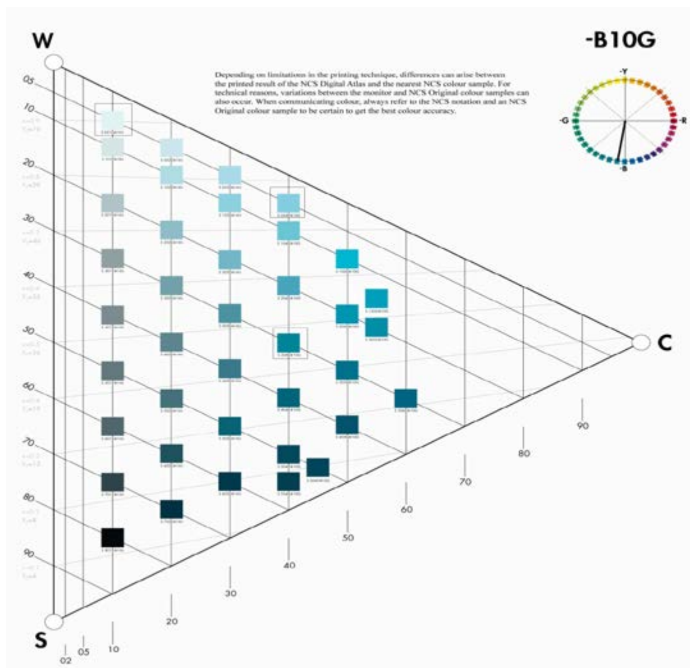

Figure 18. Selected colours (retrieved from NCS catalogue pg:28)

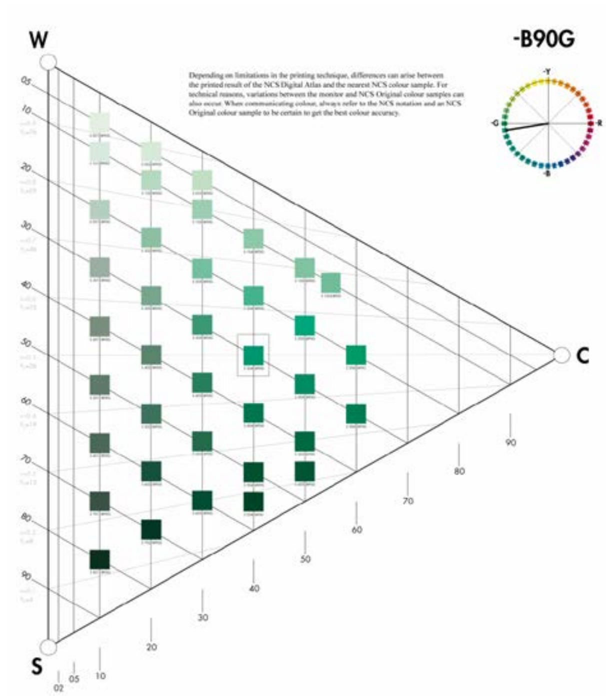

Figure 19. Selected colours (retrieved from NCS catalogue pg:36)

After the modelling in Sketch Up, and determining the colours on specific surfaces, the three different coloured settings are prepared; Setting 1 was the neutral coloured environment, Setting 2 was the warm coloured environment, and Setting 3 was the cool coloured environment (see Figures 20, 21 and 22).

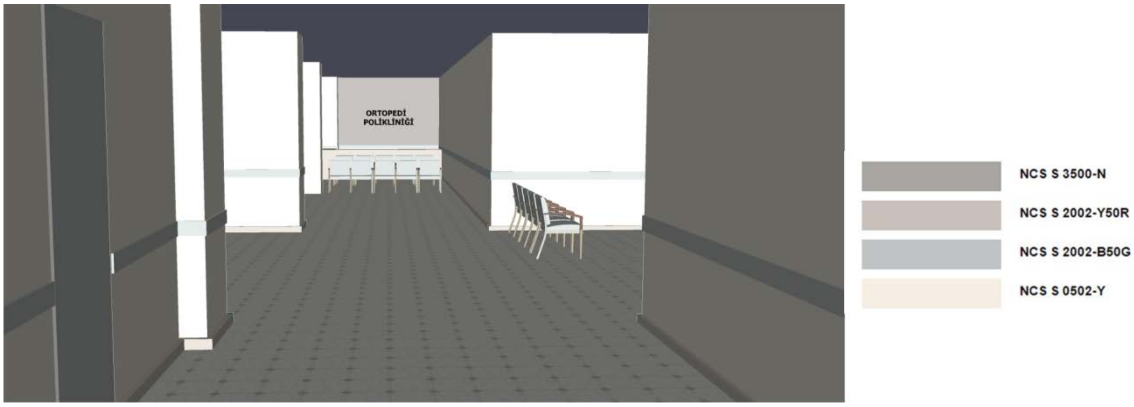

Figure 20. The neutral colour scheme used for experimental Setting 1 and NCS codes of each selected colour (Retrieved from Süzer & Olguntürk, 2018:5)

Figure 21. The warm colour scheme used for experimental Setting 2 and NCS codes of each selected colour (Retrieved from Süzer & Olguntürk, 2018:6)

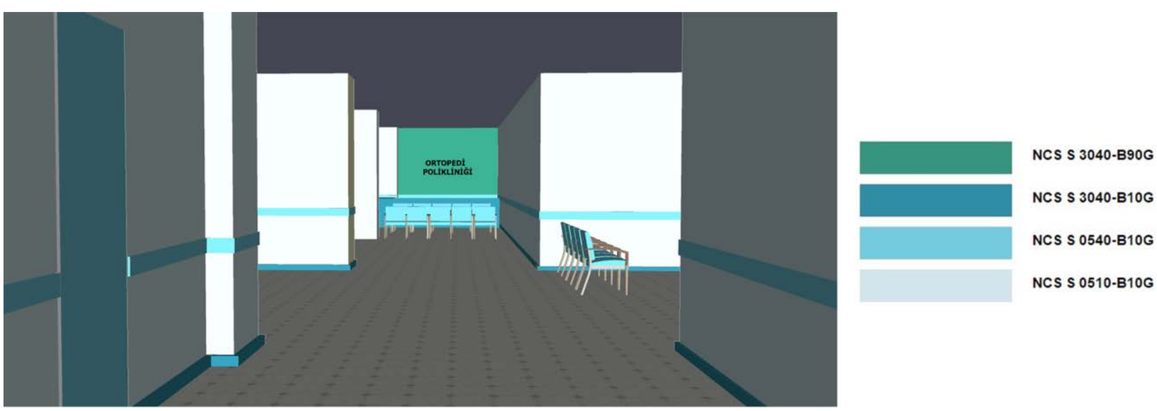

Figure 22. The cool colour scheme used for experimental Setting 3 and NCS codes of each selected colour (Retrieved from Süzer & Olguntürk, 2018:6)

4.2.4. Procedure

The experiment consists of three different phases (see Figure 23). In the first phase, the participants are asked to fill a set of questionnaire by the researcher to check their eligibility for the experiment. In the second phase, the participants are tested on computer and had two different tasks; route replication task and picture classification task. Finally, in the third phase, the participants are asked to evaluate the VR of the experiment by Presence Questionnaire.

4.2.4.1 Phase I: Eligibility Questionnaire

At the first phase, the questionnaires respectively were conducted with volunteered participants. Before the cognitive tests, a questionnaire asking the information on education level, handedness and visual impairment was answered by all participants. Participants selected and admitted to the next steps of the study were chosen from right handed, educated participants with at least 12 years of education and no severe visual impairment. Questionnaires took approximately 50 minutes (consisting of questions on sex, age, occupancy, education level, hand preference, visual deficiency test, and the MoCA, FAQ, JLO, GDS tests) for each participant. The participants who were found eligible according to the results of physical and psychological tests were included to the main experiment after a short break which was about 10 minutes.

Phase I: Eligibility Questionnaires (approx. 50 min)

1. Pre-test Questionnaire:
   a. Demographical information
   (age, sex, education, occupancy, handedness),
   b. Ishihara Test for colour blindness.
2. Montreal Cognitive Assessment (MoCA)
3. Functional Activities Questionnaire (FAQ)
4. Geriatric Depression Scale (GDS)
5. Judgement of Line Orientation Test (JLO)

Phase II: Testing On Computer (approx. 30 min)

1. Route Replication Task:
   a) Training,
   b) Learning the route,
   c) Navigating.
2. Picture Classification Task

Phase III: Presence Questionnaire (approx. 10 min)

1. Presence Questionnaire (Turkish version)

Figure 23. Phases of the experiment

4.2.4.2. Phase II: Testing on Computer

There was a 10 minutes break between Phase I and Phase II. The experiment is conducted in a room about 3x5meters, under the same lighting condition. However, because of the participants wore head mounted display, there was no environmental exposure. The second phase consisted of two tasks and totally took approximately 30 minutes for each participants.

1. Route Replication Task: The participants are stood in front of the computer and tested individually. The procedure is divided into three steps as follows:

a) Training (5 minutes), where each participant wore the head mounted display and trained to navigate in an unused part of the VE, to allow the participants to be familiarized with virtual navigation via head mounted display and controller use;

b) Learning the Route (5 minutes), where the participants watched the video from desktop computer, showing the route starting from the entrance, cardiology department, and 3rd examination room.

c) Navigating (5 minutes), after learning the route, the participants used a HTC Vive head mounted display and controller to move in the VE simulation (see Figure 24). For the route replication task participants had to recall and replicate the learned route. Thus, every movement in the VE and the four scores were noted from this task: the time spent, the number of wrong turns (when the participant navigates out of the route at a decision point, it is evaluated as a wrong turn or error), the number of experiencing hesitations and the estimated distance travelled during the navigation. In certain cases, participant hesitation was noted after a wrong turn, and some participants made even several wrong turns in the exact same intersection. In all cases, each wrong turn or hesitation was counted. The participant movements within the VR environment was recorded by the usage of a screen capture software, which enabled repeated video feed of the route taken. The aim of route replication task was to assess the participants route knowledge of the performed path.

Figure 24. An elderly participant having the experiment

2. Picture Classification Test: Cognitive mapping of the participants were measured via picture classification task. Picture classification task is known to be well performed when participants have well-developed route knowledge of the performed path (Lapeyre et al., 2011; Taillade et al, 2013a, 2013b; Wallet et al., 2008, 2009, 2010, 2011).The aim of this task was to evaluate if the participants developed a route knowledge of the performed path.

It is asked to participants to sort a series of pictures taken along the route into chronologically true order (see Appendix G for the pictures). The time of completion and sequence scores were measured. The score was evaluating sequence as follows: 1 point will be given if the photo position is parallel to the valid position in the general sequence and 0.5 point is attributed to an invalid position while the picture that follows is in chronological order. Zero point is for total misplacement. The maximum score is 11. This task evaluates the participants' route learning and within their cognitive map.

4.2.4.3. Phase III: Presence Questionnaire

In the third phase, after navigating in the VE, the participants rated their level of presence in the VE by answering the questions in the ‘Presence Questionnaire’ (PQ) (developed by Witmer and Singer, 1998, translated in Turkish by Özdinç, 2010) (see Appendix F). Presence Questionnaire took just 10 minutes for each participant.

CHAPTER - 5

RESULTS

Statistical analyses were made in respect of the research hypotheses as stated in previous chapter. Statistical Package for the Social Sciences (SPSS) 21 was used to analyse the data. In the analysis of the data, the descriptive statistics, 3x2 factorial MANOVA test, and to compare three different settings Post Hoc Scheffe test were used.

The effects of colour on visuospatial navigation were evaluated and analysed according to the results of two separate tasks: route replication task and picture classification task. There was a statistically significant difference in spatial navigation performances of elders based on the colour of environmental cues (F (12, 158) = 6.105, $p < .0005$; Wilk's $\Lambda = 0.467$, $\eta^2 =$

.317) (see Appendix I, Table I1). The Scheffe Post Hoc Tests pointed out that Setting 1 (neutral coloured environment) showed a significant difference when compared with Setting 2 (warm) and Setting 3 (cool) (see Appendix I, Table I2). The findings showed that neutral coloured virtual environment affected participants' visuopatial navigation performances' negatively compared to warm and cool coloured environments. However, there was no difference between warm and cool coloured environments (see Appendix I, Table I2).

In addition to that, statistical difference in spatial navigation performance were found in terms of both route replication and picture classification tasks, based on sex (F (6, 79) = 4.595, $p < .0005$; Wilk's $\Lambda = 0.741$, $\eta^2 = .259$) (see Appendix I, Table I1). The findings showed that males spent shorter time, did fewer wrong turns, experienced fewer hesitations and travelled shorter distances compared to females when finding the end point. Besides, males' sequenced pictures more accurately and faster than females.

5.1. Route Replication Task

The effects of colour on visuospatial navigation in terms of route knowledge were evaluated with route replication task under four metrics:

- the time spent finding the end point,
- the number of wrong turns,
- the number of experienced hesitations,
- the distance travelled.

5.1.1. The Time Spent

The time spent in finding the end point for the three participant groups (the three experiment settings of Setting 1 (neutral), Setting 2 (warm) and Setting 3 (cool) were assessed by comparing the duration of the route replication task (M=118.77, SD=37.589, N=90) (see Appendix I, Table I3). Because of the differences between three settings, exploring within females' and males' groups, 3x2 factorial MANOVA was used. The main effect for colour yielded an F ratio of $F(2, 84) = 28.9$, $p < .001$, indicating a significant difference between neutral (M=150.33, SD=41.52), warm (M=100.53, SD=20.46) and cool coloured settings (M=105.43, SD= 25.18) (see Appendix I, Table I1). 75 seconds was the minimum time and 234 seconds was the maximum time recorded in the whole group.

The Scheffe Post Hoc Tests pointed out that Setting 1 (neutral coloured environment) showed a significant difference when compared with Setting 2 (warm) and Setting 3 (cool) in terms of the time spent during finding the end point (see Appendix I, Table I2). The bar chart in Figure 25 indicates that, there is a significant difference of time spent between neutral and the other two coloured settings. However there is not any significant difference between the warm and cool coloured settings found in terms of time spent in route replication task.

Besides, the main effect for sex on the time spent during finding the end point yielded an F ratio of $F(1,84) = 18.565$, $p < .05$, indicating a significant difference between females (M=131.47, SD=40.347) and males (M=106.07, SD=30.005) (see Appendix I, Table I1). 85 seconds was the minimum time and 234 seconds was the maximum time recorded among the females group. Whereas 78 seconds was the minimum time and 210 seconds was the maximum time recorded among the males group. As it is illustrated at the bar chart, females spent more time on route replication task compared to males (see Figure 25).

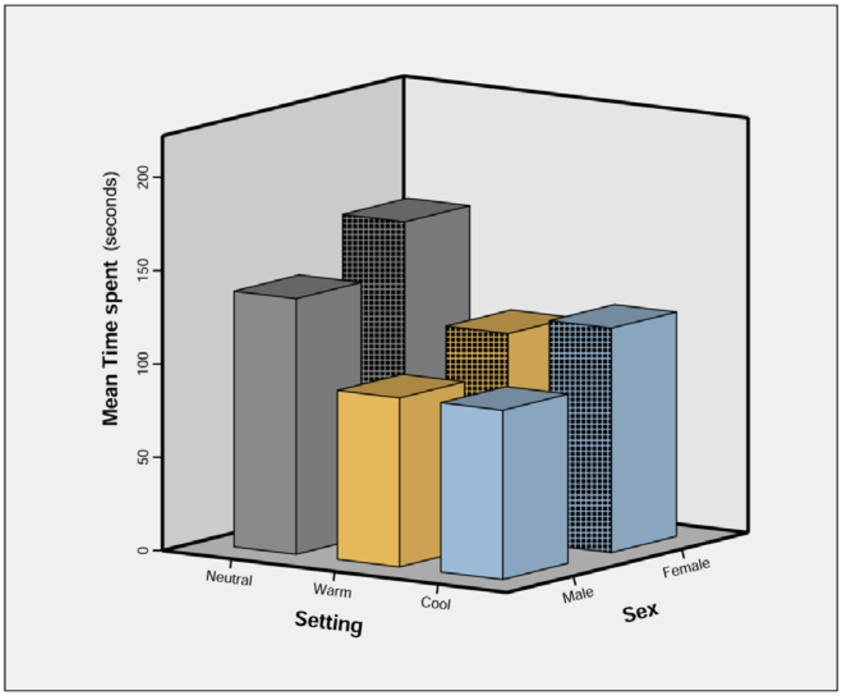

Figure 25. The bar chart showing the mean time spent in route replication task

5.1.2. The Number of Wrong Turns

The number of wrong turns during finding the final destination for the three participant groups (the three experiment settings of Setting 1 (neutral), Setting 2 (warm) and Setting 3 (cool) were assessed by comparing the duration of the route replication task (M=.33, SD=.581, N=90) (see Appendix I, Table I4). Because of the differences between three settings, exploring within females' and males' groups, 3x2 factorial MANOVA was used.

The main effect for colour on the number of wrong turns during finding the final destination yielded an F ratio of $F(2,84)=27.09$, $p<.001$, indicating a significant difference between neutral ($M= .83$, $SD=.699$), warm ($M=.07$, $SD=.254$) and cool coloured settings ($M=.10$, $SD=.305$) (see Appendix I, Table I1).

The Scheffe Post Hoc Tests pointed out that Setting 1 (neutral coloured environment) showed a significant difference when compared with Setting 2 (warm) and Setting 3 (cool) in terms of the number of wrong turns during finding the end point (see Appendix I, Table I2). As evident in Table 6, Setting 1 (neutral coloured VE) had the most number of participants taking wrong turns compared to Setting 2 (warm coloured VE) and Setting 3 (cool coloured VE). As seen in Table 6 while in Setting 1, 66.7% (20 participants) took at least one wrong turn, in Setting 2, only 6.7% (2 participants) took at least one wrong turn. Finally in Setting 3, 10% (3 participants) took at least one wrong turn.

Table 6. Cross-tabulation for number of wrong turns in finding the final destination in three experimental settings

	Neutral	Warm	Cool	Total
Wrong turns	20	2	3	25
No wrong turns	10	28	27	65
Total	30	30	30	90

Additionally, the main effect for sex on the total number of wrong turns during finding the end point yielded an F ratio of $F(1, 84) =5.344$, $p<.05$, indicating a significant difference between females (M=.44, SD=.659) and males (M=.22, SD=.471) (see Appendix I, Table I1). It was observed that on average female participants took twice as many wrong turns compared to male participants. Besides, as evident in Table 7, 15 female participants out of 45 made at least one wrong turn whereas as it is seen in Table 8, 9 male participants out of 45 made at least one wrong turn.

Table 7. Cross-tabulation for number of wrong turns of female participants in finding the final destination in three experimental settings

	Neutral	Warm	Cool	Total
Wrong turns	11	2	2	15
No wrong turns	4	13	13	30
Total	15	15	15	45

Table 8. Cross-tabulation for number of wrong turns of male participants in finding the final destination in three experimental settings

	Neutral	Warm	Cool	Total
Wrong turns	9	-	-	9
No wrong turns	6	15	15	36
Total	15	15	15	45

5.1.3. The Number of Experienced Hesitations

The main effect for colour on the number of experienced hesitations during finding the final destination yielded an F ratio of $F(2,84)=40.207$, $p<.001$, ($M=.67$, $SD=.861$, $N=90$), indicating a significant difference between neutral ($M=1.50$, $SD=.900$), warm ($M=.20$, $SD=.407$) and cool coloured settings ($M=.30$, $SD=.466$) (see Appendix I, Table I1 & I5). The Scheffe Post Hoc Tests pointed out that Setting 1 (neutral coloured environment) showed a significant difference when compared with Setting 2 (warm) and Setting 3 (cool) in terms of experiencing hesitations during finding the end point (see Appendix I, Table I2). As evident in Table 9, Setting 1 (neutral coloured VE) had the most number of participants experiencing hesitations compared to Setting 2 (warm coloured VE) and Setting 3 (cool coloured VE). As seen in Table 7 while in Setting 1, 86.7% (26 participants) experienced at least one hesitation, in Setting 2, only 20% (6 participants) experienced at least one hesitation. Finally in Setting 3, 30% (9 participants) experienced at least one hesitation.

Table 9. Cross-tabulation for number of experienced hesitations in finding the final destination in three experimental settings

	Neutral	Warm	Cool	Total
Hesitate	26	6	9	41
Not hesitate	4	24	21	49
Total	30	30	30	90

The main effect for sex on the number of experienced hesitations during finding the end point yielded an F ratio of $F(1,84)=4.098$, $p<.05$, indicating a significant difference between females (M=.80, SD=.869) and males (M=.53, SD=.842) (see Appendix I, Table I1). It was observed that on average female participants were about 51% more likely to experience at least one hesitation compared to male participants (see Table 10 and 11).

Table 10. Cross-tabulation for number of experienced hesitations of female participants in finding the final destination in three experimental settings

	Neutral	Warm	Cool	Total
Hesitate	14	4	7	15
Not hesitate	1	11	8	20
Total	15	15	15	45

Table 11. Cross-tabulation for number of experienced hesitations of male participants in finding the final destination in three experimental settings

	Neutral	Warm	Cool	Total
Hesitate	12	2	2	16
Not hesitate	3	13	13	29
Total	15	15	15	45

5.1.4. The Distance Travelled

The main effect for colour on the distance travelled during finding the final destination yielded an F ratio of $F(2,84)=18.534$, $p<.001$, ($M=56.34$, $SD=2.849$, $N=90$), indicating a significant difference between neutral ($M=58.50$, $SD=3.93$), warm ($M=55.10$, $SD=.548$) and cool coloured settings ($M=55.43$, $SD=1.357$) (see Appendix I, Table I1 & I6). 55 meters was the shortest distance and 70 meters was the longest distance walked in the whole group.

The Scheffe Post Hoc Tests pointed out that Setting 1 (neutral coloured environment) showed a significant difference when compared with Setting 2 (warm) and Setting 3 (cool) in terms of the distance travelled during finding the end point (see Appendix I, Table I2). As evident in Table 12, Setting 1 (neutral coloured VE) had the most number of participants having longer distance travelled compared to Setting 2 (warm coloured VE) and Setting 3 (cool coloured VE). In Setting 1, 36.7% (11 participants) walked the shortest distance whereas in Setting 2, 96.7% (29 participants) and in Setting 3, 90% (27 participants) walked the shortest distance.

Table 12. Cross-tabulation for the distance travelled in finding the final destination with three experimental settings

	Neutral	Warm	Cool	Total
55 meters	11	29	27	67
Longer than 55 meters	19	1	3	23
Total	30	30	30	90

Additionally, the main effect for sex on the distance travelled during finding the end point yielded an F ratio of $F(1,84)=3.957$, $p \leq .05$, indicating a significant difference between females ($M=56.84$, $SD=3.464$) and males ($M=55.84$, $SD=1.977$) (see Appendix I, Table I1). It is obviously seen in Table 13 and 14, 24 females out of 45 travelled longer than 55 meters, whereas 9 males out of 45 travelled longer distance.

Table 13. Cross-tabulation for the distance travelled of females in finding the final destination with three experimental settings

	Neutral	Warm	Cool	Total
55 meters	5	14	12	31
Longer than 55 meters	10	1	3	24
Total	15	15	15	45

Table 14. Cross-tabulation for the distance travelled of males in finding the final destination with three experimental settings

	Neutral	Warm	Cool	Total
55 meters	6	15	15	36
Longer than 55 meters	9	-	-	9
Total	15	15	15	45

5.2. Picture Classification Task

The effects of colour on visuospatial navigation in terms of survey knowledge were evaluated with picture classification task under two metrics:

- The time of completion,
- The accuracy of sequence.

5.2.1. The Time of Completion

The time of completion of picture classification task for the three participant groups (the three experiment settings of Setting 1 (neutral), Setting 2 (warm) and Setting 3 (cool) were assessed by comparing the duration (M=183.84, SD=44.872, N=90) (see Appendix I, Table I7). The main effect for colour yielded an F ratio of $F(2, 84) = 22.796$, $p < .001$, indicating a significant difference between neutral (M=218.9, SD=50.329), warm (M=164.23, SD=27.276) and cool coloured settings (M=168.4, SD= 31.41) (see Appendix I, Table I1 & I7). 122 seconds was the minimum time of completion and 310 seconds was the maximum time of completion recorded in the whole group. The average time of completion in Setting 1 was 33.2% higher compared to Setting 2 and 30% higher compared to Setting 3. The Scheffe Post Hoc Tests pointed out that Setting 1 (neutral coloured environment) showed a significant difference when compared with Setting 2 (warm) and Setting 3 (cool) in terms of the time of completion of picture classification task (see Appendix I, Table I2).

Besides, the main effect for sex on the time of completion for picture classification task yielded an F ratio of $F(1,84)=16.963$, $p<.05$, indicating a significant difference between females ($M=199.0$, $SD=42.068$) and males ($M=168.69$, $SD=42.817$) (see Appendix I, Table I1) (see Figure 26). The lowest time of completion for female participants was recorded as 145 seconds, while the lowest time of completion for male participants was recorded to be 122 seconds. Female participants had a higher average time of completion by 18% compared to male participants.

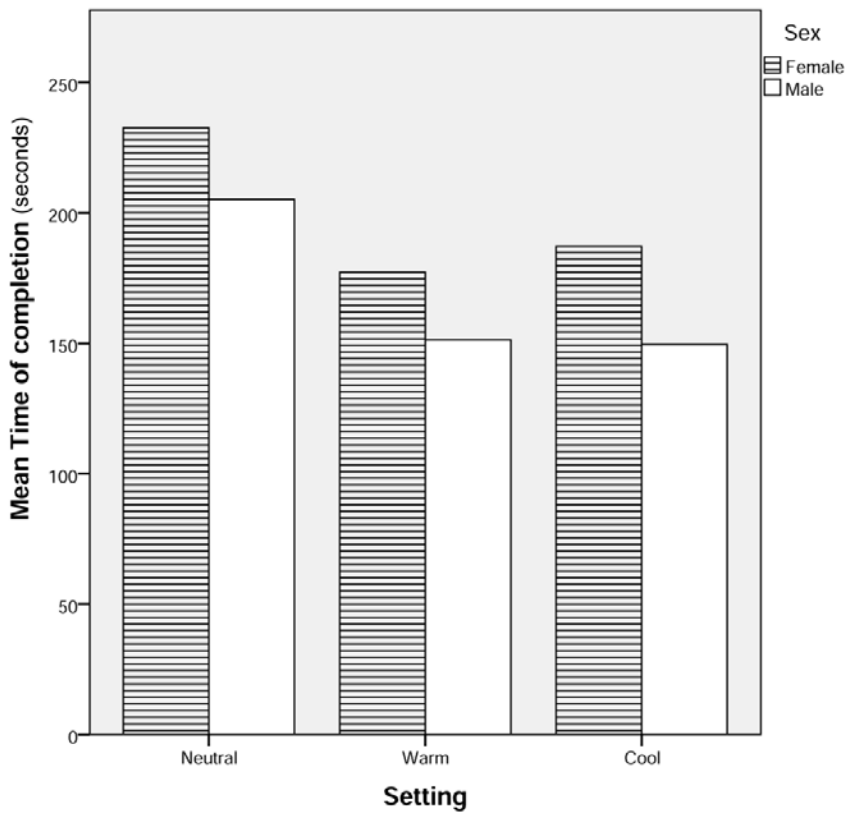

Figure 26. The bar chart showing the mean time of completion in picture classification task

5.2.2. The Accuracy of Sequence

The accuracy of sequence of picture classification task for the three participant groups (the three experiment settings of Setting 1 (neutral), Setting 2 (warm) and Setting 3 (cool) were assessed by comparing the accuracy scores ($M=9.98$, $SD=1.081$, $N=90$). The main effect for colour yielded an F ratio of $F(2,84)=26.393$, $p<.001$, indicating a significant difference between neutral ($M=9.07$,$SD=1.143$), warm ($M=10.53$, $SD=.629$) and cool coloured settings ($M=10.33$, $SD= .758$) (see Appendix I, Table I1 & I8).

The Scheffe Post Hoc Tests pointed out that Setting 1 (neutral coloured environment) showed a significant difference when compared with Setting 2 (warm) and Setting 3 (cool) in terms of the accuracy of sequence of picture classification task (see Appendix I, Table I2). As evident in Table 15, Setting 1 (neutral coloured VE) had the most number of participants having lower scores compared to the participants who had Setting 2 (warm coloured VE) or Setting 3 (cool coloured VE). In Setting 1, 60% (18 participants) had an accuracy score lower than 10, while in setting 2. 6.67% (2 participants) and in setting 3, 16.7% (5 participants) had an accuracy score lower than 10.

Table 15. Cross-tabulation for the sequence accuracy score in picture classification task with three experimental settings

	Neutral	Warm	Cool	Total
Lower than 10	18	2	5	25
10 and more than 10	12	28	25	65
Total	30	30	30	90

The main effect for sex on the accuracy of sequence score for picture classification task yielded an F ratio of $F(1,84)=6.181$, $p<.05$, indicating a significant difference between females ($M=9.76$, $SD=1.069$) and males ($M=10.20$, $SD=1.057$) (see Appendix I, Table I1). It is seen in Table 16 and 17, 17 female participants out of 45 had the scores lower than 10 in terms of accuracy of sequence in picture classification task, whereas 8 male participants out of 45 had the scores lower than 10.

Table 16. Cross-tabulation for the sequence accuracy score of female participants in picture classification task with three experimental settings

	Neutral	Warm	Cool	Total
Lower than 10	10	2	5	17
10 and more than 10	5	13	10	28
Total	15	15	15	45

Table 17. Cross-tabulation for the sequence accuracy score of male participants in picture classification task with three experimental settings

	Neutral	Warm	Cool	Total
Lower than 10	8	-	-	8
10 and more than 10	7	15	15	37
Total	15	15	15	45

5.3. Discussion

Various aspects of the possible aid of colour to elderly peoples' visuospatial navigation performance in a virtually simulated polyclinic environment, including effects of different colour schemes in terms of route learning and cognitive mapping process were explored via using HTC Vive HMD. It was hypothesized that there are different impacts of alternating preset colour settings on visuospatial navigation performances of elderly people. Three different colour schemes (neutral, warm and, cool) were compared considering two different tasks; route replication task, and picture classification task. Route replication task was evaluated under four metrics; the time spent finding the end point, the number of wrong turns, the number of experienced hesitations and, the distance travelled. Additionally, picture classification task was measured by two metrics; the time of completion and the accuracy of sequence.

The current research found that coloured visuospatial cues ease navigation of elderly people compared to neutral by; decreasing the time spent, reducing the number of wrong turns, minimizing hesitations experienced, reducing the distance travelled. However, there was no significant difference found between warm and cool coloured visuospatial cues in terms of spatial navigation performance of elderly people. There is no research found in the literature with the focus on the effects of colour on wayfinding in cognitively healthy elderly participant groups, however there is literature indicating that colour may be expected to improve route learning and cognitive mapping performances in wayfinding research concentrating on different age demographics, mostly adults and children, and elderly with dementia or Alzheimer’s disease (Dalke et al, 2005; 2006; Davis & Ohman, 2016; Davis et al., 2017; Helvacıoğlu & Olguntürk, 2011; Hidayetoğlu et al, 2012, Holscher et al, 2006; Farran et al, 2012; Kaplan, 1982; Kelly et al., 2011; Marquardt, 2011; Read, 2003; Werner & Schindler, 2004) and results of the statistical tests confirmed this, showing various specific effects.

Werner and Schindler (2004) studied the role of spatial reference frames, more specifically the spatial structure of a building and its impact to the wayfinding performance of its dwellers. A virtual environment was used for this study and color was also used as a visuospatial cue. Five target objects were included in each floor plan in the study, where each object was a differently colored sphere on a pedestal, placed on the dead-end hallways in the building. While the colour difference was not a variable for the study, colour was found to be a significant visual cue when directing the participants to certain hallways in the procedure of the experiment.

Helvacıoğlu and Olguntürk (2011) explored the effects of coloured landmarks on wayfinding performances of children in a real school environment, by comparing grey and coloured landmark usage. The experiment involved three different sample groups, where three experiment sets were created by the colour arrangement differences. The participants were 100 primary school children, aged seven to eight years old. The study's procedure includes a familiarity test with the experiment site, as well as vision deficiencies check by Ishihara's test for colour-blindness. The route was shown to the participants by the testers slowly, and the participants were asked to replicate the route after verbally describing it. It was found that colour had a significant effect on children's wayfinding performances in school environments, as the routes with coloured landmarks were easier to remember for the majority of children compared to the route with gray landmarks. Sex differences were not found to be significant in the route learning performances among children.

Dalke et al. (2006) has studied the use of colour and lighting in hospital environments. While suggesting that there is no established result for colour and design being "a definite cure for sickness and ill health", monotony in design as well as the poor conditions of hospital environment is found to be having a detrimental effect on the recovery rates of patients and the staff morale. To elaborate, grey and beige colours minimized the attention and concentration of people, which can then be translated into an inferior navigation performance in the current study.

Davis and Ohman (2016) published a study that explored the impact of the addition of salient cues in a virtual reality simulation of a senior residential building, to determine the wayfinding for older adults both with and without Alzheimer's disease. Alzheimer's disease has a direct effect on one's wayfinding abilities. Salient cues are helpful in increasing the wayfinding efficiency of elders with Alzheimer's disease to increase their independence. The salient cues in the experiment includes ten high contrast large and colourful cues placed in the route and it was found that these cues made the environment more supportive in terms of wayfinding, introducing an interaction and engagement with the environment, thus showing that especially coloured cues had a significant positive effect on wayfinding.

Farran et al. (2012) studied the use of colour as an environmental cue when learning a route. This study was also conducted in a virtual environment. The participants of this study included 6 to 9 year old children with Williams Syndrome as well as adults with it. Williams Syndrome is a significant learning disability. In the study, participants were presented a route with three mazes, each having six turns. In each maze floor, the colours of the floor path sections were different, acting as environmental cues. The colours were either focal (easy to verbalise) colours or non-focal (not easy to verbalise) colours. There was no significant route learning differences between the group with Williams Syndrome and the control group however the memory scores of focal colour environments were much higher compared to the non-focal colour settings. As a comparison to the current study, the focal colours were consisted of the typical warm and cool colours, and the non-focal colours included many neutral to lower key cool and warm colours, thus supporting the findings of this study.

Marquardt (2011) studied wayfinding for people with dementia using different architectural design cues such as lighting, colour and signage. The study found that the use of significant cues including colour is important for the patients to identify and locate rooms with similar function or form, where the distinctions can be made with colour cues. The usage of the aforementioned architectural cues including colour was found to have a positive effect on wayfinding, while allowing a better visual access and reducing the decision making difficulty for the people with dementia. As dementia is a disease that is most common in elderly people, the relation of the results is also significantly similar.

Read (2003) studied the use of colour in child care environments. In the study, Alabama Child Care environments were taken into comparison and analysis, and were found that the warm colours and bright accents in the interior settings of the classrooms, which had a positive mood effect on the children. The children reported a better spatial orientation and wayfinding within the interior environments, especially classrooms, with warm coloured settings compared to neutral settings with gray tones. Additionally, colour is found to be a flexible, accessible and significant design element at the disposal of interior designers aiming to create navigable spaces. The effects of coloured landmarks on wayfinding performances of children were explored in a real school environment, by comparing grey and coloured landmark usage. They found no significant difference between the settings of coloured landmarks, however the wayfinding performance was found to be inferior in the setting with grey landmarks compared to the coloured sets. In the current study, even though the participant group’s age demographics are different, the results were found to be very similar. The cool colour scheme including the tones of blue and the warm colour scheme including the tones of red were found to be improving the navigation performance of elderly people, while the neutral setting consisting of tones of grey and beige were found to cause inferior performances. The use of colour and lighting in hospital environments were also studied and the conclusion was that the grey and beige colours minimized the attention and concentration of people, which may have translated into an inferior navigation performance in the current study.

The results can be interpreted through the analysis of chromatic and achromatic colours. Grey and its tones, used in the neutral setting of the experiment, are achromatic colours, which are widely considered dull, indistinct and less memorable which might explain why the route replication tasks took a longer time to complete in this setting compared to chromatically coloured settings. In the warm and cool coloured settings, due to the intensity of these colours and varying effects on one's perception of space, it is understandable that better memorization of the route was reached, and a better result was achieved by the participants. The difference between cool and warm coloured settings was not significant according to the findings of this study, and this should be further analyzed to perceive how different colours may have varying effects on psychology, yet remain indifferent for spatial navigation purposes.

Besides the warm and cool colours having significant upsides compared to neutral colours in the literature, a noted reason that justifies the results of the study lies in the fact that grey and neutral colours in general have less readability compared to the colours that attract further attention. To elaborate, grey is an insignificant colour with many non-focal hues, thus being less noticeable in an environment. Therefore, if the environment's surroundings have the colour grey emphasized in them, the environment becomes less noticeable and less significant to the navigator. The usage of warm or cool colours in comparison to the neutral colours such as grey will therefore greatly increase the navigation performance, as the routes travelled will not only be more memorable, but also facilitate better spatial knowledge acquisition both according to the tasks performed in the study, and the literature reviewed.

Additionally, the sex difference was also found on the visuospatial navigation within different coloured VEs. The results showed that females; spent more time, had more wrong turns, experienced more hesitations, and travelled longer distances compared to males. There is no consensus in literature on sex difference affecting spatial abilities. The results of this study are parallel to the results obtained in previous research (Allen & Hogeland, 1978; Castelli et al., 2008; Coluccia et al., 2007; Çubukçu & Nasar, 2005; Devlin &Bernstein, 1995; Lawton, 1994; Linn & Petersen, 1985; McGee, 1979; Moffat et al., 1998; Sandstrom et al, 1998; Sevinc & Bozkurt, 2015; Suzer, Olgunturk & Guvenc, 2018; Tlauka et al., 2005) regarding the sex difference favouring males, affecting wayfinding and spatial navigation performances. However, certain studies in literature have found no sex difference or favoured females in spatial performances.

No significant sex difference was discovered in wayfinding performance of primary school children. In this current study, we found sex differences to be significant for the elderly participants between the ages 65 and 80, favouring males. The sex differences may be surfacing as a result of the experience of living in a specific culture for a long amount of time. Therefore, it is difficult to come to a clear cut conclusion on the effects of sex on visuospatial navigation due to the limited number of studies in this field regarding elderly people.

The perception of sex roles also differ in between cultures and this fact has to be taken into consideration when reviewing this study. Turkish culture is widely male dominant, where males have a higher ratio of employment and higher age of retirement, leading to a more active lifestyle on average compared to females. The higher frequency of cognitive tasks completed during the active lifestyle directly translates into better spatial cognition and environmental perception. Therefore, this might be the reason why male participants showed a better spatial navigation performance in the study.

CHAPTER - 6

CONCLUSION

The major aim of this study was to fill the gap in literature regarding the effects of colour on visuospatial navigation of elderly people in a virtually simulated polyclinic environment and therefore the results of current research provide data for designing more functional and recognizable spaces for the elderly people. The use of colour in the built environment to improve visuospatial abilities and navigation is crucial for special demographics such as elderly people or patients of dementia. Increasing elders' population should not be ignored and researchers, environmental psychologists, gerontologists, interior wayfinding designers, architects should collaborate to provide safe, functional and more navigable environments for the elderly people. It should also be noted that elderly people have a hard time navigating in complex unfamiliar structures, thus the use of cues that enhance wayfinding become increasingly important as the age average of the demographic increases.

Among other architectural cues that can be used to increase the spatial orientation and wayfinding of individuals, colour is one of the most significant cues that enhance wayfinding and navigation performance. In this study, colour was found to be a significant factor that determines certain navigation task variables such as the time spent, number of wrong turns and hesitations. As the warm and cool coloured settings provided better results in the route replication task compared to the neutral setting, the use of either warm or cool colours in the interior design structure of hospitals is highly recommended. This result is in line with a similar study by Dalke et al. (2006) who found that grey and beige settings are not favourable for wayfinding purposes and should be avoided in the design of interiors of hospitals. There was no clear difference between the use of cool or warm colours in the interior, and this should also be noted.

While the study focuses mostly on the tasks given to the elderly participants and the resulting colour setting comparisons, there are also sex differences that were measured in the process. There was a certain performance advantage of male participants in comparison to the females in the areas of number of hesitations, time spent and number of wrong turns as well as choosing a shorter path. This difference, however, may be biased due to the effect of cultural implications on this study. As the study was conducted in Turkey, with Turkish participant groups, the male bias may be a result of the patriarchal oriented Turkish culture. If the study was conducted in a different culture, different results may have prevailed.

Further spatial cognition research can be conducted in a VE through the use of a HMD, similar to the one in this study to reduce the cost of experiments both financially and physically, providing a safe, realistic feasible and easy to access alternative experience to real environments.

There were certain noted limitations in the research worth noting. First of all, due to the experiment being conducted on the elderly, the issues that rise from the high average age were serious, as loss of attention was a serious problem considering a long experiment lasting more than an hour. The three phases of the experiment was conducted with two breaks, each between phases. Besides, because the participants were very eager to contribute, the loss of attention did not obseved in this certain reasearch. Further breaks between the explanation will reduce the loss of attention thus increasing the validity of the results.

An expected limitation considering the elderly participants were the effects of potential kinesthesia due to the use of a HMD. However, since the experiment was conducted with HTC Vive as the HMD, there was no kinesthesia or nausea reported by the participants. Therefore, the use of HTC Vive as an HMD for future studies can be suggested. Additionally, it is observed that the elderly participants were able to use this tool to navigate in VR, which should also be considered for further research in the field of spatial cognition and architecture as well as universal design.

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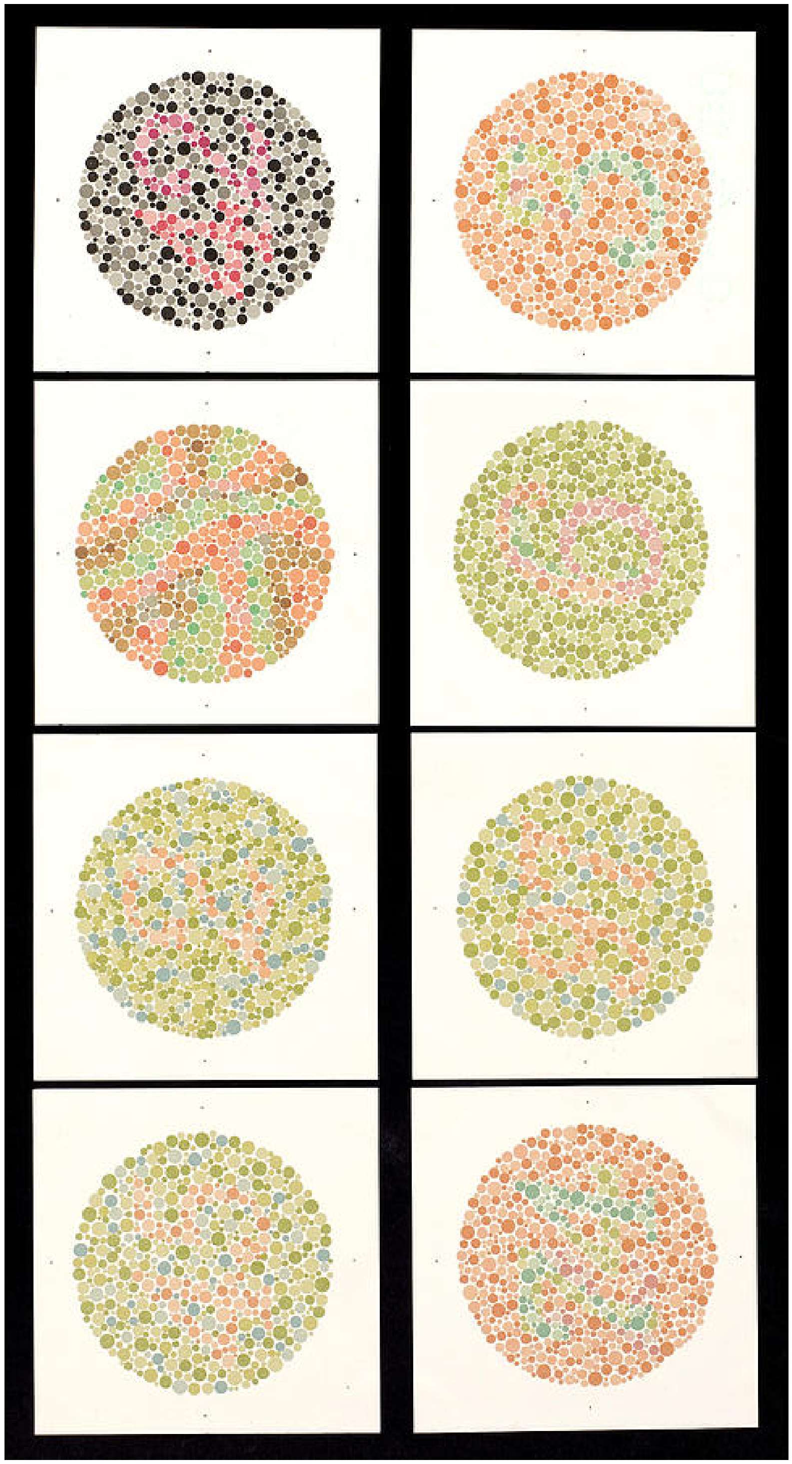
APPENDIX A: Ishihara Colour Blindness Test Sample Item and Sheet



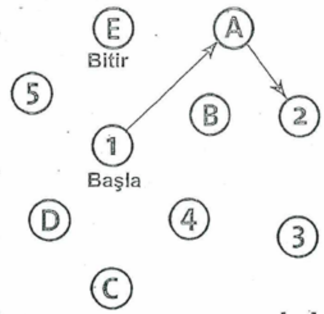
APPENDIX B : Montreal Cognitive Assessment (MOCA)

MONTREAL BİLİŞSEL DEĞERLENDİRME ÖLÇEĞİ
Montreal Cognitive Assessment (MOCA)

İsim:
Eğitim:
Cinsiyet:

Protokol:
Test Tarihi:
Doğum Tarihi:

GÖRSEL MEKANSAL / YÖNETİCİ İŞLEVLER — **PUAN**



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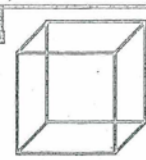


Küp Kopyalama

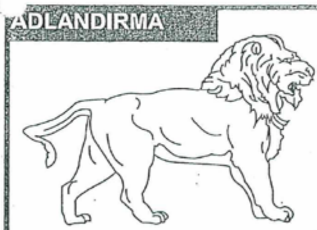
[ ]

SAAT çizme (On biri on geçe)
(3 puan)

Çevresi [ ] Rakamlar [ ] Kollar [ ]

__/5

ADLANDIRMA



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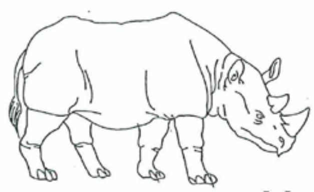

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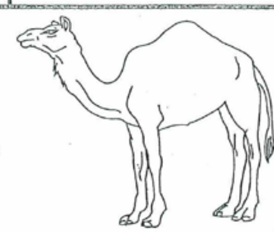

[ ]

__/3

BELLEK

Kelime listesini okuyun ve hastaya tekrar ettirin. İki deneme yapın. 5 dakika sonra tekrar sorun

	BURUN	KADİFE	CAMİ	PAPATYA	MOR
1.deneme					
2.deneme					

Puan yok

DİKKAT

Sayı listesini okuyun (1 sayı / san.) Hasta sayıları baştan sona doğru saymalı [ ] 2 1 8 5 4
Hasta sayıları sondan başa doğru saymalı [ ] 7 4 2 __/2

Harf listesini hastaya okuyun. Hastaya her A harfi okunduğunda masaya eli ile vurmasını söyleyin.
İki veya daha fazla hata var ise puan vermeyin. [ ] FBACMNAAJKLBAFAKDEAAAJAMOFAAB __/1

100 den başlayarak yedişer çıkarma [ ] 93 [ ] 86 [ ] 79 [ ] 72 [ ] 65
4 veya 5 doğru çıkarma: 3 puan, 2 veya 3 doğru çıkarma: 2 puan, 1 doğru :1 puan, 0 doğru 0 puan. __/3

LİSAN

Tekrar ettirin: Tek bildiğim bugün yardıma ihtiyacı olan kişinin Ahmet olduğudur. [ ]
Köpekler odadayken kedi hep kanapenin altında saklanırdı. [ ] __/2

Akıcılık / 1 dakikada K harfi ile başlayan maksimum sayıda kelime saydırın. [ ] ____ N ≥ 11 kelime __/1

SOYUT DÜŞÜNME

Benzerlik. Örn. muz-portakal = meyve. [ ] tren - bisiklet [ ] saat - cetvel __/2

GECİKMELİ HATIRLAMA

Kelimeleri İPUCU OLMADAN hatırlama	BURUN [ ]	KADİFE [ ]	CAMİ [ ]	PAPATYA [ ]	MOR [ ]	Sadece İPUCUSUZ hatırlanan kelimeler için puan verin
SEÇMELİ: Kategori ipucu						
Çoklu seçmeli ipucu						

__/5

YÖNELİM

[ ] Gün [ ] Ay [ ] Yıl [ ] Gün adı [ ] Yer [ ] Şehir __/6

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TOPLAM __/30

Türkçe versiyon 2009. K. Selekler & B. Cangöz

APPENDIX C : Functional Activities Questionnaire (FAQ)

İŞLEVSEL FAALİYETLER ANKETİ* (İFA)

İFA 10 adet karmaşık günlük hayat faaliyetine ilişkin performansı değerlendiren kısa ve bilgi kaynağı kişiye ait dayalı bir ankettir. Bilgi kaynağı hastanın geçmişine ve bugününe ilişkin gerçek ve doğru (güvenilir) kişisel bilgilere sahip olmalıdır. Anket genellikle, hastaya bakmakla yükümlü aile fertlerinden birine uygulanmaktadır. Bu anket kurum personeli tarafından, doktor muayenesi öncesinde ya da muayene sırasında uygulanabilir. Ölçeğin orijinali Pfeffer ve ark. (1982-*Journal of Gerontology*) tarafından geliştirilmiş olup 50+ yaş üstü Türk örneklemi üzerindeki norm belirleme çalışması Selekler ve ark.(2004) tarafından yapılmıştır.

Puanlama:

Puanlar	Hastanın her bir faaliyetteki performansı
3	Performans göstermekte tamamen başarısız
2	Yardım gerekiyor
1	Güçlük çekmesine rağmen görevi yapmayı başarıyor ya da Görevi hiçbir zaman yapmadı ancak hakkında bilgi veren kişi hastanın bu görevi güçlükle de olsa yapabileceğini düşünüyor
0	Normal performans gösteriyor ya da Görevi hiçbir zaman yapmadı ancak hakkında bilgi veren kişi hastanın şu anda bu görevi yapabileceğini düşünüyor.

Yorumlama: 50-69 yaş grubunda iki ya da daha fazla faaliyetten '5 ya da daha fazla' puan; 70 yaş ve üstü grupta üç ya da daha fazla faaliyetten '9 ya da daha fazla' puan almış olmak işlevsel faaliyetlerde bozukluk olduğuna ve bağımlılığa işaret etmektedir. Günlük hayat aktivitelerinde meydana gelen değişim ve bu değişimin hızı özellikle demans tanısı ile ilgili olabilecek işlevlerin değerlendirilmesinde klinisyen açısından kritiktir. Buna karşın, anketten alınan puan tek başına demansı belirleyici bir ölçüt değildir. Daha ileri bilişsel değerlendirmelerin yapılması gerekir.

Madde No	Günlük Hayat Faaliyetleri	Puan
1	Fatura ödemek, gelir ve giderleri dengelemek, para hesabı yapmak.	
2	Vergi, aidat, elektrik-su-telefon makbuzlarını, KDV fişlerini, işe ait evrakları tasnif etmek.	
3	Giyecek, ev ihtiyaçları veya yiyecek almak için tek başına alışverişe çıkmak.	
4	Beceri gerektiren oyun oynamak, bir hobiyle uğraşmak.	
5	Su kaynatmak, bir bardak hazır kahve ya da çay yapmak, ocağı söndürmek.	
6	Besin dengesi olan bir öğün (yemek) hazırlamak.	
7	Gündelik olayları takip etmek.	
8	Bir TV programını, kitabı veya gazeteyi dikkatle izlemek ya da okumak, anlamak, tartışmak.	
9	Randevuları, ailenin özel günlerini, tatilleri, ilaç tedavilerini (ilaç dozlarını ve ne zaman alınacağını) düzenli olarak sürdürebilmek.	
10	Şehiriçi ulaşım araçları (taksi, dolmuş, belediye otobüsü) ile bulunduğu semtin dışına seyahat etmek, şehirlerarası ulaşım araçlarından (otobüs, tren, uçak) yer ayırtmak ya da otomobil kullanmak.	
	TOPLAM PUAN	

*Selekler,K., Cangöz, B., Karakoç, B.(2004). İşlevsel Faaliyetler Anketi'nin 50 yaş ve üzeri grupta Türk kültürü için uyarlama ve norm belirleme çalışması. *Türk Nöroloji Dergisi, 10* (2), 102-107.

APPENDIX D : Geriatric Depression Scale (GDS)

Hastanın Adı, Soyadı:	Tarih:
Hastanın Yaşı ve Cinsiyeti:	Değerlendirici:

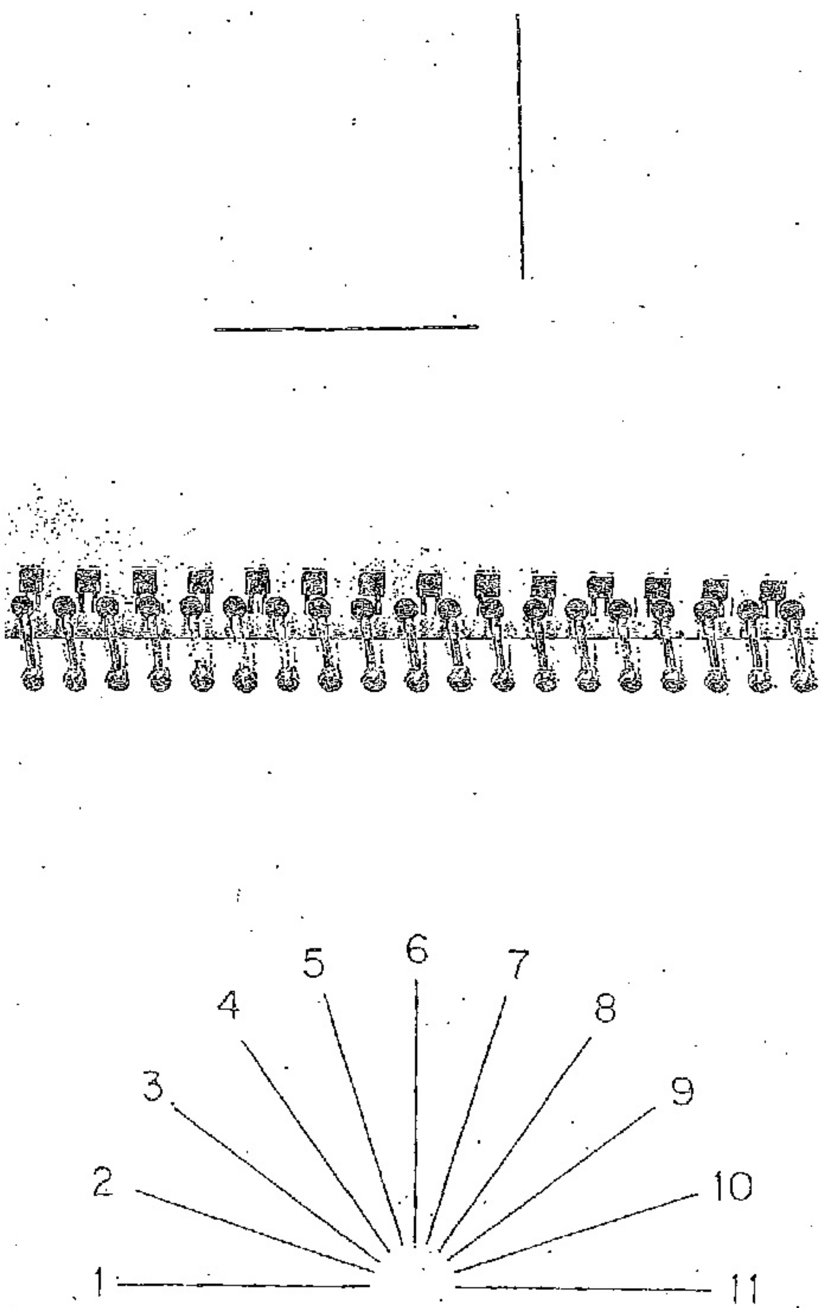
GERİATRİK DEPRESYON ÖLÇEĞİ (GDS)

Lütfen yaşamınızın son bir haftasında kendinizi nasıl hissettiğinize ilişkin aşağıdaki soruları kendiniz için uygun olan yanıtı işaretleyerek yanıtlayınız.

	Evet	Hayır
1) Yaşamınızdan temelde memnun musunuz?	☐	☐
2) Kişisel etkinlik ve ilgi alanlarınızın çoğunu halen sürdürüyor musunuz?	☐	☐
3) Yaşamınızın bomboş olduğunu hissediyor musunuz?	☐	☐
4) Sık sık canınız sıkılır mı?	☐	☐
5) Gelecekten umutsuz musunuz?	☐	☐
6) Kafanızdan atamadığınız düşünceler nedeniyle rahatsızlık duyduğunuz olur mu?	☐	☐
7) Genellikle keyfiniz yerinde midir?	☐	☐
8) Başınıza kötü bir şey geleceğinden korkuyor musunuz?	☐	☐
9) Çoğunlukla kendinizi mutlu hissediyor musunuz?	☐	☐
10) Sık sık kendinizi çaresiz hissediyor musunuz?	☐	☐
11) Sık sık huzursuz ve yerinde duramayan biri olur musunuz?	☐	☐
12) Dışarıya çıkıp yeni bir şeyler yapmaktansa, evde kalmayı tercih eder misiniz?	☐	☐
13) Sıklıkla gelecekten endişe duyuyor musunuz?	☐	☐
14) Hafızanızın çoğu kişiden daha zayıf olduğunu hissediyor musunuz?	☐	☐
15) Sizce şu anda yaşıyor olmak çok güzel bir şey midir?	☐	☐
16) Kendinizi sıklıkla kederli ve hüzünlü hissediyor musunuz?	☐	☐
17) Kendinizi şu andaki halinizle değersiz hissediyor musunuz?	☐	☐
18) Geçmişle ilgili olarak çokça üzülüyor musunuz?	☐	☐
19) Yaşamı zevk ve heyecan verici buluyor musunuz?	☐	☐
20) Yeni projelere başlamak sizin için zor mudur?	☐	☐
21) Kendinizi enerji dolu hissediyor musunuz?	☐	☐
22) Çözümsüz bir durum içinde bulunduğunuzu düşünüyor musunuz?	☐	☐
23) Çoğu kişinin sizden daha iyi durumda olduğunu düşünüyor musunuz?	☐	☐
24) Sık sık küçük şeylerden dolayı üzülür müsünüz?	☐	☐
25) Sık sık kendinizi ağlayacakmış gibi hisseder misiniz?	☐	☐
26) Dikkatinizi toplamakta güçlük çekiyor musunuz?	☐	☐
27) Sabahları güne başlamak hoşunuza gidiyor mu?	☐	☐
28) Sosyal toplantılara katılmaktan kaçınır mısınız?	☐	☐
29) Karar vermek sizin için kolay oluyor mu?	☐	☐
30) Zihniniz eskiden olduğu kadar berrak mıdır?	☐	☐

Geriatrik Depresyon Ölçeği Sayfa 1 / 1

APPENDIX E : Judgment of Line Orientation Test Sample Item and Sheet



APPENDIX F: Presence Questionnaire (PQ)

Sanal ortamda buradalık ölçeği

Bu ölçek 3 boyutlu bir sanal oryantasyon uygulamasında sizing ortama ne kadar dahil olduğunuzu ölçmeyi amaçlamaktadır. Aşağıda verilen maddeler için, kutuların altındaki açıklayıcı kelimeler doğrultusunda size uygun gelen 7 kutudan birisine "X" işareti koyunuz.

Örnek:

Sanal ortamın içerisinde etrafta hareket etme sezginiz ne ölçüde zorlandı?

Zorlayıcı Değil			Orta Derecede Zorlayıcı			Çok Zorlayıcı

Teşekkürler.

---

1. Olayları ne ölçüde kontrol edebiliyordunuz?

Fazla Değil			Orta Derecede			Çok Fazla

2. Ortam sizin başlattığınız (ya da gerçekleştirdiğiniz) eylemlere ne ölçüde cevap verebiliyordu?

Duyarlı Değil			Orta Derecede Duyarlı			Çok Duyarlı

3. Ortamla olan etkileşimleriniz ne ölçüde doğal görünüyordu?

Doğal Değil			Orta Derecede Doğal			Çok Doğal

4. Tüm duyularınız ne ölçüde tam olarak olaya dahildi?

Dahil Değildi			Orta Derecede Dahildi			Çok Dahildi

5. Ortamın görsel yanları size ne ölçüde olaya dahil etti?

Fazla Değil			Orta Derecede			Çok Fazla

6. Ortamda hareketi kontrol eden mekanizma ne kadar doğaldı?

Doğal Değildi			Orta Derecede Doğaldı			Çok Doğaldı

7. Çevrenizdeki gerçek ortamda olan olayların ne kadar farkındaydınız?

Farkında Değildim			Orta Derecede Farkındaydım			Çok Farkındaydım

8. Kullandığınız gösterim (örneğin ekran) ve kontrol araçlarının ne kadar farkıdnaydınız?

Farkında Değildim			Orta Derecede Farkındaydım			Çok Farkındaydım

9. Sanal ortamda hareket eden nesneleri algılamanız ne ölçüde zorlayıcıydı?

Zorlayıcı Değil			Orta Derecede Zorlayıcı			Çok Zorlayıcı

10. Farklı duyularınızdan gelen bilgi ne ölçüde tutarsız ya da bağlantısızdı?

Tutarsız Değil			Orta Derecede Tutarsız			Çok Tutarsız

11. Sanal ortamdaki deneyimleriniz gerçek dünyadaki deneyimlerinizle ne ölçüde tutarlı görünmekteydi?

Tutarlı Değil	Orta Derecede Tutarlı	Çok Tutarlı

12. Gerçekleştirdiğiniz eylemlerin sonucu olarak nelerin meydana geleceğini tahmin edebildiniz mi?

Tahmin Edemedim	Orta Derecede Tahmin Edebildim	Çok Tahmin Edebildim

13. Görme duyusunu kullanarak ortamı aktif bir şekilde ne ölçüde tam olarak inceleyebildiniz?

Fazla Değil	Orta Derecede	Çok Fazla

14. Sanal ortamda etrafta hareket etme sezginiz ne ölçüde zorlandı?

Zorlayıcı Değil	Orta Derecede Zorlayıcı	Çok Zorlayıcı

15. Nesneleri ne ölçüde yakından inceleyebildiniz?

Yakından Değil	Orta Derecede Yakından	Çok Yakından

16. Nesneleri çoklu bakış açılardan ne ölçüde inceleyebildiniz?

İyi Değil	Orta Derecede İyi	Çok İyi

17. Uygulamanın sonunda, kendinizi ne ölçüde kafası karışmış ve yolunu kaybetmiş hissettiniz?

Kafası Karışmış Değil	Orta Derecede Kafası Karışmış	Çok Kafası Karışmış

18. Sanal ortam deneyiminin ne ölçüde içindeydiniz?

İçinde Değildim	Orta Derecede İçindeydim	Çok İçindeydim

19. Kontrol mekanizması ne ölçüde dikkat dağıtıcıydı?

Dikkat Dağıtıcı Değil	Orta Derecede Dikkat Dağıtıcı	Çok Dikkat Dağıtıcı

20. Eylemleriniz ve beklenen sonuçları arasında ne kadarlık bir geçikme yaşadınız?

Fazla Değil	Orta Derecede	Çok Fazla

21. Sanal ortam deneyimine ne kadar çabuk uyum sağladınız?

Çabuk Değil	Orta Derecede Çabuk	Çok Çabuk

22. Deneyiminizin sonunda sanal ortamda hareket etme ve etkileşime geçme konusunda kendinizi ne ölçüde yetkin hissettiniz?

Yetkin Değil

Orta Derecede Yetkin

Çok Yetkin

23. Görsel görüntü kalitesi, verilen görevleri ya da gerekli eylemleri gerçekleştirmekten size ne ölçüde alıkoydu?

Fazla Değil

Orta Derecede

Çok Fazla

24. Kontrol aygıtları verilen görevlerin ya da diger eylemlerin gerçekleştirilmesine ne ölçüde müdahale etti?

Fazla Değil

Orta Derecede

Çok Fazla

25. Verilen görevleri ya da gerekli eylemleri gerçekleştirmek için kullanılan mekanizmalardan ziyade bu görev ve eylemlere ne ölçüde odaklandınız?

İyi Değil

Orta Derecede İyi

Çok İyi

26. Sanal ortamda yeni bilgiler öğrendiniz mi?

Öğrenmedim

Orta Derecede Öğrendim

Çok Öğrendim

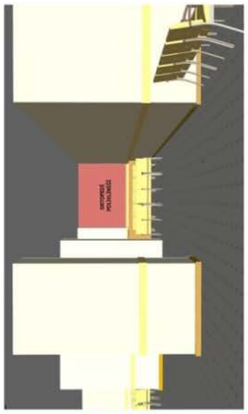
27. Oryantasyona zamanın geçtiğini fark etmeyecek kadar kendinizi kaptırdınız mı?

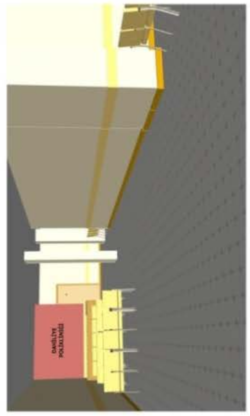
Kaptırmadım

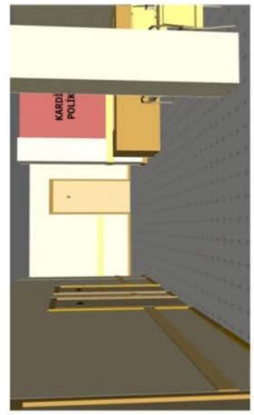
Orta Derecede Kaptırdım

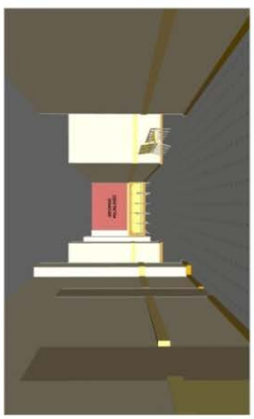
Çok Kaptırdım

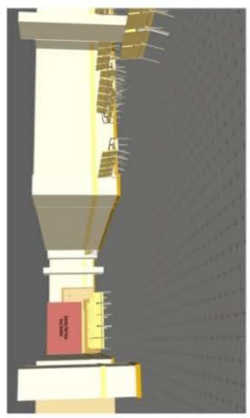
APPENDIX G. Picture Classification Task Images

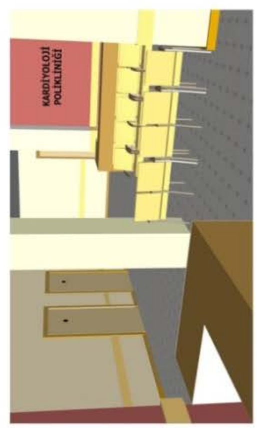


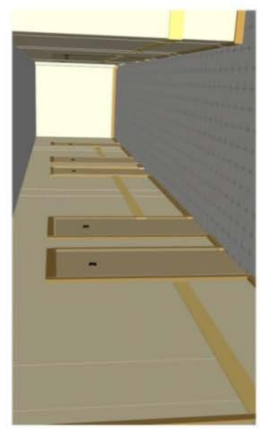


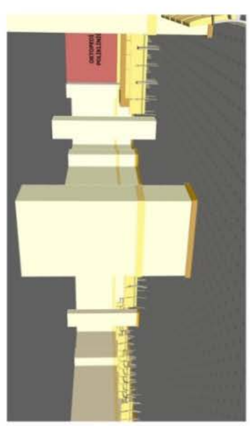


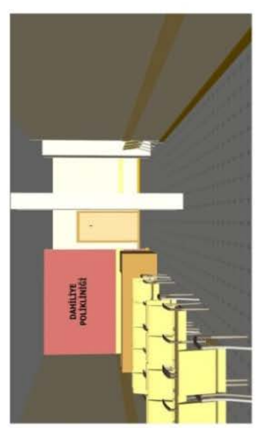


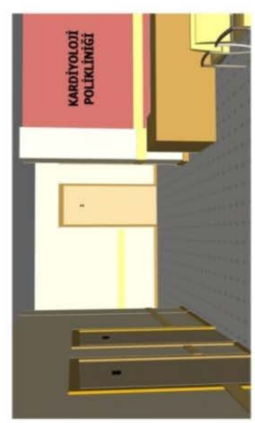












APPENDIX H : The Data

Table H1. The Data Sheet for Setting 1

				Route Replication Task				Picture Classification Task	
Participant	Setting	Sex	Age	Time	Wrong turns	Hesitations	Distance	Sequence	Time of Completion
1	1	F	70	205	1	2	58	10	245
2	1	F	74	234	2	3	64	7	305
3	1	F	65	110	1	1	55	11	160
4	1	F	66	95	0	0	55	10	190
5	1	F	73	200	1	2	58	9	210
6	1	F	78	208	1	2	60	9	200
7	1	F	66	110	0	1	55	9	205
8	1	F	72	130	1	2	58	9	272
9	1	F	67	137	0	1	55	9	244
10	1	F	66	140	0	1	55	10	210
11	1	F	74	225	2	3	70	7	310
12	1	F	68	195	2	2	66	9	216
13	1	F	69	144	1	2	60	10	195
14	1	F	77	190	2	2	65	7	277
15	1	F	68	132	1	1	58	9	250
			70.2	163.6666667	1	1.6666667	59.46666667	9	232.6
16	1	M	66	102	0	1	55	10	147
17	1	M	74	125	1	2	58	10	150
18	1	M	73	107	0	1	55	10	172
19	1	M	77	162	1	2	60	8	280
20	1	M	65	117	0	0	55	10	163
21	1	M	68	112	0	1	55	10	187
22	1	M	70	130	1	2	58	8	205
23	1	M	66	126	0	0	55	10	200
24	1	M	67	125	1	0	58	9	197
25	1	M	71	149	1	1	58	9	205
26	1	M	75	140	1	1	58	9	211
27	1	M	69	152	1	2	58	8	202
28	1	M	67	100	0	1	55	11	142
29	1	M	78	210	2	3	65	7	317
30	1	M	68	198	1	3	60	8	300
			70.2666667	132.6428571	0.666666667	1.3333333	57.53333333	9.133333333	205.2

Table H2. The Data Sheet for Setting 2

				Route Replication Task				Picture Classification Task	
Participant	Setting	Sex	Age	Time	Wrong turns	Hesitations	Distance	Sequence	Time of Completion
31	2	F	80	115	0	0	55	10	195
32	2	F	76	102	0	0	55	10	177
33	2	F	68	160	1	1	58	10	244
34	2	F	65	85	0	0	55	11	156
35	2	F	69	153	1	1	55	9	228
36	2	F	66	127	0	1	55	10	150
37	2	F	66	134	0	0	55	9	162
38	2	F	70	98	0	1	55	10	198
39	2	F	65	90	0	0	55	11	174
40	2	F	69	100	0	0	55	11	145
41	2	F	72	88	0	0	55	11	155
42	2	F	70	95	0	0	55	11	160
43	2	F	73	92	0	0	55	10	192
44	2	F	77	115	0	0	55	10	170
45	2	F	69	104	0	0	55	11	152
			70.3333333	110.5333333	0.133333333	0.2666667	55.2	10.26666667	177.2
46	2	M	73	92	0	1	55	11	140
47	2	M	80	110	0	1	55	11	180
48	2	M	70	82	0	0	55	11	143
49	2	M	66	87	0	0	55	10	167
50	2	M	79	106	0	0	55	11	152
51	2	M	67	96	0	0	55	10	187
52	2	M	65	78	0	0	55	11	122
53	2	M	67	83	0	0	55	11	136
54	2	M	70	90	0	0	55	11	152
55	2	M	72	85	0	0	55	11	140
56	2	M	66	97	0	0	55	10	166
57	2	M	71	76	0	0	55	11	160
58	2	M	65	80	0	0	55	11	130
59	2	M	68	94	0	0	55	11	143
60	2	M	74	102	0	0	55	11	151
			70.2	90.53333333	0	0.1333333	55	10.8	151.2666667

Table H3. The Data Sheet for Setting 3

				Route Replication Task				Picture Classification Task	
Participant	Setting	Sex	Age	Time	Wrong turns	Hesitations	Distance	Sequence	Time of Completion
61	3	F	73	88	0	0	55	11	155
62	3	F	65	119	0	0	55	11	174
63	3	F	69	100	0	0	55	11	145
64	3	F	77	115	0	1	55	10	170
65	3	F	68	104	0	0	55	11	152
66	3	F	80	115	0	1	55	10	195
67	3	F	74	122	0	1	55	9	207
68	3	F	68	172	1	1	58	9	244
69	3	F	66	97	0	0	55	11	186
70	3	F	69	183	1	1	60	9	245
71	3	F	66	129	0	1	55	10	160
72	3	F	67	134	0	0	55	9	205
73	3	F	79	128	1	1	60	9	198
74	3	F	71	105	0	0	55	10	180
75	3	F	72	92	0	0	55	10	192
			70.9333333	120.2	0.2	0.4666667	55.86666667	10	187.2
76	3	M	75	80	0	0	55	11	126
77	3	M	67	94	0	0	55	10	147
78	3	M	69	102	0	0	55	11	151
79	3	M	68	92	0	1	55	11	140
80	3	M	79	110	0	1	55	10	175
81	3	M	72	82	0	0	55	11	130
82	3	M	74	87	0	0	55	10	167
83	3	M	80	106	0	0	55	11	152
84	3	M	66	96	0	0	55	10	190
85	3	M	68	78	0	0	55	11	122
86	3	M	71	83	0	0	55	11	136
87	3	M	70	90	0	0	55	11	155
88	3	M	65	85	0	0	55	10	140
89	3	M	69	100	0	0	55	11	142
90	3	M	66	75	0	0	55	11	171
			70.6	91.78571429	0	0.1428571	55	10.64285714	148.0714286

APPENDIX I : Statistical Analysis

Table I1. 3X2 Factorial MANOVA Tests of Between-Subject Effects

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[g]
Corrected Model	Time spent	60075.567[a]	5	12015.113	15.367	.000	.478	76.834	1.000
	Wrong turns	12.533[b]	5	2.507	12.055	.000	.418	60.275	.998
	Hesitations	33.200[c]	5	6.640	17.005	.000	.503	85.024	1.000
	Distance	244.722[d]	5	48.944	8.608	.000	.339	43.042	.965
	Sequence accuracy	43.556[e]	5	8.711	12.115	.000	.419	60.574	.998
	Time of completion	76838.489[f]	5	15367.698	12.611	.000	.429	63.053	.999
Intercept	Time spent	1269496.900	1	1269496.900	1623.632	.000	.951	1623.632	1.000
	Wrong turns	10.000	1	10.000	48.092	.000	.364	48.092	.999
	Hesitations	40.000	1	40.000	102.439	.000	.549	102.439	1.000
	Distance	285722.678	1	285722.678	50252.732	.000	.998	50252.732	1.000
	Sequence accuracy	8960.044	1	8960.044	12460.989	.000	.993	12460.989	1.000
	Time of completion	3041890.178	1	3041890.178	2496.146	.000	.967	2496.146	1.000
Setting	Time spent	45200.600	2	22600.300	28.905	.000	.408	57.810	1.000
	Wrong turns	11.267	2	5.633	27.092	.000	.392	54.183	.999
	Hesitations	31.400	2	15.700	40.207	.000	.489	80.415	1.000
	Distance	210.756	2	105.378	18.534	.000	.306	37.068	.978
	Sequence accuracy	37.956	2	18.978	26.393	.000	.386	52.786	.999
	Time of completion	55560.556	2	27780.278	22.796	.000	.352	45.592	.996
Sex	Time spent	14516.100	1	14516.100	18.565	.000	.181	18.565	.749
	Wrong turns	1.111	1	1.111	5.344	.023	.060	5.344	.105
	Hesitations	1.600	1	1.600	4.098	.046	.047	4.098	.063
	Distance	22.500	1	22.500	3.957	.050	.045	3.957	.059
	Sequence accuracy	4.444	1	4.444	6.181	.015	.069	6.181	.139
	Time of completion	20672.178	1	20672.178	16.963	.000	.168	16.963	.688
Setting * Sex	Time spent	358.867	2	179.433	.229	.795	.005	.459	.002
	Wrong turns	.156	2	.078	.374	.689	.009	.748	.002
	Hesitations	.200	2	.100	.256	.775	.006	.512	.002
	Distance	11.467	2	5.733	1.008	.369	.023	2.017	.010
	Sequence accuracy	1.156	2	.578	.804	.451	.019	1.607	.007
	Time of completion	605.756	2	302.878	.249	.781	.006	.497	.002
Error	Time spent	65678.533	84	781.887					
	Wrong turns	17.467	84	.208					
	Hesitations	32.800	84	.390					
	Distance	477.600	84	5.686					
	Sequence accuracy	60.400	84	.719					
	Time of completion	102365.333	84	1218.635					

Table I2. Scheffe Post Hoc Comparison Test

Multiple Comparisons

Scheffe

Dependent Variable	(I) Setting	(J) Setting	Mean Difference (I-J)	Std. Error	Sig.	99.95% Confidence Interval	
						Lower Bound	Upper Bound
Time spent	Neutral	Warm	49.80*	7.220	.000	20.33	79.27
		Cool	44.90*	7.220	.000	15.43	74.37
	Warm	Neutral	-49.80*	7.220	.000	-79.27	-20.33
		Cool	-4.90	7.220	.795	-34.37	24.57
	Cool	Neutral	-44.90*	7.220	.000	-74.37	-15.43
		Warm	4.90	7.220	.795	-24.57	34.37
Wrong turns	Neutral	Warm	.77*	.118	.000	.29	1.25
		Cool	.73*	.118	.000	.25	1.21
	Warm	Neutral	-.77*	.118	.000	-1.25	-.29
		Cool	-.03	.118	.961	-.51	.45
	Cool	Neutral	-.73*	.118	.000	-1.21	-.25
		Warm	.03	.118	.961	-.45	.51
Hesitations	Neutral	Warm	1.30*	.161	.000	.64	1.96
		Cool	1.20*	.161	.000	.54	1.86
	Warm	Neutral	-1.30*	.161	.000	-1.96	-.64
		Cool	-.10	.161	.826	-.76	.56
	Cool	Neutral	-1.20*	.161	.000	-1.86	-.54
		Warm	.10	.161	.826	-.56	.76
Distance	Neutral	Warm	3.40*	.616	.000	.89	5.91
		Cool	3.07*	.616	.000	.55	5.58
	Warm	Neutral	-3.40*	.616	.000	-5.91	-.89
		Cool	-.33	.616	.864	-2.85	2.18
	Cool	Neutral	-3.07*	.616	.000	-5.58	-.55
		Warm	.33	.616	.864	-2.18	2.85
Sequence accuracy	Neutral	Warm	-1.47*	.219	.000	-2.36	-.57
		Cool	-1.27*	.219	.000	-2.16	-.37
	Warm	Neutral	1.47*	.219	.000	.57	2.36
		Cool	.20	.219	.660	-.69	1.09
	Cool	Neutral	1.27*	.219	.000	.37	2.16
		Warm	-.20	.219	.660	-1.09	.69
Time of completion	Neutral	Warm	54.67*	9.013	.000	17.87	91.46
		Cool	50.50*	9.013	.000	13.71	87.29
	Warm	Neutral	-54.67*	9.013	.000	-91.46	-17.87
		Cool	-4.17	9.013	.899	-40.96	32.63
	Cool	Neutral	-50.50*	9.013	.000	-87.29	-13.71
		Warm	4.17	9.013	.899	-32.63	40.96

Table I3. Descriptive Statistics for Time Spent

	Setting	Sex	Mean	Std. Deviation	N
Time spent	Neutral	Female	163.67	46.018	15
		Male	137.00	32.765	15
		Total	150.33	41.527	30
	Warm	Female	110.53	23.394	15
		Male	90.53	10.309	15
		Total	100.53	20.468	30
	Cool	Female	120.20	27.106	15
		Male	90.67	10.574	15
		Total	105.43	25.184	30
	Total	Female	131.47	40.347	45
		Male	106.07	30.005	45
		Total	118.77	37.589	90

Table I4. Descriptive Statistics for Wrong Turns

	Setting	Sex	Mean	Std. Deviation	N
Wrong turns	Neutral	Female	1.00	.756	15
		Male	.67	.617	15
		Total	.83	.699	30
	Warm	Female	.13	.352	15
		Male	.00	.000	15
		Total	.07	.254	30
	Cool	Female	.20	.414	15
		Male	.00	.000	15
		Total	.10	.305	30
	Total	Female	.44	.659	45
		Male	.22	.471	45
		Total	.33	.581	90

Table I5. Descriptive Statistics for Experiencing Hesitations

	Setting	Sex	Mean	Std. Deviation	N
Hesitations	Neutral	Female	1.67	.816	15
		Male	1.33	.976	15
		Total	1.50	.900	30
	Warm	Female	.27	.458	15
		Male	.13	.352	15
		Total	.20	.407	30
	Cool	Female	.47	.516	15
		Male	.13	.352	15
		Total	.30	.466	30
	Total	Female	.80	.869	45
		Male	.53	.842	45
		Total	.67	.861	90

Table I6. Descriptive Statistics for Distance Travelled

	Setting	Sex	Mean	Std. Deviation	N
Distance	Neutral	Female	59.47	4.734	15
		Male	57.53	2.774	15
		Total	58.50	3.937	30
	Warm	Female	55.20	.775	15
		Male	55.00	.000	15
		Total	55.10	.548	30
	Cool	Female	55.87	1.846	15
		Male	55.00	.000	15
		Total	55.43	1.357	30
	Total	Female	56.84	3.464	45
		Male	55.84	1.977	45
		Total	56.34	2.849	90

Table I7. Descriptive Statistics for Sequence Accuracy

	Setting	Sex	Mean	Std. Deviation	N
Sequence accuracy	Neutral	Female	9.00	1.195	15
		Male	9.13	1.125	15
		Total	9.07	1.143	30
	Warm	Female	10.27	.704	15
		Male	10.80	.414	15
		Total	10.53	.629	30
	Cool	Female	10.00	.845	15
		Male	10.67	.488	15
		Total	10.33	.758	30
	Total	Female	9.76	1.069	45
		Male	10.20	1.057	45
		Total	9.98	1.081	90

Table I8. Descriptive Statistics for Time of Completion

	Setting	Sex	Mean	Std. Deviation	N
Time of completion	Neutral	Female	232.60	43.886	15
		Male	205.20	54.025	15
		Total	218.90	50.329	30
	Warm	Female	177.20	29.221	15
		Male	151.27	18.081	15
		Total	164.23	27.276	30
	Cool	Female	187.20	30.233	15
		Male	149.60	19.294	15
		Total	168.40	31.410	30
	Total	Female	199.00	42.068	45
		Male	168.69	42.817	45
		Total	183.84	44.872	90