UPDATING SPATIAL ORIENTATION

IN VIRTUAL ENVIRONMENTS

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By

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May, 2006

I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Fine Arts.

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ABSTRACT

UPDATING SPATIAL ORIENTATION IN VIRTUAL ENVIRONMENTS

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M.F.A. in Interior Architecture and Environmental Design

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Spatial reasoning in architectural design can be better understood by considering the factors that are affecting the spatial updating of the individual in an environment. This study focuses on the issue of spatial updating during rotational and translational movements in a virtual environment (VE). Rotational and translational movements based on an egocentric frame of reference via optic flow are compared separately in order to find the movement that is more efficient in spatial updating. Alignment of the objects with the viewer, different media utilized in architectural design drawings and gender are considered as factors that affect the spatial updating within the movement types. The results indicated that translational movement was more efficient in the judgment of relative directions. Furthermore, questions related to the objects that were aligned with the viewer were more correctly answered than on the misaligned ones. In comparison of hand, computer and both as drawing media, findings indicated that computer usage in architectural design drawings was the most effective medium in spatial updating process in a VE. Contrary to the previous studies, there was no significant difference between gender and movement types.

Keywords: Gender, Rotational Movements, Spatial Updating, Translational Movements, Virtual Environments.

ÖZET

SANAL ORTAMLARDA MEKANSAL YÖN BELİRLEMENİN GÜNCELLENMESİ

İpek Sancaktar

İç Mimarlık ve Çevre Tasarımı Bölümü, Yüksek Lisans

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Mayıs, 2006

Mimari tasarım sürecinde verilen mekansal kararların daha iyi anlaşılabilmesi için, belirli bir ortamdaki bireyin mekansal güncellemesini etkileyen faktörlerin dikkate alınması gerekmektedir. Bu çalışma, sanal ortamdaki döngüsel ve çizgisel hareketler sırasında oluşan mekansal güncellemeyi ele almaktadır. Sanal ortamdaki birey merkezli referans sistemlerinde (egosentrik), döngüsel ve çizgisel hareketlerin mekansal güncellemede verimlilikleri karşılaştırılmıştır. Nesnelerin gözlemci tarafından algılanma sırası, mimari tasarım çizimlerinde kullanılan farklı araçlar ve cinsiyet, hareket türleri kapsamında mekansal güncellemeyi etkileyen faktörler olarak düşünülmüştür. Yapılan deneyde, çizgisel hareketlerin yön bulma kararlarında daha etkili olduğu bulunmuştur. Ayrıca, gözlemci tarafından algılama sırası ile aynı konumda olan nesnelerle ilgili sorulara, aynı sırada olmayan nesnelerle ilgili sorulara göre daha fazla doğru cevap verildiği gözlenmiştir. Elle çizim, bilgisayar veya her iki aracı kullanarak mimari çizim yapan denekler karşılaştırıldığında, bilgisayar kullanımının, sanal ortamdaki mekansal güncellemede en etkili araç olduğu belirlenmiştir. Önceki çalışmaların aksine, bu çalışmada cinsiyet ile iki hareket türü arasında anlamlı bir ilişki bulunmamıştır.

Anahtar Sözcükler: Cinsiyet, Döngüsel Hareketler, Mekansal Güncelleme, Çizgisel Hareketler, Sanal Ortamlar.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

Navigation is one of the important tasks that people perform in real and virtual environments in order to reach a destination. With the increase in computer usage, virtual environments (VEs) have become new areas of navigation. However, navigation in unfamiliar environments, whether virtual or real, is difficult and it has often been observed that inexperienced computer users experience great difficulties when navigating in a virtual environment (Van Dijk, op den Akker, Nijholt and Zweirs, 2003; Vinson, 1999).

Studies that have examined navigational learning in VEs have conducted their research in buildings, outdoor environments and mazes. According to Belingard and Peruch (2000), virtual environments have many advantages because they allow "the creation of environments of varying complexity" and allow "interactive navigation with continuous measurements within it" (p. 429).

In recent years, virtual environments or computer-simulated environments have been applied to a variety of fields including the study of spatial behavior (Foreman et al., 2000). Virtual environments have become a tool for spatial knowledge acquisition. Kirschen, Kahana, Sekuler and Burack (2000) indicated that virtual environments are used effectively in tests of spatial learning. "In VEs, the user can visualize and interact with the virtual, three-dimensional spatial environment in real time" (Cubukcu and Nasar, 2005, p. 399).

Navigation in VEs enables the investigation of spatial knowledge. During navigation in VEs people utilize two types of movements; these are rotational movements (turning clockwise or anticlockwise) and translational movements (moving forwards, backwards and sideways). These movement types are processed differently and they affect the way people learn their environments. Previous studies suggest that rotations are more difficult to process than translations (Creem-Regehr, 2003; Rieser, 1989). However, Tlauka (in press) indicated that rotational movements without translational movements are employed in environments with low complexity that can be learned easily. To research this dichotomy, the spatial knowledge that is acquired by the two movement types is compared in a virtual environment via optic flow since previous studies have not directly compared the two movement types in a desktop virtual environment.

1.1. Aim of the Study

Architectural design, as a problem solving activity, requires imagining spatial changes and making inferences about spatial relationships. In order to understand the spatial reasoning in architectural design, one needs to consider the factors that affect the spatial updating of the individual in an environment.

The main purpose of this thesis is to compare spatial learning based on two movement types in a desktop virtual environment. When people navigate through an environment, they use a combination of rotational and translational movements. In this study, the rotational and translational movements, which are based on optic flow, are compared separately in order to find the movement that is more accurate in learning the spatial layout of a virtual environment. Spatial knowledge is tested by having the participants indicate the relative directions of the targets.

This thesis points out the differences between the rotational and translational movements, indicates that optic flow can facilitate the learning of specific targets in a virtual environment and that performance in spatial learning can be affected by the acquaintance of 3D virtual environments during the design process. The findings of the research may suggest some clues for interior designers in designing environments that aid wayfinding.

1.2. Structure of the Thesis

The thesis consists of five chapters. The first chapter is the introduction in which the importance of navigation is stated and how virtual environments have become ideal tools for assessing spatial knowledge acquired through navigation is investigated.

The second chapter explores the concept of navigation, the development of spatial knowledge through the interaction with the environment, spatial search strategies and general factors that affect navigation. Firstly, the definition of navigation and how it is related to the virtual environment are stated since virtual environments have become new areas of navigation. Secondly, during the interaction with the environment, sensory feedback and proprioceptive feedback are described in relation to the development of spatial knowledge. Spatial knowledge that is gained, is explained within the three groups of knowledge that are landmark knowledge, route knowledge and survey knowledge. Direct experience with the environment and visual representations are depicted as the modes of spatial knowledge. Thirdly, the spatial search strategies are identified and lastly, the general factors that affect navigation are classified as environmental characteristics and individual differences that consist of gender differences and previous experience are explained.

In the third chapter, spatial orientation during navigation is examined with respect to transformations in an environment, transformations according to the reference frame and transformation types. Transformations can occur in real world environments and virtual environments, and the reference frames are distinguished according to the viewer transformations and imagined transformations. The types of transformations are identified as rotational and translational movements with respect to egocentric and imagined transformations.

In the fourth chapter, the case study is described with the aim, research questions and hypotheses. The participants are identified and the methodology of the case study is defined with respect to the research questions. Finally, the results are evaluated and discussed in relation to previous studies related to the subject. In the last chapter, major conclusions about the study are stated and suggestions for further research are generated.

2. NAVIGATION

Navigation is a core functional requirement for humans in order to reach a place. Bell and Saucier (2004) stated that navigation is "a complex spatial problem that is routinely faced and solved by humans and other animals" (p. 252). Navigation can take place in familiar environments or in novel environments in which an individual has little or no prior experience. Navigation can also occur in large environments that are difficult to perceive from a single point. A diverse set of information processing skills is required to solve navigation problems; these consist of multimodal perception, knowledge recall, mental manipulation of stored and perceived information and decision making (Bell and Saucier, 2004).

The exploration of navigation in the virtual reality formerly began with the urban design studies of the physical world (Modjeska and Waterworth, 2000). Later, navigation was applied to the spatial behavior of humans in the virtual environment. Navigation, whether it is in the real or virtual worlds, does not consist of only physical translation, but also cognitive elements, such as mental representations, route planning and distance estimations (Darken, Allard and Achille, 1999). For successful navigation, people need to plan their movements by using spatial knowledge that is acquired about the environment and is stored as cognitive maps (Ruddle and Peruch, 2004).

2.1. The Definition of Navigation

Darken and Sibert (1993) stated that navigation was “originally referred to the process of moving across a body of water in a ship” (p. 158). Later, it has been extended to include the process of determining the path for a ship or an airplane. Nowadays, this term, which is used in a broad way, is defined as “the process of determining a path to be traveled by any object through an environment” (Darken and Sibert, 1993, p. 158). Navigation is also a major task in any type of virtual environment (Grammenos, Mourouzis and Stephanidis, in press).

Montello and Freundschuh (2005) indicated that navigation is a coordinated and goal directed movement through a space. Navigation consists of two parts, travel (locomotion) and wayfinding. Travel is the actual motion from the current location to the new location. 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 and Freundschuh, 2005, p. 69). Grammenos et al. (in press) referred to the virtual environments by indicating that travel was “the minimum interaction capability offered by any VE and involves the ability of the users to control the position (i.e. to move) and orientation (i.e. gaze direction) of their virtual body” (p. 2). The second constituent of navigation, which is wayfinding, refers to the “cognitive coordination to the distant environment, beyond direct sensorimotor access, and includes activities such as trip planning and route choice” (Montello and Freundschuh, 2005, p. 69) where the path is determined by knowledge of the environment, visual cues and navigational aids. In other words, wayfinding is “the strategic and tactical element that guides movement” (Sadeghian, Kantardzic, Lozitskiy and Sheta, 2006, p. 2).

Therefore, people are aware of their current positions and of how to reach the desired goal (Grammenos et al., in press).

As Avraamides, Klatzky, Loomis and Golledge (2004) asserted, navigation depends on updating one's location and orientation with respect to the environment. People are able to navigate and stay oriented by identifying landmarks and by updating their sense of position. "Orientation is basically the ability to know one's location within the environment and the relative location of other elements, and to continually update this knowledge. Orientation ability is often a pre-requisite for successful navigation" (Parush and Berman, 2004, p. 376).

Navigation is composed of a complex series of rotations and translations within an egocentrically arranged environment with objects. This situation is "rich in information because the objects can be actively explored and the movements made by the observer provide continuous feedback for updating spatial position" (May, Peruch and Savoyant, 1995, pp. 22-23).

2.2. Interaction with the Environment

While navigating in a real or virtual environment, people interact with the environment in order to get to the desired destination. During this interaction, people gain spatial knowledge about their own movements and about the spatial relations within the environment that support spatial updating (Montello, Hegarty, Richardson and Waller, 2004). In this section, the development, the representation and the acquisition of spatial knowledge are explained in detail.

2.2.1. Development of Spatial Knowledge

Ruddle and Peruch (2004) stated that "a person develops spatial knowledge from a congruence of at least two categories of information" (p. 301) during navigational learning that can support spatial updating. The first category is based on sensory feedback or allothetic information, such as vision, audition and olfaction that is derived from sensing the environment and the secondary category is proprioceptive feedback or idiothethic information (Avraamides, 2003; Ruddle and Peruch, 2004).

2.2.1.1. Sensory Feedback

One of the mostly used senses during navigation is vision. Vision enables the person to acquire spatial knowledge at environment scales (Montello et al., 2004). Sensory feedback specifies the environment that is perceived, the current location and the orientation of the observer. As a result, moving observers can keep track of their positions and orientations while traversing an environment (Avraamides, 2003). Movement through an environment that is guided by visual information is called optic flow. Optic flow can "facilitate path integration, which involves updating a mental representation of place by combining the trajectories of previously traveled paths" and can give us the sense of self-motion (Kirschen et al., 2000, p. 801). The characteristics of optic flow are associated with the speed and direction of the locomotion and the properties of the environment, such as texture gradients and landmarks (Kirschen et al., 2000). When desktop VEs are used, idiothetic cues to self-motion are unavailable, thus leaving optic flow as only tool (Hartley, Trinkler and Burgess, 2004). Kirschen et al. (2000) claimed that optic flow can be a significant aid to wayfinding when other cues are unavailable. They showed that "salient optic flow can facilitate the learning of specific locations in synthetic environments. Additionally, this optic flow aids path integration and in forming mental representations of spatial environments" (p. 817). Correspondently, Tanrıverdi and Jacob (2000) indicated that "eye movement-based interaction is an example of the emerging non-command based interaction style" (p. 265) and it is an easy, natural and fast way of interacting with virtual environments. According to Moffat, Hampson and Hatzipantelis (1998), optic flow provided the users with the motion and movement cues that were essential to navigate through an environment. Beer (1993) showed that participants were able to make use of changes in optic flow to update a scene during visually simulated self-motion (cited in Avraamides, 2003). With respect to this, Kirschen et al. (2000) supported the idea that optic flow helped participants to learn a series of left and right turns and spatial locations while navigating through an environment. They claimed that "the absence of optic flow resulted in participants becoming disoriented and getting lost within our virtual mazes" (p. 817). Riecke, van Veen and Bülthoff (2002) also indicated that optic flow was shown to be sufficient for inexperienced participants to accomplish turns and reproduce distances. On the other hand, Chance, Gaunet, Beall and Loomis (1998) and Montello et al. (2004) claimed that visual information alone without body rotations was not sufficient to cause egocentric updating.

2.2.1.2. Proprioceptive Feedback

Spatial knowledge can also be developed via other sensory modalities, such as the vestibular senses and kinaesthesis (Montello et al., 2004). Proprioceptive feedback (idiothetic information) is developed by the motor and locomotor activity and is caused by the person's muscular tendon and joint receptors (Ruddle and Peruch, 2004). In other words, it is "the sensory information that is internally generated as a function of our bodily actions in space" (Lathrop and Kaiser, 2002, p. 20). "Proprioceptive (vestibular and kinaesthetic) information can contribute to a person's knowledge of routes (…) and to the process by which the person performs path integration to update their position within the environment as a whole" (Ruddle and Peruch, 2004, p. 301).

According to the study of Chance et al. (1998), "vestibular and proprioceptive information contribute to the ability to perform egocentric spatial updating" (p. 176) since there was a difference in performance between the walk locomotion mode, in which the participants walked normally, but their body position and heading were tracked by the head-mounted display (HMD), and the visual turn locomotion mode, in which the participants moved through the environment, controlling their turns by using a joystick. Proprioceptive feedback can be used effectively for orientation, but visual flow alone is inaccurate, unreliable and may lead to disorientation. Also, the absence of proprioceptive feedback can lead to disorientation (Bakker, Werkhoven and Passenier, 1999; Mine, Brooks and Sequin, 1997).

The contribution of proprioceptive feedback to spatial knowledge development is important because "of the many modes by which locomotion (both rotation and translation) may take place in a V.E." (Lathrop and Kaiser, 2002, p. 20). Rieser (1989) argued that "proprioceptive feedback that accompanies physical movements enables the "automatic" updating of the changing egocentric locations of objects. Because proprioceptive information is correlated with changes in visual flow during sighted movements" (cited in Avraamides, 2003, p. 427). However, a mismatch can occur between optic flow and proprioceptive feedback in a desktop VE. During navigation in a desktop VE, optic flow is available from the display, but there is a lack of proprioceptive cues (Richardson, Montello and Hegarty, 1999).

2.2.2. Types of Spatial Knowledge

When people experience a new environment, they unconsciously construct a mental map of the environment. This mental map is referred to as a cognitive map. The cognitive map enables us to find our way in unfamiliar environments and it is continually refined and updated as the environment is re-explored. The cognitive map is "a mental representation, or set of representations, of the spatial layout of the environment" (Montello and Freundschuh, 2005, p. 68).

Cognitive maps of the environment, which are formed in navigation, consist of generic components that are paths, edges, landmarks, districts and nodes (Lynch, 1960). Paths are linear separators that define channels of movement, such as streets or walkways. Edges are barriers or boundaries, such as walls or fences. Landmarks are described as visible reference points that may be large objects, which are in sharp contrast to their immediate surroundings or on a local scale. Districts consist of large sections that have recognizable, common perceived identity, homogeneity or character, which differentiates them from other areas. Nodes are focal points that consist of intensive activity to and from people may travel or with similar characteristics (Darken and Sibert, 1993; Nasar, 1998). In order to construct a cognitive map of the virtual environment, "a user should be able to orient him/herself in space and build up landmarks, route and survey knowledge" (Van Dijk et al., 2003, p. 117). The cognitive map is composed of three levels of knowledge that are landmark, route and survey knowledge (Parush and Berman, 2004).

2.2.2.1. Landmark Knowledge

Schlender, Peters and Wienhöfer (2000) stated that landmark knowledge is derived from the knowledge of noticeable objects in an environment. "Landmark knowledge involves the use of highly salient objects to help orient oneself in a new environment, providing a means of organizing, anchoring, or remembering information" (Nash, Edwards, Thompson and Barfield, 2000, p. 13). Information about the shape, size, color and contextual information about landmarks, or memorable and distinctive objects in an environment are presented in landmark knowledge (Chen and Stanney, 1999; Montello, 1998; Sadeghian et al., 2006). Landmarks do not contain spatial information, but they are believed to play critical roles in route knowledge by indicating the decision points along a path and helping the traveler to remember the procedures needed to reach a destination, and in survey knowledge by providing regional anchors that help them to determine the distances and directions (Chen and Stanney, 1999; Sadeghian et al., 2006).

2.2.2.2. Route Knowledge

Route knowledge or procedural knowledge is defined as "an internal representation of the procedures necessary for finding one's way from place to place" (Montello et al., 2004, p. 270). It refers to the person's ability to navigate from one location to another and is based on an egocentered frame of reference (Ruddle and Peruch, 2004). Route knowledge is the knowledge of routes that connect landmarks into a travel sequence (Montello, 1998; Montello and Freundschuh, 2005). Route knowledge consists of "information about the order of landmarks and minimal information about the appropriate action to perform at "choice-point" landmarks, such as "turn right" or "continue forward" (Montello, 1998, p. 144). Route knowledge is assessed either by directional pointing tasks in which the participants have to point to previously explored or unexplored targets during their navigation between two target locations, or by measuring the participants' ability to orient themselves relative to known landmarks or features in the environment (Nash et al., 2000).

2.2.2.3. Survey Knowledge

Survey knowledge is gained when routes and landmarks are combined into a cognitive map. It is characterized as "the ability to conceptualize the space as a whole" (Van Dijk et al., 2003, p. 117). Survey knowledge refers "to the global configuration of environments such as the location of objects relative to a fixed coordinate system" (Ruddle and Peruch, 2004, p. 301). Survey knowledge can be considered as the ultimate stage of navigational knowledge acquisition because it is based on a world-centered frame of reference; the user has the ability to take shortcuts, create efficient routes, point directly between landmarks and utilize increasingly abstract terms of reference, such as cardinal directions (Kallai, Makany, Karadi and Jacobs, 2005; Montello, 1998; Nash et al., 2000). "Survey knowledge is the key to successful effective navigation" (Van Dijk et al., 2003, p. 117) and a person with complete survey knowledge is said to have navigational awareness (Nash et al., 2000).

2.2.3. Modes of Spatial Knowledge

There are two modes of spatial knowledge acquisition. Spatial knowledge can be directly acquired via direct environmental experience by navigation or indirectly via visual representations of the environment.

2.2.3.1. Direct Experience

People can acquire spatial knowledge by directly exploring the environment. This direct exploration is non-symbolic since it involves "apprehension of spatial knowledge directly from the environment via sensorimotor experience in that environment" (Montello et al., 2004, p. 252). Avraamides (2003) stated that direct experience with an environment via perception is probably the primary way for constructing spatial representations. Witmer, Sadowski and Finkelstein (2002) indicated that navigating in an environment provides an egocentric perspective, which is a horizontal view from within the environment. According to Nash and his colleagues (2000), direct exposure to the environment "supports a progressive acquisition process, assisting at both the landmark and route knowledge levels" (p. 16).

2.2.3.2. Visual Representations

Spatial knowledge can be acquired via visual representations, such as maps, movies and animations. These representations are symbolic because spatial information is conveyed by showing people external representations or simulations of the environments (Montello et al., 2004). The map is one of the most effective tools for navigation (Darken and Sibert, 1993; Ruddle, Payne and Jones, 1998). "Map study allows for route and survey knowledge acquisition without the direct exposure to the environment" (Nash et al., 2000, p. 16). Maps provide an exocentric perspective that is a vertical view from the outside looking in (Witmer et al., 2002). A map, which is available during exploration in a VE, is said to increase spatial knowledge. However, the orientation of the map may influence the apprehension of the spatial knowledge (Darken and Sibert, 1996; Schlender et al., 2000; Witmer et al., 2002).

Textual information can also be used as additional information to acquire spatial knowledge that can give information about distances, directions and sequences of certain landmarks on a path (Montello et al., 2004; Schlender et al., 2000). More recently, virtual environments have become a source for spatial knowledge acquisition (Jansen-Osmann, 2002; Montello et al., 2004; Richardson et al., 1999). Jansen-Osmann (2002) stated that the VE "allows the simulation of three-dimensional environments on a computer: humans can experience those environments by active exploration, VR conveys a strong impression of movement through space" (p. 427). It has been shown that survey knowledge can be acquired in VEs without depending on maps and textual information (Wilson, Foreman and Tlauka, 1997; Witmer et al., 2002).

2.3. Spatial Search Strategies

When people navigate through real world or virtual environments, their movements are not random, but consist of motion patterns. These motion patterns are referred to as spatial search strategies that occur during spatial navigation. The strategy is utilized during the goal-directed spatial response of the individual to the environment. Kallai et al. (2005) stated that "these strategies are usually directed toward objects or boundaries or an obstacle" (p. 189).

Search strategies were found to be influential in retrieving environmental information and there are various approaches in the categorization of search strategies (Chen and Stanney, 1999). The selection of a navigational strategy depends on four factors. It depends on the representation of the environment, the complexity of the environment, gender and the kind of visual information when navigating through an environment (Janzen, Schade, Katz and Herrmann, 2001).

Thorndyke and Goldin (1981) suggested that individuals can be divided into two categories according to the search strategies that they use, as visualizers and verbalizers. Visualizers are concentrated on the perceptual information and visual details of an environment, whereas verbalizers are focused on labels and guides in order to construct a system and interactions of paths. They indicated that verbalizers have a detailed and metrically accurate map, but an insufficient knowledge of the visual properties of the environment. As a result, the differences in search strategies influence how the individuals perceive the environment and the information they acquire in order to construct cognitive maps (cited in Chen and Stanney, 1999).

Anooshian (1996) determined two groups that acquire different types of spatial knowledge based on different search strategies. The place-learning group acquired a complete spatial knowledge, which consisted of landmark, route and survey, whereas the turn-learning group acquired only the route knowledge (cited in Chen and Stanney, 1999).

Darken and Sibert (1996) indicated that the search strategies can be divided as naïve search and primed search. In the naïve search, the navigator is searching for the target, has knowledge about its appearance, but no prior knowledge about the location of the target. In the primed search, the navigator has some knowledge about the location of the target. Darken and Sibert (1996) separated exploration from the search strategies and defined exploration as a wayfinding task with no target.

Benyon and Höök (1997) classified the search strategies as to be either goal-oriented or explorative or aiming at object identification. They described 'goal-oriented' as finding a way to reach a known destination, 'explorative' as wandering and discovering what's there and 'aiming at object identification strategy' as to finding information about the objects. The 'aiming at object identification strategy' was identifying the types, the interesting configurations and the information about the objects in the environment (cited in Van Dijk et al., 2003).

According to Kallai et al. (2005), three spatial search strategies were identified by analyzing the main components of the navigation maps. These strategies were thigmotaxis, visual scanning and enfilading. The thigmotaxis search strategy enables the individual to be in a continuous contact with a stable element of the environment and "gives the person a frame of reference by virtue of its own independent existence. A 'virtual touch' is a necessarily component of the thigmotaxis because it permits the person to define his/her position in a bordered virtual environment" (p. 190). Visual scan consists of active exploration, the individual stays in a fixed spatial location and turns. Visual scan "represents an active exploration of the distal cues, the relations among them, and more importantly, shifts from one cue to another" (p. 191). Enfilading refers "to an approach-withdrawal pattern of active exploration near a target location" (p. 187). It is composed of small direction changes and non-strategic elements. The authors suggested that "the way in which humans use these search strategies are deeply related to different phases of spatial learning and are related to the process of the spatial map construction" (p. 194).

2.4. General Factors affecting Navigation

Navigation, whether in the real or virtual environment, can be influenced by factors related to the environmental characteristics and to the individual differences that consist of gender differences and previous experience.

2.4.1. Environmental Characteristics

The complexity of the spatial layout and the navigational cues, which consist of local and global landmarks, can affect the navigational performance of the people. "The number and configuration of decision points within a maze have been considered as the most important markers for environmental complexity" (Janzen et al., 2001, p. 150). The complexity of the spatial layout was originally defined by using the graph theory, in which the intersections between paths were defined as the nodes and the paths were the links. However, it was seen that environments with different configurational layouts could have the same graph layout. As a result, the architectural theory of space syntax was developed by Hillier and his colleagues (Ruddle and Peruch, 2004). Space syntax reduced an environment to an axial map that consisted of a minimum number of lines of sight that passed along all the paths (see Figure 2.1.; Ruddle and Peruch, 2004). Ruddle and Peruch (2004) indicated that "space syntax is based on lines of sight" (p. 304).

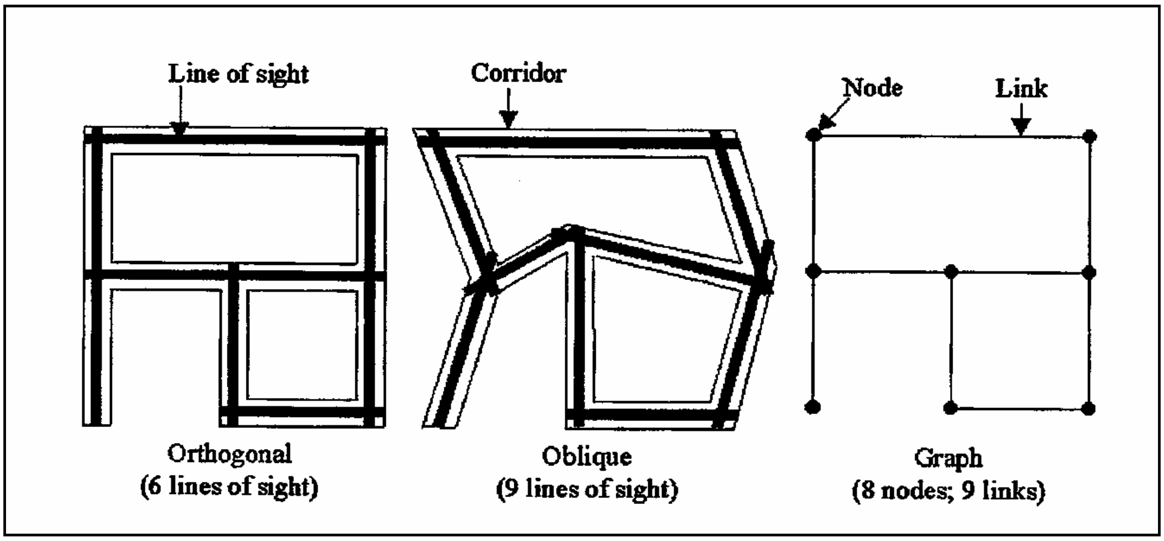

Figure 2.1. Axial maps showing the lines of sight of orthogonal (left) and oblique (middle) environments. The graph structure of both environments is identical (right) (Ruddle and Peruch, 2004, p. 304).

According to the space syntax theory, the spaces are broken down into components, analyzed as networks of choices and represented as maps and graphs that describe the relative connectivity and integration of those spaces (Wikipedia, n.d.). As indicated by the space syntax theory, orthogonal environments are more navigable than topologically identical oblique environments since orthogonal environments contain fewer lines of sight (Ruddle and Peruch, 2004). Janzen et al.'s study (2000) showed that virtual mazes with oblique angled intersections were more difficult to navigate.

The presentation of visible navigational aids in the real or virtual environment is important since it improves navigational performance (Sayers, 2004; Witmer et al., 2002). The lack of navigation aids lead to user disorientation. Studies have indicated positive effects of the presence of visual navigation aids on user navigation performance in a desktop VE. Navigational cues enable users to orient themselves and navigate throughout an environment with confidence and efficiency (Kallai et al., 2005; Sayers, 2004). "These cues need to have memorable forms if subjects' navigational efficiency is to be improved" (Kallai et al., 2005, p. 189). The environment can consist of landmarks that can "act as visual anchors that identify different regions (…), or provide an organizational structure that facilitates location points that are nearby" (Ruddle and Peruch, 2004, pp. 302-303). Jansen-Osmann (2002) stated that landmarks aid orientation and a path with landmarks is learned faster than one without landmarks. They provide navigational information that may occur in many forms. From a navigational standpoint two types of landmarks can be observed that provide different types of information.

Local landmarks are the objects at decision points that are visible only from a small distance (Ruddle et al., 1998; Steck and Mallot, 2000; Wiener, Schnee and Mallot, 2004). They are associated with route knowledge since "they define places where changes of direction must be made and provide confirmation that the path being traveled is correct" (Ruddle and Peruch, 2004, p. 303). "Navigation by local landmarks relies on a sequence of intermediate goals defined by these local landmarks" (Steck and Mallot, 2000, pp. 69-70). Local landmarks can be used as either reference points that guide the observer to the immediate goal or as pointers that direct the observer's way.

Global landmarks are distant landmarks that are visible from a large area, such as towers and mountains, and are associated with route and survey knowledge (Ruddle et al., 1998; Steck and Mallot, 2000; Wiener et al., 2004). "In the route knowledge global landmarks provide general directional indicators and in survey knowledge they provide world-centered framework, but little information about the position of the person" (Ruddle and Peruch, 2004, p. 303).

2.4.2. Individual Differences

Individual differences are one of the important factors that influence navigation. Various aspects of individual differences have been identified, such as age, educational background, learning style and spatial familiarity, but with respect to the case study gender differences and previous experience of the individuals are recognized as the most important factors.

2.4.2.1. Gender Differences

Gender differences are found in the ability to acquire spatial information and navigate through real and virtual environments due to the different types of information that males and females focus within their environments (Saucier, Bowman and Elias, 2003; Tlauka, Brolese, Pomeroy and Hobbs, 2005). Studies have shown that males and females employ different types of strategies and focus on different properties of the environment (Sandstrom, Kaufman and Huettel, 1998).

Sandstrom et al. (1998) reported that males and females used different navigational strategies during the self-report measures. Males employed a Euclidean strategy, which relied on distances and directions, whereas females used topographic strategies, which used landmarks (Dabbs, Chang, Strong and Milun, 1998). Males formed a more accurate representation of the Euclidean or geometric properties, whereas females formed a more accurate representation of the landmarks in the 2D environment (Sandstrom et al., 1998). Females are superior at using landmark-based strategies when navigating and they have better memories for identity and location of landmarks, whereas males have enhanced knowledge of the Euclidean properties of the environment (Dabbs et al., 1998; Iachini, Sergi, Ruggiero and Gnisci, 2005; Sandstrom et al., 1998; Saucier et al., 2003). Dabbs et al. (1998) suggested that the memory of object location assisted the use of landmarks in navigation, whereas three-dimensional visualization developed the use of abstract Euclidean navigation.

When people give navigational directions to others, females refer more to landmarks and other visual objects along a route, show greater accuracy in recalling landmarks and in estimating distances to landmarks, and report using a route-based navigation strategy. On the other hand, males use more cardinal directions and an orientation strategy (Lawton and Morrin, 1999; O'Laughlin and Brubaker, 1998; Saucier et al., 2003). There has been a significant advantage of males for spatial route learning through an unfamiliar environment (Moffat et al., 1998; Tlauka et al., 2005). Studies have shown a male superiority on tasks requiring survey knowledge, for example pointing directions, drawing a sketch map and estimating travel distances (Cubukcu and Nasar, 2005; Devlin and Bernstein, 1995; Lawton and Morrin, 1999; O'Laughlin and Brubaker, 1998). However, Iachini et al. (2005) found no gender differences in object recognition and in remembering absolute distance and categorical spatial relations, but males were better than females in remembering the distance between the objects and the size of the layout.

Tlauka et al. (2005) expressed that gender was a predictor of spatial performance in the real world and in the virtual environments. With respect to the acquisition of spatial knowledge through virtual navigation, an inconsistent pattern of gender differences were revealed. Some studies reported a male advantage in a virtual maze navigation task (Lawton and Morrin, 1999; Moffat et al., 1998; Sandstrom et al., 1998; Waller, 2000), however, no gender differences were revealed in spatial knowledge tests in virtual environments (Darken and Sibert, 1996; Wilson et al., 1997).

2.4.2.2. Previous Experience

Another factor of individual differences is the previous spatial experience of people with respect to their spatial abilities. "Different sources and amounts of experience may result in spatial knowledge and different usage of spatial knowledge over time" (Chen and Stanney, 1999, p. 676). Males and females show differences in spatial knowledge and abilities due to the different utilizations of previous experience.

"Males have more extensive experience with activities that help develop spatial skills, such as model planes and carpentry and video games" (Lawton and Morrin, 1999, p. 75). Lawton and Morrin (1999) showed that prior experience with video games involving navigation through virtual environment resulted in higher pointing accuracies for males since video games were perceived as a masculine domain.

Computer-related experiences, such as computer-games, computer applications (computer-aided design and drawing) and video games have improved the spatial abilities of individuals (Quaiser-Pohl, Geiser and Lehmann, 2006). Quaiser-Pohl et al. (2006) proposed that "individuals' admission of playing certain types of computer games is a useful predictor of spatial abilities" (p. 617), also playing computer-games was seen as a boys toy and a male domain since males indicated that they played computer-games more frequently than females. Since males have more experience with video games, they report that they have more comfort and confidence with the computer (Waller, Hunt and Knapp, 1998). The relationship between computer-game experience and spatial ability revealed an advantage for males. Their results indicated that spatial ability could be developed and be improved with prior computer experience (Quaiser-Pohl et al., 2006). As a result, previous experience or training may decrease gender differences and increase individual's environmental familiarity (Chen and Stanney, 1999; Lawton and Morrin, 1999).

As a result of the interaction with the environment, individuals need to update their spatial orientation within an environment. The next chapter explains updating spatial orientation with respect to transformations in an environment, according to the reference frames and the types.

3. UPDATING SPATIAL ORIENTATION

Spatial ability is an internal mechanism that affects the learning process of an individual (Nash et al., 2000). Spatial ability "may be useful for successful performance in a wide variety of professions such as architecture, graphic design, medicine, engineering" and it involves "the retention, manipulation, and recognition of spatial stimuli" (Albert and Golledge, 1999, pp. 9-10). Creem-Regehr (2003) defined spatial updating as "the human ability to keep track of spatial locations relative to oneself during one's own movement or movement of objects in the environment" (p. 941). Spatial updating is determined by an internal mechanism that continuously computes the egocentric locations of objects as people move in the environment (Avraamides, 2003). Studies on spatial updating have used pointing as the response medium. A typical model that has been used for examining spatial updating involves presenting a layout of objects at various locations and having participants point to objects after they have moved to a new position in the array or after they have changed their facing direction (Avraamides, 2003). Spatial updating is examined by using different paradigms consisting of real and imagined spatial transformations. In this chapter, transformations in an environment, according to the reference frames and the types are explained.

3.1. Transformations in an Environment

Navigation can occur in two different types of environments: real world environments and virtual environments. Transformation within the two movements enables the people to orient themselves in all kinds of environments.

In real world environments, people learn the environment by experiencing it directly with physical transformations. The exploratory behavior is guided by an internalized set of rules (Zacharias, in press). Learning is related to information derived from two principal sources that are body motion and orientation, and movement through the environment (Zacharias, in press). The cognitive system of individuals updates the locations and orientations of objects in the environment as they move (Wraga, Creem-Regehr and Proffitt, 2004). Motion through a real world environment is active, self-directed and updating of orientation in the environment is sensed by proprioceptive feedback and vision (Hegarty et al., 2006).

In virtual environments (VEs), people learn the environment by the visualization of movement in a desktop display (Zacharias, in press). Movement through the VE is more passive than the real world environment (Hegarty et al., 2006). Transformations in the VE are sensed via vision. The individual updates the locations and orientations of objects in the environment via optic flow. Orientation and displacement in a desktop virtual environment are controlled either by a mouse, a keyboard or a joystick that changes the individual's viewpoint.

3.2. Transformations according to the Reference Frames

To avoid getting lost or disoriented, the individuals need to update their location and orientation with respect to familiar elements of the environment as they navigate (Mou, McNamara, Valiquette and Rump, 2004b). The representation of the location of objects in memory is important for the human beings. Shelton and McNamara (2001) proposed that "learning and remembering the spatial structure of the surrounding environment involve interpreting the layout in terms of a spatial reference system" (cited in Mou, Zhang, McNamara, 2004a, p. 172). The location of an object needs to be specified or described with respect to a frame of reference (Mou and McNamara, 2002; Mou et al., 2004a). Taylor, Gagne and Eagleson (2000) indicated that the reference frame choice is determined by the relative orientation of the objects in the display. A spatial reference system is:

> "a relational system consisted of located objects, reference objects, and the spatial relations that may obtain between them. The reference objects may be any objects whose positions are known or assumed as a standard and include the observer; landmarks; coordinate axes; the planes defined by the walls, floor, and ceiling of a room" (Shelton and McNamara, 2001, p. 275).

The spatial reference system is divided into two categories: egocentric reference frame (viewer transformation) and intrinsic reference frame (imagined transformation). Transformations in spatial relations can occur from bodily movements of the viewer or imagined perspective changes within the environment (May, 2004).

3.2.1. Viewer Transformation

When individuals physically move to a different viewing position, their views of other aspects of the environment and of the particular object change (Wang and Simons, 1999; see also Figure 3.1). In the viewer transformation, the location and orientation of an object is specified with respect to the observer. It codes "self-to-object spatial relations in body-centered coordinates, using the body axes of front-back, right-left, and up-down" (Mou et al., 2004b, p. 153). During viewer transformation (self-movement), the human cognitive system has to continuously update spatial information with respect to the environment and the body. The environmental reference frame encodes spatial information with respect to the cardinal directions and the egocentric reference frame encodes the object's position and orientation with respect to the coordinate system of the body (Wraga, 2003).

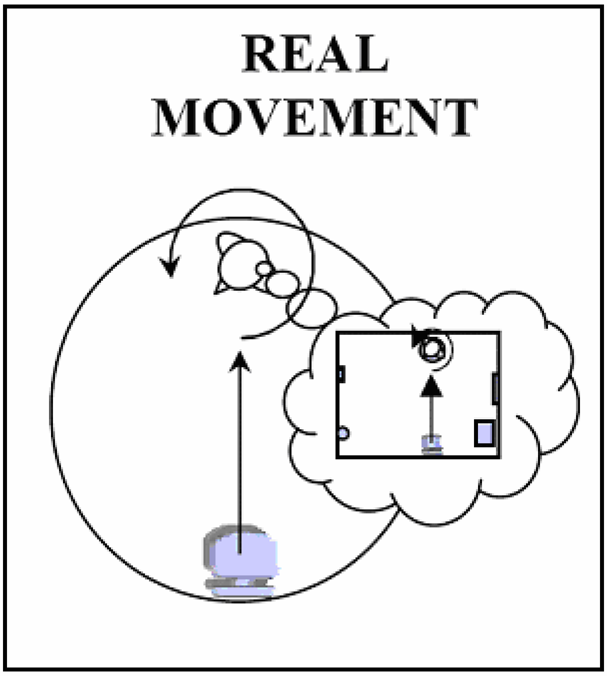

Figure 3.1. Real movement (Le and Landau, n.d.)

The egocentric reference system provides a framework for spatially directed motor activity and it is continuously updated as the individual moves through the environment. Parush and Berman (2004) expressed that the individual has "an ego-centric viewpoint that is within the environment and it visually affords the experience of movement, rotation, and changing the elevation of the view in this environment" (p. 376). Egocentric relations, which are self-to-object directions and distances, are updated easily when individuals change their position or their facing orientation in the environment (Avraamides, 2003). "Knowledge of egocentric directions is especially important for guiding behaviors such as reaching or locomotion that occur in local space" (Montello, Richardson, Hegarty and Provenza, 1999, p. 981).

Viewer transformations are rotations and translations of one's point of view relative to that reference frame (Wraga et al., 2005; Zacks, Ollinger, Sheridan and Tversky, 2002). "In a viewer-centered frame of reference, objects or places are represented in a retinocentric, head-centered, or body-centered coordinate system based on viewer's perspective of the world" (Amorim and Stucchi, 1997, p. 229). Zacks, Mires, Tversky and Hazeltine (2000) indicated that "the relationships between the environmental coordinate frame and those of the objects in the environment remain fixed, while each of their relationships with the observer's egocentric coordinate frames are updated" (p. 329). It is thought that proprioceptive feedback during viewer transformation plays a crucial role and spatial updating during viewer transformation is accomplished through continual alignment of the egocentric reference frame with the observer's current heading (Klatzky et al., 1998; Wraga, 2003).

3.2.2. Imagined Transformation

If individuals want to construe an object at a different orientation without physically moving, they can perform two mental transformations. They can either imagine the object moving to its new orientation (object-relative or intrinsic reference frame) or imagine moving themselves to a new viewpoint corresponding to the new orientation (egocentric or relative reference frame) (see Figure 3.2). As a result, different spatial reference frames can be utilized in multiple ways to transform objects mentally (Wraga, Creem and Proffitt, 1999). May (2004) stated that changes in spatial relations can result from "imagined switches of perspective to other points in the environment" (p. 164). In the imagined transformation, the intrinsic frame remains fixed, but the observer's relative frame of reference changes with respect to the environment (Wraga et al., 1999).

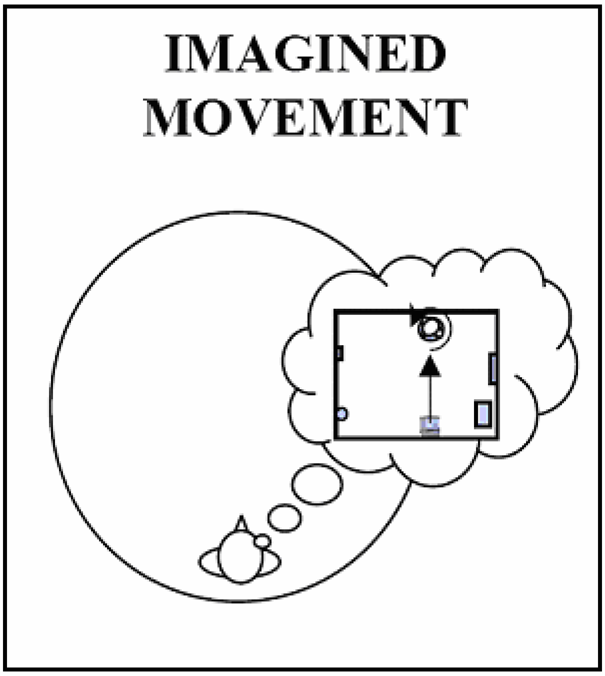

Figure 3.2. Imagined movement (Le and Landau, n.d.)

For imagined transformations, the individuals have to imagine the position or orientation change (Wang and Simons, 1999). Kozhevnikov and Hegarty (2001) indicated that "imagining a different orientation involves movement of the egocentric frame of reference, which encodes object locations with respect to the front/back, left/right, and up/down axes of the observer's body" (p. 745). "The ability to imaginally switch perspectives is often described as a development progress from an exclusively egocentric- or self-centered- mode of spatial processing to a dominantly allocentric- or environment-centered- mode" (May, 2004, p. 164). Imagined transformations are difficult when the observers have to imagine being situated at a position different from the one they are currently situated at (May, 2004). When transforming to a new position, imagined transformation requires additional cognitive transformations of object coordinates because it constitutes "a complex cognitive task including processes of stimulus identification, spatial memory retrieval, transformation of position and object coordinates, as well as response planning and execution" (May, 2004, p. 165).

May (2004) assumed imagined transformations to be an analog process of mental rotation and translation.

3.3. Transformation Types

The navigation behavior of an individual is composed of rotational and translational movements. Depending on the environment and the task, these movements can be combined together or utilized independently (Riecke et al., 2002; Tlauka, in press).

3.3.1. Rotational Movements

Creem-Regehr (2003) stated that "pure rotational movements involve a change in orientation with respect to a reference axis, without linear displacement" (p. 941). Rotational movements, which consist of turning clockwise or anticlockwise, can occur in two forms that are imagined (object-based) and egocentric transformations (Lourenco and Huttenlocher, in press).

Wang and Simons (1999) indicated that imagined and egocentric transformations lead to difference in performance. According to Zacks et al. (2000), imagined transformations and egocentric transformations involve "updating of the relationship between the environmental reference frame, the intrinsic reference frames of the objects in the environment, and the observer's egocentric reference frame" (p. 329). Both transformations have the effect of changing the relation between the viewer and the spatial layout, but they do not implement the same process for determining location (Lourenco and Huttenlocher, in press). Lourenco and Huttenlocher (in press) expressed that these processes may be influenced by task-related factors, such as the viewers may be questioned about their relation to a single object or to an array of objects. The individual's performance on object location tasks "may depend on whether movements of the viewer or of the spatial layout are involved" (Lourenco and Huttenlocher, in press, p. 3). Differences in performance have been reported in tasks consisting of physical movements of the viewer vs. imagined movements of the viewer (Lourenco and Huttenlocher, in press; Vasilyeva, 2002; Wang and Simons, 1999; Wraga et al., 2004).

3.3.1.1. Imagined Rotations

In the imagined viewer rotations, the intrinsic frame remains fixed, but the observer's relative frame of reference rotates with respect to the environment (see Figure 3.3). Performance on the imagined viewer rotation may be affected by various factors, such as the type of task and direct manipulations of the observer's own egocentric frame (Wraga et al., 1999). Wraga et al. (1999) also indicated that viewer rotations "adhere to the physiological and kinematic constraints of corresponding physical actions rather than constraints of external space. Movements that are awkward to perform take longer to imagine" (p. 258).

In the imagined rotations, individuals can either imagine a rotation of their own viewpoint (imagined viewer rotation) or imagine a rotation of the object itself (imagined object rotation). In the imagined viewer rotation, the intrinsic frame remains fixed and the relative frame moves with respect to the environment since the front-back and right-left axes of the relative frame belong to the observer. However, in the imagined object rotation, the intrinsic frame moves with respect to the environment, whereas the observer's relative frame remains fixed (Wraga et al., 1999; Wraga et al., 2004). Studies have shown that updating during imagined self rotation is faster and more accurate than imagined rotation of the object (Amorim and Stucchi, 1997; Creem, Wraga and Proffitt, 2001; Wraga et al., 1999; Wraga et al., 2004). The locations of objects are easily updated after imagined rotations of the viewer rather than imagined rotations of the object (Wraga et al., 1999).

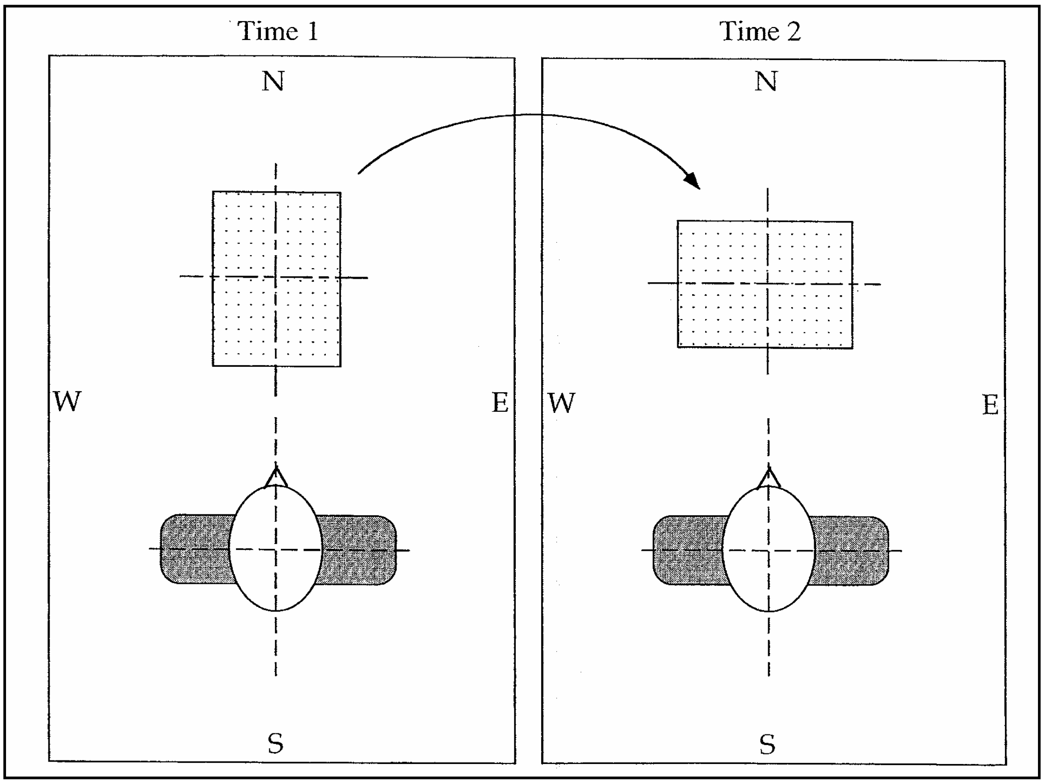

Figure 3.3. Rotation of the object (Wraga et al., 1999, p. 251)

"Imagined viewer rotations are less susceptible to manipulations of the environmental frame than are imagined object rotations" (Wraga et al., 1999, p. 250). Amorim and Stucchi (1997) indicated that their participants performed better in the viewer rotation than the object rotation, which was presented by faster response times and fewer errors. The reason for imagined viewer rotations being less problematic is related to the structure of the relative reference frame (egocentric). But when an observer imagines rotating to a new viewpoint rather than physically rotating, spatial updating is relatively slow, cognitively effortful and more error-prone (Klatzky et al., 1998; Rieser, 1989; Wraga, 2003).

3.3.1.2. Egocentric Rotations

When individuals physically move to a different viewing position, their views of other aspects of the environment and of the particular object change (Wang and Simons, 1999). "Rotation of the viewer around the object predominantly utilizes an egocentric or relative reference frame, which specifies the location of external objects with respect to the major up/down, front/back, and right/left axes of the observer's body" (Wraga et al., 1999, p. 249; see Figure 3.4).

Wraga et al. (2000) asserted that the tasks involving viewer vs. spatial layout (object) movements implement different frames of reference, egocentric vs. object-relative, respectively. Differences in performance have been reported in tasks involving physical movements of the viewer and the spatial layout (Lourenco and Huttenlocher, in press; Vasilyeva, 2002; Wang and Simons, 1999; Wraga et al., 2004).

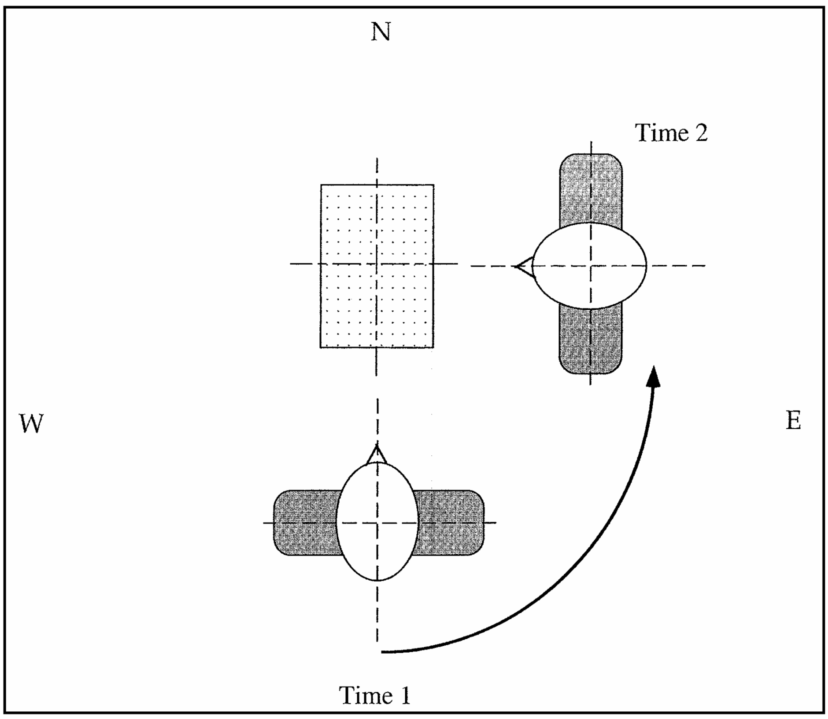

Figure 3.4. Rotation of the observer (Wraga et al., 1999, p. 252)

The egocentric reference frame can be transformed cohesively and effectively, whereas the object-based reference frame, which defines the relations among the objects in an array, is transformed piecemeal. As a result, egocentric transformations are easier than object-based transformations. "The object-relative reference frame is difficult to transform because it lacks internal cohesion" (Lourenco and Huttenlocher, in press, p. 4). Spatial updating was faster, easier and more accurate in the viewer rotation than in the object rotation (Creem et al., 2001; Wraga et al., 2004). Likewise, Wang and Simons (1999) pointed out that recognizing objects was easier after physical movements of the viewer than after real object rotations of the same magnitude.

Presson and Montello (1994) found that spatial updating during egocentric rotations was more efficient than imagined rotations. They suggested that the difficulty in imagined rotations resulted from a conflict between primary and secondary frames of reference. The primary egocentric frame consists of one's front/back, right/left and up/down axes relative to the environment. A secondary egocentric frame of reference (a new front, back, right and left) is constructed when imagining a rotation that conflicts with the primary frame of reference. However, egocentric rotations remove this conflict by aligning the two frames of reference (cited in Creem-Regehr, 2003).

3.3.2. Translational Movements

Creem-Regehr (2003) stated that "translational movements involve a linear displacement without a change in orientation" (p. 941), and denoted that imagined and egocentric translations engaged different mechanisms for spatial updating (see Figure 3.5). Rieser (1989) stated that spatial knowledge could be assessed after translations, but not after rotations (cited in May, 2004).

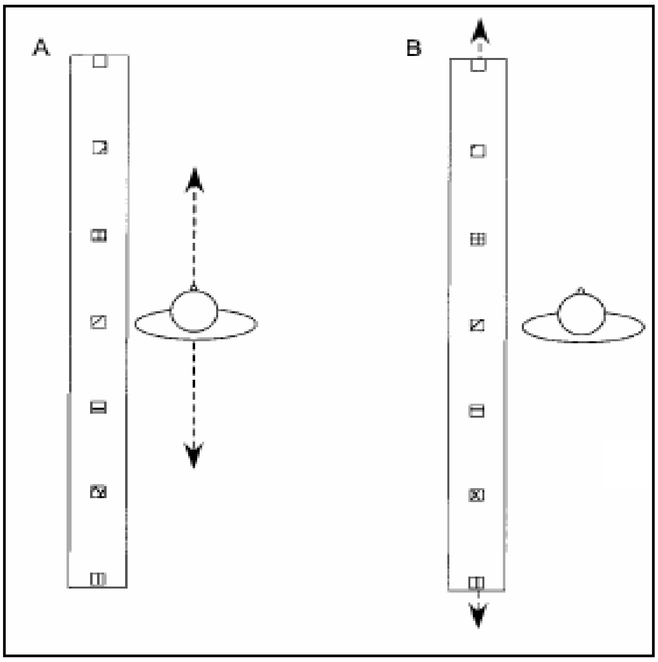

Figure 3.5. (A) Egocentric translations, (B) Imagined translations (Creem-Regehr, 2003, p. 944)

3.3.2.1. Imagined Translations

According to Creem-Regehr (2003), imagined viewer translations were performed more quickly and accurately than imagined object translations. The participants were faster and more accurate at updating the positions of objects after imagined viewer translation than after object translation. The distinction between viewer and imagined translations could result from the people's differential ability to predict the outcome of a moving frame of reference other than the one with which people have extensive experience (Creem-Regehr, 2003). Creem-Regehr (2003) reported that in the object translation task, the participants found it more difficult to imagine and update the objects, which resulted in increased response times and errors.

Easton and Sholl (1995) and Rieser (1989) proposed that imagined translations were easier to perform than imagined rotations (cited in Wraga et al., 1999). Rieser (1989) showed that imagined self translation was easy, fast and performance remained constant (cited in Wang, 2005). When comparing imagined translations with imagined rotations, imagined translations are easier than imagined rotations because translations allow for a direct access to object locations, whereas rotations produce extra costs due to additional processes (May, 2004). May (2004) found that pointing to unseen object locations after imagined egocentric rotations and egocentric translations resulted in larger pointing latencies and errors for imagined rotations than imagined translations.

3.3.2.2. Egocentric Translations

When Creem-Regehr (2003) compared the egocentric translations with the imagined translations, she reported that egocentric translations were performed more quickly than the imagined translations. "In updating tasks involving visual translation without body movement, participants appear to treat the information about a translating display in a similar way as information about translation resulting from the physical movement of one's body" (Creem-Regehr, 2003, p. 947). However, there was no difference in the spatial updating between egocentric translations and imagined translations.

Self-translational movements were found to be more efficient at spatial decisions than self-rotational movements (Creem-Regehr, 2003; Presson and Montello, 1994). Presson and Montello (1994) did not find a difference in spatial updating between egocentric translation and imagined translation. They indicated that with imagined translation, the axes of an individual's primary frame of reference remain parallel to the secondary frame of reference, which is a new front, back, right and left, allowing for ease of pointing to an object from a new viewpoint. Likewise, Rieser (1989) reported that participants were equally good at pointing to objects from an imagined novel location and from their actual location (cited in Avraamides, 2003).

According to the movement types with respect to the transformations, a case study was conducted based on egocentric- rotations and translations via optic flow in a desktop virtual environment. In order to assess the spatial updating performance of the two movements a pointing task was utilized.

4. THE EXPERIMENT

4.1. Aim of the Study

Architectural design is a problem solving activity that requires imagining spatial changes. Transformations allow imagining an object in different orientations. Movements in a space require one to make inferences about spatial relationships after certain transformations. This study examines the differences between rotational and translational movements based on an egocentric frame of reference during navigation in a virtual environment. Previous studies have compared physical rotational and translational movements either in a real environment or the integration of the user with a keyboard, mouse or head mounted display (HMD) in a VE. However, this study compares rotational and translational movements only via optic flow in a desktop VE. The way the participants perceived and learned the VE with one of the movement types is studied in this research. The research issues consist of the movement types and their relation with gender, computer abilities and spatial updating.

4.1.1. Research Questions

1. Is there a significant difference between visual rotational and translational movements with respect to the correctly answered question types?

   a) That are aligned with the viewer

   b) That are misaligned with the viewer

2. Is there a significant difference between the correctly answered questions on objects aligned and misaligned with the viewers in a movement type?

   a) In rotational movement

   b) In translational movement

3. Is there a significant relationship between gender and the correctly answered questions on objects aligned or misaligned with the viewer in a movement type?

a) In rotational movement

b) In translational movement

4. Is there a significant relationship between the preferred drawing medium and the correctly answered questions on objects aligned or misaligned with the viewer in a movement type?

a) In rotational movement

b) In translational movement

4.1.2. Hypotheses

1. There is a significant difference between the rotational and the translational movements. The rotational movement leads to be more accurate in the pointing task than the translational movement. Rotational movement is more efficient in learning a VE.

2. There is a significant difference between the correctly answered questions on objects aligned and misaligned with the viewers in each movement type (i.e. rotational and translational movements). The responses to the questions on objects aligned with the viewer are more accurate than the questions on objects misaligned with the viewer in each movement type.

3. There is no significant relationship between gender and the movement types in a VE (i.e. both genders within the two movement types will perform equally well in the pointing task).

4. The participants who use the computer medium in their Interior Design jury submissions are more successful in answering the questions on objects aligned and misaligned with the viewers within the rotational and translational movements.

4.2. Participants

The sample group consisted of 2005-2006 academic year 4th year students of the Department of Interior Architecture and Environmental Design at Bilkent University. Eighty 4th year students were chosen randomly from the Interior Design studios. The Interior Design is a studio based compulsory course that every student has to attend each semester during their education. At the beginning of the course, a project that has to be designed and drawn, is given to each student. At the end of the semester, each finished project is submitted and presented in a jury that is graded by the jury members. The students are free to utilize any media, which consist of hand, computer or both, during the design process of the project and for the jury submissions. As 4th year students, they were familiar with computer-based environments, due to the computer-based courses that they took during the second and third years of their education and had sufficient design education background. There were 42 (52.5%) females and 38 (47.5%) males whose age range was from 20 to 38. The mean age was 23.81, the median age was 23.00 and the standard deviation was 2.45.

4.3. Procedure

The study was conducted in two phases. In the first phase, the participants filled a computer usage questionnaire (see Appendix A). The questionnaire consisted of two parts. In the first part, the participants indicated their frequency of computer usage, their reasons for using the computer, the computer courses that they took within and outside the university, the type of media they preferred to use in 2D and 3D drawings separately and for their Interior Design jury submissions, and the program types they utilize in their drawings. In the second part, the participants ranked their abilities and attitudes towards using the computer on a 1 to 5 scale. They indicated their comfort, confidence, intimidation, frustration, skillfulness levels in computer usage and the level they think that the computers are enjoyable and encouraging.

The participants were distributed into three groups according to the media they preferred to use in their Interior Design jury submissions (i.e. hand, computer or both). Each group was evenly distributed among the two movement types (i.e. rotational and translational), considering a similar gender distribution of the participants. The distribution of the participants according to the preferred medium for design submissions in the rotational and translational movement experiment groups are depicted in Table 4.1.

Table 4.1. Preferred media for the design drawings

	Medium			
Movement	Hand	Computer	Both	Total
Rotation	13	10	17	40
Translation	14	10	16	40
Total	27	20	33	80

In the second phase, the evenly distributed participants in each group experienced the desktop VE with one of the viewer-based movement types. The participants were seated at the computer and were tested individually. They were asked to watch the virtual tour of the interior of a public space, which was a restaurant with a bar and a semi-visible kitchen, three times since the tour lasted approximately a minute and learn the locations of the objects in the VE. A restaurant was selected as the experimental environment because it was a public place that had a simple plan in which the objects were distinct in their shapes and colors, but the participants were unfamiliar with the restaurant. The rotational tour consisted of a counterclockwise rotation with the viewer at the center of the space. In both cases, only the viewer's viewpoint changed. At the end of the third trial, the computer was closed and a pointing task was conducted by using the direction circle method.

Waller, Beall and Loomis (2004) indicated that the 'direction circle' method is an effective tool for assessing knowledge of relative directions. In the direction circle method, participants are shown a circle; they have to imagine being at the location indicated at the center of the circle marked as X and facing to the direction of the location indicated at the top of the circumference of the circle marked as Y. The participants draw an arrow from the center of the circle (X) to the target object (Y). This arrow represents the relative direction of the target object (see Figure 4.1). "The first two objects established the imagined vantage point and heading and the third object was the target" (Shelton and McNamara, 2001, p. 282).

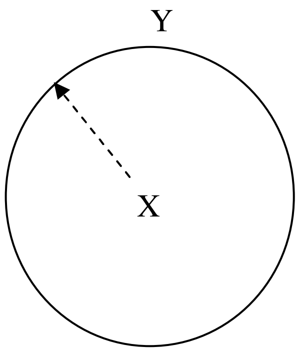

Figure 4.1. Example of the Direction Circle Method for assessing directional knowledge

The pointing task, which utilized the direction circle method, consisted of two parts each with eight questions. In all of the questions, the participants were asked to imagine being at a location, turning to face a different orientation and point to the target object. Participants had to acquaint themselves with the imagined location and environmental surrounding. The questionnaire consisted of seven objects: the white sitting area, the red sitting area, the bar, the toilets, the kitchen, the free-standing red seats and the entrance (see Figure 4.2 and Appendix B).

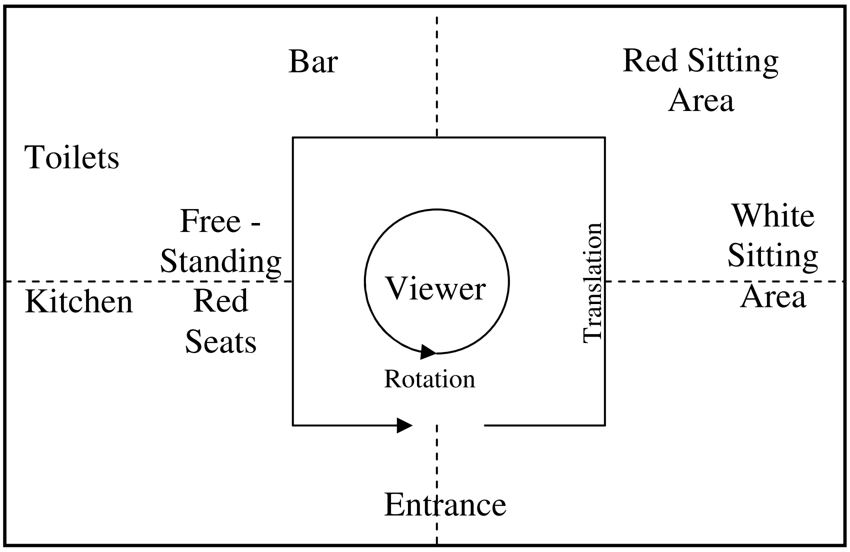

Figure 4.2. Spatial layout of the experimental environment

In the first part, the questions on objects were aligned with the viewer, in other words the objects in the questionnaire were in the order that the participants viewed them. For example, "imagine you are at the white sitting area (X) and facing the red sitting area (Y), point to the bar". The second part consisted of questions on objects misaligned with the viewer; the objects that they saw were in the reverse order of the study view, for example, "imagine you are at the kitchen (X) and facing the toilets (Y), point to the white sitting area (see Appendix C).

The pointing direction (the direction of the target object relative of the heading) was varied systematically with 45° increments. A circle was divided into eight sections: 0°, 45°, 90°, 135°, 180°, 225°, 270° and 315°, and the right answer for each question was at one of these degrees. The pointing task took approximately 5-10 minutes in total. Each correct answer was marked as one point and the maximum point was 8 for both question types. The participants were evaluated according to the number of right answers they gave.

Two separate pilot studies were conducted. The first pilot study was carried out with 12 participants to test the clarity of the computer usage questionnaire. The second pilot study was done with 5 participants to check if they understood the objects in the pointing task after watching the virtual tours.

4.4. Results

Statistical Package for the Social Sciences (SPSS) 12.0 was used to analyze the data. In the analysis of the data, the correlated and uncorrelated t-tests, chi-square test and frequency tables were used.

4.4.1. Related to Computer Usage Questionnaire

In the Computer Usage Questionnaire, the participants indicated that they mostly (95 %) used the computer more than once a week (see Appendix D, Table D1). Their first priority in using the computer was Internet, second was for drawing their Interior Design projects, third was using the Office Programs and lastly for playing games (see Appendix D, Tables D2-D5). The participants mostly took the Computers and Geometry course two years ago (see Appendix D, Table D6), and the Computer Aided Design (CAD) course either two years ago or last year (see Appendix D, Table D7). Thirty-seven and a half percent of the participants took extra lessons consisting mainly of 3D Max, Photoshop and AutoCad (see Appendix D, Tables D8-D11). For the 2D drawings, 51.3% of the participants preferred to use the both media, mainly utilizing the AutoCad program (see Appendix D, Tables D12 and D13). Forty-seven and a half percent of the participants preferred to use the both media for the 3D drawings, mainly utilizing AutoCad and 3D Max together (see Appendix D, Tables D14 and D15). Some of the participants (41.3%) again preferred to use the both media for their Interior Design jury submissions, mainly using AutoCad and 3D Max (see Appendix D, Tables D16 and D17). This preference of using both media is followed by 33.8% in hand medium and 25.0% in computer medium.

The participants indicated their attitudes and abilities towards computer usage in the second part of the Computer Usage Questionnaire. The positive statements were ranked as 4.04, whereas the negative statements were 2.36 (see Figure 4.3).

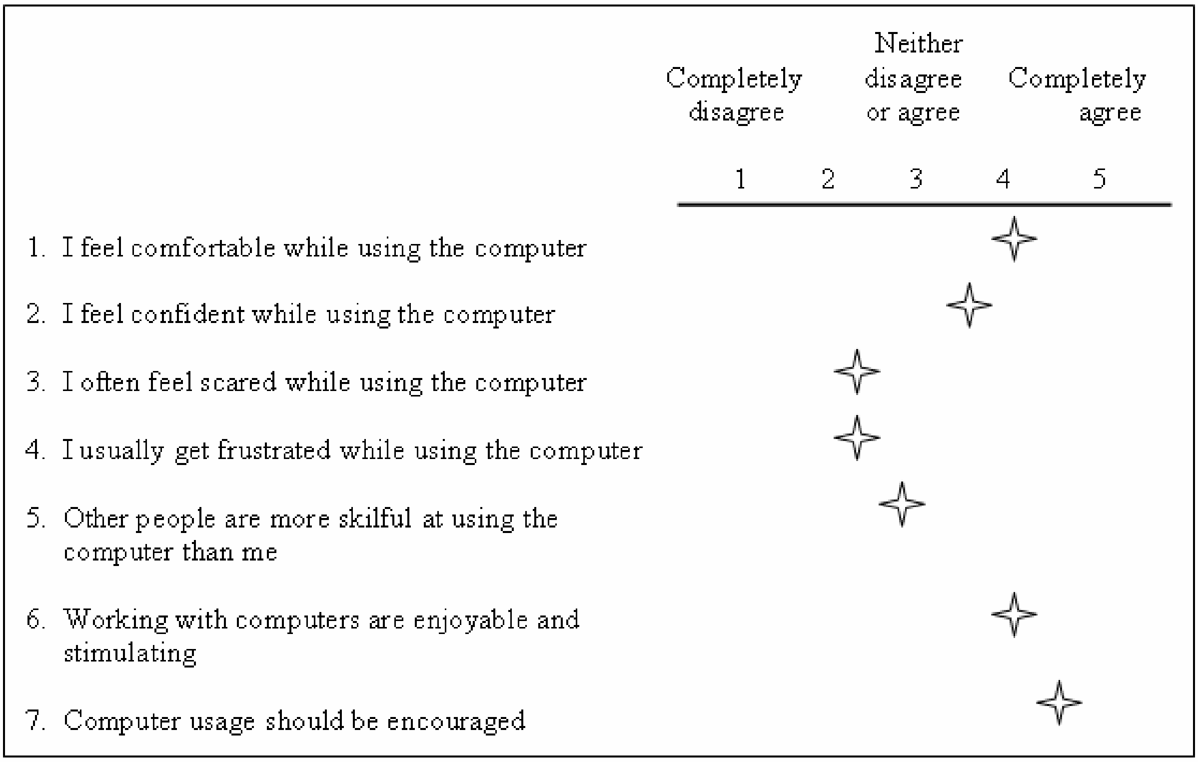

Figure 4.3. Attitudes and abilities towards computer usage

4.4.2. Related to Visual Rotational and Translational Movements

In order to test whether rotational or translational movements were efficient in the VE with respect to the correctly answered questions on objects aligned and misaligned with the viewers, an independent sample t-test and a bivariate correlation test were conducted. The mean of the correctly answered questions on objects aligned with the viewer in the translational movement (M = 4.80, SD = 1.52) was significantly higher than that of the rotational movement (M = 4.05, SD = 1.26) (see Appendix D, Table D18). According to the questions on objects aligned with the viewer, there was a significant difference in the rotational and translational movements (t = 2.40, df = 78, two-tailed p = 0.019; see Appendix D, Table D19). With respect to the correlation test, there was a low negative significant relationship between the translational and rotational movements in the correctly answered questions on objects aligned with the viewer (r = -0.26, df = 78, p<0.019; see Appendix D, Table D20).

According to the questions on objects misaligned with the viewer, there was no significant difference with respect to the rotational and translational movements (M = 3.30, SD = 1.07 and M = 3.58, SD = 1.71; respectively and t = 0.86, df = 78, two-tailed p = 0.390; see Appendix D, Tables D19 and D21). As a result, participants performed better in the translational movement.

4.4.3. Related to Objects Aligned and Misaligned with the Viewers

The questions on objects aligned and misaligned with the viewers were assessed within each movement type by using a correlated t-test. In the rotational movement, the two means differed significantly (t = 3, df = 39, two-tailed p<0.005; see Appendix D, Table D22) and there was no correlation between the correctly answered questions on objects aligned and misaligned with the viewers (see Appendix D, Table D23). The mean of the correctly answered questions on objects aligned with the viewer were at 4 ($M = 4.05$, $SD = 1.26$) and that were misaligned with the viewer at 3 ($M = 3.30$, $SD = 1.07$; see Appendix D, Table D24).

For the translational movement, there was a significant difference between the correctly answered questions on objects aligned and misaligned with the viewers ($t = 5.66$, $df = 39$, two-tailed $p<0.001$; see Appendix D, Table D25). The mean of the correctly answered questions on objects aligned with the viewer were at 5 ($M = 4.80$, $SD = 1.52$) and that were misaligned with the viewer at 4 ($M = 3.58$, $SD = 1.71$; see Appendix D, Table D26). The correlation test showed that there was a positive medium relationship ($r = 0.65$, $df = 38$, $p<0.001$; see Appendix D, Table D27) between the correctly answered questions on objects aligned and misaligned with the viewers.

4.4.4. Related to Gender Differences in each Movement Type

The gender differences were examined between the correctly answered questions on objects aligned and misaligned with the viewers in each movement type. The mean scores of the correctly answered questions on objects aligned and misaligned with the viewers were calculated in each movement type (see Appendix D, Tables D28 and D29). In the rotational movement, the mean of the correctly answered questions on the objects aligned with the viewer was 4.05 and 3.30 for the questions on objects misaligned with the viewer. In the translational movement, the mean of the correctly answered questions on objects aligned with the viewer was 4.80 and 3.58 for the questions on objects misaligned with the viewer. Then, the participants were grouped into two categories according to the mean score as below and above the mean.

In the rotational movement, the mean score for the correctly answered questions on objects aligned with the viewer was rounded off to 4. There were 10 female and 8 male participants below the mean, and 11 female and 11 male participants above the mean (see Appendix D, Table D30). The mean score for the correctly answered questions on objects misaligned with the viewer was rounded off to 3. There were 6 female and 5 male participants below the mean, and 15 female and 14 male participants above the mean (see Appendix D, Table D32).

Chi-square analysis was used to find out if the success of the correctly answered questions on objects aligned and misaligned with the viewers were independent of gender in rotational movements. According to the Chi-square test, there was no significant relationship between gender and the correctly answered questions on objects aligned and misaligned with the viewers ($\chi^2 = 0.12$, df = 1, p = 0.73 and $\chi^2 = 0.025$, df = 1, p = 0.87; respectively) in the rotational movement (see Appendix D, Tables D31 and D33).

In the translational movement, the mean score for the questions on objects aligned with the viewer was rounded off to 5. There were 10 female and 7 male participants below the mean, and 11 female and 12 male participants above the mean. For the questions on objects misaligned with the viewer, the mean score was rounded off to 4. There were 13 female and 9 male participants below the mean, and 8 female and 10 male participants above the mean (see Appendix D, Tables D34 and D36).

The Chi-square analysis indicated that there was no significant relationship between gender and the correctly answered questions on objects aligned and misaligned with the viewers ($\chi^2 = 0.47$, df = 1, p = 0.49 and $\chi^2 = 0.85$, df = 1, p = 0.36; respectively) in the translational movement (see Appendix D, Tables D35 and D37). Therefore, it can be concluded that gender is independent from the correctly answered questions on objects aligned and misaligned viewer within the rotational and translational movements.

According to the independent t-tests, there were no significant differences in gender with respect to the correctly answered questions on objects aligned and misaligned with the viewers in rotational movements (t = -0.76, df = 38, two-tailed p = 0.45 and t = 0.21, df = 38, two-tailed p = 0.84; respectively) and in translational movements (t = -1.00, df = 38, two-tailed p = 0.33 and t = -0.75, df = 38, two-tailed p = 0.46; respectively) (see Appendix D, Tables D39 and D41).

4.4.5. Related to Interior Design Medium in each Movement Type

The mean (M) and standard deviation (SD) values for the correctly answered questions on objects aligned and misaligned with the viewers in each movement type are depicted in Table 4.2. The participants who preferred computer as a medium had the highest means at each category in each movement type.

Table 4.2. Group Statistics for Viewer Groups and Medium

		Medium					
		Hand		Computer		Both	
Movement	Viewer	M	SD	M	SD	M	SD
Rotation	Aligned	3.69	1.18	4.50	1.08	4.06	1.39
	Misaligned	3.08	1.12	4.20	0.79	2.94	0.90
Translation	Aligned	4.36	1.39	6.60	0.70	4.06	1.06
	Misaligned	3.57	1.16	5.70	0.95	2.25	1.00

To determine if there was a significant relationship between the preferred drawing medium and the correctly answered questions on objects aligned and misaligned with the viewers, with respect to the rotational and translational movements, chi-square analysis tests were conducted. The participants were grouped into categories according to the mean score as below and above mean. In the rotational movement, the mean score for the correctly answered questions on objects aligned with the viewer was 4 and that were misaligned with the viewer was 3. In the translational movement, the mean score for the correctly answered questions on objects aligned with the viewer was 5 and that were misaligned with the viewer was 4.

In the rotational movement, there was a significant relationship between the preferred medium and the correctly answered questions on objects aligned with the viewer ($\chi^2 = 8.06$, df = 2, p = 0.018; see Appendix D, Table D43). Participants who used the computer medium answered more questions correctly that were above the mean. However, there was no significant relationship between the preferred medium and the correctly answered questions on objects misaligned with the viewer ($\chi^2 = 5.10$, df = 2, p = 0.078; see Appendix D, Table D45).

In the translational movement, there were significant relationships between the preferred medium and the correctly answered questions on objects aligned and misaligned with the viewers ($\chi^2 = 9.86$, df = 2, p = 0.007 and $\chi^2 = 19.08$, df = 2, p = 0.001; respectively) (see Appendix D, Tables D47 and D49). In both question types (i.e. aligned and misaligned), the computer medium users answered more questions correctly that were above the mean.

The uncorrelated analysis of variance (ANOVA) test was conducted to find if the number of correctly answered questions on objects in the three media have different means. In the rotational movement, there was a significant difference between the three media only for the questions on objects misaligned with the viewer ($F_{2,37} = 6.05$, $p = 0.005$; see Appendix D, Tables D53). In the translational movement, there was a significant difference between the three media in both question types ($F_{2,36} = 17.43$, $p = 0.001$ and $F_{2,37} = 33.44$, $p = 0.001$; respectively) (see Appendix D, Tables D55 and D57).

Furthermore, correlated t-test analysis was conducted with each medium in order to see if there was a difference in answering the questions on objects aligned and misaligned with the viewers. In the hand medium, according to the paired-sample t-test, there was no significant difference between the questions on objects aligned and misaligned with the viewers within the rotational movement ($t = 1.34$, $df = 12$, two-tailed $p = 0.206$; see Appendix D, Table D59). However, there was a significant difference between the questions on objects aligned and misaligned with the viewers within the translational movement ($t = 2.24$, $df = 13$, two-tailed $p = 0.043$; see Appendix D, Table D62).

In the computer medium, there was no significant difference between the question types within the rotational movement ($t = 0.58$, $df = 9$, two-tailed $p = 0.58$; see Appendix D, Table D65). However, there was a significant difference between the question types within the translational movement ($t = 3.86$, $df = 9$, two-tailed $p = 0.004$; see Appendix D, Table D68).

In the both media, there was a significant difference between the question types within the rotational movement (t = 3.08, df = 16, two-tailed p = 0.007; see Appendix D, Table D71) and the translational movement (t = 4.65, df = 15, two-tailed p = 0.001; see Appendix D, Table D74).

4.5. Discussion

Riecke et al. (2002) demonstrated that purely visual path integration was sufficient for basic navigation tasks like rotations and translations. According to the correctly answered questions within the rotational and translational movements, the translational movement was more efficient in the virtual navigation. Participants were able to accurately update rotations from optic flow, but with reduced accuracy when compared to translation. It was hypothesized that rotational movement would be efficient in a virtual environment with respect to Tlauka (in press), who stated that "rotations (without translations) are commonly used in small-scale environments, i.e. spaces of low complexity that can be learned relatively quickly" (p. 2). The translational movement was seen to be less error-prone than the rotational movement because the participants were able to visualize themselves in the VE. The results are in line with Creem-Regehr's (2003) study in which rotations are more difficult to process than translations. Klatzky et al. (1998) proposed that the difficulty in spatial updating during rotational movements is due to the lack of proprioceptive cues that assist self rotation.

The questions on objects aligned with the viewer were correctly answered more than the questions on objects misaligned with the viewer. This indicated that spatial updating of the virtual environment was orientation-specific – the orientation in which it was learned, and the layout of the virtual environment was mentally represented in terms of orientation-specific reference system as indicated by Shelton and McNamara (2001). Hutcheson and Allen (2005) stated that “if a participant is tested in the same orientation in which they learned the path, they should not have high latencies and errors in pointing” (p. 69). Likewise, Richardson et al. (1999) reported that the judgments of relative direction were more accurate when the orientation or the imagined heading was aligned with the original viewpoint seen at the beginning of the exploration (Mou et al., 2004b; Shelton and McNamara, 2001). In agreement with the previous studies, questions on objects aligned with the study proved to be more accurate.

There was no relationship between gender and the movement types in the virtual environment. Contrary to the previous studies (Saucier et al., 2003; Tlauka et al., 2005) that found gender differences in the ability to acquire spatial information and a male superiority in judgment of relative directions (Cubukcu and Nasar, 2005; Devlin and Bernstein, 1995; Lawton and Morrin, 1999; O’Laughlin and Brubaker, 1998), both genders within the two movement types performed equally well in the pointing task. Even though computers are seen as a male domain and as a boys toy (Quaiser-Pohl et al., 2006), the present study revealed no gender differences. The reason for this indifference might be due to the similar computer experiences of the genders. Both genders were familiar with the computer since they used it more than once a week. Also, they had the same educational background and they were familiar with computer-based environments due to the compulsory computer-based courses that they took during the second and third years of their education.

The participants who used the computer medium in their Interior Design jury submissions were proven to be more successful in answering the questions on objects aligned and misaligned with the viewers within the translational movements and only the questions on objects misaligned with the viewer in the rotational movement. The computer users were more accurate because they drew their 2D and 3D drawings with the computer. Using the computer, particularly for doing the 3D drawings enabled the users to utilize the virtual tour property of the computer software programs. As a result, users of these programs were familiar with a virtual tour and they were able to visualize themselves within the virtual environment. However, participants who used both media might not prefer to use the computer for their 3D drawings, but draw with their hands and use the computer for their 2D drawings. Because of this possibility they may not be familiar with the software programs and they might not have enough experience of using the computer for their 3D drawings.

5. CONCLUSION

According to the findings of the research, navigation in the form of translational movement via optic flow in a desktop virtual environment was found to be more beneficial and accurate than rotational movement in spatial updating of the virtual environment. The learning style of the spatial layout of the VE had an affect on the question types. The questions on objects aligned with the viewer were correctly answered more than the questions on objects misaligned with the viewer. It can be stated that spatial updating of the VE was orientation-specific. There was no gender difference between the male and female participants. Both genders performed equally well in the pointing task. The drawing media was effective in answering the questions on objects aligned and misaligned with the viewers within the translational movement and only the questions on objects misaligned with the viewer in the rotational movement. Participants who used the computer medium performed better than the hand and both media in the pointing task.

VE technology offers the opportunity of controlling and manipulating the characteristics of a real world environment. Spatial knowledge acquired from the VEs can be effectively transferred to real world environments. With the VEs, designers and planners are able to assess and improve their designs and understand the environmental requirements that can ease the wayfinding difficulties for people with different characteristics.

This study suggests that computer usage in architectural design drawings is the most effective medium in the spatial updating process in a VE. Computer users are able to utilize the virtual tour properties of the computer software programs and visualize the environment without difficulty. This study can help interior architecture students in the presentations of their architectural design drawings when using the computer. The presentation of the designed environment is effectively learned and visualized during a translational movement rather than a rotational movement.

For further studies, navigation in different environments that can be complex based on the movement types and the drawing media can be compared. The effects of color and texture within the environments can be researched. The relationship between the angular disparity effect and the response times can be investigated with respect to the movement types and the drawing media.

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APPENDIX A

This survey is a part of a research conducted in the department of IAED. It does not have any grade value related to the design studio or any other coursework.

Computer Usage Questionnaire

Name:

A. Please answer the following questions:

1. Female ☐ Male ☐

2. Age:

3. How often do you use the computer?
Less than once in a week ☐ Once in a week ☐ More than once a week ☐

4. Rank the following reasons for using the computer according to the degree of usage?
(1 = mostly used, 4 = least used)
Drawing ☐ Office Programs ☐
Playing games ☐ Others (specify) ☐ ……………
Internet ☐

5. When did you take the required computer courses?
Computers & Geometry: This year ☐ Last year☐ Two years ago☐

CAD: This year ☐ Last year☐ Two years ago☐

6a. Did you take any extra computer lessons in the university years?
Yes ☐ No ☐

6b. If yes, which software programs did you use?

7a. Which media do you prefer to use in 2D drawings?
Hand ☐ Computer☐ Both ☐

7b. If computer is used in 2D drawings, which program do you mostly prefer to use?
(If necessary, rank your choices according to the degree of usage).
AutoCad ☐ 3D Max ☐ Photoshop☐ Others (specify) ☐…………

8a. Which media do you prefer to use in 3D drawings?
Hand ☐ Computer☐ Both ☐

8b. If computer is used in 3D drawings, which program do you mostly prefer to use?
(If necessary, rank your choices according to the degree of usage).
AutoCad ☐ 3D Max ☐ Photoshop☐ Others (specify) ☐…………

9a. For your Interior Design jury submissions which media do you mostly prefer?
Hand ☐ Computer ☐ Both ☐

9b. If computer is used, which program do you mostly prefer for your Interior Design jury submissions? (If necessary, rank your choices according to the degree of usage).
AutoCad ☐ 3D Max ☐ Photoshop ☐ Others (specify) ☐…………

B. Please rate the following questions:

	Completely disagree		Neither disagree or agree		Completely agree
1. I feel comfortable while using the computer	1	2	3	4	5
2. I feel confident while using the computer	1	2	3	4	5
3. I often feel scared while using the computer	1	2	3	4	5
4. I usually get frustrated while using the computer	1	2	3	4	5
5. Other people are more skilful at using the computer than me	1	2	3	4	5
6. Working with computers are enjoyable and stimulating	1	2	3	4	5
7. Computer usage should be encouraged	1	2	3	4	5

Thank You

APPENDIX B

Photographs of the Experimental Environment

Figure B1. A view of the White Sitting Area

Figure B2. A view of the Red Sitting Area

Figure B3. A view of the Bar and the Free-Standing Red Seats

Figure B4. A view of the Entrance of the Toilets

Figure B5. A view of the Kitchen and the Free-Standing Red Seats

Figure B6. A view of the Entrance

APPENDIX C

Name:

Pepper Mill Orientation Form

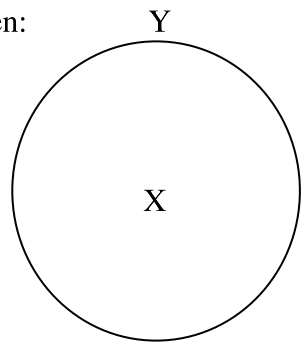
Please answer the following questions by drawing an arrow on the circle as shown in the example.

Part I

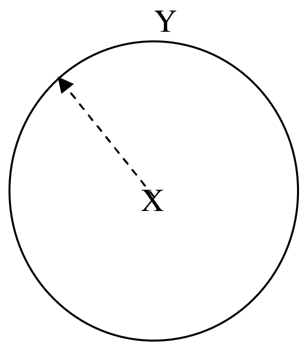
Example:

Imagine you are at the middle of the white sitting area (X) and facing the red sitting area at the corner (Y), point to the bar.

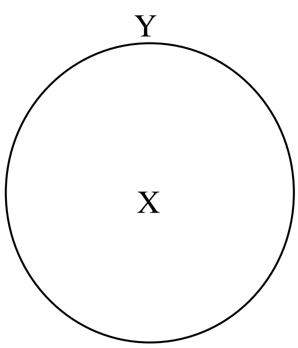
Given:



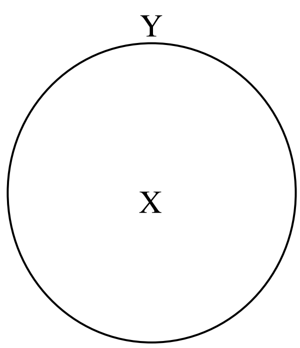
Answer:



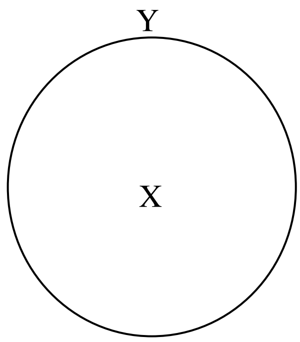
1. Imagine you are at the centre of the space (X) and facing the red sitting area at the corner (Y), point to the middle of the white sitting area.



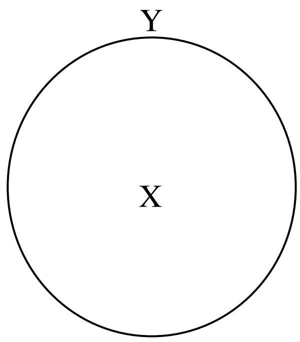
2. Imagine you are at the red sitting area at the corner (X) and facing the middle of the white sitting area (Y), point to the bar.



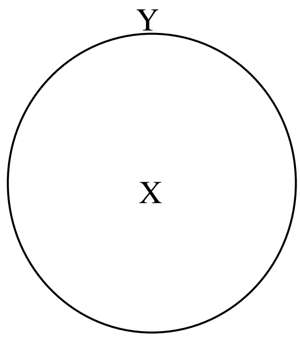
3. Imagine you are at the bar (X) and facing the red sitting area at the corner (Y), point to the kitchen.



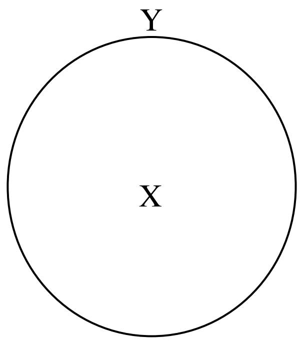
4. Imagine you are at the toilets (X) and facing the kitchen (Y), point to the bar.



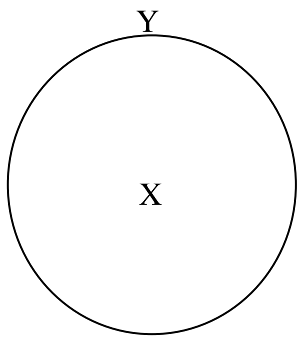
5. Imagine you are at the free-standing red seats (X) and facing the middle of the white sitting area (Y), point to the toilets.



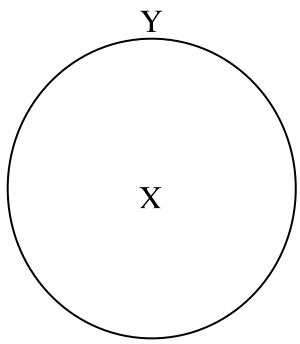
6. Imagine you are at the kitchen (X) and facing the free-standing red seats (Y), point to the toilets.



7. Imagine you are at the entrance (X) and facing the bar (Y), point to the kitchen.

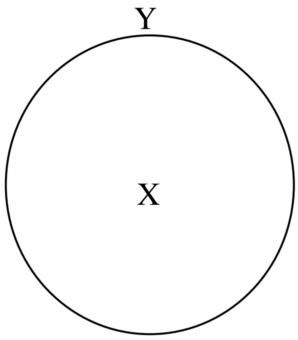


8. Imagine you are at the middle of the white sitting area (X) and facing towards the centre of the space (Y), point to the free-standing red seats.

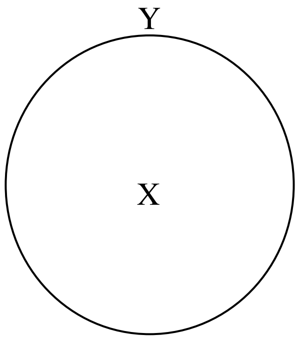


Part II

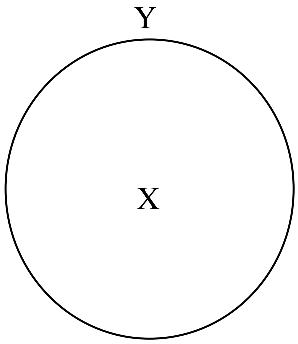
1. Imagine you are at the middle of the white sitting area (X) and facing the entrance (Y), point to the toilets.



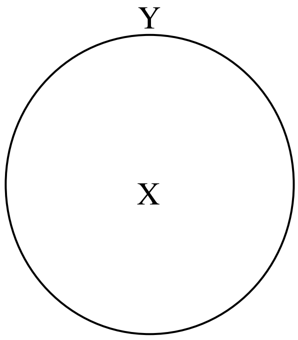
2. Imagine you are at the entrance (X) and facing the kitchen (Y), point to the middle of the white sitting area.



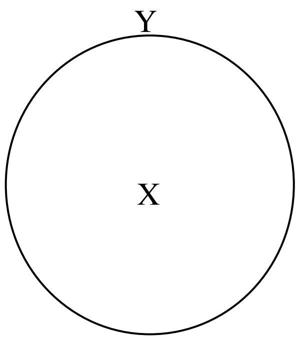
3. Imagine you are at the kitchen (X) and facing the toilets (Y), point to the entrance.



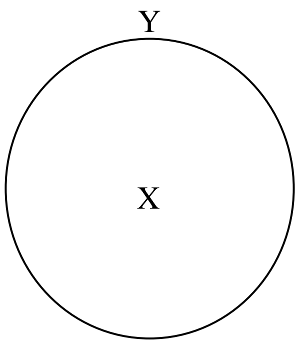
4. Imagine you are at the free-standing red seats (X) and facing the middle of the white sitting area (Y), point to the kitchen.



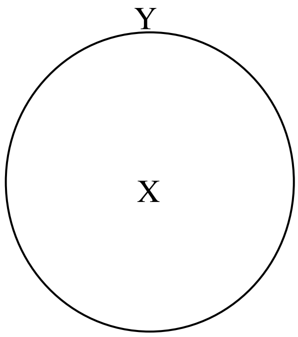
5. Imagine you are at the toilets (X) and facing the kitchen (Y), point to the red sitting area at the corner.



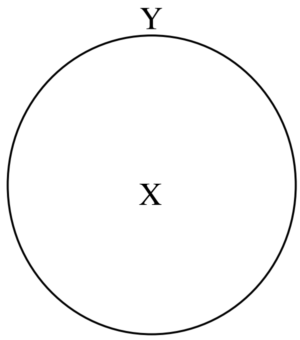
6. Imagine you are at the bar (X) and facing the toilets (Y), point to the free-standing red seats.



7. Imagine you are at the red sitting area at the corner (X) and facing the kitchen (Y), point to the entrance.



8. Imagine you are at the centre of the space (X) and facing the free-standing red seats (Y), point to the kitchen.



APPENDIX D

Table D1. Frequency of Computer Usage

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than once a week	3	3,8	3,8	3,8
	Once in a week	1	1,3	1,3	5,0
	More than once a wee	76	95,0	95,0	100,0
	Total	80	100,0	100,0	

Table D2. 1st Priority in Computer Usage

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Drawing	22	27,5	27,5	27,5
	Playing Games	3	3,8	3,8	31,3
	Internet	54	67,5	67,5	98,8
	Office Programs	1	1,3	1,3	100,0
	Total	80	100,0	100,0	

Table D3. 2nd Priority in Computer Usage

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Drawing	31	38,8	38,8	38,8
	Playing Games	16	20,0	20,0	58,8
	Internet	11	13,8	13,8	72,5
	Office Programs	19	23,8	23,8	96,3
	Film/Music	3	3,8	3,8	100,0
	Total	80	100,0	100,0	

Table D4. 3rd Priority in Computer Usage

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Drawing	20	25,0	26,3	26,3
	Playing Games	12	15,0	15,8	42,1
	Internet	9	11,3	11,8	53,9
	Office Programs	35	43,8	46,1	100,0
	Total	76	95,0	100,0	
Missing	System	4	5,0		
Total		80	100,0		

Table D5. 4th Priority in Computer Usage

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Drawing	6	7,5	9,1	9,1
	Playing Games	36	45,0	54,5	63,6
	Internet	6	7,5	9,1	72,7
	Office Programs	18	22,5	27,3	100,0
	Total	66	82,5	100,0	
Missing	System	14	17,5		
Total		80	100,0		

Table D6. Year for taking the Computers and Geometry Course

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Last year	9	11,3	11,3	11,3
	Two years ago	69	86,3	86,3	97,5
	More than two years	2	2,5	2,5	100,0
	Total	80	100,0	100,0	

Table D7. Year for taking the Computer Aided Design (CAD) Course

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	This year	8	10,0	10,4	10,4
	Last year	34	42,5	44,2	54,5
	Two years ago	34	42,5	44,2	98,7
	More than two years	1	1,3	1,3	100,0
	Total	77	96,3	100,0	
Missing	System	3	3,8		
Total		80	100,0		

Table D8. Taking Extra Lessons in the University Years

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	30	37,5	37,5	37,5
	No	50	62,5	62,5	100,0
	Total	80	100,0	100,0	

Table D9. 1st Priority in taking Software Programs in the University Years

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	AutoCad	6	7,5	20,0	20,0
	3D Max	18	22,5	60,0	80,0
	Photoshop	5	6,3	16,7	96,7
	Adobe Writer	1	1,3	3,3	100,0
	Total	30	37,5	100,0	
Missing	System	50	62,5		
Total		80	100,0		

Table D10. 2nd Priority in taking Software Programs in the University Years

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3D Max	2	2,5	11,1	11,1
	Photoshop	10	12,5	55,6	66,7
	Adobe Premiere	2	2,5	11,1	77,8
	Rhino	1	1,3	5,6	83,3
	Office Programs	1	1,3	5,6	88,9
	Arcon	2	2,5	11,1	100,0
	Total	18	22,5	100,0	
Missing	System	62	77,5		
Total		80	100,0		

Table D11. 3rd Priority in taking Software Programs in the University Years

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Photoshop	2	2,5	25,0	25,0
	Adobe Premiere	3	3,8	37,5	62,5
	Rhino	2	2,5	25,0	87,5
	Office Programs	1	1,3	12,5	100,0
	Total	8	10,0	100,0	
Missing	System	72	90,0		
Total		80	100,0		

Table D12. Media Preferences for 2D Drawings

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Hand	18	22,5	22,5	22,5
	Computer	21	26,3	26,3	48,8
	Both	41	51,3	51,3	100,0
	Total	80	100,0	100,0	

Table D13. Program Preferences for 2D Drawings

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	AutoCad	38	47,5	61,3	61,3
	Rhino	3	3,8	4,8	66,1
	AutoCad & 3D Max	3	3,8	4,8	71,0
	AutoCad & 3DMax & Photoshop	8	10,0	12,9	83,9
	AutoCad & Photoshop	7	8,8	11,3	95,2
	AutoCad & Rhino	1	1,3	1,6	96,8
	AutoCad & Photoshop & Architectural Desktop	1	1,3	1,6	98,4
	AutoCad & 3D Max & Rhino	1	1,3	1,6	100,0
	Total	62	77,5	100,0	
Missing	System	18	22,5		
Total		80	100,0		

Table D14. Media Preferences for 3D Drawings

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Hand	28	35,0	35,0	35,0
	Computer	14	17,5	17,5	52,5
	Both	38	47,5	47,5	100,0
	Total	80	100,0	100,0	

Table D15. Program Preferences for 3D Drawings

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	AutoCad	17	21,3	32,7	32,7
	3D Max	1	1,3	1,9	34,6
	Rhino	3	3,8	5,8	40,4
	Cinema 4D	9	11,3	17,3	57,7
	AutoCad & 3D Max	15	18,8	28,8	86,5
	AutoCad & 3DMax & Photoshop	4	5,0	7,7	94,2
	AutoCad & Rhino	1	1,3	1,9	96,2
	AutoCad & Architectura Desktop	1	1,3	1,9	98,1
	AutoCad & 3D Max & Rhino	1	1,3	1,9	100,0
	Total	52	65,0	100,0	
Missing	System	28	35,0		
Total		80	100,0		

Table D16. Media Preferences for Interior Design Jury Submissions

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Hand	27	33,8	33,8	33,8
	Computer	20	25,0	25,0	58,8
	Both	33	41,3	41,3	100,0
	Total	80	100,0	100,0	

Table D17. Program Preferences for Interior Design Jury Submissions

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	AutoCad	20	25,0	37,7	37,7
	Rhino	3	3,8	5,7	43,4
	AutoCad & 3D Max	12	15,0	22,6	66,0
	AutoCad & 3DMax & Photoshop	13	16,3	24,5	90,6
	AutoCad & Photoshop	2	2,5	3,8	94,3
	AutoCad & Photoshop & Rhino	1	1,3	1,9	96,2
	AutoCad & Architectura Desktop	2	2,5	3,8	100,0
	Total	53	66,3	100,0	
Missing	System	27	33,8		
Total		80	100,0		

Table D18. Group Statistics of the Movement Types

	Movement	N	Mean	Std. Deviation	Std. Error Mean
Aligned	Translational	40	4,80	1,522	,241
	Rotational	40	4,05	1,260	,199
Misaligned	Translational	40	3,58	1,708	,270
	Rotational	40	3,30	1,067	,169
Total	Translational	40	8,38	2,932	,464
	Rotational	40	7,35	1,718	,272

Table D19. Independent Samples Test for the Movement Types

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Aligned	Equal variances assumed	2,370	,128	2,400	78	,019	,750	,312	,128	1,372
	Equal variances not assumed			2,400	75,361	,019	,750	,312	,128	1,372
Misaligned	Equal variances assumed	10,124	,002	,864	78	,390	,275	,318	-,359	,909
	Equal variances not assumed			,864	65,416	,391	,275	,318	-,361	,911
Total	Equal variances assumed	14,981	,000	1,907	78	,060	1,025	,537	-,045	2,095
	Equal variances not assumed			1,907	62,949	,061	1,025	,537	-,049	2,099

Table D20. Correlation Test for Translational Movement

		Movement	Aligned
Movement	Pearson Correlation	1	-,262*
	Sig. (2-tailed)	.	,019
	N	80	80
Aligned	Pearson Correlation	-,262*	1
	Sig. (2-tailed)	,019	.
	N	80	80

*. Correlation is significant at the 0.05 level (2-tailed).

Table D21. Correlation Test for Rotational Movement

		Movement	Misaligned
Movement	Pearson Correlation	1	-,097
	Sig. (2-tailed)	.	,390
	N	80	80
Misaligned	Pearson Correlation	-,097	1
	Sig. (2-tailed)	,390	.
	N	80	80

Table D22. Paired Sample Test for Rotational Movement

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Aligned-Misaligned	,750	1,581	,250	,244	1,256	3,000	39	,005

Table D23. Paired Sample Correlation Test for Rotational Movement

		N	Correlation	Sig.
Pair 1	Aligned & Misaligned	40	,084	,607

Table D24. Paired Sample Statistics of Rotational Movement

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Aligned	4,05	40	1,260	,199
	Misaligned	3,30	40	1,067	,169

Table D25. Paired Sample Test for Translational Movement

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Aligned-Misaligne	1,225	1,368	,216	,788	1,662	5,664	39	,000

Table D26. Group Statistics of Translational Movement

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Aligned	4,80	40	1,522	,241
	Misaligned	3,58	40	1,708	,270

Table D27. Paired Sample Correlation Test for Translational Movement

		N	Correlation	Sig.
Pair 1	Aligned & Misaligned	40	,647	,000

Table D28. Statistic Table for Rotational Movement

		Aligned	Misaligned
N	Valid	40	40
	Missing	0	0
Mean		4,05	3,30
Median		4,00	3,50
Mode		3	4
Std. Deviation		1,260	1,067

Table D29. Statistic Table for Translational Movement

		Aligned	Misaligned
N	Valid	40	40
	Missing	0	0
Mean		4,80	3,58
Median		5,00	3,00
Mode		3	3
Std. Deviation		1,522	1,708

Table D30. Crosstabulation for Aligned Rotational Movement

		Rotational Aligned		
		Below Mean	Above Mean	Total
Gender	Female	10	11	21
	Male	8	11	19
Total		18	22	40

Table D31. Chi-Square Test for Aligned Rotational Movement

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	,123[b]	1	,726		
Continuity Correction[a]	,001	1	,975		
Likelihood Ratio	,123	1	,726		
Fisher's Exact Test				,761	,488
Linear-by-Linear Association	,119	1	,730		
N of Valid Cases	40				

a. Computed only for a 2x2 table

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 8,55.

Table D32. Crosstabulation for Misaligned Rotational Movement

		Rotational Misaligned		Total
		Below Mean	Above Mean	
Gender	Female	6	15	21
	Male	5	14	19
Total		11	29	40

Table D33. Chi-Square Test for Misaligned Rotational Movement

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	,025[b]	1	,873		
Continuity Correction[a]	,000	1	1,000		
Likelihood Ratio	,025	1	,873		
Fisher's Exact Test				1,000	,578
Linear-by-Linear Association	,025	1	,875		
N of Valid Cases	40				

a. Computed only for a 2x2 table

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 5,23.

Table D34. Crosstabulation for Aligned Translational Movement

		Translational Aligned		Total
		Below Mean	Above Mean	
Gender	Female	10	11	21
	Male	7	12	19
Total		17	23	40

Table D35. Chi-Square Test for Aligned Translational Movement

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	,474[b]	1	,491		
Continuity Correction[a]	,136	1	,713		
Likelihood Ratio	,476	1	,490		
Fisher's Exact Test				,538	,357
Linear-by-Linear Association	,462	1	,497		
N of Valid Cases	40				

a. Computed only for a 2x2 table

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 8,07.

Table D36. Crosstabulation for Misaligned Translational Movement

		Translational Misaligned		
		Below Mean	Above Mean	Total
Gender	Female	13	8	21
	Male	9	10	19
Total		22	18	40

Table D37. Chi-Square Test for Misaligned Translational Movement

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	,852[b]	1	,356		
Continuity Correction[a]	,366	1	,545		
Likelihood Ratio	,854	1	,355		
Fisher's Exact Test				,525	,273
Linear-by-Linear Association	,830	1	,362		
N of Valid Cases	40				

a. Computed only for a 2x2 table

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 8,55.

Table D38. Group Statistics of Gender in Rotational Movement

	Gender	N	Mean	Std. Deviation	Std. Error Mean
Aligned	Female	21	3,90	1,091	,238
	Male	19	4,21	1,437	,330
Misaligned	Female	21	3,33	1,238	,270
	Male	19	3,26	,872	,200

Table D39. Independent Sample Test for Rotational Movement

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Aligned	Equal variances assumed	2,234	,143	-,762	38	,451	-,306	,401	-1,118	,506
	Equal variances not assumed			-,752	33,481	,457	-,306	,407	-1,133	,521
Misaligned	Equal variances assumed	1,945	,171	,205	38	,839	,070	,342	-,622	,763
	Equal variances not assumed			,209	35,935	,836	,070	,336	-,612	,752

Table D40. Group Statistics of Gender in Translational Movement

	Gender	N	Mean	Std. Deviation	Std. Error Mean
Aligned	Female	21	4,57	1,469	,321
	Male	19	5,05	1,580	,363
Misaligned	Female	21	3,38	1,564	,341
	Male	19	3,79	1,873	,430

Table D41. Independent Sample Test for Translational Movement

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Aligned	Equal variances assumed	,094	,761	-,998	38	,325	-,481	,482	-1,457	,495
	Equal variances not assumed			-,994	36,865	,326	-,481	,484	-1,462	,499
Misaligned	Equal variances assumed	,278	,601	-,751	38	,457	-,409	,544	-1,509	,692
	Equal variances not assumed			-,744	35,253	,462	-,409	,549	-1,522	,705

Table D42. Crosstabulation for Design Media and Objects Aligned with the Viewer in Rotational Movement

		Rotational Aligned		
		Below Mean	Above Mean	Total
DesignMedia	Hand	9	4	13
	Computer	1	9	10
	Both	8	9	17
Total		18	22	40

Table D43. Chi-Square Test for Objects Aligned with the Viewer in Rotational Movement

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	8,063[a]	2	,018
Likelihood Ratio	8,993	2	,011
Linear-by-Linear Association	1,043	1	,307
N of Valid Cases	40		

a. 1 cells (16,7%) have expected count less than 5. The minimum expected count is 4,50.

Table D44. Crosstabulation for Design Media and Objects Misaligned with the Viewer in Rotational Movement

		Rotational Misaligned		
		Below Mean	Above Mean	Total
DesignMedia	Hand	5	8	13
	Computer	0	10	10
	Both	6	11	17
Total		11	29	40

Table D45. Chi-Square Test for Objects Misaligned with the Viewer in Rotational Movement

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	5,095[a]	2	,078
Likelihood Ratio	7,656	2	,022
Linear-by-Linear Association	,002	1	,968
N of Valid Cases	40		

a. 3 cells (50,0%) have expected count less than 5. The minimum expected count is 2,75.

Table D46. Crosstabulation for Design Media and Objects Aligned with the Viewer in Translational Movement

		Translational Aligned		
		Below Mean	Above Mean	Total
DesignMedia	Hand	8	6	14
	Computer	0	10	10
	Both	9	7	16
Total		17	23	40

Table D47. Chi-Square Test for Objects Aligned with the Viewer in Translational Movement

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	9,858[a]	2	,007
Likelihood Ratio	13,497	2	,001
Linear-by-Linear Association	,003	1	,956
N of Valid Cases	40		

a. 1 cells (16,7%) have expected count less than 5. The minimum expected count is 4,25.

Table D48. Crosstabulation for Design Media and Objects Misaligned with the Viewer in Translational Movement

		Translational Misaligned		Total
		Below Mean	Above Mean	
DesignMedia	Hand	8	6	14
	Computer	0	10	10
	Both	14	2	16
Total		22	18	40

Table D49. Chi-Square Test for Objects Misaligned with the Viewer in Translational Movement

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	19,076[a]	2	,000
Likelihood Ratio	23,873	2	,000
Linear-by-Linear Association	3,163	1	,075
N of Valid Cases	40		

a. 1 cells (16,7%) have expected count less than 5. The minimum expected count is 4,50.

Table D50. Descriptive Statistics for Drawing Medium in Aligned Rotational Movement

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Hand	13	3,69	1,182	,328	2,98	4,41	3	6
Computer	10	4,50	1,080	,342	3,73	5,27	3	7
Both	17	4,06	1,391	,337	3,34	4,77	2	7
Total	40	4,05	1,260	,199	3,65	4,45	2	7

Table D51. ANOVA Test for Drawing Medium in Aligned Rotational Movement

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3,690	2	1,845	1,173	,321
Within Groups	58,210	37	1,573		
Total	61,900	39			

Table D52. Descriptive Statistics for Drawing Medium in Misaligned Rotational Movement

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Hand	13	3,08	1,115	,309	2,40	3,75	1	4
Computer	10	4,20	,789	,249	3,64	4,76	3	6
Both	17	2,94	,899	,218	2,48	3,40	2	5
Total	40	3,30	1,067	,169	2,96	3,64	1	6

Table D53. ANOVA Test for Drawing Medium in Misaligned Rotational Movement

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	10,936	2	5,468	6,046	,005
Within Groups	33,464	37	,904		
Total	44,400	39			

Table D54. Descriptive Statistics for Drawing Medium in Aligned Translational Movement

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Hand	14	4,36	1,393	,372	3,55	5,16	3	7
Computer	10	6,60	,699	,221	6,10	7,10	6	8
Both	16	4,06	1,063	,266	3,50	4,63	3	6
Total	40	4,80	1,522	,241	4,31	5,29	3	8

Table D55. ANOVA Test for Drawing Medium in Aligned Translational Movement

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	43,848	2	21,924	17,426	,000
Within Groups	46,552	37	1,258		
Total	90,400	39			

Table D56. Descriptive Statistics for Drawing Medium in Misaligned Translational Movement

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Hand	14	3,57	1,158	,309	2,90	4,24	2	6
Computer	10	5,70	,949	,300	5,02	6,38	5	7
Both	16	2,25	1,000	,250	1,72	2,78	1	4
Total	40	3,58	1,708	,270	3,03	4,12	1	7

Table D57. ANOVA Test for Drawing Medium in Misaligned Translational Movement

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	73,246	2	36,623	33,435	,000
Within Groups	40,529	37	1,095		
Total	113,775	39			

Table D58. Paired Sample Statistics for Hand Medium in Rotational Movement According to Viewer Groups

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Aligned	3,69	13	1,182	,328
	Misaligned	3,08	13	1,115	,309

Table D59. Paired Sample Test for Hand Medium in Rotational Movement According to Viewer Groups

		Paired Differences Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Aligned-Misaligned	,615	1,660	,460	-,388	1,619	1,336	12	,206

Table D60. Paired Sample Correlation for Hand Medium in Rotational Movement According to Viewer Groups

		N	Correlation	Sig.
Pair 1	Aligned & Misaligned	13	-,044	,887

Table D61. Paired Sample Statistics for Hand Medium in Translational Movement According to Viewer Groups

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Aligned	4,36	14	1,393	,372
	Misaligned	3,57	14	1,158	,309

Table D62. Paired Sample Test for Hand Medium in Translational Movement According to Viewer Groups

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1 Aligned-Misaligned	,786	1,311	,350	,029	1,543	2,242	13	,043

Table D63. Paired Sample Correlation for Hand Medium in Translational Movement According to Viewer Groups

	N	Correlation	Sig.
Pair 1 Aligned & Misaligned	14	,484	,080

Table D64. Paired Sample Statistics for Computer Medium in Rotational Movement According to Viewer Groups

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Aligned	4,50	10	1,080	,342
	Misaligned	4,20	10	,789	,249

Table D65. Paired Sample Test for Computer Medium in Rotational Movement According to Viewer Groups

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1 Aligned-Misaligned	,300	1,636	,517	-,871	1,471	,580	9	,576

Table D66. Paired Sample Correlation for Computer Medium in Rotational Movement According to Viewer Groups

	N	Correlation	Sig.
Pair 1 Aligned & Misaligned	10	-,522	,122

Table D67. Paired Sample Statistics for Computer Medium in Translational Movement According to Viewer Groups

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Aligned	6,60	10	,699	,221
	Misaligned	5,70	10	,949	,300

Table D68. Paired Sample Test for Computer Medium in Translational Movement According to Viewer Groups

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Aligned-Misaligned	,900	,738	,233	,372	1,428	3,857	9	,004

Table D69. Paired Sample Correlation for Computer Medium in Translational Movement According to Viewer Groups

		N	Correlation	Sig.
Pair 1	Aligned & Misaligned	10	,637	,048

Table D70. Paired Sample Statistics for Both Media in Rotational Movement According to Viewer Groups

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Aligned	4,06	17	1,391	,337
	Misaligned	2,94	17	,899	,218

Table D71. Paired Sample Test for Both Media in Rotational Movement According to Viewer Groups

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Aligned-Misaligned	1,118	1,495	,363	,349	1,886	3,082	16	,007

Table D72. Paired Sample Correlation for Both Media in Rotational Movement According to Viewer Groups

		N	Correlation	Sig.
Pair 1	Aligned & Misaligned	17	,203	,435

Table D73. Paired Sample Statistics for Both Media in Translational Movement According to Viewer Groups

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Aligned	4,06	16	1,063	,266
	Misaligned	2,25	16	1,000	,250

Table D74. Paired Sample Test for Both Media in Translational Movement According to Viewer Groups

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Aligned-Misaligned	1,813	1,559	,390	,982	2,643	4,652	15	,000

Table D75. Paired Sample Correlation for Both Media in Translational Movement According to Viewer Groups

		N	Correlation	Sig.
Pair 1	Aligned & Misaligned	16	-,141	,602