THE INFLUENCE OF FIELD DEPENDENCE / INDEPENDENCE, GENDER, AND EXPERIENCE ON NAVIGATIONAL BEHAVIOR AND CONFIGURATIONAL KNOWLEDGE ACQUISITION IN A DESKTOP VIRTUAL REALITY ENVIRONMENT

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CHAPTER I

Over the past few years there has been an increased focus on using technology to assist in the education of learners. Recent advances in virtual reality (VR) technology have opened the door to the development of new non-traditional instructional methods, which have shown promise in preparing people for the work place. Ausburn, Ausburn, Cooper, Kroutter, and Sammons (2007) argued that:

> Virtual reality technologies offer transformational changes in the way people learn and work. They have been the subject of a considerable body of research, and now are generally accepted as having strong potential for education and professional training. Medical education, engineering education, numerous types of technical education, and general K-12 education have all seen successful applications of virtual reality. In addition, many occupations and industries are now turning to virtual reality to provide effective and cost efficient ways of doing business. (p. 7)

Virtual Reality and Virtual Environments

Davies (2004) defined VR as a "…technique of using computers to model real (or imaginary) environments in a three dimensional space that allows people to interact with the environment in a fashion that is both natural and intuitive" (p. 3). Ausburn and Ausburn (2004) provided a broader definition of VR to better illustrate the complexities of this technology. They stated:

> VR can range from simple environments presented on a desktop computer to fully immersive multi-sensory environments experienced through complex headgear and body suits. In all its manifestations, VR is basically a way of simulating or

> replicating an environment and giving the user a sense of ‘being there’, taking control, and personally interacting with that environment with his/her own body (p. 34).

VR researchers (e.g. Ausburn, Marten, Dotterer, & Calhoun, 2009; Di Blas & Poggi, 2007) have contended that it is “presence,” or ability to give learners a feeling they have actually *been* somewhere rather than just seeing it, that gives the technology its power. Despite the growing body of literature supporting the success and acceptance of virtual reality technology, relatively little is currently known about the individual differences of users as they maneuver and learn within virtual environments. Waller (2000) asserted, “Computer-simulated environments hold promise for training people about real-world spaces. However little research has examined the role of user characteristics and abilities in determining the effectiveness of these virtual environments (VE’s) for training spatial knowledge” (p. 3). The interaction between user characteristics and VR was also touched upon by Ausburn and Ausburn’s (2003) argument that past research tended to “focus on comparing instructional treatments and designs as main effects rather than on examining interactions between treatments and specific types of learners” (p. 2.).

Before adopting new technologies, we need to understand that a given technology may not fit all learners. Virtual reality technology has benefits and drawbacks. Research (e.g. Ausburn, Fries, Mahan, et al. 2009; Darken & Peterson, 2002; Dotterer, Calhoun, Kroutter, Jennings, Burkett, & Braithwaite, 2008; Hunt & Waller, 1999; Kennedy, Kennedy, & Bartlett, 2002; Waller, Hunt, & Knapp, 1998a, 1998b) has indicated that while some learners do very well in acquiring knowledge from VR technology, others have experienced physiological and psychological difficulties such as dizziness, nausea and disorientation (lost in hyperspace) as they maneuvered within the virtual environment (VE). Why does VR benefit some and hinder others? The answer may lie in the individual differences of learners themselves. A better understanding of these individual differences is necessary in order to design and develop VR curricula that reduce or eliminate the ill effects of the technology for some while enhancing positive outcomes for all learners.

Learner Differences and Virtual Reality

A large body of research has shown that people orient, navigate, and find their way in both the real world and virtual worlds differently. Several learner variables arise from the research literature that may underpin individual differences in orienting and navigating. One possible explanation for some of the individual differences found in wayfinding may lie in the cognitive styles of the individuals. Cognitive style can be defined as the "psychological dimensions that represent consistencies in an individual's manner of acquiring and processing information" (Ausburn & Ausburn, 1978, pp. 337-338). Cognitive style is concerned with "individual differences in the processes of cognition, which generally include all processes by which knowledge is acquired: perception, thought, memory, imagery in the 'picture-in-the-mind' sense defined by Fleming (1977), and problem solving" (as cited in Ausburn & Ausburn, 1978, p. 338). In particular, the cognitive style dimension of field dependence/field independence may shed light on how and why individuals tend to navigate virtual environments differently.

Field dependence/field independence are terms used by Witkin (1967) to denote the contrasting differences between field dependent (global) and field independent (articulated) cognitive styles. Witkin (1967) found "In a field-dependent mode of perception, the organization of the field as a whole dominates perception of its parts; an item within a field is experienced as fused with organized ground. In a field-independent mode of perception, the person is able to perceive items as discrete from the organized field of which they are a part" (p. 236). The cognitive constructs of field dependence/field independence maybe important to differential performance in virtual environments because they have a direct bearing on the perception, acquisition and processing of environmental information, which enables individuals in orienting themselves within the environment.

Gender differences are another learner variable that may help explain variations in navigational behaviors and learning outcomes. Literature has noted several differences between men and women as they interact with virtual reality technologies (Ausburn, Martens, Washington, Steele, & Washburn, 2009; Hunt & Waller, 1999; Jansen-Osmann, Schmid, & Heil, 2007; Lawton, 1994; Waller, Hunt, & Knapp, 1998a, 1998b). Another factor which may influence learning in virtual environments is prior domain knowledge or prior experience. Lawless, Schrader, and Mayall (2007) asserted: "One of the most prominent variables both in terms of number of studies, as well as findings indicating a significant influence on navigation, is prior knowledge" (p. 292). Similarly, Lawless and Kulikowich (1998) concluded that "One consistent finding supported by the literature examining traditional texts is that the more domain knowledge one has, the better one can employ strategies to competently process related text" (p. 53). Earlier studies by Alexander and Judy (1988) and Garner, Alexander, Gillingham, Kulikowich, and Brown (1991) provided findings that supported this conclusion. The literature has shown that individuals who possess a greater and heightened awareness of their domain knowledge prior to reading or engaging in multimedia activities learn more (Eveland & Dunwoody, 1998; Lawless & Kulikowich, 1998; Lawless, Schrader, & Mayall, 2007).

Knowing how and why people orient and navigate differently in virtual environments and what learner variables contribute to these performance differences could be beneficial in both design and development of future desktop virtual reality educational curricula. This possibility provided the impetus for the study reported here.

Virtual Reality and Crime Scene Investigation

The researcher has been a police officer for 32 years and a law enforcement educator for much of that time. As an educator, the researcher saw the potential of desktop VR as an instructional delivery technology. Desktop VR appeared ideal for simulating actual crime scene investigation. It was developed as an economical instructional tool to provide police officers an opportunity to develop the knowledge, skills and abilities needed to become proficient crime scene investigators.

The virtual crime scene would allow individuals to explore and investigate the crime scene without destroying evidence, contaminating the scene, or exposing themselves to potential hazards found at real crime scenes. A virtual crime scene would also allow officers to visit as often as they want to practice various techniques such as search patterns, identification of evidentiary items, crime scene sketching, and evidence collection procedures.

In the real world, many officers rarely get an opportunity to practice crime scene investigation prior to actual exposure to a real scene. Due to the legal nature of the crime scene, access is limited only to the detectives and first officers on the scene. Additional benefits of a virtual crime scene are that a large number of officers can explore it at the same time and no search warrant is needed to return to the virtual scene of the crime. The desktop VR crime scene was chosen as the central component for this study because of its real world application to law enforcement workforce development.

Theoretical and Conceptual Framework

This research is part of a five-year on-going line of inquiry regarding the efficacy of desktop virtual reality technology in education being conducted by the Occupational Education Studies program at Oklahoma State University. This study examined differences in navigation and survey knowledge acquisition in a virtual environment of individuals possessing field independent and field dependent cognitive styles. The theoretical framework for this research was drawn from orienting, navigating and wayfinding theory; cognitive style theory; and research findings related to other learner variables.

Orienting, Navigating, and Wayfinding Theory and Survey Knowledge

Orienting is the ability to acquire one's bearings in an environment. Blade and Paddgett (2002) defined orientation as a sense of up and down or north, south, east, and west. Orientation allows individuals to determine where they are, which direction they came from, and where they want to go. Hunt and Waller (1999) described orientation as "Our awareness of the space around us, including the location of important objects in the environment. Orientation in space is crucial for finding one's way (or wayfinding) from one location to another" (p. 4). Hunt and Waller explained that "A person is oriented when he knows his own location relative to other important objects in the environment, and can locate those objects relative to each other" (p.4).

Wayfinding refers to an individual's cognitive and behavioral abilities to follow a path from a current location to a target destination (Krafft, 2001). Jul (2001) explained wayfinding as "the task of determining how to get to where one wants to go and directing the activities needed to get there" (p. 1). It involves the process of using spatial and environmental information to navigate through an environment. In other words, wayfinding is the ability of an individual to find his or her way to a destination.

Darken and Peterson (2002) clearly linked wayfinding to cognitive processing, claiming that "Wayfinding is the cognitive element of navigation. It involves the tactical and strategic parts that guide movement…Wayfinding and motion are intimately tied together in a complex negotiation that is navigation" (p. 494). Darken and Peterson argued, "Navigation is the aggregate task of wayfinding and motion. It inherently must have both the cognitive element (wayfinding) and the motoric element (motion)" (p. 494).

Lynch (1960) stated, "In the process of wayfinding, the strategic link is the environmental image, the generalized mental picture of the exterior physical world that is held by an individual" (p. 4). This also links wayfinding to cognitive or mental processing. Lynch believed urban elements like paths, landmarks and districts should be used to divide an environment into smaller, clearly connected, and more manageable pieces, which could then be directly encoded into a hierarchy of spatial knowledge. He also believed it was important to provide frequent directional cues to assist individuals in orienting themselves in the environment (Darken & Sibert, 1996; Krafft, 2001; Lynch, 1960; Muhlhausen, 2006; Raubal & Egenhofer, 1998; Reiss, 2001).

Darken and Peterson (2002) asserted that “The need to maintain a concept of the space and the relative locations between objects and places is essential to navigation. This is called spatial comprehension, and like verbal comprehension, involves the ability to perceive, understand, remember, and recall for future use” (p. 494). Darken and Peterson also tied wayfinding to cognitive processing with their claim that “An essential part of wayfinding is the development and use of a cognitive map, also referred to as a mental map” (p. 494).

Satalich (1995) contended that wayfinding was only one component of navigational awareness. She defined navigational awareness as “having complete navigational knowledge of an environment” (p. 2). She explained there are two very distinct types of navigational knowledge and each type affords different behaviors. According to Satalich, the first type of navigational knowledge is called *procedural knowledge or route knowledge* and is usually gained by personal exploration of a new area. An individual with procedural knowledge can successfully navigate from one location to another along a known route, but does not recognize alternate routes, such as short-cuts. Satalich’s second type of navigational knowledge is *survey knowledge*, which is attained by multiple explorations of an environment using multiple routes. Survey knowledge also links navigation to cognition, because it allows individuals to create a cognitive or mental map of the environment. Satalich asserted, when individuals acquire both procedural knowledge and primary survey knowledge, they then have complete navigational awareness.

Raubal and Egenhofer (1998) explained the process involved in the development of a cognitive map: “The cognitive map develops from a mental landmark map to a mental route map and should eventually result in a mental survey map. The last stage is closest to a cartographic map, though it still contains inaccuracies and distortions" (p. 3). Raubal and Egenhofer noted that humans construct and develop their cognitive maps by recording of information through their perception, natural language, and inferences. They also believed that complex environmental structures may inhibit development of cognitive maps and lead to representational inaccuracies.

Darken and Sibert (1996), in discussing spatial knowledge, asserted that wayfinding involves the ability of the navigator to conceptualize the space as a whole. In this type of topological or survey knowledge, objects and inter-object locations are encoded in terms of a geocentric, fixed, frame of reference. According to Darken and Sibert, survey knowledge is map-like in nature and can be acquired either directly from the use of a map or by prolonged exposure to navigating an environment directly. Darken and Sibert also noted that survey knowledge obtained from a map tended to be orientation-specific, whereas prolonged exposure to actively navigating an environment was more likely to result in orientation-independent survey knowledge. The more familiar one becomes with an area, the easier it becomes to move from one location to another. Darken and Sibert posited "Survey knowledge is the key to successful wayfinding in any environment" (p. 4). They argued that survey knowledge is significantly different from procedural knowledge, which involves the sequence of actions required to follow a specific route. Darken and Sibert also stated, "The route may make use of landmark knowledge which is static information about the visual details of a specific location" (p. 2).

Darken and Sibert (1996) addressed wayfinding in virtual environments. They contended that people often have problems wayfinding in large virtual worlds because they cannot grasp the overall topological structure of the space. They may wander aimlessly throughout the virtual environment attempting to locate a place, or once they have found a specific location, they may have difficulty returning to it at a later time. According to Darken and Sibert, “Anytime an environment encompasses more space than can be viewed from a single vantage point, these problems will occur” (p. 2). In addition, they found that in large virtual environments adequate directional cues are necessary, otherwise individuals become disoriented which inhibits both wayfinding performance and the acquisition of spatial knowledge.

Darken and Sibert (1996) also discussed disorientation in wayfinding. They found when individuals are not given an adequate source of directional cues; disorientation can inhibit both wayfinding performance and the acquisition of spatial knowledge. Disorientation also appears to inhibit learning in technology-based environments. According to Graff (2003), “The lack of ability to orient oneself within a web-based environment may cause an individual to experience disorientation. The more disoriented the user becomes, the more they must focus on navigation and less on processing the information content, which reduces the amount of learning that can take place” (p. 408).

Cognitive Style Theory

Cognitive style research over the last five decades has revealed that individual differences exist among learners, in manners of information processing. Cognitive styles (also called cognitive controls), or the way we perceive, acquire and process information, vary from person to person. Several cognitive style/control dimensions have been systematically studied over the years including visual/haptic perceptual types (Lowenfeld & Brittain, 1970), field dependence/independence (Faterson & Witkin, 1970; Witkin, 1967; Witkin, Moore, Goodenough, & Cox, 1977; Witkin, Price-Williams, Bertini, Christiansen, Oltman, Ramirez, & Van Meel, 1974), holist-serialist (Pask, 1972; Pask & Scott, 1972), leveling/sharpening cognitive control (Santostefano, 1964; Santostefano, 1978; Santostefano, 1985-1986), flexible/constricted field control (Santostefano & Paley, 1964; Stroop, 1935) and reflective/impulsive cognitive tempo (Kagan, 1965; Kagan, 1976; Kagan & Kogan, 1970; Kagan & Messer, 1975).   Research has found each of these various dimensions of cognitive style/controls are stable over time; develop early during childhood; are related to personality, socialization and cultural behavior variables; are independent from general intellectual ability; and are resistant to training and change (Ausburn & Ausburn, 1978; Ausburn & Brown, 2006).

Riding and Cheema (1991) noted that "The term 'cognitive style,' was used by Allport (1937) and has been described as a person's typical or habitual mode of problem solving, thinking, perceiving and remembering" (p. 194).   Several researchers have contended that "Among the cognitive styles identified to date, the field-dependence-independence dimension has been the most extensively studied and has had the widest application to educational problems (Witkin, Dyk, Faterson, Goodenough, & Karp, 1962/1974; Witkin, Lewis, Hertzman, Machover, Meissner, & Wapner, 1954/1972; Witkin, 1976)" (as cited in Witkin, Moore, Goodenough, & Cox, 1977, p. 1). Because of its wide applicability in learning and its relationship to processing visual information and environments, the field independent/dependent dimension of cognitive style was selected for inclusion as a learner variable in this study of navigation in virtual environments.

Field Dependence and Field Independence are terms originated by Witkin (1967) to denote the contrasting differences between global and articulated cognitive or perceptual styles. Witkin found “In a field-dependent mode of perception, the organization of the field as a whole dominates perception of its parts; an item within a field is experienced as fused with organized ground. In a field-independent mode of perception, the person is able to perceive items as discrete from the organized field of which they are a part” (p. 236).

Witkin, Moore, Goodenough, and Cox (1977) noted several characteristics that differ between individuals with field dependent/independent cognitive styles. In the studies of Witkin and his associates, the field dependent individual’s perception was strongly dominated by the prevailing field. They tended to adhere to the organization of the perceptual field as presented and were likely to use the structure or organization of the provided field. Field dependent individuals were also more in tune with social components and the environment. They were sensitive to social cues and were interested in what others say and do. Field dependent individuals were drawn to people and liked to be with people.

In contrast, field independent individuals perceived items as more or less separate from the surrounding field. They were more likely to overcome the organization of the field or to restructure it when presented with a field having a dominant organization. Field independent individuals were more likely to impose their own structure and organization. They were viewed as more analytical and were interested in the abstract and theoretical. They were more socially independent—less influenced by their peers, teachers or authority figures. They possessed a more impersonal orientation and were not as sensitive to social undercurrents (Witkin, Moore, Goodenough, & Cox, 1977).

Regarding field dependence/independence, Witkin (1967) asserted that:

> Perception may be conceived as articulated, in contrast to global, if the person is able to perceive item as discrete from organized ground when the field is structured (analysis), and to impose structure on a field, and so perceive it as organized, when the field has little inherent organization (structuring). Progress from global to articulated, which comes about with growth, occurs not only in perception, where we are dealing with an immediately present stimulus configuration, but in thinking as well, where symbolic representations are involved. Articulated experience is a sign of developed differentiation in the cognitive sphere. (p. 254)

According to Witkin (1967):

> Extensive research (Witkin, Lewis, Hertzman, Machover, Meissner, and Wapner, 1954; Witkin et al., 1962) has shown that a tendency toward more global or more articulated functioning is a consistent feature of a given individual's manner of dealing with a wide array of perceptual and intellectual tasks. Because it represents the characteristic approach which the person brings to situations with him, we consider more global or more articulated functioning to be an individual's cognitive style. (p. 235)

Navigation and Cognitive Style

Prior wayfinding research to this point has primarily focused on the visual-spatial abilities of individuals in assessing wayfinding and navigation in virtual environments. In this study it was reasoned that the cognitive constructs of field dependence and field independence are relevant to orienting and navigation in a virtual environment because they have a direct bearing on the perception, acquisition and processing of environmental information, which enables individuals in orienting themselves within the environment. Furthermore, the cognitive style characteristics of field dependence and field independence may help to explain differences in navigational behaviors.

The aim of this research was to examine how individual differences in cognitive style influence navigational behaviors and the acquisition of survey/configurational knowledge in a virtual crime scene instructional environment. Wayfinding and cognitive style theory were hypothesized to be important in developing an understanding of how individual characteristics influence learning in virtual reality environments. An individual's cognitive style may be a critical variable in understanding individual differences in navigational behaviors and learning outcomes. This supposition is supported in the research literature. Graff (2003) argued, "Cognitive style is…related to an individual's ability to detect his/her spatial location or orientation in space" (p. 409). Witkin's studies regarding the perception of the upright revealed individual differences existed in spatial orientation abilities (Witkin & Asch, 1948; Witkin, Moore, Goodenough, & Cox, 1977). Thus it was hypothesized that individuals' cognitive style, or how they perceive and process information, may have a bearing to how they orient themselves and navigate within an environment, whether that environment is virtual or real.

In this study, it was proposed that field dependence/independence might provide insight and help to explain why some police officers overlooked crucial items of evidence as they investigated a crime scene. It was reasoned that the field dependent officer may have difficulty identifying and separating a piece of evidence from its surrounding background or field. Conversely, a field independent police officer may be able to immediately distinguish the piece of evidence because he/she can isolate or separate it from the visual background. The perceptual/cognitive characteristics of the field dependent and field independent individual could help explain differences in navigational search behaviors. According to Witkin, Moore, Goodenough, and Cox (1977), field independent individuals are more analytical in their approach. They may exhibit a more detailed and linear navigational style, systematically searching and analyzing specific areas of the environment. In contrast, field dependent individuals tend to be more global or holistic in their approach. They look for the bigger picture or an overview of an environment. Their approach may be more non-linear. In a crime scene environment, they may initially conduct a superficial search or scan of the environment by moving from one location to another in an attempt to understand the different relationships items or rooms have with one another.

Other Learner Variables and Navigational Behavior

In addition to cognitive style, individual differences in gender and prior experience or *domain knowledge* have been found to influence navigational behaviors in virtual environments. Several studies have found significant gender differences exist between men and women regarding several variables related to performance in virtual environments. These variables include: (a) spatial ability and mental rotation as measured by paper-and-pencil tests (Ardito, Costabile, & Lanzilotti, 2006; Lawton, 1994; Waller, Hunt, & Knapp, 1998a); (b) navigational performance (Ausburn, Martens, Washington, et al., 2009; Lawton, 1994; Vila, Beccue, & Anandikar, 2002; Waller, 2000, Waller, Hunt, & Knapp, 1998a); and (c) disorientation (Ausburn, Martens, Washington, et al., 2009; Darken, 1995; Waller, Hunt, & Knapp, 1998a). Gender differences have also been found in affective domain of attitudes toward computers and perceived technology confidence, self-efficacy, frustration, and anxiety (Ausburn, Martens, Washington, et al., 2009; Lawton, 1994; Whitley, 1997). This research evidence led this researcher to include gender as a variable in the present study.

Another important learner variable in virtual environments may be prior domain knowledge. Prior domain knowledge may be defined as any related knowledge an individual brings to a learning situation which may or may not assist in information acquisition or understanding (Chi & Ceci, 1987; Lawless, Schrader, & Mayall, 2007). Several lines of reported research support this proposition. "One consistent finding supported by the literature examining traditional texts is that the more domain knowledge one has, the better one can employ strategies to competently process related text (Alexander & Judy, 1988; Garner, Alexander, Gillingham, Kulikowich, & Brown, 1991)" (as cited in Lawless & Kulikowich, 1998, p. 53).

Chen and Ford (1998) extended this research on prior domain knowledge into the realm of electronic technology. They found that existing knowledge seemed to influence how individuals interacted with a hypermedia learning system and that individuals with higher levels of prior knowledge tended to use more reference links, navigational tools and resources. However, those with little domain knowledge were either not capable of or interested in exploring deeper levels of content. In examining individual differences in hypermedia navigation and learning, Ford and Chen (2000) found greater experience in an area correlated with higher performance in the same or closely related area. Furthermore, they found that prior experience correlated with cognitive style, noting that field independent individuals displayed higher levels of experience (p. 303). Lazonder, Bremans, and Wopereis (2000) argued that "Domain expertise enhances search performance. Those with high domain knowledge tend to take less time completing search tasks and produce a greater number of correct solutions" (p. 576). Echoing this finding, Roy and Chi (2003) asserted that search skills improve with greater domain knowledge. Extension of this line of research led this researcher to include prior domain knowledge as a variable in the present study.

Conceptual Framework

The conceptual framework for this study applies wayfinding theory filtered through the individual cognitive styles of field independence/field dependence, gender, and prior experience or domain knowledge, which is predicted to result in differences in navigational behaviors. These different navigational behaviors and perceptions of the spatial environment are in turn predicted to influence the acquisition and quality of survey knowledge. This conceptual framework is shown in Figure 1.

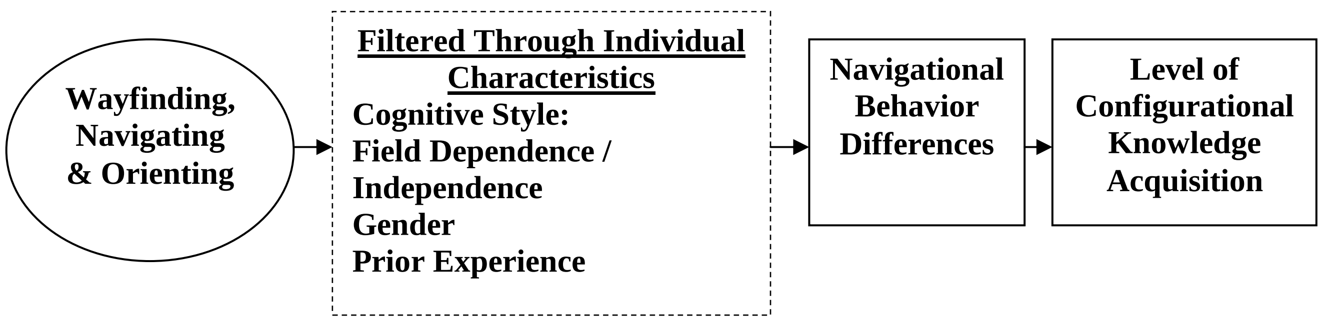

Figure 1. Theoretical/Conceptual framework for this study.

Statement of the Problem

The problem is there is a lack of research specifically addressing the influence of field dependent and field independent cognitive styles, gender, and prior domain knowledge upon navigational behavior and survey knowledge acquisition of individuals in a desktop virtual reality environment. This is problematic because it makes it impossible to predict performance in such a learning environment or to adjust the environment to accommodate differences among learners on these variables. Very little research has been found regarding how an individual's cognitive style, specifically Witkin's field dependence/field independence, interacts with navigational behaviors of individuals in desktop VR environments. Several studies were found in related digital media, which suggest applicability of these variables to navigational issues in virtual environments. Researchers have studied the effects of cognitive style in relation to navigating Internet web pages (Dong & Lee, 2008; Fiaola & MacDorman, 2008), hyper-text navigation (Ford, 2000; Korthauer & Koubek, 1994), web-based instruction (Alomyan, 2004; Governor, 1999; Monereo, Fuentes, & Sanchez, 2000), E-learning systems (Lu, Yu, & Liu, 2003; Rumtshofer & Wöb, 2003), hypermedia links (Ayersman & Minden, 1995; Chen, 2002; Chen & Ford, 1998; Ford & Chen, 2000; Kim & Allen, 2002; Weller, Repman, & Rooze, 1994), and hypermedia lab simulation (Andris, 1996). The present study specifically extended this line of research to examine and explain how individuals with field dependent and field independent cognitive styles as well as differences in gender and prior domain knowledge navigate within a visually complex desktop virtual reality scene. The context for the study was crime scene investigation by police officers on a suburban police force.

Purpose of the Study

The purpose of this study was to describe through quantitative and qualitative empirical techniques the VR navigational behaviors and levels of configurational knowledge acquisition of police officers with differing cognitive styles, gender, and domain knowledge when interacting with a desktop VR crime scene environment. The study focused on gaining understanding of how police officers with different cognitive styles, genders, and domain knowledge orient themselves and navigate within a virtual crime scene environment.

Research Questions

This study addressed several general questions. What is the relationship between learners' cognitive styles and their navigational behavior in a desktop VR environment? Does navigational pattern based on cognitive style affect the acquisition of configurational or survey knowledge? What are the influences of gender and prior knowledge upon navigation and configurational knowledge acquisition?

To gain understanding of how individual learner characteristics may influence VR navigational behavior, the following specific questions guided this research:

The research questions for this study were:

1. Are there general patterns in how police officers navigate in a virtual crime scene?

2. Is there a difference in the way field dependent and field independent police officers navigate the virtual crime scene?

3. Is there a difference in configurational knowledge proficiency between field independent and field dependent officers?

4. Is there a difference in the way individuals with differing prior experience or knowledge navigate a virtual crime scene?

5. Is there a difference in configural knowledge acquisition from a virtual crime scene among individuals with differing experience?

6. Is there a difference in how male and female police officers navigate a virtual crime scene environment?

7. Is there a difference in configurational knowledge acquisition between male and female officers?

8. Is there a difference in the way law enforcement officers interact with the virtual crime scene and a real world crime scene?

Definitions of Key Terms

Conceptual Definitions

Virtual reality (VR). "VR can range from simple environments presented on a desktop computer to fully immersive multi-sensory environments experienced through complex headgear and bodysuits. In all its manifestations, VR is basically a way of simulating or replicating an environment and giving the user a sense of 'being there', taking control, and personally interacting with that environment with his/her own body" (Ausburn & Ausburn, 2004, p. 34).

Virtual environment (VE). "Virtual environments denote a real-time graphical simulation with which the user interacts via some form of analog control, within a spatial frame of reference and with user control of the viewpoint's motion and view direction" (Moshell & Hughes, 2002, p. 893).

Desktop virtual reality. Desktop VR is the newest form of virtual reality and "uses Quick Time, Java, or Flash technology to present high-resolution panoramic imagery on a desktop computer" (Ausburn, Fries, Mahan, et al, 2009, p. 2). Desktop virtual environments are created by taking a series of digital photographs, then uploading them into special VR software that stitches and blends the images into a single panoramic scene that a user can enter and explore interactively using a mouse or joy stick navigational device. Additional panoramic scenes or objects can be linked together using “hot spots” to allow the user to move beyond the initial scene, inspect an item closer or to explore different areas.

Cognitive style. Cognitive style refers to the manner in which individuals acquire and process information. “Cognitive style measures do not indicate the content of the information but simply how the brain perceives and processes the information” (Hansen, 1995, p. 2).

Field dependent/Field independent. Field dependence and field independence are terms used by Witkin (1967) to denote the contrasting bipolar differences between field dependent (global) and field independent (articulated) cognitive styles. “In a field-dependent mode of perception, the organization of the field as a whole dominates perception of its parts; an item within a field is experienced as fused with organized ground. In a field-independent mode of perception, the person is able to perceive items as discrete from the organized field of which they are a part” (Witkin, 1967, p. 236).

Prior domain knowledge. This term refers to one’s pre-existing knowledge and understanding about a particular subject or field of study. It consists of knowledge, skills or abilities that have been obtained through educational processes, training, or prior experiences and stored in one’s knowledge base (Dochy, Segers, & Buehl, 1999; MaKinser, Beghetto, & Plucker, 2002).

Navigation. “Navigation is the aggregate task of wayfinding and motion. It inherently must have both the cognitive element (wayfinding) and the motoric element (motion)" (Darken & Peterson, 2002, p. 494). "Wayfinding is the cognitive element of navigation. It involves the tactical and strategic parts that guide movement…Wayfinding and motion are intimately tied together in a complex negotiation that is navigation" (p. 494).

Orientation. Orienting is the ability to acquire one's bearings in an environment. Orientation as a sense of up and down or north, south, east, and west (Blade & Paddgett, 2002). Orientation allows an individual to determine where they are, which direction they came from and where they want to go.

Configurational or survey knowledge. These interchangeable terms refer to a navigator's ability to conceptualize a space as a whole. Configurational/survey knowledge represents configurational or topological information. In this type of topological knowledge, objects and inter-object locations are encoded in terms of a geocentric, fixed, frame of reference. Survey/configurational knowledge is map like in nature and can be acquired either directly from the use of a map or by prolonged exposure to navigating an environment directly (Darken, 1995; Darken & Sibert, 1996). Survey/configurational knowledge attained by multiple explorations of an environment, using multiple routes, allow individuals to create a cognitive or mental map of the environment (Satalich, 1995). The terms configurational knowledge and survey knowledge are used interchangeably in this study.

Operational Definitions

Field independent. Field independent refers to individuals who can perceive an item or object as separate from its surrounding background. In this study, field independent individuals are those who score high on the *Group Embedded Figures Test*

(GEFT). To be considered field independent in this research, a participant must score between 13 and 18 on the GEFT and been in the highest-scoring 15 subjects of a preliminary pool of 75.

Field dependent. Field dependent refers to individuals who are unable to separate an item or object from its surrounding background or field and perceives items to be a part of or fused with their background. In this study, field dependent individuals are those who score low on the *Group Embedded Figures Test* (GEFT). To be considered field dependent in this research, a participant must have scored between zero and eight on the GEFT and been in the lowest-scoring 15 subjects of a preliminary pool of 75.

Prior knowledge. Prior knowledge is any pre-existing domain-related knowledge an individual possesses which may or may not assist them in a task. Individual differences in age, education level, computer experience, work, and life experiences are some of the factors that can contribute to one's prior knowledge. For this study, prior knowledge was the number of years an individual had worked in law enforcement.

Virtual crime scene environment. The virtual reality crime scene used in this study was developed by this researcher and members of the Oklahoma State University Virtual Reality Research Team. It was a desktop VR that depicted a realistic homicide crime scene with evidentiary items located within five rooms of a house. Hot spots or links embedded within the virtual scene allowed users to move from room to room as if they were there physically. Clickable learning objects were embedded into the scene which provided users with a more detailed examination of evidentiary items and video clips demonstrating evidence collection procedures. The zoom buttons allow viewers to zoom in and out on objects or rooms for closer inspection.

Navigation. Navigation refers to one's ability to move between two points or a series of points to a given destination. In this study, navigation was assessed using frequency counts of each navigational movement. Frequency counts were obtained on the number of times a participant moved left, right, up, down, or zoomed in and zoomed out. The path or direction taken by participants was assessed by the sequence of nodes accessed. Navigational movements were documented by recording on-screen performances with Camtasia software. Additional evidence was collected through observations and comment logs recorded by the researcher.

Configurational/Survey knowledge. The level of survey or configurational knowledge acquired by individual participants was assessed by having them draw a crime scene sketch from memory after they had finished navigating the on-screen desktop virtual crime scene environment. Each crime scene sketch was assessed for accuracy, detail, and completeness by three experts using a five-point Likert-type scale and rubric developed by this researcher.

Limitations of the Study

One limitation of the study is its small sample size. A small purposive sample of officers from a single police department was necessary in this study because of the intensive observations and analysis conducted on each participant. Because this purposive sample was small (n = 30) and limited to a single police department, it is not possible to generalize the study's findings beyond this sample of law enforcement officers. Further research will be necessary to establish generalizability.

A second limitation of the study is that it was limited to a single dimension of cognitive style. Further research to analyze the interactions of other cognitive style dimensions with virtual environments would extend this study's findings.

A final limitation was the narrowness and specificity of the operationalization in this study of pre-existing domain knowledge (e.g. years of prior experience) and attained configurational knowledge (e.g. accuracy and quality of a map drawn from memory). Further research could address other aspects of these variables.

Significance of the Study

This study will add to the body of knowledge regarding how individual characteristics of cognitive style, gender, and prior knowledge may influence navigational behavior and the acquisition of configurational/survey knowledge in a desktop VR environment. At present, virtually nothing is known about how people actually orient, wayfind, and navigate in desktop virtual reality environments, or about how learner differences affect these behaviors. If specific patterns of navigation can be identified as related to individual differences in these variables, this information could be used to inform future instructional design of desktop virtual reality curricula.

A five-year line of research on desktop VR in the Occupational Education program at Oklahoma State University has revealed some interactions of VR and learner variables and has suggested that much needs to be learned about how different individuals actually orient and navigate in on-screen VR learning environments. This knowledge is critical in the development and establishment of guidelines for sound design and implementation of VR. Without such guidelines, desktop VR cannot be maximized as an instructional technology despite its strong potential as a tool for facilitating the types of environmental exploration and mastery that characterize a considerable amount of technical and job-specific education. This study represents an initial step in understanding how learners orient and navigate in a desktop virtual environment, how they acquire configurational knowledge in such an environment, and how individual differences affect this navigation and knowledge acquisition. From a program of research of the type presented by this study, instructional principles and guidelines may eventually emerge that will let desktop virtual reality realize its potential as an instructional technology for technical education and workforce development.

CHAPTER II

Review of Literature

Virtual Reality and Virtual Environments

Virtual reality (VR) technology is not a new phenomenon to education and training. VR has been evolving since the first flight simulator was developed by Edwin Link in 1929. The Link Trainer was created out of the need to teach new pilots how to fly by instruments. The Link Trainer was the predecessor to the more sophisticated flight simulators used today. One of the first attempts to create an immersive virtual environment occurred in 1956 when film maker Morton Heilig developed a mechanical virtual display device he called *Sensorama* (Blade & Padgett, 2002, pp. 1167-1168). "*Sensorama* provided a multisensory experience of riding a motorcycle by combining three-dimensional (3-D) movies seen through a binocular like viewer, stereo sound, wind, and enticing aromas" (Stanney & Zyda, 2002, p. 2). As noted above, *Sensorama* was a mechanical device which predated digital computing technology. The 3D movies gave the user a sense of presence or what it was like to ride a bicycle through Brooklyn or a motorcycle through the countryside. As individuals interacted with *Sensorama* they felt the wind in their hair and could smell the scents one might encounter on such a ride.

The need to develop safe, economical, and effective training devices has evolved from relatively simple mechanical devices, like the Link Trainer and Sensorama, to the more sophisticated computer interfaced training modalities referred to as virtual reality or virtual environments. Davies (2004) defined VR as a "…technique of using computers to model real (or imaginary) environments in a three dimensional space that allows people to interact with the environment in a fashion that is both natural and intuitive" (p. 3). Ausburn and Ausburn (2004) provided a broader definition of VR to better illustrate the complexities of this technology. They stated:

> VR can range from simple environments presented on a desktop computer to fully immersive multi-sensory environments experienced through complex headgear and body suits. In all its manifestations, VR is basically a way of simulating or replicating an environment and giving the user a sense of 'being there', taking control, and personally interacting with that environment with his/her own body. (p. 34)

A basic definition of virtual environments (VEs) was put forth by Moshell and Hughes (2002) who asserted that "Virtual environments denote a real-time graphical simulation with which the user interacts via some form of analog control, within a spatial frame of reference and with user control of the viewpoint's motion and view direction" (p. 893). Ausburn, Martens, Dotterer, and Calhoun (2009) argued that "VEs are finite spaces with specific spatial boundaries; within the boundaries presented users can move, experience, socialize, work and learn" (p. 1).

The term virtual reality currently encompasses several technologies ranging from head-mounted displays (HMDs), fully immersive CAVE environments, simulators, augmented reality, and telepresence technologies like telerobotics and telemedicine, to the less immersive desktop applications presented on personal computers (Ausburn & Ausburn, 2004; Ausburn, Ausburn, Cooper, Kroutter, & Sammons, 2007; Blade & Padgett, 2002).

Head-mounted Displays (HMDs)

HMDs were one of the first VR devices to provide immersive experiences with computer-generated imagery. This form of VR originated during the second half of the 1960s and after extensive development by NASA and the Department of Defense, became commercially available in 1989. In essence, the HMD "houses two small display screens and an optical system that channels the images from the screens to the eyes, while a motion tracker continuously lets an image-generating computer adjust the scene to the user's current view" (Ausburn & Ausburn, 2004, p. 2). According to Stanney and Zyda (2002) visual displays, especially HMDs, "have come down substantially in weight but are still hindered by cumbersome designs, obstructive tethers, suboptimal resolution, and insufficient field of view" (p. 3). McCauley-Bell (2002) has claimed that individuals today do not voluntarily spend long periods of time in the HMDs because of discomfort. She stated that "This discomfort can be attributed to a number of factors including inappropriate fit, movement obstruction from tethers, excessive HMD weight, and improper distribution of this weight, which can produce premature muscular fatigue and inhibit the quality of the experience in a virtual environment" (p. 810).

CAVE Environments

The "Cave Automatic Virtual Environment (CAVE), developed by the University of Illinois at Chicago" (Ausburn & Ausburn, 2004, p. 2), is an immersive VR technology in which realistic 3D images are projected into a darkened room to create a holographic effect and can be seen through special glasses. With the computer generated 3D models, researchers can manipulate the images by zooming in or out on the images and rotating them on the walls and floor of the darkened room (Mandel, 2002; Sensen et al., 2002).

As an example, this immersive VR technology made it possible to convert 2D echocardiographic data into dynamic 3D animated images or holograms of a human heart. The images were projected into a CAVE environment, and doctors using polarized glasses were able to view the heart's anatomy in 3D. The three dimensional holograms allowed doctors to examine the beating heart in greater detail and view the interior parts of the organ. Using a pointer device, doctors were able to virtually dissect the heart and diagnosis heart conditions within ten minutes (van der Bosch, Koning, Meijboom, Simoons, van der Spek, & Bogers, 2005).

Simulators

Simulators are a branch of VR devices designed to replicate a particular phenomenon which is likely to occur in actual performance. For example, flight simulators replicate the flight controls and flight characteristics of a variety of air, space, and marine craft. Driving simulators are used to safely train individuals how to operate an assortment of vehicles and equipment. Equipment simulators are used to familiarize and orient individuals with the operation of vehicles and equipment. They are used to help develop the cognitive and psychomotor skills needed for individuals in a variety of fields such as military, health care professionals, emergency response personnel, as well as the workforce in business and industry.

A different type of simulator has been used in the medical profession. Researchers at Emory University Hospital designed one of the first human mannequin VR simulators to train physicians in carotid stenting procedures. Physicians learned to thread a catheter through an artificial circulatory system and view angiograms of the simulated mannequin "patient". The physicians received objective feedback on their performance of the procedure during and after the completion of the simulated surgical procedure. Dr. Christopher Cates, one of the simulator designers said, "There is mounting evidence that virtual reality (VR) training is a better, faster and safer way for physicians to learn endovascular procedures than the traditional training routes." Cates also noted that residents trained with VR acquired technical skills which approximated those of experienced attending surgeon operators, and VR trained physicians made fewer intraoperative errors (Emory University Woodruff Health Sciences Center, 2004).

VR simulators have also been used to train surgeons in laparoscopic surgical techniques. One study found the use of virtual reality surgical simulation designed to reach specific targeted criteria was found to significantly improve the operating room performance of residents during laparoscopic cholecystectomy (Seymour, Gallagher, Roman, O'Brien, Bansal, Andersen, & Satava, 2002).

Augmented Reality (AR)

Augmented reality (AR) as defined by Blade and Padgett (2002) is "the use of transparent glasses on which a computer displays data so the viewer can view the data superimposed on real-world scenes (p. 17). In one application, augmented reality technology has helped individuals with restricted peripheral fields of view (known as tunnel vision), enabling them to more quickly search, locate and identify objects outside their view. To accomplish this, researchers at Harvard Medical School invented a device which augments the wearer's vision. Eye glasses fitted with a camera and a transparent display on one lens was connected to a small computer about the size of a cigarette pack. The camera fed wide angle images to the computer which processed the images by identifying the edges of objects and stripping away details, leaving the outline of the objects. The computer then fed the object outlines to the display on the glasses. The computer-generated image outlines were superimposed over real scenes, via the transparent display, to provide a wider field of vision (Luo & Peli, 2006). Another example of augmented reality was described by Kaplan-Leiserson (2004) who found that technicians at Boeing, mechanics at American Honda Motor Company, some automotive courses at vocational technical colleges, and military maintenance crews were using hands-free augmented reality (AR) devices. The "Heads Up" display (HUD) visors were used to reflect schematics, vehicle history and maintenance information into the user's eye. Use of the devices resulted in a 30 to 40 percent gain in efficiency and higher-quality work by less experienced technicians.

Telepresence

Telepresence is another form of VR that refers to the "perception that one is at a different location, created by sensory data transmitted from that location and possibly interaction with the environment at that location through telemanipulators" (Blade & Padgett, 2002, p. 24). *Telepresence* has been used to remotely operate equipment, such as bomb squad robots, tactical surveillance robots and unmanned aircraft (drones) from a distance.

Researchers at Iowa State University developed a virtual reality control room for the military's unmanned aerial vehicles. The control room's virtual environment allowed operators to observe vehicles, the terrain, surrounding airspace, and information from instruments, cameras, radar, and aircraft weapons systems. A single operator could control several vehicles from this virtual control room (Iowa State University News Service, 2006). Teleconference communication technology is one example of *telepresence* in business. Bloomburg Business Week has noted that “More and more businesses are turning to telepresence solutions to reduce travel time and costs, build better relationships across distances, and to make their companies ‘greener.’ Telepresence technology allows companies and organizations to interact with remote colleagues and clients, as if they were in the same room” (“Telepresence,” n.d.). In the automotive industry, a form of telepresence technology consisting of remote controlled robots are commonly used to weld and paint new vehicles (University of Texas Robotics Research Group, n.d.). *Telepresence* technology has also enabled doctors to conduct examinations and surgical procedures remotely using *telemedicine*. NASA’s telemedicine system makes it possible for medical specialists in different parts of the world to collaborate, make diagnoses, plan surgeries and operate from remote sites. Using high fidelity NASA 3D imaging software, specialists can view and manipulate the virtual patient’s 3D scanned images. They can analyze the images and discuss issues with other specialists. The specialists can then guide a general practitioner, or a robot operator, in treating the patient (Bluck, Zona, & Rachul, 1999).

Desktop VR Technology

The newest form of VR technology is generally referred to as *desktop virtual reality.* According to Ausburn and Ausburn (2004):

> As virtual reality has continued to develop, applications that are less than fully immersive have developed. These non-immersive or desktop VR applications are far less expensive and technically daunting than their immersive predecessors and are beginning to make inroads into industry training and development. Desktop VR focuses on mouse, joystick, or space/sensorball-controlled navigation through a 3D environment on a graphics monitor under computer control. (p. 3)

Ausburn et al. (2007) explained that “In contrast to immersive VR systems, the new desktop VR is technically far simpler and less expensive” (p. 8). Similarly, Williams (2008) asserted that "Because of substantially lower cost, training viability, and ease of use, VR formats that are not fully immersive have gained popularity. These VR formats have been identified as desktop VR (Ausburn & Ausburn 2004; Hunt & Waller, 1999)" (p. 29).

Desktop VR "uses Quick Time, Java, or Flash technology to present high-resolution panoramic imagery on a desktop computer" (Ausburn, Fries, Mahan, et al., 2009, p. 2). Desktop virtual environments are created by taking a series of digital photographs, then uploading them into special VR software that stitches and blends the images into a single panoramic scene that a user can enter and explore interactively using a mouse or joy stick navigational device. Additional panoramic scenes or objects can be linked together using "hot spots" to allow the user to move beyond the initial scene, inspect an item closer or to explore different areas of the on-screen environment.

Fidelity and Effectiveness of VEs

In recent years attention has focused on the potential value of using VR technologies as education and training tools for CTE, workforce, and professional development. Questions have arisen as to whether VEs can provide accurate representations of the real world and if so, does the knowledge gained from interacting with the VE transfer to real world applications? The first part of this question concerns the *fidelity* of virtual environments, while the second part questions their effectiveness in learning transfer to real environments. Waller, Hunt, and Knapp (1998a) defined fidelity as "the extent to which the VE and interactions with it are indistinguishable from the participant's observations of and interaction with a real environment" (p. 4). They explained that:

> There are three information domains in VE training: the real world environment, the training environment, and the trainee's mental representation of the environment. In general, information about a real world environment will never be preserved perfectly in either the training environment or the trainee's mental representation…because there are systematic differences in people's representation of real environments, even after years of experience in them (Tversky, 1981). On the other hand, some structures are preserved in the mappings between the three domains. Fidelity is concerned with the quality of these mappings. (p. 6)

Waller, Hunt, and Knapp (1998a) went on to assert that:

> Environmental fidelity depends on the degree to which variables in the training environment resemble those in the real world. This means that environmental fidelity is a psychological rather than an engineering concept, because it depends on a psychological judgment of similarity rather than a mathematical correspondence between values of variables. Interface fidelity deals with the mapping of the variables in the training environment to those in the trainee's mental representation of the environment. It addresses the degree to which the input and output devices associated with the VE function similarly to the way in which the trainee would interact with the real world. Of course, the trainee's assessment of an intuitive interface is also a psychological judgment. (p. 7)

In Waller, Hunt, and Knapp's (1998a) study, they maintained that "Researchers now no longer need to question whether VE's can be effective in training spatial knowledge" (p. 4). They found that "Short periods of VE training were no more effective than map training; however, with sufficient exposure to the virtual training environment, VE training eventually surpassed real world training" (p. 2). In addition, they stated that "training in a VE of relatively low fidelity allows people to develop useful representations of a large scale navigable space…" (p. 27). Similarly, in Wilson, Foreman, and Tlauka's (1997) study on the transfer of spatial information from a virtual to a real environment, they found that configural spatial information acquired from a 3D desktop computer simulation can transfer to an equivalent real environment. Ausburn and Ausburn (2004) reported that VR technologies have been used to provide "training in circumstances where real world training would be difficult, expensive or dangerous" (p.

2). Ausburn and Ausburn (2008b) argued that "Virtual reality (VR) has demonstrated effectiveness as an instructional technology in many technical fields" (p. 54). Similarly, Ausburn, Fries, Mahan, et al. (2009) cited recent literature reviews and reported that:

> Published research has consistently demonstrated the effectiveness of virtual reality (VR) as a learning tool in a variety of educational fields and settings, including K-12 education, technical education, medical education, and engineering education. In addition, many occupations and industries are now turning to VR to provide effective and cost effective ways of doing business (c.f., Ausburn & Ausburn, 2004, 2008a, 2008b; Ausburn, Ausburn, Cooper, Kroutter, & Sammons, 2007; Ausburn, Ausburn, Ashton, Braithwaite, Dotterer, Elliott, Fries, Hermes, Siling, & Williams, 2006). (p. 1)

This issue of transfer of training from virtual environments to the physical reality of the real world was specifically addressed by Bollman and Friedrich (n.d.). These researchers reported positive transfer effects and concluded this was a benefit of VE as a training technology.

Concerns About VEs and Their Effectiveness

Despite the growing popularity of desktop VR, the research literature has revealed several concerns regarding the physical and psychological effects some users experience with VR technologies. Researchers (e.g. Ausburn, Fries, Mahan, et al., 2009; Darken & Peterson, 2002; Dotterer, et al., 2008; Hunt & Waller, 1999; Kennedy, Kennedy, & Bartlett, 2002; Waller, Hunt, & Knapp, 1998a, 1998b) have indicated that while some learners do very well in acquiring knowledge from VR technology, others have experienced physiological and psychological difficulties such as visual distortion, dizziness, nausea, disorientation (lost in hyperspace), and spatial anxiety as they maneuvered within a virtual environment (VE). Some of these problems have been linked to individual differences in learner's gender or cognitive style.

A review of the research literature has indicated several factors that may lead to the disorientation of learners in virtual environments: The complexity of the VE design (Darken, 1995; Raubal & Egenhofer, 1998; Waller, 2000; Waller, Hunt, & Knapp, 1998a); lack of ability to orient one's self within the VE (Graff, 2003); difficulty adjusting to the navigational control devices (Chen & Ford, 1998; Lawton, 1994; Waller, 2000); and the quantity or complexity of information to process (Alomyan, 2004; Ausburn, Martens, Washington, Steel, & Washburn, 2009; Boling, 2000; Chen & Ford, 1998). All these factors can lead to cognitive overload which could inhibit learning, which implies a place for cognitive load theory in the study of virtual environments and their effectiveness.

Cognitive load and VE effectiveness. Cognitive load theory was codified by Sweller (1988) in the assertion that proposed optimum learning occurs in humans when the load on the working memory is kept to a minimum to best facilitate the changes in long term memory. Cognitive load theory is concerned with the amount of information that individuals are able to store and process in their working memory before transferring it to the long term memory. The working memory is limited in both time and space. The storage capacity of the working memory is estimated to be from 5 to 30 seconds (Merriam & Caffarella, 1999). In his landmark discussion of information processing and memory, G.A. Miller (1956) argued that the working or short term memory capacity is limited to storing seven plus or minus two digits of information at a time. Miller asserted that "by grouping similar items into a collection, called a 'chunk', short term memory could be expanded" (as cited in Golbeck, 2002, p. 1).

Feinberg and Murphy (2000) explained that “the mental resources of working memory can be overloaded; any information that ignores cognitive load may interfere with the process of acquiring knowledge and skills” (p. 1). An individual’s ability to learn is limited by the ability “to process, absorb, and assimilate information from both the learning activity (content) and the learning process (activity). Because of the time and space limitations of the working memory, care should be taken to minimize the memory requirements and cognitive load on the working memory” (Dotterer, Calhoun, Kroutter, Jennings, Burkett, & Braithwaite, 2008). Cognitive load can lead to disorientation, which causes learners to become frustrated. With rising frustration, anxiety increases and disrupts learning. Learners who become disoriented become distracted and must focus more perceptual attention and cognitive processing on navigation within the virtual environment and less attention on processing information contained within the environment (Graff, 2003).

Gender and VE effectiveness. Research suggests that gender differences may be another source of difference in the effectiveness of VEs. According to Hunt and Waller (1999), “Women have more trouble with virtual environment training than men do” (p. 68). Lawton (1994) found that “Women also reported higher levels of spatial anxiety, or anxiety about environmental navigation than did men. The orientation strategy was found to be positively correlated with spatial perception ability and negatively correlated with spatial anxiety” (p. 765). In other words, the greater one’s ability in spatial perception, the better one is at orienting to the virtual environment. Conversely, the more spatial anxiety one experiences, the poorer his/her orientation strategy, and the more disoriented one becomes. Waller, Hunt, and Knapp (1998b) reported that:

> Disorientation in virtual mazes was particularly severe for women. Several (7) women – and no men had an average bearing errors in excess of 40^{o} for both the virtual and transfer phases of the experiment. However, the gender difference between real world errors was much smaller. These results corroborate earlier findings that understanding the spatial characteristics of VE's may be more challenging for women than for men. (p. 4)

Similarly, in a study on Internet navigation, Chen and Ford (1998) found that "women reported significantly more disorientation than males when searching for information on the World Wide Web" (p. 76). Hunt and Waller (1999) expressed concern that "there are very strong male-female differences in the ability to benefit from VE training" (p. 69).

Cognitive styles and learning strategies in VE effectiveness. Research suggests that learner styles and instructional strategies may also impact the effectiveness of digital environments. Cognitive style issues have surfaced recently regarding navigation in hypermedia environments. This is important because both hypermedia and VEs have non-linearity in common. Non-linearity is a basic feature in hypermedia learning environments. This feature allows the learner to jump freely from one idea to another, without concern for a predetermined order or sequence (Alomyan, 2004; Chen & Ford, 1998; Ford & Chen, 2000). Alomyan (2004) expressed concern that "for some students especially field dependent students, giving such freedom might cause problems such as disorientation, learner control and cognitive overload problems" (p. 189). Likewise, Somyürek, Güyer, and Atasoy (2008) explained that the non-linear structure of computer-based instruction has been touted for providing learners the opportunity of flexible navigation through the instructional content in order to accommodate the learner's needs. However, this non-linear structure may lead to problems like disorientation, cognitive overload or inefficient navigation for some learners.

Chen and Ford (1998) also addressed non-linearity in learning, viewing it positively in their claim that:

> Non-linear access is related to self-paced instruction in that both offer each learner the choice of speed and navigation route through the subject content. Such choices are related to the notion of individual differences in that the same instructional system can potentially offer each learner navigational choices suited to his or her particular needs. … It has been suggested that non-linear knowledge access within hypermedia can enhance learning in comparison to relatively linear access. (p. 68)

Some studies have indicated that when learning strategies have been imposed on students in relatively linear conditions, there is evidence that learning outcomes can be positively affected (Ford, 1985, 1995; Pask & Scott, 1973, 1979). However, when students are allowed more control over navigation in relatively nonlinear learning environments (including hypermedia), the evidence is less consistent, and a number of studies have reported no significant differences in learning outcomes despite learners displaying their characteristic and preferred learning strategies (Ellis, Ford, & Wood, 1992; Ford & Ford, 1992; Frey & Simonson, 1994; Liu and Reed, 1994; Wilkenson, Crerar, & Falchikov, 1997) (as cited in Ford & Chen, 2000, pp. 305-306).

Spatial Abilities, Spatial Knowledge, Wayfinding and VE Interface Training

Literature has shown several individual difference variables such as spatial ability, cognitive ability, cognitive style, prior experience with computer systems, interface proficiency, prior domain knowledge, age, and gender influence variance in navigational behaviors and learning outcomes in virtual environments (Chen & Ford 1998; Hunt & Waller, 1999; Jansen-Osmann, Schmid, & Heil; 2007; Lawless, Schrader, & Mayall, 2007; Waller, 2000; Waller, Knapp, & Hunt, 1999). Waller (2000) argued that:

> The most plausible account of increased variance in VE-related measures is that learning about a space in a VE requires all or most of the abilities that are required for learning about a real world space, but that VE training places additional demands on trainees. Individual differences in the ability to handle these additional demands account for the increased variance in VE-related performance. (p. 7)

According to Waller (2000) "Spatial ability is significantly associated with spatial knowledge acquisition in a virtual environment" (p. 3). Waller explained that "spatial orientation, a dimension of spatial ability, is the ability to manipulate visual stimuli using self as a reference point and is closely related to the ability to change perspectives" (p. 8).

Waller, Knapp, and Hunt (1999) citing Waller (1999), reported:

> In general, tests of spatial visualization (the ability to manipulate figures mentally) and spatial orientation (the ability to account for changes in viewpoint) are more predictive of the ability to acquire spatial information in a VE than are tests of visual memory (the ability to remember the configuration, location, and orientation of figures) or spatial scanning (the ability to explore visually a complex spatial array). (p. 5)

Two dimensions of spatial aptitude are spatial visualization and spatial orientation. Spatial visualization, the strongest dimension, is a term used to describe an individual's ability to manipulate objects or figures without reference to one's self. Spatial orientation, on the other hand, refers to an individual's ability to manipulate visual stimuli using the self as a reference point and is closely related to the ability to change perspectives (Waller, 2000). Kozhevnikov and Hegarty (2001) found these were two different aptitudes and reported that "the ability to mentally rotate and manipulate an imagined object (as measured by tests of spatial visualization and spatial relations) and the ability to reorient the imagined self (as measured by the perspective-taking tests) are separable spatial abilities" (p. 745). They further concluded that "a person's ability to mentally manipulate a visual stimulus from a stationary point of view (object manipulation ability) does not reflect his/her ability to reorient him/herself in space (spatial orientation ability). Although they are highly correlated, object manipulation and perspective-taking tests do not appear to reflect the same construct" (p. 755).

Spatial learning and its correlates have been addressed in research on virtual environments. Jansen-Osmann, Schmid, and Heil (2007) argued that "cognitive development in general is important for spatial learning in a large-scale environment" (p. 49). According to Waller (2000) "The three most powerful predictors of spatial knowledge acquisition in VE's—spatial ability, interface proficiency, and gender – collectively were able to account for approximately 25% of the variance in measures of VE spatial knowledge" (p. 42).

Waller (2000) related skill with a VE's navigation interface to successful acquisition of information. He found that "proficiency with the navigational interface and spatial ability are found to make a substantial contribution to individual differences in the ability to acquire spatial information from a virtual environment" (p. 3). Waller reported that in his studies "spatial ability and interface proficiency had the strongest effect on VE spatial knowledge acquisition" (p. 34) and the "largest single contributor to individual differences was proficiency with the navigational interface, which accounted for approximately 16% of the variation in performance measures of VE spatial knowledge" (p. 36). He asserted:

> Because acquiring congurational spatial knowledge requires attentional resources (Linberg & Gärling, 1983), the effort spent understanding and using the interface devices of a VE system probably interferes to some degree with the cognitive processes or resources required to form spatial knowledge. If people differ in their abilities to learn and automatize these devices, then these differences may account for much of the differences in spatial knowledge acquisition in a VE. (pp. 13-14)

According to Waller (2000), "It is crucial that experimental participants are adequately trained to high proficiency with the interface before being tasked with learning the spatial characteristics of a VE" (p. 37). He believed "using interfaces with which users are most comfortable and familiar with will enhance VE performance" (p. 39). In other words, when adequately trained in how to use a computer interface device, the participant's attention is less likely to be distracted from the spatial learning task. Concerned that very strong male-female spatial skill difference may inhibit women's ability to benefit from VE training, Hunt and Waller (1999) argued that "Presumably, appropriate pretraining can reduce the gender difference in interface proficiency…" (p. 69).

In their studies of learner variables in spatial knowledge acquisition in virtual spaces, Waller, Knapp, and Hunt (1999) found that differences between individuals on characteristics such as gender, prior computer use and cognitive ability accounted for more variance in performance on tasks requiring spatial knowledge acquisition from a VE than did major differences in visual fidelity of the VE (p. 19). Waller (2000) found that "a woman who uses a desktop VE is statistically less likely to derive accurate spatial information from it than a man. However, because other variables are primarily responsible for this gender effect, it is likely that women can be trained in a way that eliminates or reduces gender differences" (p. 41).

Jansen-Osmann, Schmid, and Heil (2007) examined the "effect of regularity in environmental structure on wayfinding behavior and spatial knowledge" (p. 41). In this study, 60 participants divided into three groups ranging from 7 to 8 years old, 11 to 12 years old and adults, performed self-determined movements in two desktop virtual maze environments, one consisting of a regular structure and the other a irregular structure. They found that in most measurements of wayfinding performance and spatial knowledge, there was an overall developmental progress from younger children to adults, yet the exploration behavior did not differ between adults and children. They concluded that their data "strengthened the assumption of a disassociation between wayfinding performance and spatial knowledge" (p. 48).

Orienting, Wayfinding, and Navigation

Orienting

Orienting is the ability to acquire one's bearings in an environment. Blade and Paddgett (2002) defined orientation as a sense of up and down or north, south, east, and west, and identified orientation as what allows individuals to determine where they are, which direction they came from, and where they want to go. Hunt and Waller (1999) described orientation as "Our awareness of the space around us, including the location of important objects in the environment. Orientation in space is crucial for finding one's way (or wayfinding) from one location to another" (p. 4). They explained that "A person is oriented when he knows his own location relative to other important objects in the environment, and can locate those objects relative to each other" (p. 4).

One's cognitive style has been linked to orientation ability. Graff (2003) argued "Cognitive style is also related to an individual's ability to detect his/her spatial location or orientation in space" (p. 409). Witkin's studies regarding the perception of the upright revealed existence of individual differences in spatial orientation abilities (Witkin & Asch, 1948; Witkin, Moore, Goodenough, & Cox, 1977). Individuals' cognitive style or how they perceive and process information appears to have a bearing to how they orient themselves and navigate within an environment. According to Graff (2003) the lack of ability to orient oneself within a web-based environment may cause an individual to experience disorientation. The more disoriented the users become, the more they must focus on navigation and less on processing the information content, which reduces the amount of learning that can take place (p. 408).

Wayfinding

Wayfinding is a term first coined by Kevin Lynch in his classic 1960 work, *Image of the City* (Krafft, 2001; Muhlhausen, 2006; Raubal & Egenhofer, 1998; Reiss, 2001). Lynch used this term to refer to maps, street numbers, directional signs and other elements in an urban environment as wayfinding devices. Wayfinding involves the process of using spatial and environmental information to navigate within a constructed world or environment. Many of the wayfinding principles identified by Lynch can be applied to computer environments. According to Jul (2001), wayfinding is fundamental to most human activity, including interaction with computers. Jul asserted that wayfinding consists of "the task of determining how to get to where one wants to go and directing the activities needed to get there…" (p. 1). Jansen-Osmann, Schmid, and Heil (2007) claimed that "Wayfinding behavior is based on viewpoint updating; the measurements of spatial cognition tasks demand a cognitive processing of spatial information" (p. 41). Krafft (2001) felt that wayfinding refers to an individual's cognitive and behavioral abilities to follow a path from a current location to a target destination. In summary, wayfinding is the ability of an individual to find his or her way to a destination.

Within the context of architecture, wayfinding refers to individuals' ability to orient themselves and choose a path to direct their movement within the built environment. Wayfinding also refers to the architectural and design elements that assist in orientation. Wayfinding is the process of using spatial and environmental cues to navigate through an environment (Corbin Design, n.d.; Center for Inclusive Design and Environmental Access, 2010). Reiss (2001) pointed out that "Architects in the physical world and navigation designers in cyberspace face many of the same problems as they attempt to guide visitors through their respective environments" (p 1). Jul (2001) explained that "Work on wayfinding design usually focuses on using general cognitive considerations to provide guiding information, such as signage, landmarks, etc." (p. 2).

In virtual spaces as in physical ones, individuals need wayfinding devices to assist them in navigating unknown territory. These devices need to be clear and consistent. Research indicates that consistency in terminology, application, and location need to be considered in design of virtual environments. Muhlhausen (2006) maintained that wayfinding can be improved through consistent signage and structural environmental designs. Darken and Sibert (1996) found that in large virtual environments adequate directional cues are necessary, otherwise individuals become disoriented which inhibits both wayfinding performance and the acquisition of spatial knowledge. According to Boling (2000), the more complicated the content is, the more care one should take to simplify the navigation required for individuals to use it. She also noted that occasionally designers have to give instructions to users and recommended instructions be given in plain language, right in the place where people need the instruction, and make sure the directions do not overwhelm everything else around the user.

The inclusion of navigational aids in VEs was also supported by Darken and Sibert (1996) who found that environmental cues such as maps and grids placed in a VE decreased directional errors on hand-drawn maps. Furthermore, participants trained on a map in their experiment exhibited better configurational knowledge of the real environment. Darken and Sibert concluded that providing a map or other navigational aids within the VE during training could enhance the acquisition of survey knowledge.

Boling (2000) addressed the issue of prior knowledge and navigation devices. She found that "people tend to try to apply their prior knowledge to new situations, so if you begin to use navigation signals in ways that look the same but act differently than the ones that people are used to… they will apply their prior knowledge and get very frustrated" (p. 4). Boling recommended "creating a consistent structure that helps people know at any given time where they are, where they can go, how to get back, and how to get out" (p. 8). This concept was also echoed by Muhlhausen (2006) who argued that wayfinding can be improved through consistent signage and structural environmental designs. Professional designers agree, that wayfinding and signage systems need to communicate clearly and consistently and be coordinated with other communications (Corbin Design, n.d.; Center for Inclusive Design and Environmental Access, 2010). Waller, Knapp, and Hunt (1999) asserted that "If one is interested in designing a VE that maximizes the user's ability to learn its spatial characteristics, one should focus on including aids that specifically enhance spatial knowledge-not on creating a VE that looks exactly like the real world" (p. 20).

Darken (1995) addressed ways to find one's way to a target destination, claiming that finding the way to the target within a real or virtual environment requires the navigator to engage in one of three wayfinding tasks. According to Darken "Wayfinding tasks can be classified into three primary categories: naïve searches, primed searches and exploration" (p. 45). Darken defined a naïve search as "any searching task in which the navigator has no *apriori* knowledge of the whereabouts of the target in question. A naïve search implies that an exhaustive search is to be performed" (p. 45). A primed search, on the other hand, is any searching task where the navigator already knows the targets location. A primed search is non-exhaustive. Darken defined an exploration as "any wayfinding task in which there is no target" (p. 45).

According to Darken (1995) "Wayfinding tasks in general require the navigator to be able to conceptualize the space as a whole. This is analogous to what Thorndyke… refers to as survey knowledge" (p. 45). Darken asserted that "exploration is the basic task of spatial comprehension. Its objective is to develop survey knowledge" (p. 46). Darken believed that "…survey knowledge is the key to successful wayfinding in any environment" (p. 46) and that:

> Survey knowledge represents configurational or topological information. Object locations and inter-object distances are encoded in terms of geocentric, fixed, frame of reference. Survey knowledge is map-like in nature. Accordingly, it can be acquired directly from map use. However, survey knowledge acquired from a map tends to be orientation-specific. Prolonged exposure to navigating an environment directly results in survey knowledge which tends to be orientation-independent. (p. 45)

Darken and Sibert (1996) distinguished survey knowledge from procedural knowledge and claimed that survey knowledge is significantly different from procedural knowledge. They identified procedural knowledge as involving the sequence of actions required to follow a specific route. They also stated, "The route may make use of landmark knowledge which is static information about the visual details of a specific location" (p. 2).

Navigation

Darken and Peterson (2002) differentiated wayfinding and navigation. They claimed "Wayfinding is the cognitive element of navigation. It involves the tactical and strategic parts that guide movement…Wayfinding and motion are intimately tied together in a complex negotiation that is navigation" (p. 494). Darken and Peterson argued that "Navigation is the aggregate task of wayfinding and motion. It inherently must have both the cognitive element (wayfinding) and the motoric element (motion)" (p. 494).

Hunt and Waller (1999) identified three problems for navigation. They claimed that "In order to use a configural representation, navigators have to solve three problems. The first two are alignment of a direction in the representation with directions on the ground and positioning the starting point before exploration begins…The navigator's third problem is to determine distance" (p. 35). For Hunt and Waller, navigation focused on information processing requirements.

Boling (2000) used a different approach and described navigation by using landmarks, routes and maps. According to Boling, in landmark navigation individuals typically select an identifiable feature of the environmental landscape and use it as a base. Using the base to orient themselves, they move out away from the base to explore. They return to the base whenever they become disoriented or lost or when they want to explore in another direction. In route navigation, individuals learn the routes between their current location and to a target location or multiple target destinations. "Route navigators tend to learn many routes and then connect these, or use their intersections to navigate to places for which a route has not yet been learned" (p. 2). In map navigation, people form a mental or cognitive map of the space in which they are moving and utilize it to orient and direct themselves by spatial relationships rather than by landmarks or routes (Boling, 2000).

Hunt and Waller (1999) were interested in gender differences in how people navigate. They felt that "What people remember about a space depends upon how they interact with it" (p. 49) and that could be related to gender. Research has indeed found wayfinding strategy differences between men and women which may influence acquisition of survey or configurational knowledge. Hunt and Waller asserted that "The route learner thinks of space as a set of objects connected by paths. The navigator thinks of space as a system of positions from which distance and bearing (configurational information) may be computed" (p. 33). They cited Lawton in pointing out gender differences in acquiring configurational information that may relate to wayfinding or navigating strategies:

> The male advantage in acquiring configurational information may at least partly be due to a difference in the strategy used during wayfinding. Men report noticing bearings to landmarks, while women report strategies that depend on describing control points and noticing cues to the route, such as street signs. (p. 44)

Hunt and Waller (1999) concluded that "Women tend to use strategies appropriate to tracking and piloting, while men use strategies appropriate for navigation" (p. 44). Furthermore, in describing maps and map routes, they cited several researchers who found that "Women are more likely than men to give piloting rather than navigational instructions. This would be expected given male-female differences in wayfinding itself

(Dabbs et al., 1998; Galea & Kimura, 1993; Ward, Newcombe, & Overton, 1986)" (p. 51).

Cognitive and Mental Processing in Orienting, Wayfinding, and Navigation

Several researchers have offered theories and propositions related to cognitive and spatial processing and human wayfinding and navigating. Darken and Peterson (2002) argued "The need to maintain a concept of the space and the relative locations between objects and places is essential to navigation. This is called spatial comprehension, and like verbal comprehension, involves the ability to perceive, understand, remember, and recall for future use" (p. 494). They asserted "An essential part of wayfinding is the development and use of a cognitive map, also referred to as a mental map" (p. 494). Lynch (1960) also supported a link between mental processing and wayfinding/navigating, stating that "In the process of wayfinding, the strategic link is the environmental image, the generalized mental picture of the exterior physical world that is held by an individual" (p. 4). Lynch believed urban elements like paths, landmarks and districts should be used to divide an environment into smaller, clearly connected, and more manageable pieces, which could then be directly encoded into a mental hierarchy of spatial knowledge. He also believed it was important to provide frequent directional cues to assist individuals in orienting themselves in the environment (Darken & Sibert, 1996; Krafft, 2001; Lynch, 1960; Muhlhausen, 2006; Raubal & Egenhofer, 1998; Reiss, 2001).

Waller and his associates have extensively studied human navigation, variables affecting it, and cognitive processes controlling it. They cited Seigel and White's (1975) statement that psychologists have identified three development stages in individuals' cognitive representation of a large-scale navigable space (Waller, Hunt, & Knapp, 1998a). Waller, Hunt, and Knapp's (1998a) discussion of this cognitive representation development cited the work of several researchers working with environmental mastery:

> During an initial period of familiarization, a person focuses on the important locations in the environment. Knowledge in this stage consists of a disconnected set of landmarks. After more exposure to an environment, people are able to link together important landmarks into routes. Knowledge of this type is said to be a *route representation*. With additional exposure, some people may develop a more flexible, map-like representation of the environment called a *survey representation* (also known as configurational knowledge). An individual with a survey representation of a space understands the spatial relationship between the various landmarks in an environment independently of the routes that connect these landmarks. Survey representations facilitate spatial inferences and can allow people access to spatial information regardless of orientation (Sholl, 1987); however, they differ from real environments in well-documented ways (e.g. Tversky, 1981; McNamara, Hardy, & Hirtle, 1989; Engebretson & Huttenlocher, 1996). (pp. 9-10)

Satalich (1995) investigated what she called navigational awareness and its underlying cognitive processes. She argued wayfinding was only one component of navigational awareness, which she defined as "having complete navigational knowledge of an environment" (p. 2). She explained there are two very distinct types of navigational knowledge and each type affords different behaviors. The first type of navigational knowledge Satalich called *procedural knowledge* or route knowledge, which she said is usually gained by personal exploration of a new area. An individual with procedural knowledge can successfully navigate from one location to another along a known route, but does not recognize alternate routes, such as short-cuts. The second type of navigational knowledge according to Satalich, is *survey knowledge*, which she claimed is attained by multiple explorations of an environment using multiple routes. Survey knowledge allows individuals to create a cognitive or mental map of the environment. Satalich asserted that when individuals acquire both procedural knowledge and primary survey knowledge, they then have complete navigational awareness.

Raubal and Egenhofer (1998) elaborated on the mental process involved in the development of a cognitive map of an environment. They contended that “the cognitive map develops from a mental landmark map to a mental route map and should eventually result in a mental survey map. The last stage is closest to a cartographic map, though it still contains inaccuracies and distortions” (p. 3). They also noted that humans construct and develop their cognitive maps by recording of information through their perception, natural language, and inferences. Furthermore, research suggests that complex environmental structures may inhibit development of cognitive maps and lead to representational inaccuracies. Several studies have reported representational inaccuracies in object locations and distances. For example, in a study by Waller, Hunt, and Knapp (1998b), participants were exposed to two maze environments. One was a virtual maze using desktop VR and the other was a real maze. The participants’ knowledge of distances and directions between objects located in the physical mazes were tested. Spatial knowledge transfer from the virtual to the physical mazes was then examined by testing participants in the real-world maze after they had learned in the virtual maze. Waller, Hunt, and Knapp found that the accuracy with which their research participants made bearing judgments was significantly influenced by gender. Furthermore, bearing estimation errors of the men were smaller than those for the women. They also found women’s bearing estimation errors were particularly high in the virtual environment maze. They believed that errors in distance estimations were more affected by measurement type than by gender or the interaction of gender and measurement type. Similarly, Wilson, Foreman, and Tlauka (1997) also found estimating distance to be difficult in a desktop virtual environment.

Another possible explanation for representational inaccuracies and distortions may lie in the virtual environment design itself and its effects on users' mental grasp of the environment. Darken (1995) claimed that:

> Problems associated with wayfinding have been encountered in every virtual environment laboratory in every large-scale virtual world. These problems may manifest themselves in a number of ways depending on the task being performed. Virtual world navigators may wander aimlessly when attempting to find a place for the first time. They may then have difficulty relocating places recently visited. They are often unable to grasp the overall topological structure of the space. Any time an environment encompasses more space than can possibly be viewed from a single vantage point, these problems will occur. (p. 45)

Similarly, Darken and Sibert (1996) argued that "people often have problems wayfinding in large virtual worlds because they cannot grasp the overall topological structure of the space. They may wander aimlessly throughout the virtual environment attempting to locate a place or once they have found a specific location, they may have difficulty returning to it at a later time" (p. 2). Waller, Hunt, and Knapp (1998a) cited Sholl in explaining this problem:

> The problem of developing a survey representation in a VE is confounded by two important characteristics of VE's compared to real environments. VE's typically have restricted fields of view compared to real environments, and restricted fields of view have been shown to interfere with spatial learning in the real world. (p. 11)

Regarding the problem with restricted fields of view, a recent research development has supported Waller, Hunt, and Knapp's argument and offers promising results for females. In a study by Tan, Czerwinski, and Robertson (2003), they concluded that "female 3D navigation performance can be enhanced and that gender difference may be significantly reduced with a larger field of view" (p. 2). They found that "increasing field of view leads to perceptual, visual, and motor improvements in various navigation performance tasks" (p. 2).

Measuring, Orienting, Wayfinding, and Navigating

Numerous approaches have been used in research studies for operationalizing wayfinding, orienting and navigating. Many studies have used real or virtual mazes (Jansen-Osmann, Schmid, & Heil, 2007; Waller, 2000; Waller, Hunt, & Knapp, 1998a, 1998b; Waller, Knapp, & Hunt, 1999), city environments (Waller, Beall, & Loomis, 2004); buildings (Satalich, 1995; Wilson, Foreman, & Tlauka, 1997), or virtual open ocean environments (Darken & Sibert, 1996). Wayfinding devices such as maps, compasses, directional arrows, grid lines and the sun have been used to aid subjects in traversing and locating objects and landmarks within these environments. Most of the research has measured route replication, survey or configurational knowledge and spatial ability of participants.

Navigational route replication measures have included the number of wrong turns, route traversal time, route traversal distance, and the number of misidentified landmarks. Configurational or survey knowledge has been measured by participants drawing a sketch or map of the environment from memory (Darken & Sibert, 1996; Wilson, Foreman, & Tlauka, 1997). These maps or diagrams have been used to assess directional accuracy, relative distance estimation and relative shape, placement and scale of the target landmarks or objects (Darken & Sibert, 1996). Survey or configurational knowledge has also been measured by the number of correct responses to pen and paper tests. The orientation, wayfinding, and navigation research has frequently shown that even with navigational and structural aids, people navigate differently and can get lost in a virtual world. It can be generally concluded from reviewing the research literature that more information is needed concerning the interaction between individual learner characteristics and virtual environment technology.

Cognitive Style

Numerous researchers and theorists have asserted that cognitive style is not the same as learning style or learning strategy. Conti and Kolody (1999) have been primary advocates of learning *strategies* as a learner variable, particularly as they apply to adults. They claimed that "Learning strategy research has revealed that adult learners have a distinct preference for the types of learning strategies that they use when approaching a learning task in daily life" (p.1). By contrast, they cited Keefe's (1982) definition of learning *styles* as "cognitive, affective, and physiological traits that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment (p. 1). Similarly, Conti (2009) cited Smith's (1993) concept of learning style as an individual's characteristic ways of processing information, feeling, and behaving in learning situations. Ausburn and Ausburn (1978) did an extensive review of *cognitive style* research and identified this concept as related specifically to stable abilities and preferences in the way individuals perceive and mentally process information. Ausburn (2004) later used the term learning styles for this construct, stating that "Learning styles have long been generally accepted as stable and deeply ingrained in internal cognitive processes for taking in and processing information" (p. 3). In describing the difference between cognitive style and learning style, Merriam and Caffarella (1999) concurred with Ausburn and Ausburn (1978) that "it appears that the real difference between these two concepts (learning and cognitive styles) lies in the emphasis placed by the learning style researchers on the learning situation versus the more general notion of how people perceive, organize, and process information" (p. 209). Riding and Sandler-Smith (1992) also concurred with the ingrained and "set" nature of cognitive styles and differentiated them from the more fluid learning strategies:

> Cognitive style needs to be distinguished from 'learning strategy'. In the present context, a style is considered to be a fairly fixed characteristic of an individual, while strategies are the ways that may be used to cope with situations and tasks. Strategies may vary from time to time and may be learned and developed. Styles, by contrast, are static and are relatively in-built features of the individual. Cognitive style has been defined succinctly by Tennant (1988); 'an individual's characteristic and consistent approach to organizing and processing information.' (pp. 323-324)

Conti and his associates also supported the more flexible nature of learning strategies, describing them as techniques or skills selected by an individual to use in order to accomplish a learning task. These researchers felt learning strategies differ from learning style in that they are techniques rather than stable or innate traits and they are selected for a specific task (Conti & Kolody, 1997, 1998, 1999; Fellenz & Conti, 1989). Conti, Kolody, and Schneider (1997) agreed with McKeachie (1998) that "Learning strategies are those techniques or specialized skills that the learner has developed to use in both formal and informal learning situations" (p. 2). Ausburn (2004) also concurred that "Learning strategies are believed to be less rigid than learning styles, and more related to personal preferences and choices developed through experience and elected by learners in undertaking and accomplishing learning tasks" (p. 3).

Cognitive style consistently refers in the literature to the manner in which individuals habitually acquire and process information and are thus anchored to human perception and cognition. Hansen (1995) argued that "Cognitive style measures do not indicate the content of the information but simply how the brain perceives and processes the information" (p. 2). Riding and Cheema (1991) noted "The term 'cognitive style,' was used by Allport (1937) and has been described as a person's typical or habitual mode of problem solving, thinking, perceiving and remembering" (p. 194). Chen and Ford (1998) concurred that "Cognitive styles…are characteristic ways of processing information displayed relatively consistently by individuals" (p. 67). Alomyan (2004) citing Riding and Rayner (1998) also agreed that "Cognitive style is an individual's preferred and habitual approach to organizing and representing information" (p. 189).

According to Hansen's (1995) conceptualization of the stable and cognitively-based nature of cognitive styles, they "can be described in a variety of ways, including hemispherical lateralization (left versus right brain), sequential or parallel processing, field dependence/independence, and spatial visualization" (p. 2). Rumetshofer and Wöb (2003) argued that "Cognitive styles are considered as bipolar dimensions whereby having a certain cognitive style determines a tendency to behave in a certain manner. It influences attitudes, values, degree of social interaction or shortly the preferred way a person processes information" (p. 20).

Many researchers have provided similar and related views and definitions of cognitive styles. What these views have in common is an emphasis on the consistency and stability of these styles and their relationship to the cognitive processes of perception and mental processing of information. Ford and Chen (2000) reviewed cognitive style literature and cited several other researchers in concluding that "Cognitive styles are tendencies that are consistently displayed by individuals to adopt a particular type of information processing strategy (Brumby, 1982; Entwistle, 1981; Ford, 1995; Miller, 1987; Riding & Cheema, 1991; Schmeck, 1985)" (p. 283). Chen and Ford (1998) also acknowledged Witkin's well-known conceptualization of cognitive style:

> Witkin and Goodenough (1981) described the term cognitive styles as stylistic preferences consistently exhibited by individuals in the ways in which they organize, stimuli, and construct meanings for themselves out of their experiences. Cognitive styles can be classified in a variety of ways, such as Global-Holistic vs. Focused-Detailed, Field-Dependent vs. Field-independent, Right-Brained vs. Left-Brained. (p. 69)

Witkin (1967) had earlier described his view of the specific nature of cognitive style:

> Extensive research (Witkin, Lewis, Hertzman, Machover, Meissner, and Wapner, 1954; Witkin et al., 1962) has shown that a tendency toward more global or more articulated functioning is a consistent feature of a given individual's manner of dealing with a wide array of perceptual and intellectual tasks. Because it represents the characteristic approach which the person brings to situations with him, we consider more global or more articulated functioning to be an individual's cognitive style. (p. 235)

While Witkin's articulated/global or field independent/dependent conceptualization of cognitive style has been heavily researched, research over the last five decades has revealed other dimensions of individual differences in cognitive styles or the way humans perceive, acquire and process information. Several cognitive style or cognitive control dimensions have been systematically studied over the years and include visual/haptic perceptual types (Lowenfeld & Brittain, 1970); field dependence/independence (Faterson & Witkin, 1970; Witkin, 1967; Witkin, Moore, Goodenough & Cox, 1977; Witkin, Price-Williams, Bertini, Christiansen, Oltman, Ramirez, & Van Meel, 1974); holist-serialist (Pask, 1972); leveling/sharpening cognitive control (Santostefano, 1964; Santostefano, 1978; Santostefano, 1985-1986); flexible/constricted field control (Santostefano & Paley, 1964; Stroop, 1935); and reflective/impulsive cognitive tempo (Kagan, 1965; Kagan, 1976; Kagan & Kogan, 1970; Kagan & Messer, 1975). Ausburn and Ausburn (1978) presented an extensive review of cognitive style and its numerous dimensions and their assessment instruments. Research has shown each of these various dimensions of cognitive style/controls are stable over time; develop early during childhood; are related to personality, socialization and cultural behavior variables; are independent from general intellectual ability; and are resistant to training and change (Ausburn & Ausburn, 1978; Ausburn & Brown, 2006).

Witkin's Field Dependence/Field Independence Cognitive Styles

While considerable research has been conducted on several dimensions of cognitive style, Witkin's well-known dimension of field dependence/independence is arguably the most studied. Witkin himself asserted: "Among the cognitive styles identified to date, the field-dependence-independence dimension has been the most extensively studied and has had the widest application to educational problems…" (Witkin, Moore, Goodenough, & Cox, 1977, p. 1). Witkin et al., (1977) found "cognitive styles play an identifiable role, apparently starting early in life, in the complex process of an individual's educational-vocational evolution" (p. 52). Witkin also asserted that his cognitive style dimension was independent of measures of academic success and that "field dependence-independence does not show much relation to overall achievement measures, such as college grade-point average" (p. 45).

Field dependence and field independence are terms used by Witkin (1967) to denote the contrasting differences in perceiving and processing visual fields between field dependent (global) and field independent (articulated) cognitive styles. Witkin (1967) claimed "In a field-dependent mode of perception, the organization of the field as a whole dominates perception of its parts; an item within a field is experienced as fused with organized ground. In a field-independent mode of perception, the person is able to perceive items as discrete from the organized field of which they are a part" (p. 236).

According to Wilkin (1967), an individual with a field dependent cognitive style has a tendency to perceive and adhere to an existing, externally imposed framework. The field independent individual, on the other hand, has a tendency to restructure the perceived information into a different framework. Witkin, Moore, Goodenough, and Cox (1977) also argued that the perceptual/cognitive aspects of field articulation had social correlates and that "taken collectively, the social characteristics that distinguish persons with contrasting styles suggest that relatively field-dependent persons, in contrast to more field-independent ones, are likely to be attentive to and make use of prevailing social frames or references" (p. 10). Witkin (1967) further extended this social aspect to propose a cultural hypothesis: "Evidence now exists that individual differences in cognitive style are related to differences in family experiences while growing up. To the extent that cognitive styles are end-products of particular socialization processes, they may be used in the comparative study of these processes" (p. 234). Seven years later this hypothesis was tested when Witkin, Price-Williams, Bertini, Christiansen, Oltman, Ramirez, and Van Meel (1974) examined the role of socialization experiences in the development of psychological differentiation in three countries: Holland, Italy and Mexico. In each country, two villages were selected for their contrasting degree of emphasis on conformity to family, religious and political authority. Witkin et al., found "individual differences in cognitive style are largely the end product of differences in socialization experiences" (p. 12). Based on their cultural study, Witkin et al., (1974) argued that encouragement of autonomous functioning as an emphasis in child rearing is associated with the development of a more field-independent cognitive style and greater field differentiation; and that, on the other hand, field-dependence and limited field differentiation tend to be associated with demand of adherence to parental authority" (p. 13). They concluded that "individual differences in cognitive style are affected by child rearing practices, an interplay with ecology and social structure" (p. 14).

Witkin (1967) argued that perceptual field independence is evidence of developed articulation or differentiation in the cognitive sphere. He also proposed that this cognitive development was related to physical identity and stated that "persons with an articulated cognitive style are likely to give evidence of an articulated body concept and a developed sense of separate identity…. An articulated cognitive style, an articulated body concept, and a sense of separate 'identity' are all taken as indicators of developed differentiation" (p. 235). According to Witkin, individuals tend to show a high degree of consistency in performance across these three manifestations and "the performance of relatively field-dependent or field-independent fashion was a highly stable feature of an individual's cognitive functioning over time" (pp. 236-237).

Test of Field Dependence/Independence

Field dependence and field independence is a bi-polar construct which could be thought of as the extreme end points on a continuum. According to Witkin, Moore, Goodenough, and Cox (1977), "Most people fall between the two extremes" (p. 5). Witkin et al., (1974) believed that field dependence and field independence could be assessed by controlled objective procedures (p.12). Witkin assessed psychological differentiation in the perceptual domain through tests of field-dependence-independence and in the body-concept domain through figure drawing productions. Witkin and his colleagues developed a number of tests to measure field dependence-independence cognitive style. The following provides a glimpse of this evolutionary process.

Rod-and-Frame Test (RFT). In this test participants were escorted into a dark room where they viewed a movable luminescent rod contained within a movable luminescent frame. The task was to position the rod so it was vertical. Field independent participants tended to see the rod and frame as separate objects and were able to manipulate the rod to a vertical position regardless of the position of the frame. Conversely, individuals who were more field dependent, tended to position the rod in relation to the frame (field). The participant's score was the mean number of degrees of deviation of the rod from the true upright position on eight trials. In the early experiments, the mechanical device used was too large to be used outside the laboratory. A smaller portable desktop device called the portable rod-and-frame test (PRFT) was developed by Oltman in 1968. It made the darkroom unnecessary (Witkin, Moore, Goodenough, & Cox, 1977, p. 8).

Body Adjustment Test (BAT). Structurally similar to the rod-and frame test, the second test was the body-adjustment test. In this test the "object of perception was the body rather than an external object, such as a rod, and the issue was how people determine the position of the body itself in space" (Witkin, Moore, Goodenough, & Cox, 1977, p. 4). In other words, this test was to see how people orient themselves within a space. To take the BAT, a participant was seated in a chair which was projected into a small room. Both the chair and room could be tilted either clockwise or counter clockwise independently of one another. After the participant was seated, the chair and the room were rotated to a prepared tilted setting. The participant was then asked to adjust the chair to a position where he/she experienced it as upright. Witkin, Moore, Goodenough, and Cox (1977) found individuals who were more field independent were able to bring their body more or less to the upright regardless of the position of the surrounding room. Field independent subjects were able to apprehend the body as an entity discrete from the surrounding field (p. 5). They also found "individual differences in performance of the body-adjustment situations are very similar to those described for the rod-and-frame situation. There are some people who perceive their own bodies as upright when they are fully aligned with the surrounding tilted room" (p. 5). This concurred with Witkin's (1967) earlier finding that:

> Some subjects require that the body be more or less aligned with the room, tilted at 35 degrees, in order for the body to be perceived as straight. In this field dependent way of performing perception of body position is dominated in an extreme degree by the axes of the surrounding field. Other subjects' whose perception is field independent, seem able to keep body separate from field in experience and to adjust the body close to the upright independently of the rooms position. (p. 234)

Articulation-of-Body Concept (ABC). In the articulation-of-body concept, participants are asked to draw a male and female. Drawings were assessed using the Witkin Articulation-of-Body Concept scale (ABC), which was a 5-point scale with a single score assigned for both drawings. A higher score reflected a more articulated (field independent) representation of the human body in the figure drawings (Witkin et al., 1974, p. 21).

Embedded-Figures Test (EFT). In the Embedded- Figures Test (EFT), participants are shown a simple geometric figure. The figure is removed and the participant must then locate the geometric figure within a complex figure designed to embed it. According to Witkin (1967):

> Some subjects quickly break up the complex figure in order to find the simple figure within it; this is a field-independent performance. For other subjects, at the opposite extreme, the simple figure seems to remain 'fused' with the complex

> organized design; they take a good deal of time to ‘tease out’ the simple figure. (p. 236)

Witkin explained the complex figure was composed by using up the lines of the simple figure in various subwholes of the complex figure, so that perceptually, the simple figure no longer appears to be there. Witkin, Moore, Goodenough, and Cox (1977) posited “What is at issue is the extent to which the surrounding visual framework dominates perception of the item within it” (p. 6). For field-independent subjects the sought-after simple figure quickly emerged from the complex design. Field-dependent subjects were not able to identify the simple figure in the time allowed for the search. “The score is the mean time taken to find the simple figure in the complex design in 12 trials of the test” (Witkin et al., 1974, p. 21).

Variations of Embedded Figures Test

Children’s Embedded Figure Test (CEFT). This test was designed for younger children (preschool 3-5 and children 5-9 years old) (Witkin, Moore, Goodenough, & Cox, 1977, p. 8). The score is the number of correct identifications of the sought-after simple figure in the complex design containing it, out of a possible total of 25 (Witkin et al., 1974, p. 21).

Group Embedded Figure Test (GEFT). The *GEFT* was developed in 1971 by Witkin, Oltman, Raskin, and Karp and is still widely used in cognitive style research. It was designed for adults and is a visually oriented pen and paper instrument containing 18 items. Participants are required to read the instructions then identify in each test item a simple geometric shape contained in a complex figure. “Subjects who correctly identify most of the simple figures are considered field independent while subjects who cannot identify the simple figure in the complex figure are considered field dependent" (Hansen, 1995, p. 3).

Cognitive Style and Virtual Environments

Only a small number of studies (Satalich, 1995; Waller, 2000; Waller, Hunt, & Knapp, 1998a; Waller, Knapp, & Hunt, 1999) in the area of wayfinding, orienting, and navigating within virtual environments have attempted to assess subjects' cognitive style and include it as a variable. The test selected most often was the *Guilford-Zimmerman Spatial Orientation Test*, which has been used to assess spatial ability. Waller (2000) went further in assessing different cognitive style dimensions. In his study he administered a battery of 10 cognitive ability instruments to measure visual, spatial and verbal ability characteristics. Among these tests were the *Guilford-Zimmerman Test* for assessing spatial orientation and the Ekstom et al., *Hidden Figures Test* which many researchers have considered to be a marker for field independence and related to spatial ability (Waller, 2000).

Waller (2000) noted field dependence had been shown to correlate highly with measures of wayfinding in the real world. The problem with most of these studies was that they primarily focused on interaction with various navigational devices rather than on individual characteristics of the learners. Only one of these studies attempted to examine the effects field dependence or field independence may have on navigational behaviors in a virtual reality environment.

Cognitive Style and Hypermedia Environments

As noted above, very little research has been found regarding how an individual's cognitive style, specifically Witkin's field dependence/field independence, interacts with navigational behaviors of individuals in desktop VR environments. On the other hand, several studies were found in related technology genres, which address navigational issues in hypertext, hypermedia, and web-based environments.

Researchers have studied the effects of cognitive style in relation to navigating Internet web pages (Dong & Lee, 2008; Fiaola & MacDorman, 2008); hyper-text navigation (Ford, 2000; Korthauer & Koubek, 1994); web-based instruction (Alomyan, 2004; Governor, 1999; Monereo, Fuentes, & Sanchez, 2000); E-learning systems (Lu, Yu, & Liu, 2003; Rumtshofer & Wöb, 2003); hypermedia links (Ayersman & Minden, 1995; Chen, 2002; Chen & Ford, 1998; Ford & Chen, 2000; Kim & Allen, 2002; Weller, Repman, & Rooze, 1994); and hypermedia lab simulation (Andris, 1996).

Chen and Ford (1998) made a positive case for including cognitive style as a variable in studies of how learners process information:

> Many studies have shown evidence of individual differences and their significance in learning, ranging from gender differences (Ford & Miller, 1996; Francis, 1993), system experience (Marchionini & Liebscher, 1991), to cognitive styles (Liu & Reed, 1994; Leader & Klein, 1996). Among these differences, cognitive styles are especially related to the manner in which information is acquired and processed. (p. 69)

Parkinson and Redmond (2002), in their assessment of how cognitive styles affect learning performance in different computer media, found "only Field Dependence-Field Independence interacted with overall learning performance at a statistically significant level…" (p. 39). They also found cognitive styles affected learner performance in different computer media and that "Witkin's Field dependence-Field independence is the most consistent predictor of final score irrespective of treatment" (p. 42). In addition, their results indicated that Field dependence-Field independence was the most consistent predictor of final score in the Internet environment, while the conceptually similar

Riding's Wholist-Analytic cognitive style was a significant predictor of final score in the CD-ROM environment.

Chen and Ford (1998) examined the relationship between cognitive style and navigation strategies using a web-based hypermedia learning system. In this study they defined the difference between hyper-text and hypermedia, stating that hyper-text generally refers to text-based systems which may also include some graphical content, while hypermedia is more encompassing and contains text, graphics, audio and video or moving pictures. They found "students with different cognitive styles and characteristics employed different navigation strategies within the hypermedia learning environment" (p. 76). In particular, they observed field dependent individuals generally adopted a more passive approach to learning and tended to require more structure and guidance. Furthermore:

> Field independent students learned more efficiently than did the Field dependent or Intermediate students, in that they made less navigational moves overall, to engage in less duplication when visiting pages, and to make less use of the Previous/Next buttons—despite exploring deeper levels in the subject hierarchy and reporting fewer problems with the volume and depth of content than their Field dependent counterparts. (p. 77)

Chen and Ford (1998) also found that subject knowledge, gender, and level of Internet experience significantly correlated with the time spent interacting with the hypermedia system. They suggested that tools providing structure and guidance may be more important for relatively Field Dependent students while rich use of referenced links and other means for obtaining relevant information would benefit students with Intermediate and Field Independent cognitive styles.

Kim and Allen (2002) explored cognitive style and task influences on Web searching behavior. They found that although cognitive styles and problem solving styles had an impact on the ways individuals searched for information on the Web, they all eventually found the information they needed. They concluded that the search task was significantly more important than either cognitive style or problem solving style.

Lee, Chen, Chrysostomou, and Liu (2009) investigated the relationship between cognitive style and student learning behavior which they operationalized as navigational behavior. They used data mining techniques to analyze their data. In their study, 65 subjects were administered Riding's *Cognitive Style Analysis* (CSA) test to assess field dependence cognitive style levels. Participants were provided instruction for navigating a Web-based learning program and were given 90 minutes to interact with the program. Interactions were recorded in a log file for later analysis. The results of this study demonstrated that learners with different cognitive styles exhibited different learning/navigating behaviors using the Web-based learning program. Specifically, Lee et al., found field independent subjects used the overview less frequently; tended to take a serialist approach, concentrating primarily on procedural details when processing information in the learning context; and spent less time for navigation, possibly due to the tendency to be more analytical and task oriented. The researchers felt that Field Independents may have only paid attention to those particular topics related to their learning, which resulted in less navigational behavior. They reported that Field Independent subjects tended to favor use of the Backward/Forward buttons to jump freely within the learning environment and also that "Field independents preferred a non-linear navigational approach and spent less time for navigation" (p. 3462). In contrast, Lee et al. found that Field Dependents spent more time looking at examples (external frames of reference). They frequently used the main menu, which provided an overview of subject content and extra guidance. Field Dependents had more repeat visits to pages, which the researchers felt was possibly due to being disoriented or lost in hyperspace. Field Dependents tended to prefer a linear (page by page) approach in the presentation of learning material and may have had difficulty in non-linear learning. Lee et al. also found that Field Intermediate students were a blend of both the field dependent and field independent cognitive styles. They tended to be equally comfortable utilizing either learning path and employed a more versatile learning strategy, which allowed them to adapt to suit the learning program (Lee et al., 2009).

Several researchers have investigated relationships among individual differences in cognitive styles, learning or navigational strategies, and learning outcomes in non-linear technology-based environments, with mixed results. Ford and Chen (2000) reported that some studies investigating global and analytic learning styles in the form of holist and serialist biases have used non-linear environments (i.e., environments in which students can choose their own navigation paths through subject matter). They cited several studies that found no significant differences in learning outcomes, despite differences in learning strategies and concluded that in these studies, learners achieved similar levels of learning performance via different strategic routes. Liu and Reed (1994) reached similar conclusions. They investigated different learning strategies of field dependent and field independent international students in a hypermedia-assisted language learning setting and found that Field Dependent and Field Independent cognitive style groups used different learning strategies in accomplishing the same task. They also concluded that "hypermedia technology has the potential to accommodate learners with different needs through its rich environment" (p. 419). Similarly, Weller, Repman, and

Rooze (1994) found that Field Dependent and Field Independent students "were served differently by hypermedia-based instruction" (p. 402).

Graff (2003) argued that because web-based instructional systems feature the potential for displaying different pieces of information on different pages, learners need to understand the overall structure. Therefore, they felt users having a cognitive style enabling them to understand the structure of the system should derive greater learning benefit. However, a study by Ford and Chen (2000) did not support this expectation. The study by Ford and Chen measured the learning behavior and performance of 65 post-graduate students using a hypermedia-based tutorial. Ford and Chen gathered data on cognitive style, levels of prior experience, motivation, age, and gender. They found a link between field-dependent/independent cognitive styles and strategic differences in navigation behaviors. They found that levels of prior experience were also linked to quantitative differences in both navigation behavior and learning performance. They also found a correlation between experience and cognitive style, with field independent individuals displaying higher levels of experience. However, they did not find any significant correlation between field dependent/field independent cognitive styles and measures of learning outcomes.

Cognitive Style and Hypermedia Navigation

In studies examining Field Dependence and Field Independence in hypermedia navigation strategies, several findings have been reported. For example, Ford and Chen (2000) found that in a hypermedia-based tutorial relatively Field Dependent learners tended to use the map more and the index less and to use the back/forward button less. They spent a greater proportion of their time studying higher levels in subject content hierarchy (levels 1 & 2) and a smaller percentage of time studying in deeper levels (level 5). Relatively Field Dependent learners spent a lower proportion of their time exploring the "Detailed Techniques" section of the tutorial and adopted a relatively "random order" approach to the elements of the practical assessment task. In contrast, the relatively Field Independent learners in the Ford and Chen study—as in a study by Liu and Reed (1994)—tended to use the map less and the index more. They spent less of their time studying higher levels in subject content hierarchy (levels 1 and 2) and a greater portion of time studying the deeper levels of subject content (level 5). Relatively Field Independent students made greater use of the "Detailed Techniques" section of the tutorial and were linked less with a relatively "random order" approach to elements of the practical assessment task. However, Ford and Chen reported that despite their navigational differences, Field Dependent and Field Independent cognitive style were linked to the adoption of different learning strategies but not to learning quality or learning performance (p. 299).

In an earlier study of cognitive style and navigational behavior in hypermedia, Chen and Ford (1998) found that Field Independent subjects made significantly less use of the main menu and previous/next buttons than the Field Dependent and Field Intermediate subjects. Field Intermediates seemed to favor using reference links, while the Field Dependents tended to use the main menu more often than the others. The researchers reasoned that "Arguably, the use of the main menu signifies an interest on relatively global aspects of navigation, since the main menu gives an overview of all available topics" (p. 72). Chen and Ford reported that "students with different cognitive styles and characteristics employed different navigation strategies within this hypermedia learning environment" (p. 76) and that their findings were in line with previous research studies showing that individual differences influence navigational behaviors. Chen and Ford concluded:

> Field independent students learned more efficiently than did Field dependent or intermediate students, in that they tended to make less navigational moves overall, to engage in less duplication when visiting pages, and to make less use of the Previous/Next buttons-despite exploring deeper levels in the subject hierarchy and reporting fewer problems with the volume and depth of content than their field dependent counterparts. (p. 77)

Gender, Spatial Skills, and Digital Media

For nearly two decades research literature has noted several gender-related differences in the interactions of individuals with both virtual and hypermedia environments. Gender has been cited as related to differences found in performance (Hunt & Waller, 1999; Jansen-Osmann, Schmid, & Heil, 2007); use of navigational tools (Chen & Ford, 1998); navigation speed (Chen & Ford, 1998; Jansen-Osmann, Schmid, & Heil, 2007); frustration (Ford & Miller, 1996); disorientation (Ford & Miller, 1996; Schwarz, 2001; Waller, Hunt, & Knapp, 1998a, 1998b; Waller, Knapp, & Hunt, 1999); spatial processing (Hunt & Waller, 1999; Lawton, 1994; Waller, 1999; Waller, Knapp, & Hunt, 1999); and self-efficacy, confidence, perceived task difficulty, anxiety, and cognitive overload (Ausburn, Martens, Washington, Steele, & Washburn, 2009; Chen & Ford, 1998).

Gender and Performance

Waller, Hunt, and Knapp (1998a) argued that the performance differences observed in their study of virtual environments were not because of differences in the acquisition of spatial knowledge, but rather "…are more likely due to gender differences in the effectiveness of VE's for training" (p. 29). They noted that "Psychologists have shown that in general, men have more experience with video games (Philips, Rolls, Rouse, & Griffiths, 1995) and report more comfort and confidence with computers (Temple & Lips, 1989)" (p. 29). Jansen-Osmann, Schmid, and Heil (2007) found gender differences existed only in regard to exploration behavior and drawing tasks. They found that females walked shorter distances in a virtual maze and scored lower on map drawing correctness than the males, and that this pattern held true for all three age groups examined in their study. In contrast, Ardito, Costabile, and Lanzilotti (2006) found no significant gender differences in navigational performance, attitudes, or user experience in subjects interacting with a Web-based virtual museum.

Hunt and Waller (1999) cited studies by Lawton in proposing that "The male advantage in acquiring configurational information may at least partly be due to a difference in the strategy used during wayfinding. Men report noticing bearings to landmarks, while women report strategies that depend on describing control points and noticing cues to the route, such as street signs" (p. 44). Hunt and Waller reported that "Women tend to use strategies appropriate to tracking and piloting, while men use strategies appropriate for navigation" (p. 44). Furthermore, they cited research showing that in describing maps and map routes, "Women are more likely than men to give piloting rather than navigational instructions. This would be expected given male-female differences in wayfinding itself (p. 51). Ford and Chen (2000) found a correlation between gender and motivation. They reported that females tended to be motivated more by extrinsic reasons for attending a technology-based tutorial and made fewer requests for guidance than males.

Gender and Spatial Abilities

According to Waller (2000), based on his studies there is some evidence that gender differences in VE spatial knowledge are significantly associated with differences in the abilities required to interact with computers because gender differences on real-world spatial tasks can be much smaller than gender differences on identical VE spatial tasks (p. 12).

Hunt and Waller (1999) supported male advantage in spatial orientation and VEs. They argued that “On average men outperform women in spatial orientation tasks” (p. 68) and that “Women have more trouble with virtual environment training than men do” (p. 68). They reported that “Most of the effect of gender in VE spatial learning is statistically associated with differences in spatial ability (as assessed by paper-and-pencil test) and proficiency with the navigational interface” (p. 69).

Lawton (1994) also reported gender differences in wayfinding/navigating and spatial skills. He examined gender differences in self-reported wayfinding strategies and their relationship to spatial ability and spatial anxiety. Lawton found “Women were more likely to report using a route strategy (attending to instructions on how to get from place to place), whereas men were more likely to report using an orientation strategy (maintaining a sense of their own position in relation to environmental reference points)” (p. 765). Lawton reported that “Women also reported higher levels of spatial anxiety, or anxiety about environmental navigation than did men. The orientation strategy was found to be positively correlated with spatial perception ability and negatively correlated with spatial anxiety” (p. 765).

Waller (2000) argued that “A woman who uses a desktop VE is statistically less likely to derive accurate spatial information from it than a man. However, because other variables are primarily responsible for this gender effect, it is likely that women can be trained in a way that eliminates or reduces gender differences” (p. 41).

In contrasting studies of gender effects in spatial tasks, Jansen-Osmann, Schmid, and Heil (2007) found:

> The assumption that some of the variance in spatial tasks results from the influence of prior computer experience (Waller, 2000; Waller, Knapp, & Hunt, 2001) might not hold true for the exploration behavior in this study. However, although females and males did not differ in their computer use, females might hesitate to push the joystick and explore the maze straight ahead. Because rotation and translation speed was controlled, we might assume that they stop more often than males. (p. 48)

Tan, Czerwinski, and Robertson (2003), found no significant differences in the spatial abilities of men and women. They measured spatial ability by paper folding tests prior to a VE treatment. In this study they found that a wider field of view allowed users to more quickly and more accurately recall going in the forward direction than going backward.

Gender and Disorientation

Several studies have demonstrated greater disorientation in virtual environments for females than for males. Addressing this issue, in a 2001 interview with University of Washington reporter Joel Schwarz, psychologist Earl Hunt asserted “Gender differences could become important if virtual environments are adopted as training or educational devices, unfairly penalizing women and girls” (Schwarz, 2001 Press Release, p. 1). Based upon his recent study of gender differences in virtual environments, Hunt argued that the “Overwhelming majority of people who get ‘lost’ in this exercise were women”

(p. 1). This supported the results of previous studies by Hunt and his associates. Waller, Hunt, and Knapp (1998b) found:

> Disorientation in virtual mazes was particularly severe for women. Several (7) women – and no men had average bearing errors in excess of 40º for both the virtual and transfer phases of the experiment. However, the gender difference between real world errors was much smaller. These results corroborate earlier findings that understanding the spatial characteristics of VE's may be more challenging for women than for men. (p. 4)

Similarly, Waller, Knapp, and Hunt (1999) found that in virtual mazes, distortion was, "on average, quite severe for women…Moreover, gender differences in the ability to point to objects in the VE by using a joystick showed enormous gender differences" (p. 21).

Other researchers have reported similar findings in technology-based environments. Chen and Ford (1998) found "women reported significantly more disorientation than males when searching for information on the World Wide Web" (p. 76). Ford and Miller (1996) reported that in their studies with university students, "The clearest findings related to gender differences, with females reporting significantly greater levels of disorientation and disenchantment in relation to the Internet" (p. 183). They found "Significant correlations suggesting that males felt more confident in their understanding, whilst females experienced more disorientation problems" (p. 75). They reported that men seemed to enjoy browsing around the Internet, often with no clear plan, searching for personally interesting material, while women seemed relatively disoriented and disenchanted with the Internet, felt unable to find their way around effectively, and tended to use the Net only for work purposes when they had to. However, Ford and Miller admitted that it was possible that the female disorientation and disenchantment observed in their study "may simply represent a realistic appraisal of the current state of the Internet as a useful and valuable work tool for those particular students" (p. 188). This is arguably a fair conclusion given the status of the Internet when they conducted their study in 1996. A replication today could perhaps yield completely different outcomes.

Gender and Computer Navigational Interface Proficiency

Proficiency with computer navigational controls is generally believed to enhance learning, based on the logic that if users are comfortable with the navigation device, they are able to focus more on the task at hand and not be distracted with navigating a virtual environment. However, literature regarding computer interface proficiency and gender appears to be mixed. Waller, Knapp, and Hunt (1999) claimed that understanding the spatial characteristics of a VE may be more challenging for women than for men and that a gender-related difference in proficiency with the VE's navigational interface is a particularly important determinant of people's ability to acquire spatial information from a VE. Hunt and Waller (1999) expressed concern that the very strong male-female differences may inhibit women's ability to benefit from VE training. They argued that while gender differences in spatial ability is unlikely to be reduced by training, appropriate pretraining may reduce the gender difference in interface proficiency. In contrast to the studies of the Hunt and Waller team, Chen and Ford (1998) found there was no interaction between the selection of navigation tools and gender in a hypermedia environment.

Miscellaneous Studies of Gender Differences in Virtual and Hypermedia Environments

Numerous approaches have been taken studying relationships of gender to navigation behavior and learning outcomes in virtual and hypermedia environments. This section illustrates the variety of methodologies, research purposes, and findings presented in the literature.

Jansen-Osmann, Schmid, and Heil (2007) investigated the influences of environmental structure on wayfinding behavior and spatial knowledge across ages and gender in a virtual environment. To operationalize this investigation, they constructed two virtual mazes: The regular maze was constructed with 90 and 45 degree angles, the irregularly shaped maze was constructed with 45, 90, and 135 degree angles. Jansen-Osmann, Schmid, and Heil's expectation that the regular maze would yield better learning performance was based on Thorndike and Hayes-Roth's regularity hypothesis which proposes that the regularity of an environment has an effect on how rapidly a person is able to learn spatial relationships. This study found that wayfinding performance of older children and adults was not influenced by environmental structure. The researchers believed this could be due to the fact that with increasing age, individuals might be more able to regularize irregular features. In addition, the study found gender differences present only regarding exploration behavior and in a map task. Results showed that females walked shorter distances and scored lower on a map correctness measurement than males. Furthermore, the registered straight line distance in this study was significantly shorter for males. These patterns of results held true for all three age groups and were thus independent of age.

Vila, Beccue, and Anandikar (2002) studied the effect of gender on navigation and wayfinding in a virtual maze. They found the tendency to take left and right turns was influenced by gender. In this study, females took more left turns than males during the initial exposure to a VR environment and there was a decreasing effect of gender on turning tendency as the exposure to the VR environment increased. In the Vila, Beccue, and Anandikar study, gender did not influence the time traveled or the number of rooms visited in the virtual mazes.

Ausburn and Ausburn and their associates in the Oklahoma State University (OSU) Virtual Reality Research Team have studied the effects of gender on learning and confidence in desktop virtual environments in non-technical and technical applications. Ausburn and Ausburn (2008b) conducted a quasi-experimental study comparing the effectiveness of desktop VR with traditional color still images in a non-technical environment. Subjects were divided into two groups. One group viewed color photographs of several rooms in a house while the other group interacted with a desktop VR presentation of the same rooms. After receiving these treatments, subjects were required to complete three testing instruments to measure scenic orientation, recall of scenic details and perceived confidence in scenic comprehension. Ausburn and Ausburn found that contrary to much research on virtual environments, the females in their study significantly outperformed the males in both scenic orientation and recall of scenic details. The females tended to be more confident regarding their understanding of the house scene and benefitted more from the VR presentation than the males on both performance and confidence variables. Regarding these results, Ausburn and Ausburn stated:

> The superior performance of the females overall in scenic orientation and recall of details and their trend for greater confidence were unexpected based on a lengthy research history of stronger skills in mental spatial manipulation among males in both paper-and- paper and virtual environments…. (pp. 77-78)

In a second study by the OSU VR team gender effects in desktop VR were examined in the context of a highly technical surgical operating room environment. In this study, participants were presented one of two alternative VR presentations of a set of unfamiliar operating rooms. One VR presentation had only the standard "hot spot" navigation features of desktop VR, while the other had an additional mapping feature to assist users in orienting themselves and locating items relative to themselves. Both VR treatments were visually complex, showed the same technically demanding environments that was unfamiliar to the research participants. After subjects completed the VR presentations they were required to complete four testing instruments which measured scenic orientation, recall of scenic details, self-reported perceived confidence in scenic comprehension and a self-reported perceived task difficulty. The findings of this study showed a reversal of gender results from the 2008 Ausburn and Ausburn study (Ausburn, Martens, Washington, Steele, & Washburn, 2009).

Ausburn, Martens, Washington, et al., (2009) conducted a cross-case analysis of these two studies to address the disparity of their findings. The researchers reported that the findings in the second study were dramatically different from those in the first study of the familiar non-technical house environment. In the second study, females scored significantly lower than the males on the test of scenic orientation. Females were significantly less confident and rated the learning task significantly more difficult than their male counterparts. The researchers concluded that the disparate findings were likely related to the nature of the virtual environment. They stated that "When the VR environment became unfamiliar, technical, visually complex and navigationally difficult…the females appeared to experience more difficulty and to lose the performance and confidence advantage they exhibited in the house environment" (p. 26).

Waller, Hunt, and Knapp (1998a) examined gender and performance real-world and virtual training alternatives. In their study, 125 people (61 men and 64 women) between 18 and 40 years of age participated in several experimental treatments. Participants were randomly assigned to one of six treatment exposure conditions: blind, real, map, desktop VR, immersive VR and long immersive VR. In the blind exposure group, subjects were not exposed to the maze room. In the real exposure group, participants were given one minute to explore a real maze. In their initial exploration, participants were shown the appropriate route between objects then they were allowed to wander through the maze. Participants in the map condition were given one minute to study a map of the maze. At first, the experimenter oriented the map for the subjects and pointed out the correct routes to take. The remaining three exposures were variations of virtual conditions.

In this Waller, Hunt, and Knapp (1998a) experiment, participants in the virtual maze environments were given 30 to 75 minutes of instruction on how to use the navigational input devices prior to interacting with their assigned VR condition. Participants in the desktop VR condition were allowed two minutes to study a virtual replica of the maze. The maze in this condition was navigated using a joystick interface device. Like those in the real world condition, the desktop VR participants were initially told which way to go so they could get to each location in order. Furthermore, arrows in the virtual maze were used to provide path information. In the immersive VR condition, participants used the same virtual maze as the desktop VR but it was displayed using a VR4 HMD (head mounted display). Motion and gaze were controlled by a joystick. During the initial orientation, participants were give a two-minute exposure and direction on which route to take. The long immersive VR condition was the same as the immersive VR except at each trial, the participants were allowed five minutes of exposure time.

After participants had encountered either a virtual; the real world; or the map version of the maze, they were then blindfolded and taken to the real world maze. They were given directions to touch each object in order, as quickly as they could, while minimizing the number of times they touched or bumped the walls of the maze. The process of exposure to the maze followed by a blindfolded walk-through was repeated six times. After the sixth time, the experimenters altered the maze and instructed participants to go from the first object as quickly as possible to the third object. Results showed that subjects' performance in all conditions improved steadily over the six trials and "the rate of improvement depended on the type of training the participant received" (p. 21). Regarding their experiment, Waller, Hunt, and Knapp explained that:

> Participants who were allowed only one minute of exposure to the real maze were able to traverse it blindfolded much faster on the first two trials than those participants in the other conditions. On average, subjects in all VR conditions performed worse in the initial trials than those people in either the real world or map conditions. By the second trial, only the group that was given a much longer training time in the immersive VR was able to outperform participants trained on the map…. By the sixth trial, participants in the long immersive condition outperformed those in the real world training group, although this difference is not significant. (pp. 22-23)

For all training conditions, Waller, Hunt, and Knapp (1998a) reported men averaged higher scores than women on a true and false test, in which they identified whether a given map of the room correctly represented a portion of the maze. Map training for both genders yielded the best performance while the two minute VR immersed group yielded the worst performance. They noted that "On average, in all non-blind experimental groups, men outperformed women at the blindfold task…" (p. 26).

Waller, Hunt, and Knapp (1998a) found that in their study virtual environments were particularly disadvantageous to females. They found that disorientation in the virtual mazes was particularly severe for women and observed that:

> A gender effect was particularly strong for women who trained in the three VE conditions. VE-trained women performed significantly worse than men in the VE conditions…. They also performed significantly worse than women trained in the real world…. Moreover, there was not a significant difference between women and men who trained in the real world. (p. 26)

In contrast to the Waller, Hunt, and Knapp study, Ardito, Costabile, and Lanzilotti (2006) conducted a study in which 50 masters and Ph.D. students performed a set of predefined tasks as they interacted with a 3D representation of a virtual museum. At the conclusion of the experimental session, participants were administered a questionnaire. Analysis of the data revealed very similar behavior by males and females, indicating there was no significant gender difference in this case. No gender difference was found in attitudes, performance, or user experience towards the 3D virtual environment.

Tan, Czerwinski, and Robertson (2003) were interested in assessing the effects of optical flow in navigation through a virtual environment. They defined optical flow as "the relative motion of stationary objects around a moving observer" (p. 2). To test the effects of this optical phenomenon, they used a spatial memory task in which participants first learned their way through a complex virtual maze and were then tested for their memory of the route to the target location. Prior to the experiment, participants were given the widely validated VZ2 "paper folding" tests from Eckstrom et al. *Kit of Factor-Referenced Cognitive Tests* to measure their spatial skills.

In the Tan, Czerwinski, and Robertson (2003) experiment, the researchers constructed a virtual maze similar to the *DOOM* game. The virtual maze was displayed on a 43 inch curved screen which provided either a 100 or 120 degree field of view. "Each path through the maze involved a randomly selected path through 14 rooms. There were exactly 8 turns (left and right) and 6 straight movements in each path and paths were allowed to cross back over themselves" (p. 3). Each room looked identical with three doors. Participants were required to create some internal representation of the layout and were encouraged to form a cognitive map of the environment. To reinforce developing a cognitive map, after entering each room, participants were asked if they had previously been in that room. Only by building a cognitive map of the space could they accomplish this task.

Tan, Czerwinski, and Robertson (2003) found the illusion of animation created by optical flow helped females more than males, although there was an overall effect in favor of optical flow. They did not find any significant differences in the spatial abilities of men and women as measured by the paper folding tests prior to the VE treatment. The researchers found the wide field of view on the viewing screens allowed users to more quickly and accurately recall going in the forward direction than going backward, but there was no reliable performance difference between the 100 degree and 120 degree conditions, which indicates there is no advantage to increasing the field of view beyond 100 degrees for the particular navigational tasks examined.

Roy and Chi (2003) studied gender differences in search and navigation strategies on the Internet and relationship of strategy patterns to learning outcomes. They found "the overall patterns of search behavior were different for boys and girls" (p. 343) and the nature of these patterns suggested that boys tended to filter information at an earlier stage in the search cycle than girls. They also found a trend for girls to demonstrate proportionally more vertical movement between documents, which suggested girls were more linear and thorough navigators than boys. Roy and Chi reported that target-specific performance gains were significantly and positively related to the proportion of horizontal movement between *submitting* a search and *scanning* search results and that there was a trend for a substantial negative relationship between knowledge gains and the proportion of vertical downward *movement between documents.* However, none of the search variables were related to performance on the target-related questions.

The Roy and Chi (2003) experiment found there was a significant association between knowledge gain and search preference with all students who demonstrated *high* learning gains demonstrating a *horizontal* search preference, regardless of gender. They observed no overall preference for *horizontal* or *vertical* search pattern for students who had a *low* learning gain. They concluded this analysis provided converging evidence that learning gains were related to differences in search patterns in a manner that is independent of gender. These researchers felt their study, identified two distinct global patterns of Internet search behavior that reliably and independently distinguished girls' performance from boys', and high-knowledge-gain performers from low-gain performers. They found that boys had a tendency to be horizontal searchers, oscillating between submitting searches and scanning document excerpts returned as search results. Girls, on the other hand, tended to be vertical searchers, opening and browsing entire documents without preliminary filter scanning. Successful learners, regardless of gender, tended to be horizontal searchers.

Prior Knowledge/Experience, Learning, and Digital Media

"One of the most prominent variables both in terms of number of studies, as well as findings indicating a significant influence on navigation, is prior knowledge" (Lawless, Schrader, & Mayall, 2007, p. 292). Prior knowledge can be defined as any related knowledge an individual brings to a learning situation that may or may not aid in acquiring information or understanding (Alexander & Judy, 1988; Anderson & Pearson, 1984; Chi & Ceci, 1987; Lawless, Schrader, & Mayall, 2007). Prior knowledge has also been defined as:

> The whole of a person's actual knowledge that: (a) is available before a certain learning task, (b) is structured in schemata, (c) is declarative and procedural, (d) is partly explicit and partly tacit, (e) and is dynamic in nature and stored in the knowledge base (Dochy, 1994, p. 4699) (as cited in Dochy, Segers, & Buehl, 1999, p. 146).

Lawless, Schrader, and Mayall (2007) cited the work of several researchers in reporting that "Within more traditional learning environments, findings have indicated that learners with greater pre-existing knowledge about a topic typically understand and remember more than those with more limited prior knowledge (p.292). They also reported several studies in concluding that "Prior knowledge also biases the information that is learned and the strategies a learner employs in a given learning situation" (p. 292).

Alexander and Judy (1988) also summarized research on prior knowledge to conclude:

> Research in cognitive psychology during the past two decades has produced two undisputed findings about academic performance. First, those who know more

> about a particular domain generally understand and remember better than do those with only limited background knowledge….Second, those who monitor and regulate their cognitive processing appropriately during task performance do better than those who do not engage in such strategic processing…. (p. 375)

Alomyan (2004) similarly reported that "Significant literature review generally indicates that prior knowledge can account for a high level of variance in most learning situations" (p. 191). Several researchers have reported specific examples of relationship between prior related knowledge and superior learning performance. Lawless and Kulikowich (1998) reported that "One consistent finding supported by the literature examining traditional texts is that the more domain knowledge one has, the better one can employ strategies to competently process related text" (p. 53). Lawless, Schrader, and Mayall (2007) pointed to literature linking prior knowledge to improved navigation and learning in hypermedia environments, and multimodal digital text.

Learners with greater pre-existing knowledge about a topic typically understand and remember more than those with more limited prior knowledge (Lawless, Schrader, & Mayall, 2007). Several researchers have associated this with search skills. Roy and Chi (2003) found that search skills improve with greater domain knowledge. Lazonder, Bremans, and Woperers (2000) also found "domain expertise enhances search performance. Those with high domain knowledge tend to take less time completing search tasks and produce a greater number of correct solutions" (p. 576). Similarly, MaKinser, Beghetto, and Plucker (2002) asserted that:

> Higher levels of domain knowledge will greatly enhance an individual's ability to focus a search, as well as employ useful and logical decisions. Domain knowledge can also guide identification and selection of search terms and determine a user's expectations about an answer to a particular action. (p. 157)

Ford and Chen (2000) examined individual differences in hypermedia navigation and learning. They found greater experience in an area correlated with higher performance in the same or closely related areas. Furthermore, they found prior experience correlated with cognitive style, noting that field independent individuals displayed higher levels of experience. Interestingly, "Yoon (1994) found that field dependent students with low prior knowledge can facilitate their learning in program control treatment, and field independent students with low prior knowledge can improve their performance in learner control treatment whereas these strategies did not affect students with high prior knowledge" (As cited in Alomyan, 2004, p. 191).

Prior Domain Knowledge and Navigation in Digital Environments

Few studies have examined the influence of prior experience or domain knowledge on navigational behaviors and performance outcomes in VEs. However, several studies in related electronic genres (e.g. hypertext, hypermedia and Internet exploration) have examined the influence of prior domain knowledge, prior computer experience, navigation, and learning outcomes. Prior knowledge has been found to influence navigational behavior. For example, Lawless, Schrader, and Mayall (2007), in examining the relationship between prior knowledge and Internet browsing outcomes, argued "one of the most prominent variables both in terms of number of studies, as well as findings indicating a significant influence on navigation, is prior knowledge" (p. 292).

Similarly, Chen and Ford (1998) found existing knowledge seemed to influence how individuals interacted with a hypermedia learning system. They found that individuals with higher levels of prior knowledge tended to use more reference links, navigational tools and resources, while those with little domain knowledge were either not capable of or not interested in exploring deeper levels of content. Roy and Chi (2003) also reported research demonstrating that Internet search skills improve with prior domain knowledge. In reviewing the literature related to individuals with high prior domain knowledge and their interactions with hypertext environments, Lawless, Schrader, and Mayall (2007) reported several characteristics of high domain knowledge individuals. They offered the following description of their findings in the literature:

> [High domain knowledge individuals] tend to constrain their navigation selections to specific topics within a hypertext-system (Carmel, Crawford, & Chen, 1992; Dillon, 1994); they tend to explore these topics in greater detail (Chen & Ford 1998; Mitchell, Chen, and Marcredie, 2005); they tend to move in a more non-linear manner through information space (Eveland and Dunwoody, 1998; Recker, 1994).
>
> Individuals with a low level of prior knowledge tend to navigate toward bells and whistles (e.g. graphics, animations, sound effects and movies) (Lawless & Kulikowich, 1996). They rely more heavily on navigational aids (Barab, Bowdish, & Lawless, 1997; McDonald & Stevenson, 1998). They are more predisposed to becoming disoriented or lost within the environment (Hammond, 1989; Last, O'Donnell, & Kelly, 2001; Rouet & Levonen, 1996). Collectively, the evidence suggests that novices within a domain not only lack a breath and depth of knowledge, but they also lack the conceptual structure of the content area needed to orient and direct their navigation through a hypermedia system (Chen, Fan, and Macredie, 2006). (Lawless, Schrader, & Mayall, 2007, p. 292).

Based on their review of literature, Lawless, Schrader, and Mayall (2007) concluded that:

> Navigation describes not only the behavioral actions of movement (e.g., linking one information node to another) but also elements of cognitive ability (e.g. determining and monitoring path trajectory, comprehension, and goal orientation)…. (p. 291)

Prior Computer Experience and Navigation/Wayfinding Behaviors

Literature on the influence of prior computer experience and wayfinding behaviors is limited and appears to be mixed. Waller (2000) asserted "The amount of prior experience with computers is probably the most powerful predictor of a person's ability to perform computer tasks effectively" (p. 12). In contrast, findings from Jansen-Osmann, Schmid, and Heil's (2007) study revealed there were no significant correlations between computer experience and the measurement of wayfinding performance and spatial knowledge, nor were any gender effects observed.

Ford and Chen (2000) found that levels of prior computer experience were linked to superior learning performance and differences in learning behavior in a hypermedia environment. Students with relatively high levels of computer use, Internet use, and Web design experience viewed a greater number of pages, visited a greater total of levels in the subject hierarchy, spent less time learning, and spent less time attempting the practical assessment task (p. 295).

Prior Domain Knowledge and Hypertext, Hypermedia and Internet Navigation

Lawless and Kulikowich (1998) replicated prior research on hypertext navigation and confirmed the existence of three different navigational profiles: (a) knowledge seekers, (b) feature explorers, and (c) apathetic hypertext users. Lawless and Kulikowich characterized knowledge seekers by the number of times they visited knowledge-based hypertext cards. Users who seemed extremely intrigued by special features and resources found in the computer environment were classified as feature explorers. These users tended to spend a great deal of time exploring the hypertext terrain. The apathetic hypertext users showed no apparent nonlinear trends in their navigational selections. They also spent very little time exploring the hypertext environment. When Lawless and Kulikowich examined users' prior domain knowledge, they found:

> It appears that the special features of the computerized environment may distract those readers who have a lower amount of domain knowledge. The 'bells and whistles' of the environment may seduce these low-knowledge readers away from pertinent material by sparking high situational interest. Rather than ferreting out

> information, they seem to explore the hypertext in search of more special features, creating a very nonlinear path. This is the trend that appears to occur with the feature explorers group. (p. 66)

Lawless and Kulikowich (1998) further reported, "Where domain knowledge is high in a given content area, readers appear dissuaded from engaging in an exploration of the text" (p. 66). High-Knowledge learners tended to navigate toward pages that contained content directly related to the task and disregarded pages that were either unrelated or only tangentially related to comprehension. Apathetic users tended to have high levels of domain knowledge and high recall scores. They exhibited no connection between knowledge and interest. On the other hand, feature explorers tended to possess low levels of domain knowledge. They spent most of their time searching the hypertext for more features rather than informational content. Knowledge seekers appeared to possess moderate levels of domain knowledge. They tended to strategically maneuver through the hypertext to maximize knowledge acquisition and create as many opportunities as possible to connect information. Using an open recall measure, Lawless and Kulikowich found that high-knowledge navigators outperformed all other groups on outcome performance. These researchers concluded that:

> Other studies have corroborated these findings, indicating that individuals with greater domain expertise not only appropriate different navigational styles, but that their resulting navigation paths are more efficient and effective, leading to higher levels of comprehension…. (pp. 292-293)

Wang, Liebscher, and Marchionini (1988) examined the effect of a system's human interface on fact retrieval in an electronic hypertext environment. They conducted two experiments; the first examined the effect on user performance in searching both a paper and electronic version of an encyclopedia. They found subjects completed searches faster in the paper version but the search success was the same for both printed and electronic versions. Search strategy and prior computer experience were explored in the second experiment which examined the effect of two distinct search strategies (index use and browsing), on subject performance in the electronic version of the same encyclopedia. In this second experiment, the researchers found the index strategy was more successful than the browsing strategy. They also found that previous computer and online experience did not have a significant effect on subject performance.

In their study of navigation strategies in hypermedia, Chen and Ford (1998) found that:

> Subjects with more subject knowledge used more reference links, section buttons and back/forward buttons (possibly they wished to locate more specific information than those with less experience). Furthermore, there were significant correlations found between Internet experience and the number of pages browsed, number of navigational moves, and information processing time. Subjects with a lot of Internet experience spent longer interacting with the hypermedia system. (p. 75)

In the Chen and Ford (1998) study, correlations were also found between the levels of subject knowledge and the number of pages browsed, navigation moves, level of depth explored in the subject hierarchy, and information processing time. These researchers believed that levels of subject knowledge possibly influenced learning motivation. They found that both students with considerable Internet experience and those with more subject knowledge thought the depth of the content of the hypermedia system was too brief and superficial.

Monereo, Fuentes, and Sanchez (2000) examined the Internet navigational behaviors of individuals with varying levels of prior domain knowledge and computer skills. They found individuals with high levels of prior domain (content) knowledge and expert computer skills tended to plan their search in advance. They ignored moves which would take them away from their goal. Furthermore, they did not read the information they found in depth but merely skimmed through the texts. They selected appropriate links and achieved their goal by taking a shorter route.

Monereo, Fuentes, and Sanchez (2000) found individuals with lower levels of domain knowledge but high levels of computer skill also tended to plan in advance and ignore moves that would not bring them closer to the goal. These individuals knew how to navigate but lacked prior content knowledge and so spent a greater portion of time reading each block of information. They took the appropriate links and reached the goal by a short route, but took considerably longer to process the information.

Individuals in the Monereo, Fuentes, and Sanchez (2000) study with prior domain knowledge and low computer skills did not plan the steps to take in advance. Since the Web environment was relatively new to them, they initially spent more time looking at and interacting with the links. Later, they began to ignore links that did not bring them closer to their goal. Once these individuals found the informational block they were looking for, they skimmed through the content and skipped several levels until they found the point they were looking for. These individuals took appropriate links and found their goal but took a much longer route. The design of the Web site appeared to make these subjects pay less attention to the subject matter and more attention to finding their way through the hypermedia environment.

According to Monereo, Fuentes, and Sanchez (2000) the fourth group of subjects possessed low content knowledge and low computer skills. They did not plan their search process in advance. They took a trial and error approach and failed to monitor or control their progress through the Web site until they got lost. These individuals spent a large amount of time clicking and reading menus and took the longest time of all subjects studied. They were unable to describe the structure of the Web site and only had a vague understanding of the most general informational blocks. Monereo, Fuentes, and Sanchez found overall that those with higher prior domain knowledge were able to conduct efficient searches to find information in order to meet their task. Those with prior domain knowledge tended to take a nonlinear search and navigation path, whereas those with less domain knowledge tended to take a more linear path.

In a study that examined the relationship between prior knowledge and Internet browsing outcomes in 42 undergraduate and graduate students, Lawless, Schrader, and Mayall (2007) asserted "one of the most prominent variables both in terms of number of studies, as well as findings indicating a significant influence on navigation, is prior knowledge" (p. 292). In this study the researchers examined the relationship between prior knowledge and Internet browsing outcomes (i.e., navigation behavior and knowledge gain) within the context of a genetics Web site. The treatment group was given a pre-reading activity to increase their prior knowledge within the subject domain of genetics. Lawless, Schrader, and Mayall found that the prior knowledge treatment group demonstrated higher learning outcome scores than the control group who received no pre-reading activity. The treatment group spent more time browsing, viewed more media resources, and used more in-text embedded links than the control group. From their study, Lawless, Schrader, and Mayall concluded that:

> Readers who engaged in the prereading activity were more nonlinear in their selections within the environment, navigating by following the embedded links and viewing the information across modalities (text-based and visual) more often than the control group. Further, the control group members were more constrained in their navigation selections than the treatment group and more

> dependent on explicit navigational schemes (e.g., main menu for finding information. (p. 298)

Lawless, Schrader, and Mayall (2007) also reported "the navigational path taken by the treatment group is more complex than that followed by the control group, and as such, it appears that the treatment group was able to make more use of the benefits of the Internet-based learning environment in their exploration of the content" (p. 299).

In a study by Roy and Chi (2003), 14 eighth grade students between 13 and 14 years of age were studied to see how they used the Web to search for, browse and find information in response to a specific prompt (how mosquitoes find their prey). The students were given a pretest to determine their prior knowledge regarding mosquito behavior. After the students completed their Web search, they were given a post-test to assess target-specific knowledge. Students were allowed to take notes and bookmark up to 30 pages of Internet resources during their search. The students were allowed to refer to their notes and bookmarks during the post test. However, after the posttest, the students were given an unannounced target-related test to measure incidental facts that they may have gained during their search. They were not permitted to use their notes for this assessment. Roy and Chi found boys and girls did not differ in prior knowledge of the target domain based on the pretest analysis. They did not differ in their familiarity or access to computers, with using Google, or with using the Web. There was no significant difference in the total number of search moves or the amount of time spent searching the Web.

What We Do Not Know: Conceptual Link to the Present Study

Waller (2000) argued most of the reported research regarding the use of computer-simulated environments for training spatial knowledge has focused on examining aspects of VEs that are associated with their training effectiveness. There has been very little systematic research into how trainees' characteristics and prior abilities affect the usefulness of VEs for training spatial knowledge. He believed this was unfortunate because individual differences are a major source of performance variation in both the real world and the virtual world (p. 4).

A search of available literature reveals that little is known about individual differences of learners as they maneuver within virtual environments. Chen and Ford (1998) asserted that in hypermedia environments the "findings provide support for the notion that individual differences may have an effect on navigational patterns" (p. 68). "Jonassen (1988) advocated that it is important to investigate how learners navigate through hypermedia systems and how individual differences could predict those paths. If learning environments can be aware of such differences, then they may be able to offer appropriate support, possibly resulting in higher quality learning" (cited in Chen & Ford, 1998, p. 68).

Waller (2000) asserted "Computer-simulated environments hold promise for training people about real-world spaces. However little research has examined the role of user characteristics and abilities in determining the effectiveness of these virtual environments (VE's) for training spatial knowledge" (p. 3). Echoing this concern about the interaction between user characteristics and VR, Ausburn and Ausburn (2003) argued that past research has tended to "Focus on comparing instructional treatments and designs as main effects rather than on examining interactions between treatments and specific types of learners" (p. 2).

According to Ausburn and Ausburn (2008b), “VR research has generally lacked a sound theory base to provide explanatory or predictive strength. Further, research into the effectiveness of new desktop technologies that place VR within the reach of schools and teachers is currently embryonic” (p. 54). It is the contention of this researcher that more research is needed regarding how individual differences influence navigational behaviors and learning during interactions with virtual environments, how navigation patterns manifest themselves, and what theoretical foundations might inform such inquiry. These concerns provided impetus for the study reported in this dissertation.

CHAPTER III

Methodology

Research Design and Variables

This study used a mixed method research model based on a quasi-experimental research design. In this design, two groups, divided on their individual cognitive style (field dependence/ field independence), interacted with the same desktop VR treatment of a crime scene. An extreme-group design was used to assign subjects to the two cognitive style groups based on their *Group Embedded Figures Test* (GEFT) scores. Gender, years of law enforcement experience, and levels of computer experience were self-reported by subjects. Navigational behaviors in the virtual environment were recorded through observation and Camtasia 6.0 screen capture software for quantitative and qualitative analysis of differences. Configurational or survey knowledge acquisition was measured by having subjects draw a crime scene sketch from memory, after they had completed interacting with the VR treatment. The sketches were assessed independently by three crime scene experts, and quantitative measures of inter-judge reliability were calculated.

The independent variables in this research study were the desk top VR crime scene environment; the cognitive style dimensions of field dependence/field independence; and the demographic variables of gender, prior domain experience as defined by years of experience as a police officer, education level, computer use, and level of computer experience. The dependent variables consisted of the participants' navigational behaviors in the VE and their scores on the crime scene sketch. Navigational behavior measures consisted of:

- The total time in the treatment,

- Time spent in each node or scene,
- The sequence or order in which the nodes were navigated,
- Changes in perspective (number of times the subject scrolled up or down and zoomed in or out),
- Mouse/cursor movements (direction, speed, continuous or panning vs. jumping movements),
- Returns (the number of times a subject revisited or navigated the same node), and
- The total number of nodes visited.

The sketches were scored by three independent crime scene investigators using a five-point Likert-type scale and rubric developed by the researcher. The sketches were scored on accuracy of the drawing, quantity of details recalled, and completeness of the drawing. Inter-judge reliability was calculated for each of the three items scored using the kappa coefficient.

Population and Sample

A population according to Gravetter and Wallnau (2007) is “the set of all individuals of interest in a particular study” (p. 5). Gravetter and Wallnau defined a sample as “a set of individuals selected from a population, usually intended to represent the population in a research study” (p. 5). Fraenkel and Wallen (2006) explained that sampling is “the process of selecting a number of individuals (a sample) from a population, preferably in such a way that the individuals are representative of the larger group from which they were selected” (Glossary p. G-7).

Control of variables and randomization in the selection and assignment of subjects to groups are hallmarks of true experimental designs. This study however, uses a quasi-experimental design. This choice was deliberately made to accommodate the theoretical and operational needs of the study. According to Fraenkel and Wallen (2006), a quasi-experimental design is “a type of experimental design in which the researcher does not use random assignment of subjects to groups” (Glossary p. G-7). In the present research study, the primary focus was to examine and describe the influence of field dependence and field independence on navigational behaviors and learning in a desktop VR environment. Therefore a purposive sample deliberately split on these cognitive style dimensions was used. A purposive sample is “a nonrandom sample selected because prior knowledge suggests it is representative, or because those selected have the needed information” (Fraenkel & Wallen, 2006, Glossary p. G-6). The sample for this study was also non-random because it relied on volunteer participation.

The population for this study consisted of full time sworn police officers employed at Broken Arrow Police Department in Northeastern Oklahoma. This context was chosen for this study of desktop VE because of the potential value of this technology for professional training in the law enforcement field. The Broken Arrow Police Department is comprised of 123 sworn police officers. Table 1 depicts the demographic makeup of this police department.

Table 1

2009 Demographic Makeup of Protective Services Officers of Broken Arrow Police Department (N = 123)

	N	Percent	Totals
Male			
Black	3	2%	
White	102	83%	
Hispanic	1	1%	
Asian/Pacific Islander	0	0%	
American Indian/Alaskan Native	4	3%	
Gender Total			110 (100%)
Department Total			110 (89%)
Female			
Black	0	0%	
White	12	10%	
Hispanic	0	0%	
Asian/Pacific Islander	0	0%	
American Indian/Alaskan Native	1	1%	
Gender Total			13 (100%)
Department Total			13 (11%)

Note. From the 2009 City of Broken Arrow Equal Opportunity Plan.

The sample for this study was obtained through a two-phase process. A non-random purposive sample of 30 participants was selected through procedures described below from a larger sample of 75 law enforcement officers who volunteered for the study. Data on the demographic variables of gender, age range, education level, years of law enforcement experience, computer use, and computer experience were obtained from each of the 30 participants using a “Participant Survey Form” developed by this researcher (See Appendix D). To fully describe the study’s sample, frequency distributions were obtained on each of the demographic variables and are depicted in Tables 6 – 10. The gender composition of the study’s final sample (n = 30) is depicted in Table 2.

Table 2

Gender Distribution of the Study’s Sample (N = 30)

	Frequency	%	Cumulative %
Male	26	86.7	86.7
Female	4	13.3	100.0
Total	30	100.00	

The gender distribution for this sample had two percent more females than the target population, which is not unreasonable. Low female representation is also typical of most police departments in Oklahoma. The remaining variables in this sample were also reasonably representative of the population of the Broken Arrow police officer population.

The frequency distribution for the variable of age range of the study’s sample is depicted in Table 3.

Table 3

Age Range of the Study's Sample (N = 30)

Years of age	Frequency	%	Cumulative %
26 – 30	8	26.7	26.7
31 – 35	4	13.3	40.0
36 – 40	8	26.7	66.7
41 – 45	4	13.3	80.0
46 – 50	3	10.0	90.0
50 +	3	10.0	100.0
Total	30		

Prior knowledge or experience variables consisted of the participant's education level, years of law enforcement experience, computer use, and computer experience. Tables 4 and 5 present the education levels and years of prior law enforcement experience of participants in this sample.

Table 4

Education Level of the Study's Sample (N = 30)

	Frequency	%	Cumulative %
Some college	3	10.0	10.0
Associate degree	12	40.0	50.0
Baccalaureate degree	13	43.3	93.3
Master's degree	2	6.7	100.0
Total	30	100.0	

Table 5

Years of Law Enforcement Experience of the Study's Sample (N = 30)

	Frequency	%	Cumulative %
1 – 5	3	10.0	10.0
6 – 10	9	30.0	40.0
11 – 15	9	30.0	70.0
16 – 20	5	16.7	86.7
21 – 25	1	3.3	90.0
26 – 30	3	10.0	100.0
Total	30	100.0	

Computer use and programming experience reported by the 30 participants in this sample is depicted in Table 6.

Table 6

Computer Use and Programming Experience of the Study's Sample (N = 30)

	Frequency	%	Cumulative %
Use of word Processing for school or work			
Yes	28	93.3	93.3
No	2	6.7	100.0
Total	30	100.0	

Table 6 (continued) *Computer Use and Programming Experience of the Study's Sample (N = 30)*

	Frequency	%	Cumulative %
Browsing of Internet for research or fun			
Yes	30	100.0	100.0
Playing of computer games			
Yes	18	60.0	60.0
No	12	40.0	100.0
Total	30	100.0	
Computer programming experience			
Yes	1	3.3	3.3
No	29	96.7	100.0
Total	30	100.0	

Subjects in the sample were asked to rate their level of computer experience as none, novice/beginner, moderate/average, or advanced/very experienced. The majority (26 or 86.7%) of participants rated their computer experience as moderate or average. Table 7 presents the frequency distribution of their self-assessed computer experience responses.

Table 7

Self-Reported Computer Experience of the Study's Sample (N = 30)

	Frequency	%	Cumulative %
None	0	0.0	0.0
Novice/Beginner	2	6.7	6.7
Moderate/Average	26	86.7	93.3
Advanced/Very Experienced	2	6.7	100.0
Total	30	100.0	

Instrumentation and Technologies

Group Embedded Figures Test

The *Group Embedded Figure Test* (GEFT) was developed by Witkin, Oltman, Raskin, and Karp (1971). GEFT is a timed test used to measure and identify the cognitive style dimensions of field independence/field dependence. Its construct validity has been accepted for many years through usage in many research studies. GEFT is now considered a standard measure of the field independence/field dependence construct. GEFT was designed for adults and can be administered simultaneously to large groups. It is visually oriented and requires reading for the instructions only. The GEFT is an 18-item pen and paper instrument that requires identification of simple figures embedded or hidden within more complex ones. Scores on GEFT range from 0 to 18. Participants who correctly identify most of the simple figures are considered field independent while those who cannot identify the simple figures contained in the complex figures are considered field dependent (Hansen, 1995, p.3). According to Witkin, Oltman, Raskin, and Karp (1971), when GEFT is correlated between parallel forms of the test, it has been shown to have a reliability coefficient of 0.82 (p. 28). See Figure 2 for a sample item from the *Group Embedded Figures Test* (GEFT).

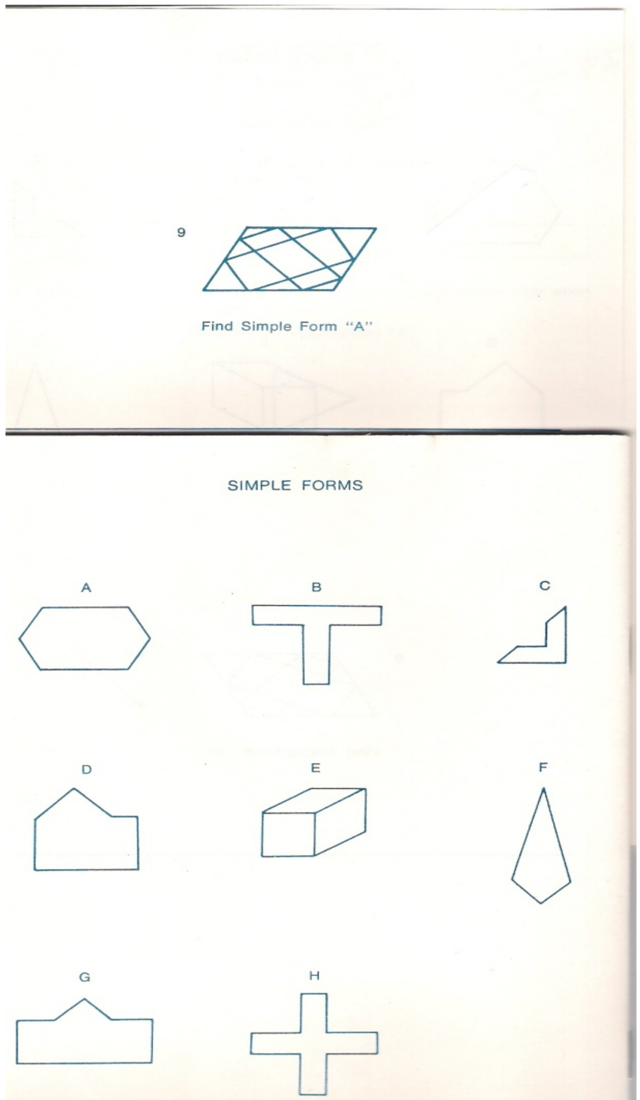

Figure 2. Sample of *Group Embedded Figures Test* (GEFT) item (Source: Witkin, Oltman, Raskin, and Karp, 1971).

Participant Survey Form (Questionnaire)

A participant survey was developed by the researcher to collect demographic information from the participants prior to taking the *Group Embedded Figures Test* (GEFT). The questionnaire consisted of questions to obtain details regarding each participant's gender, age range, education level, number of years of law enforcement experience, computer usage, and computer experience. See Appendix D to view the Participant Survey Form.

VR Treatment

In this research, the desktop VR treatment consisted of a crime scene investigation environment developed by the researcher and members of the Oklahoma State University Occupational Education Studies VR Research Team. The virtual crime scene environment depicted a realistic homicide scene consisting of a house with five rooms and several clickable learning objects embedded within the virtual scene. The clickable objects (or hot spots) allowed participants to move from room to room, view evidentiary items in more detail, or view evidence collection video clips. Figure 3 depicts a Camtasia screen shot of a view of the virtual crime scene with hotspots, which appear as blue squares in the central portion of the screen.

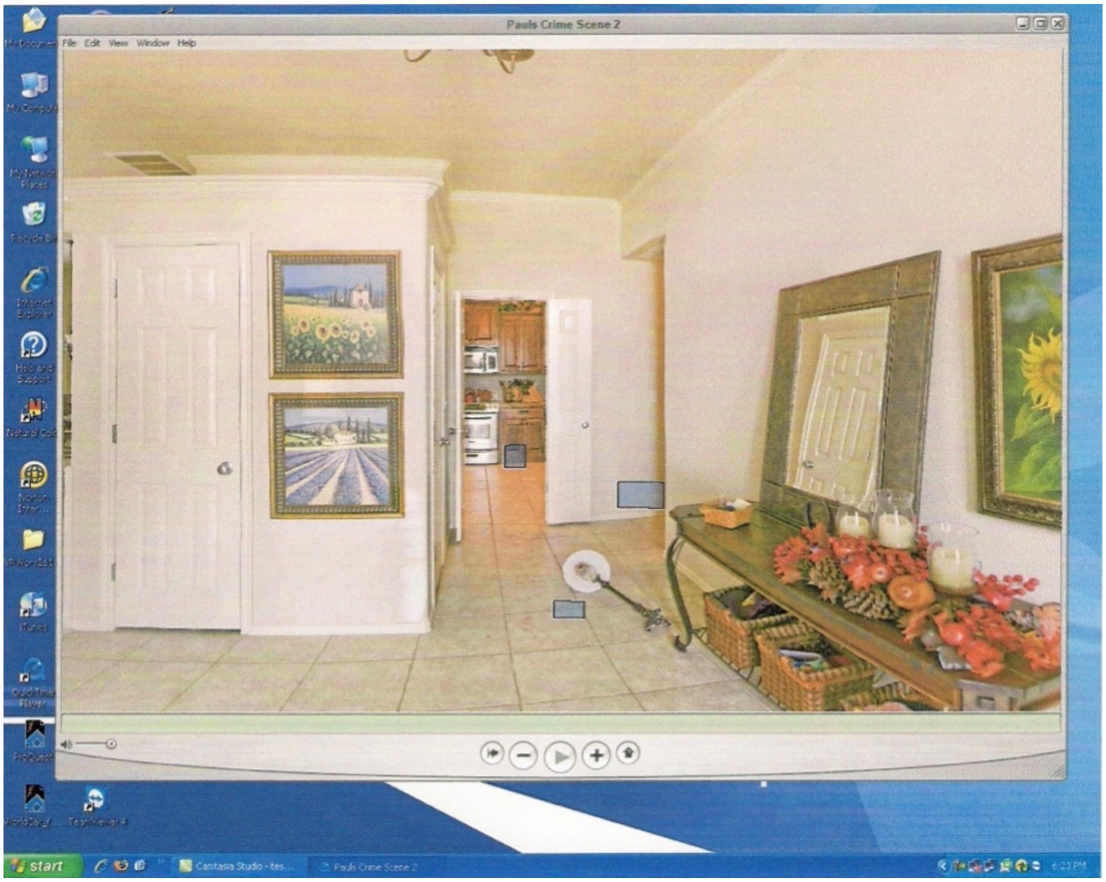

Figure 3. Camtasia screen shot of virtual crime scene with hotspots.

Figure 4 illustrates the Crime Scene VR Node diagram used to develop the virtual crime scene treatment and to track navigational behaviors of participants for analysis. The large circles represent the primary rooms visited by participants. Nodes 2, 3, 4 and 5 allowed participants to pan 90 degrees, 180 degrees, or 360 degrees. The smaller circles represent hotspots of items embedded into the primary scenes. The smaller nodes consisted of photographs of evidentiary items and movie clips demonstrating evidence collection methods. The directional arrows represent hyperlinks (hotspots) from one node to another.

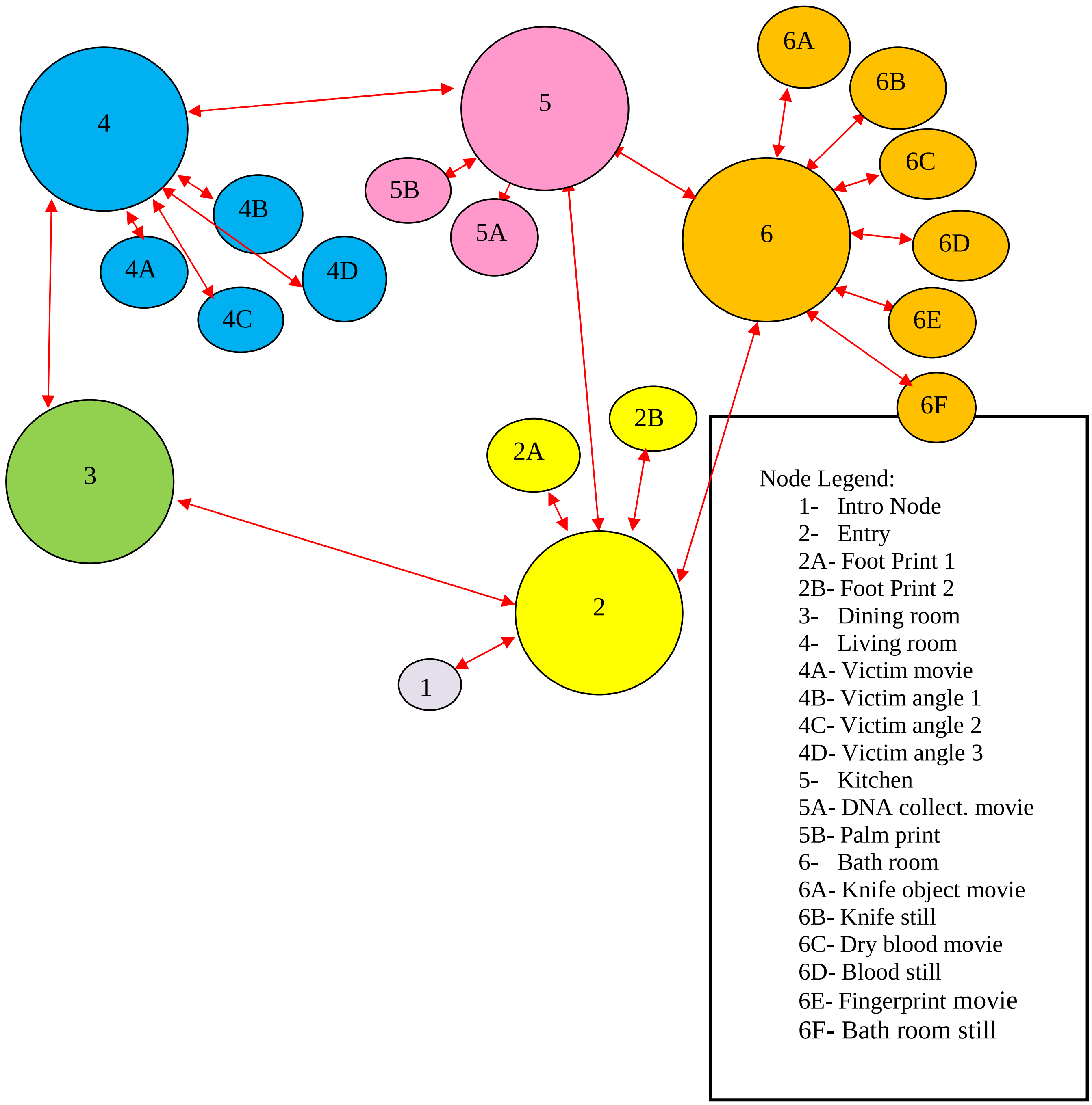

Figure 4. VR Crime Scene Node Diagram.

A copy of the virtual crime scene treatment was uploaded with this dissertation. It can be opened using QuickTime Player®. Copies of the VR crime scene can also be provided by the researcher upon request.

Camtasia 6.0 Software

Camtasia 6.0 is a commercially produced screen capture software program normally used to make dynamic multi-media presentations. The screen capture characteristics of this software program made it ideal for recording the navigational movements and comments of each participant in the study as they maneuvered within the virtual environment. Camtasia software allowed the researcher to highlight and record each individual cursor movement and mouse click. It accurately tracked the total time participants were in each node, the path or direction they took, the cursor movements, and sequence of nodes accessed by the participants. During the analysis of the Camtasia sessions for each participant, navigational movements could be examined frame by frame if they were too fast for the human eye to follow. Navigational behavior data were coded and logged in a participant observation log using an Excel spreadsheet (Appendix A). All oral participant comments or questions captured by Camtasia were transcribed for later qualitative analysis. All navigational moves were tabulated at the bottom of each column of the observation log for statistical analysis. A sample of navigational moves entered on the Participant Observation Log is shown in Table 8.

Table 8

Sample Participant Observation Log Entries.

Sub	Node	MouseClick	Pan	Right	Left	Up	Down	ZoomIn	ZoomOut
							1		
					1				
							1		
		1							1
						1			
					1	1			
					1				
		1							
					1				
hs2		1							
	2								
				1			1		

Navigational movements are read from top down. In the participant observation log example in Table 8, this participant moved down then left and down again. The participant clicked the mouse to zoom out then moved up. The participant then moved up and to the left. The participant then moved left again. The participant then clicked the mouse and moved left once more. Next the participant clicked on hotspot 2 and traveled to node 2. From there the participant moved right and down.

Crime Scene Sketch Likert-Type Scale

This instrument was developed by the researcher based on similar instruments used in the research literature to assess a subject's configurational or survey knowledge after viewing a virtual environment. A rubric was developed by the researcher to provide consistency in the scoring of the crime scene sketches. The more accurate, detailed and complete the drawings, the higher the score and the greater the acquisition of configurational knowledge. In studies by Darken and Sibert (1996) and Wilson, Foreman, and Tlauka (1997), subjects were required to draw a sketch or map of virtual environments from memory to measure survey knowledge. These maps or diagrams were used to assess directional accuracy; relative distance estimation; and relative shape, placement, and scale of the target landmarks or objects (Darken & Sibert, 1996). See Appendix B to examine the Crime Scene Sketch Likert-type scale and rubric.

Procedures

A memorandum from the Chief of the Broken Arrow Police Department was sent out to all 123 sworn law enforcement officers, requesting volunteers for the research. Seventy-six subjects initially volunteered to participate in the study. One subject withdrew after reading the instructions for the *Group Embedded Figures Test* (GEFT).

Phase 1

After granting informed consent, the 75 participants each completed the participant survey form to provide demographic data. Participants were then administered Witkin, Oltman, Raskin, and Karp's, (1971) *Group Embedded Figures Test* (GEFT) in accordance with test instructions. The *Group Embedded Figures Test* (GEFT) was administered to several groups of police officers either during in-service training sessions at the Broken Arrow Police Academy or at the beginning of their work shift. Officers from the detective division and all three shifts of the patrol division took part in this portion of testing. The GEFT was used to screen participants for the field dependence/field independence cognitive style dimension.

After all participants had completed the GEFT, the test booklets were scored. Subjects were then assigned to one of three groups: field independent (FI) with high scores on the GEFT ranging from 13-18; field dependent (FD) with low scores ranging from 0-8 on the GEFT; and intermediates with scores ranging from 9-12 on the GEFT. A non-random purposive sample of 30 participants were selected from this larger sample of 75 law enforcement officers.

An extreme-groups design was used to identify and select the top 15 field independent (n = 15 FI) subjects on the GEFT and the bottom 15 field dependent (n = 15 FD) subjects on the GEFT. This extreme-groups design was used to ensure maximum difference in cognitive style between the two groups. Only the top-scoring field independents (n = 15, with scores ranging from 15 - 18) and the lowest-scoring field dependent subjects (n = 15, with scores ranging from 0 - 5) participated in Phase-2 of the study. The remaining 45 participants (field dependent n = 16, intermediate n = 15, and field independent n = 14) were excluded from the study. The *Group Embedded Figures Test* (GEFT) score distribution of the final sample of 30 are shown in Table 9.

Table 9

Participants' Group Embedded Figure Test (GEFT) Scores

Score	Frequency	%	Cumulative %
0	1	3.3	3.3
1	4	13.3	16.7
3	2	6.7	23.3
4	3	10.0	33.3
5	5	16.7	50.0
15	1	3.3	53.3
16	7	23.3	76.7
17	2	6.7	83.3
18	5	16.7	100.0
Total	30	100.0	

Phase 2

Prior to exposing participants to the virtual crime scene environment (treatment), subjects individually completed a simple non-treatment-related VR training tutorial showing a house environment to ensure they could successfully use the navigational interfaces. Once participants demonstrated they could use the navigational tools and indicated they felt comfortable navigating the virtual environment, the non-treatment VR was closed.

Participants were then informed that they had been assigned to assist Sergeant Cross with processing a crime scene. Their task was to explore the scene on the computer screen and gather enough information to draw a detailed crime scene sketch. Participants were advised that when the VR treatment began, there would be a short video clip in which Sergeant Cross would explain what he wanted them to do. The participants were instructed that after the video ended, the researcher would resize the computer screen and they would enter the virtual crime scene.

After the introduction video ended, the computer screen was resized and the Camtasia software was activated to capture and record all movements made on the screen by the participants. Participants were then told they were now in the virtual crime scene and could explore the crime scene as long as they wanted in order to gather as much information as possible for their detailed crime scene sketch.

Because police officers are trained to take notes in order to document crimes, it was not unreasonable to anticipate that officers, based on their prior experience, might request to take notes while exploring the virtual crime scene. One of the variables in this study was prior experience, therefore, note taking was permitted if participants asked to take notes while exploring the virtual environment. If they took notes, they were instructed that they could not use their notes or view the VR as they drew the crime scene sketch. They were instructed that they would be given 60 seconds to review their notes prior to drawing the sketch. They were advised that the sketch was to be drawn from their memory of the crime scene.

As the opening video ended, the desktop VR treatment opened. Once the screen was resized and Camtasia activated, participants were timed from this point to the end of the session. Separate times were kept for the duration spent in each of the virtual rooms of the treatment. Participants were encouraged to talk aloud as they navigated the virtual crime scene. The Camtasia software was used to capture their comments for later qualitative analysis.

It was initially planned that navigational movements would be recorded by direct observation of the researcher and supported by the Camtasia software. However, within the first few seconds of the first participant, the researcher realized that direct observation and recording of each navigational movement was impossible. The participants moved too fast to record each of their movements. A decision was therefore made by the researcher at this point to make general observations of each participant and to answer navigational questions while Camtasia accurately recorded times, all screen movements, and comments by the participants. After each participant navigated the virtual crime scene, the Camtasia screen capture data were saved under the participant's assigned identification number. Camtasia files for each participant were later analyzed twice, once to obtain navigational movements and a second time to obtain time and node sequence data. Frequency counts of navigational movements were then recorded on an Excel participant observation log (See APPENDIX A).

Each participant was allowed to view the virtual crime scene as long as they wanted. Once they completed viewing the virtual crime scene, they were given writing materials and a ruler and asked to draw a crime scene sketch of the virtual scene. Their actions, comments and questions were closely monitored and documented by the researcher. The participants were timed on how long it took to complete the rough sketch of the virtual crime scene.   After all data had been collected for each participant they were recorded on the participant data form (See APPENDIX C).

Using a rubric created by the researcher, the drawings were scored on a five-point Likert-type scale for accuracy, completeness, and evidentiary detail by three experienced crime scene investigators familiar with the virtual crime scene treatment. An example of the five-point Likert-type scale is shown in APPENDIX B. The three raters scored the sketches independently of one another. Inter-rater reliability tests were performed to assess the degree of agreement between the raters.

Prior to scoring the crime scene sketches, each rater was provided with a copy of the VR treatment, the researcher's crime scene diagram, and copies of the five-point Likert-type scale for guidance in scoring the participant sketches. Raters were instructed in how to operate the VR and familiarized with the scoring instrument. Furthermore, one of the raters helped to create the crime scene depicted in the VR treatment and was thoroughly familiar with the crime scene. A copy of the researcher's sketch is shown in Figure 5.

A. Foot Print 1	F. Body	K. Band-aid wrappers	P. Blood Spatter
B. Foot Print 2	G. Possible Suspect Blood	L. Over turned chair	Q. 90^0 Drops on victim's shirt
C. Bloody Palm	H. Latent Palm Print	M. Cast off spatter	
D. Wet Blood Stain	I. Knife	N. Turned over lamp	
E. Magazine	J. Dry Blood Stain	O. Over turned fruit	

Figure 5. Crime Scene Diagram developed by researcher.

Data Analysis

Inter-Rater Reliability

Accuracy of the crime scene drawing by the participants after using the VR instructional treatment was an important dependent variable in this study. This variable was measured by ratings by three crime scene experts. In using expert ratings, the validity and reliability of the judges' scorings is extremely important. According to Shrock and Coscarelli (1989) "Reliability is a prerequisite for validity. Therefore, if there is no inter-rater reliability, i.e., if the judges are inconsistent, their decisions cannot possibly be valid" (p. 136).

One method for assessing inter-rater reliability is based upon a corrected percentage of agreement figure (kappa or κ). The other method is a correlation coefficient (phi or φ). Both tests yield comparable results and are the same tests used to determine test-retest reliability. In this study, the kappa coefficient was used. Shrock and Coscarelli (1989) argued that "The kappa coefficient (κ) was designed to measure the agreement between two judges" (p. 137). They explained that averaging procedures in the kappa coefficient allow for the calculation of kappa for more than two judges. They recommended more than two judges be used when trying to establish the reliability of performance testing procedures.

Shrock and Coscarelli (1989) explained:

> The calculation of kappa begins by figuring the percentage of test-takers consistently classified by two judges. This number, called the agreement coefficient (p_o), is inflated by chance agreements. In other words, this number will give you a false sense of security in the reliability of your judges. So this percentage of observed agreement (p_o) is corrected for these chance agreements by subtracting the number of agreements that would be expected due to chance alone (p_{chance}). The result of this subtraction is then divided by $1 - p_{chance}$. The result of this subtraction represents the maximum possible improvement over

> chance agreement that the two judges could possibly make; so the result of the division represents the proportion of possible improvement in agreement beyond chance agreement actually achieved by the two judges. In this same way kappa is calculated for each pair of judges that you have. The resulting kappa coefficients are then averaged to determine the kappa coefficient for your entire panel of judges. (p. 137)

In order to determine the kappa coefficient between the original two judges in this study, participant crime scene scores were split into two groups, to accomplish the calculations for this procedure. Subjects who receive rating scores of 4 or 5 were assigned to the expert group, while subjects receiving scores of 1, 2, and 3 were assigned to the novice group. Initially two crime scene experts rated the participant crime scene sketches. However, Shrock and Coscarelli (1989) recommended three or more judges and an averaging procedure for the kappa coefficient when trying to establish the reliability of performance testing procedures. Therefore, a decision was made to solicit a third crime scene expert from a large metropolitan police department to review and score participants' sketches. Having three raters would increase the inter-rater reliability.

Shrock and Coscarelli (1989) asserted that "An average kappa coefficient of .60 is considered a minimum" (p. 143). The higher the kappa coefficient value, the greater the inter-rater reliability. They argued that the kappa coefficient value should be higher as the criticality of the performance test increases.

In this study the averaged kappa (κ) coefficients between the three raters on the three crime scene drawing measures are depicted in Table 10.

Table 10

Averaged Kappa Coefficients for the Three Judges on the Three Drawing Measures

Item	Mean Kappa Coefficient
Accuracy of the floor plan	$\bar{\kappa}_2 = .39$
Quality of details recalled	$\bar{\kappa}_2 = .60$
Completeness of the drawing	$\bar{\kappa}_2 = .70$

While the averaged kappa coefficient for the accuracy of the floor plan was relatively low, indicating less inter-judge reliability on the scores, the quality of details recalled and completeness of the drawing had greater averaged kappa coefficients, which indicated a high level of inter-rater reliability on these items. Based on this result the researcher felt it appropriate to include the crime scene drawing in the findings of this study.

Research Questions Data

Quantitative data in this study were analyzed using SPSS version 18.0 statistical software. Descriptive statistics were used to help describe the observed outcomes and characteristics of subjects. Independent samples t-tests were used to analyze the differences in means of the various individual characteristics, navigation behaviors and configurational/survey knowledge scores. One way analysis of variance was used to determine the statistical significance of interactions between the multiple group variables of age range, education levels, and years of law enforcement experience. Qualitative data derived from observation notes, participant crime scene sketches, transcripts of participants' comments, and participant questions recorded during the Camtasia sessions were analyzed using content analysis techniques. Peer checks were used to verify themes identified in the content analysis. Quantitative and qualitative data were analyzed separately then merged during the interpretation and analysis phase of this study.

The research questions for this study were:

1. Are there general patterns in how police officers navigate in a virtual crime scene?

2. Is there a difference in the way field dependent and field independent police officers navigate the virtual crime scene?

3. Is there a difference in configurational knowledge proficiency between field independent and field dependent officers?

4. Is there a difference in the way individuals with differing prior experience or knowledge navigate a virtual crime scene?

5. Is there a difference in configural knowledge acquisition from a virtual crime scene among individuals with differing experience?

6. Is there a difference in how male and female police officers navigate a virtual crime scene environment?

7. Is there a difference in configurational knowledge acquisition between male and female officers?

8. Is there a difference in the way law enforcement officers interact with the virtual crime scene and a real world crime scene?

This mixed method study used a triangulation convergence design in which multi-levels of quantitative and qualitative data sets were gathered concurrently, assigned equal weight and then merged during interpretation and analysis (Creswell & Plano Clark, 2007, p. 85).

Table 11 shows the research questions, the data sources used, and the type of analysis performed for each question.

Table 11

Research Questions, Data Sources, and Data Analysis

Research Questions	Data Source	Analysis
1, 2, 4, 5, 6, 7, 8	Observed navigational behaviors. Cognitive Styles, years of experience and gender data obtained from participant data sheet.	Descriptive statistics; independent samples t-tests and One-way ANOVA
3, 5, 7	Scores on crime scene sketch	Independent samples t-tests and One-way ANOVA
1, 2, 4, 5, 6, 7, 8	Comments of subjects captured by observation and Camtasia software	Content analysis

CHAPTER IV

Findings

Research Question 1:
Are There General Patterns in how Police Officers Navigate in a Virtual Crime Scene?

General Navigation Behaviors

Research literature has reported individual differences in navigation behaviors in both virtual and real world environments. This study supports previous findings that individuals do indeed navigate differently. The general navigation behaviors for this study were derived from direct observation by the researcher, analysis of the observation logs and analysis of the Camtasia video file for each participant. In this research study, no two participants' navigational behaviors in the virtual crime scene were exactly alike. They moved in different directions and at different speeds. Some participants moved extremely fast through the virtual crime scene, while others were slower, took more time, and appeared more methodical in their exploration of the virtual crime scene. Some of the participants scanned up, down, and zoomed in and out more often while others appeared to scan the rooms at one level. Many of the participants traveled through the scene to get an overview of the environment. On their second walk-through they tended to slow down and scan mid-level, then low and high. Most participants viewed each clickable hotspot, while two subjects completely missed hotspots in the bathroom (nodes 6a-6f). Each participant explored the virtual environment at his or her own pace.

Participants' exploration times were all different and ranged from 6 minutes and 10 seconds (370 seconds) to 61 minutes and 8 seconds (3,668 seconds).

Disorientation Experiences and Behaviors

Another aspect of navigation in VEs discussed in the literature is disorientation by some individuals. Virtual reality research literature has often reported examples of participants becoming disoriented or lost in the virtual environment. This study found evidence of disorientation. Through observations and statements of participants as they navigated the virtual crime scene as well as analysis of their post-treatment crime scene sketches, incidents of disorientation were discovered in half (n = 15) of the participants in this study. Disorientation or spatial confusion was exhibited in some participants' individual navigational behaviors. In some cases participants quickly jumped from node to node repeatedly, spending only a second or two in each node. Some became confused and frustrated at some points in the virtual crime scene. For example Subject 1 (male, 51+ years of age, field dependent) stated, "I got frustrated. I kept revisiting the same things. I'm not techno savvy." Subject 53 (male, 46 – 50 years old, field independent) appeared disoriented when he entered the bathroom hall (node 6). This node seemed to confuse the subject; he physically pulled back and looked puzzled. Subject 53 advised the researcher that he thought the hotspot was where he jumped to, to look down the hall. He did not realize that the hotspot transported him to the far end of the hallway facing back the way he came. This hotspot was similar to the hotspot in the living room scene (node 4). Subject 53 had difficulty with this location in the virtual environment. His disorientation was also reflected in his sketch of the crime scene. In this participant's drawing, the bathroom was positioned on the opposite side of the hallway.

Eleven participants experienced similar problems with this location in the virtual crime scene. It is possible that this disorientation may have been caused by a flaw in the design of this portion of the VE. On the other hand, there is also a possibility that these subjects experienced spatial visualization difficulty, specifically the ability to mentally rotate visual images as suggested by Waller (2000).

Another area where some participants became confused or disoriented was in node 6A. This node contained an object movie of a knife positioned vertically on a turntable which enabled participants to rotate the knife 360 degrees, to observe all sides of the weapon. Six participants became confused when they viewed the knife object movie. Clarification had to be given to explain the purpose of the knife object movie and how to rotate it. The researcher believes that because the knife was mounted vertically in the object movie instead of its original horizontal position on the bathroom counter as observed in node 6B, some participants became confused. Subjects 57 (male, 41 – 45 years old, field dependent), 61 (male, 26 – 30 years of age, field independent), and 64 (male, 36 – 40 years old, field independent) asked if it was the same knife that they saw on the bathroom counter. Subject 16 (male, 26 – 30 years old, field dependent) just stared at the knife until explanation was given as to what it was and how to rotate it.

Summary

Overall, these findings support the view of variations in navigational behaviors and experiences in a virtual environment as individualistic and related primarily to individual differences and preferences of users. No generalizable patterns of navigation behaviors were observed for the police officers who participated in the study.

Research Question 2:
Is There a Difference in the Way Field Dependent and Field Independent Police Officers Navigate the Virtual Crime Scene?

Navigational Behaviors

The level of significance for this study was set at $p = .05$. Possible trends were defined as $.09 \leq p > .05$. For all *t*-tests, Levenes test for homogeneity of variances was performed to determine whether pooled or unpooled variance should be used. An independent samples *t*-test with equal variances assumed based on a non-significant Levene's Test was used to measure the difference in means of each navigation variable between the cognitive style dimensions of field dependence and field independence. Navigational variables tested were:

- The total time in the treatment,
- Time spent in each node or scene,
- The sequence or order in which the nodes were navigated,
- The changes in perspective (number of times the subject scrolled up or down and zoomed in or out),
- The total number of mouse/cursor movements (direction, speed, continuous or panning vs. jumping movements),
- The number of returns (the number of times a subject revisited or navigated the same node), and
- The total number of nodes visited.

There were no significant differences in the navigational behaviors of the field dependent and field independent groups regarding the total number of mouse clicks, panning, left, right, or perspective changing movements up, down, zooming in, and zooming out. There was no significant difference in the number of nodes accessed or revisited more than three times.

However, significant differences were found between the cognitive style groups in time spent exploring node 5 (kitchen) and node 6E (bathroom-fingerprint processing movie). Trends were also found for the time spent in nodes 4A (DNA collection movie) and for 6C (bathroom - dry blood collection movie). In node 5 (the kitchen scene), field dependent subjects spent a greater time exploring than the field independent subjects as shown in Table 12 (t = 2.157; df = 28; p = .040). The researcher observed that field dependent subjects tended to jump back and forth between node 5 (the kitchen), node 2A (bloody foot print in the entry) and node 6A (the knife object movie). It is proposed that this movement was related to the field dependent cognitive style dimension. Research literature supports the global nature of field dependents in their quest to understand relationships. They tend to gather information from multiple sources before they make a decision. In this study the field dependents, while in node 5, tended to focus on the kitchen knife holder on the counter top and on the victim's shoes. It appears that the field dependents may have been looking for a possible relationship between the victim's shoes and the bloody foot print in the entry; and/or between the missing knife from the kitchen and the knife found in the bathroom. The extended time in the kitchen node (node 5) produced by shifting back and forth from node to node in these instances appeared to be for comparison purposes, which would be consistent with the field dependent tendency to seek relationships.

Table 12

Node 5 Exploration Time in Seconds by Cognitive Style

Cognitive Style Group	*M*	*SD*	*N*	*df*	*t*	Sig. (2-tailed)
Field Dependent	251.47	140.239	15	28	2.157	.040
Field Independent	159.90	87.533	15			

Field independent subjects, on the other hand, spent a significantly greater amount of time in node 6E (bathroom-fingerprint processing movie) than field dependents (t = -2.188; *df* = 28; p = .037). Table 13 show the statistical details for the node 6E exploration time by cognitive style group.

Table 13

Node 6E Exploration Time in Seconds by Cognitive Style Group

Cognitive Style Group	*M*	*SD*	*N*	*df*	*t*	Sig. (2-tailed)
Field Dependent	179.07	96.411	15	28	-2.188	.037
Field Independent	233.53	.743	15			

Trends that fell short of statistical significance but that were strong enough to merit further investigation were also found in favor of field independents regarding the time they spent in nodes 4A (DNA collection movie) and 6C (bathroom - dry blood collection movie). Statistical data for these trends are shown in Table 14. In node 4A, field independents spent a greater time in this node than field dependent subjects (t = -1.909; *df* =28; p = .067). Similarly, in node 6C, field independents spent more time exploring this node than their field dependent counterparts (t = -1.907; df = 28; p = .067).

A possible reason the field independent subjects spent more time in nodes 4A, 6C, and 6E may be related to the content of these nodes. All three were movie nodes that presented complex procedures. Each of these nodes contained very detail-oriented step-by-step instructions on the evidence collection process. Literature has reported that field independent individuals tend to be very linear, analytical and detail oriented when processing information. More time may have been spent in these nodes by field independents in order to fully process the details of the sequences of evidence collection steps.

Table 14

Exploration Time in Seconds by Cognitive Style Group

Cognitive Style Group	*M*	*SD*	*N*	*df*	*t*	Sig (2-tailed)
Node 4A						
Field Dependent	90.47	37.667	15	28	-1.909	.067
Field Independent	113.40	27.312 15	15			
Node 6C						
Field Dependent	76.00	51.356	15	28	-1.907	.067
Field Independent	105.07	29.090	15			

Participants' Comments Patterns

Qualitative data obtained through content analysis of observation notes, interviews, and Camtasia audio files and verified by peer review revealed seven general threads evolving from comments made by participants during or after their experience with the virtual crime scene. Transcripts of the Camtasia files and the researcher's observation notes were analyzed, and the following comment threads surfaced from the qualitative data: (1) task clarification; (2) navigational questions or comments; (3) orienting questions or comments; (4) confusion or disorientation; (5) small talk; (6) acute observations; and (7) analysis of evidence.

In the *task clarification category*, participants generally asked questions or made statements regarding the exploration and drawing tasks. They also asked about any time constraints in performing these tasks. *Navigational questions or comments* dealt with how to move through the virtual environment or take closer looks at evidentiary items. *Orienting questions or comments* revolved around what direction were they looking at or where specific rooms or items were located in relation to the participant's position within the virtual environment. *Statements of confusion, frustration, or disorientation* generally involved navigational issues or questions about evidentiary items. Incidents of *small talk* involved participants attempting to engage the researcher in conversations about the residence, furnishings, who the victim was, and who created the virtual crime scene. *Acute observations* consisted of participants pointing out discrepancies contained in the VE, such as different colored flowers hanging on the front door, or why the scene contained both wet and dry blood evidence in different rooms. *Analysis of evidence comments* consisted of participants describing evidentiary items, how they related to the scene, and explanation as to what may have occurred based on the evidence observed. A comparison of frequency of the comment threads by field dependent and field independent participants is shown in Figure 6.

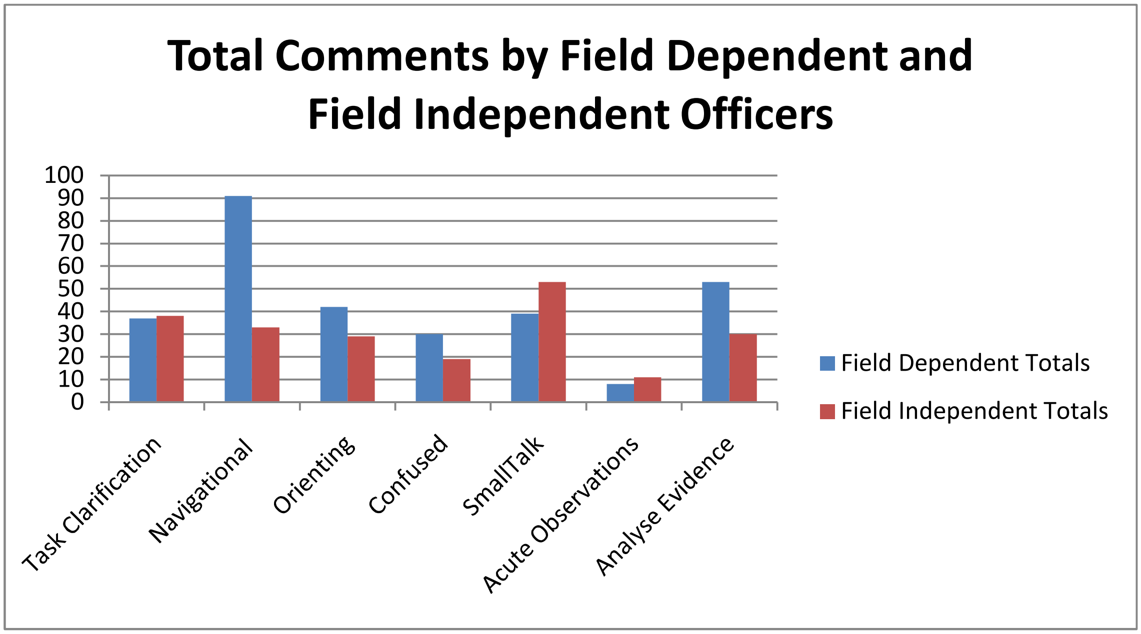

Figure 6. Frequency of comment types by field dependent and field independent officers.

As shown in Figure 6, field dependent officers tended to make more navigational and orienting questions or statements than field independent officers. This appears to indicate field dependents experienced greater navigation difficulties. Field dependent officers also indicated they were confused or disoriented more frequently than field independent officers. This disorientation was also supported by a decrease in small talk and acute observations made by field dependent participants. Field dependents may have spent less time talking because they were more pre-occupied with trying to navigate the virtual crime scene. Field dependents also tended to talk more about the evidence they observed and how it related to the scene. They tended to analyze the evidence in greater detail and provide possible explanations as to how the crime occurred based on the evidence they observed. This may relate to the tendency of field dependents to seek relationships in what they see and experience.

Research Question 3:
Is There a Difference in Configurational Knowledge Proficiency Between Field Independent and Field Dependent Officers?

Accuracy, Quality, and Completeness of Learning Product

In this study no significant statistical differences were found in the acquired configurational or survey knowledge proficiency between field independent and field dependent officers after experiencing the virtual crime scene. The cognitive style dimension of field dependence and field independence used in this study did not appear to have a significant impact on what the participants learned from the virtual environment as evidenced by their crime scene sketch sum (Σ) scores. Crime scene sketch Σscore for each participant was created by adding each of the three expert rater's scores on each of the three assessment items (floor plan accuracy, quality and location of evidentiary detail, and overall completeness of the crime scene sketch). Statistical data for this analysis are shown in Table 15. This result indicated that despite individual differences in navigational behaviors and disorientation, both field dependent and field independent participants were able to acquire from the virtual environment the configurational/survey knowledge needed for successful completion of the crime scene sketch task.

Table 15

Crime Scene Sketch Σscore by Cognitive Style Group

Cognitive Style Group	*M*	*SD*	*N*	*df*	*t*	Sig (2-tailed)
Field Dependent	27.80	11.583	15	28	-1.083	.288
Field Independent	32.07	9.932	15			

Qualitative Nature of the Learning Product

While quantitative learning performance differences were not observed between crime scene sketches of field dependent and field independent police officers, qualitative differences in the nature of their sketches were observed. These differences fit the theory base of this dimension of cognitive style. Witkin (1967) proposed that cognitive development was related to physical identity and stated that:

> Persons with an articulated cognitive style are likely to give evidence of an articulated body concept and a developed sense of separate identity…. An articulated cognitive style, an articulated body concept, and a sense of separate 'identity' are all taken as indicators of developed differentiation. (p. 235)

When viewing the sketches of the participants with the articulation-of-body concept in mind, cognitive style differences were observed. Articulated or field independent participants tended to be more detailed in their sketching. They attempted to draw the victim's body and appendages proportionally and accurate visually rather than as stick figures. Field independents also in several cases drew long hair on the female victim and cushions on the chairs and couch, suggesting an attempt to reproduce what they had observed in the visual field. An example of a field independent sketch is shown in Figure 7.

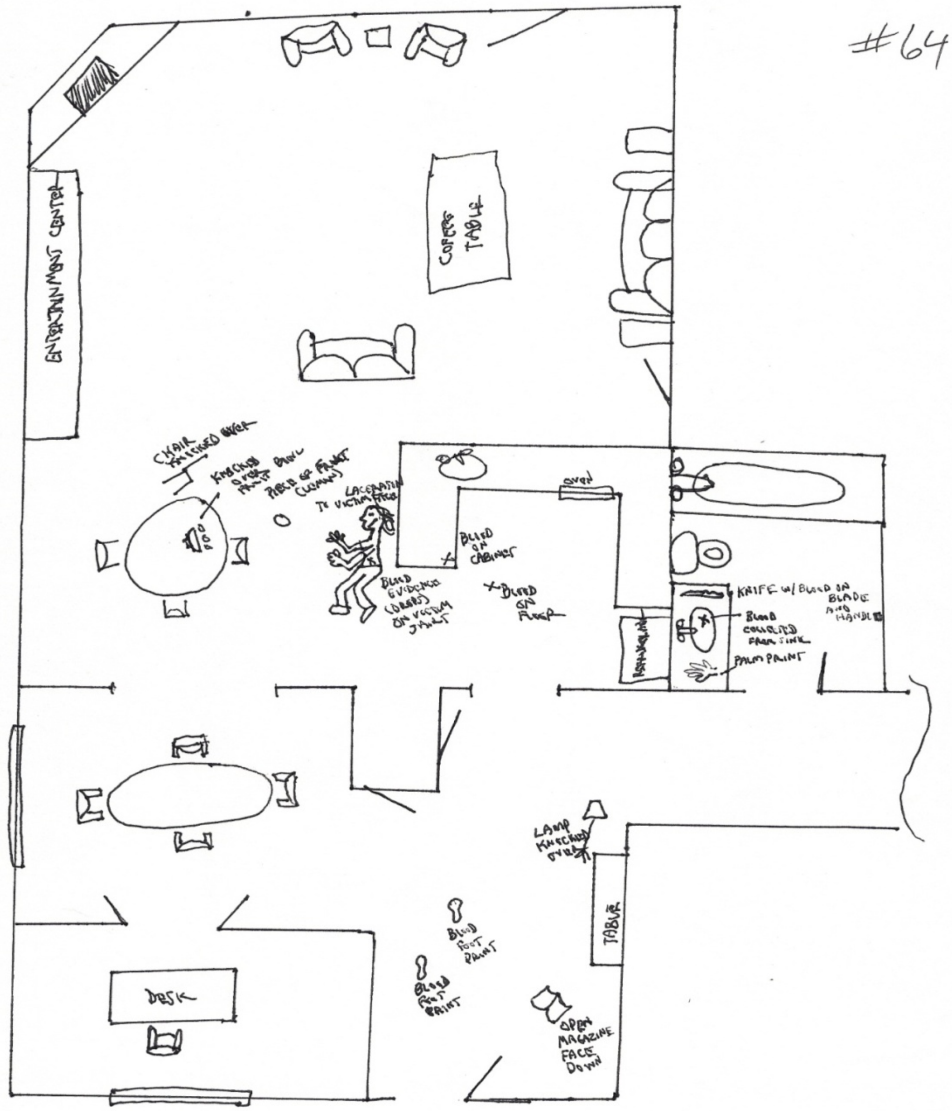

Figure 7. Crime scene sketch drawn by a field independent participant.

In Figure 7, the victim's body was drawn with fingers, hair, nose, eyes, a shirt, pants and shoes. Faucets and knobs were drawn on the sinks and bathtub. Chairs were drawn with arms and cushions rather than rectangles. The knife in the bathroom was drawn with a handle and in the approximate location in which it appeared in the virtual crime scene. In contrast, Figure 8 depicts a crime scene sketch drawn by a field dependent participant.

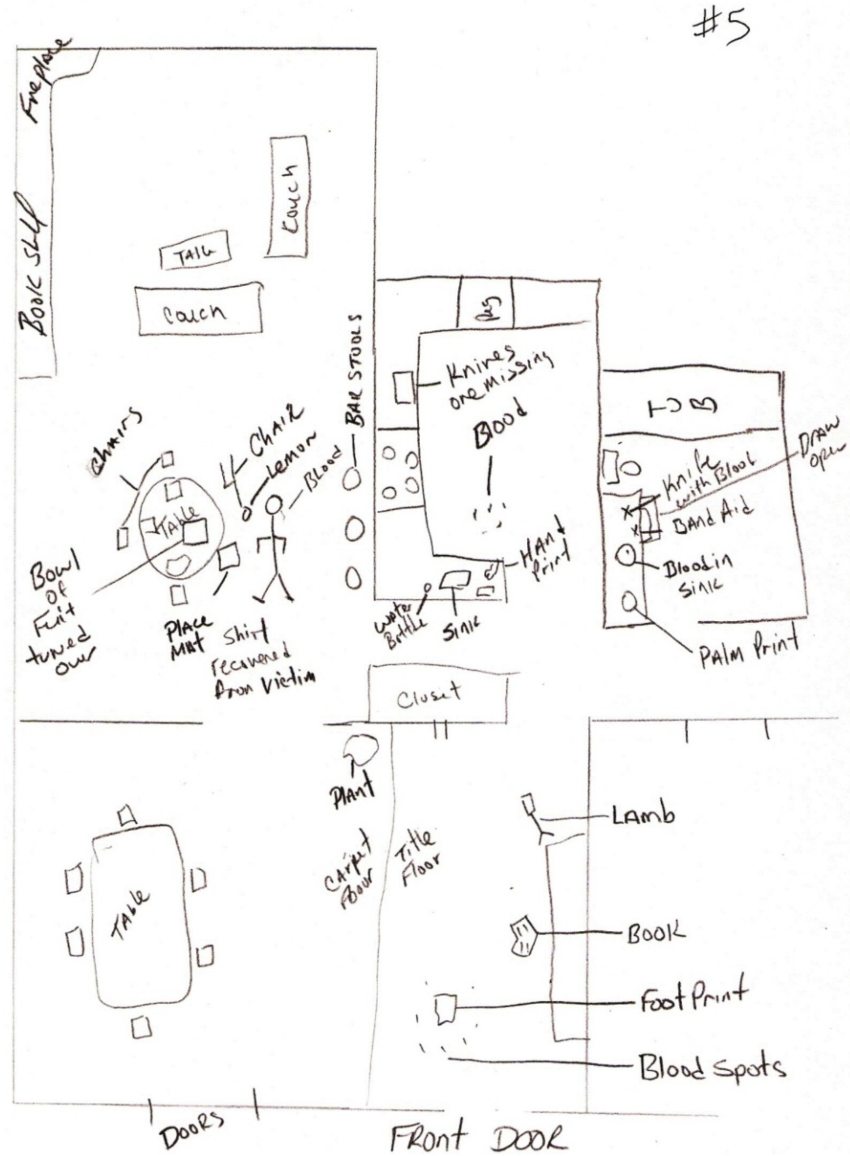

Figure 8. Crime scene sketch drawn by a field dependent participant.

In Figure 8, the victim was drawn as a stick figure. Objects such as tables, chairs and evidentiary items were depicted simply as oval or rectangular shapes. No attempt was made to reproduce the actual visual details presented in the virtual crime scene; the learner was satisfied with simple geometric representations showing placement only.

Disorientation

Analysis of the crime scene sketches drawn by the 30 participants in this study showed that 15 participants exhibited indications of disorientation. Eleven of the 15 participants drew the bathroom on the wrong side of the hallway. Two participants omitted the bathroom altogether from their drawing. To understand why the bathroom was left out of these drawings, review of observation notes and Camtasia files for these two subjects was conducted. It was found that both of these subjects jumped from node 2 (front entry), node 5 (the kitchen), and node 6 (the bathroom) numerous times without panning left or right. They appeared lost, confused or disoriented as they tried to find their way through the crime scene. Both participants completely missed the six hotspots located in the bathroom. This may explain why the bathroom was omitted entirely from their sketches.

Two participants appeared to have gotten disoriented in node 4 (the living room). Participants could access the living room (node 4) from the dining room (node 3) or from the kitchen (node 5). When participants clicked on the node 4 hotspot they were transported into the living room looking back in the direction they had been (kitchen or dining room). From the vantage point in node 4, participants could rotate their view 360 degrees. Their sketches portrayed the kitchen, breakfast nook with the victim's body, and the living room in reverse order of the actual floor plan. The living room node was similar to the bathroom node in portraying a view of the scene.

As previously stated, 11 participants in this study became disoriented when they moved to the bathroom (node 6) from either the entry (node 2) or the kitchen (node 5). Node 6 transported subjects to the far end of the hallway and had them facing the direction they were previously at. This required participants to mentally rotate their mental image of the scene 180 degrees. From this viewpoint, the bathroom was on the right as one faced east. Those who were not able to perform this mental rotation became disoriented. This may indicate an unnecessary complication introduced by a weakness in the navigation design of the virtual crime scene. The disorientation problem was further revealed in the crime scene drawings of the confused subjects. Figure 9 is an example of a sketch from a disoriented field dependent subject.

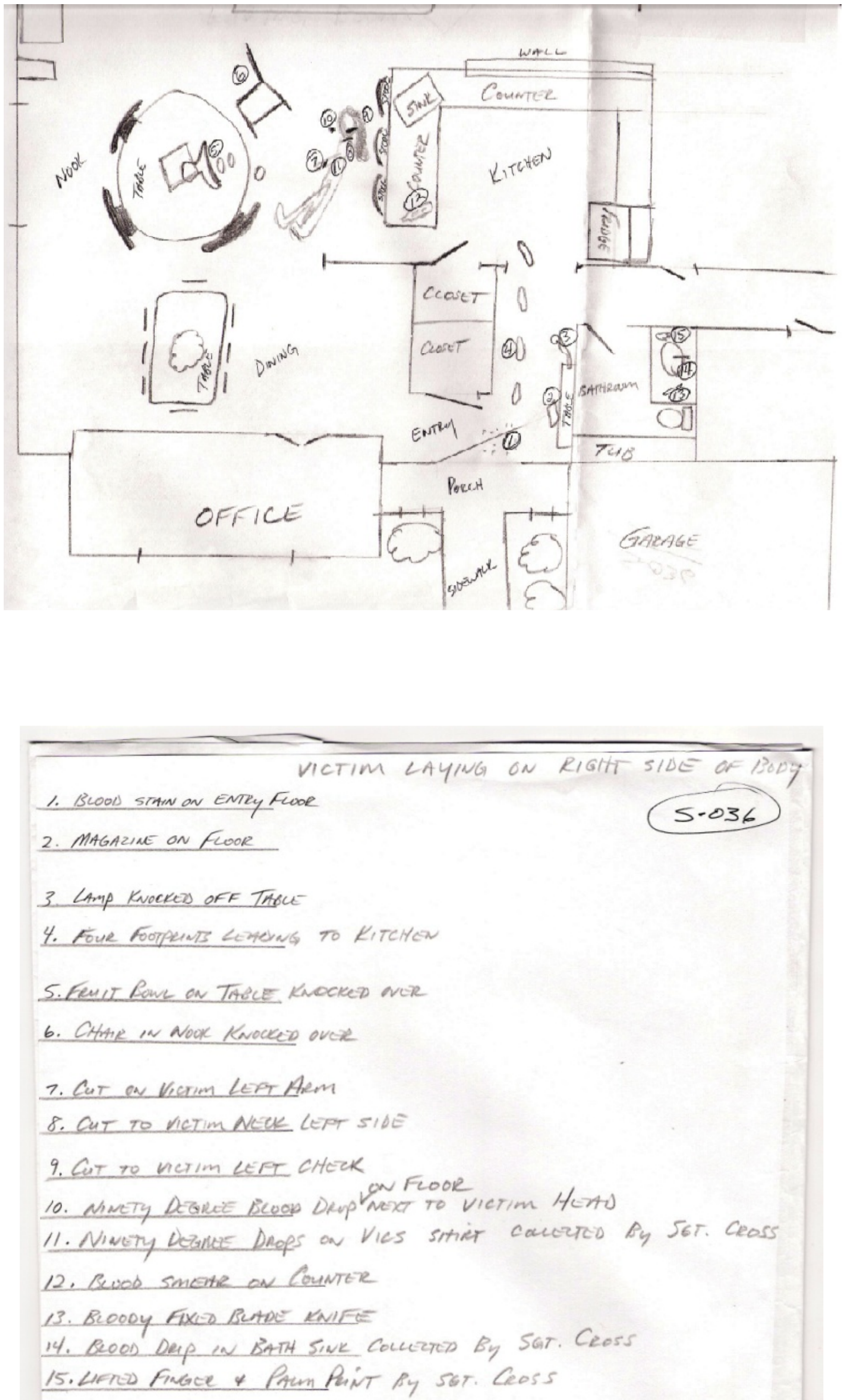

Figure 9. Crime scene sketch by a disoriented participant.

Figure 9 depicts a typical sketch drawn by a participant who experienced disorientation. On closer examination of the 15 sketches that displayed disorientation, 12 or 80 percent were drawn by field dependent subjects. Only three of the 15 were drawn by field independent participants. The majority of field dependents (12 out of 15) experienced disorientation and appeared to have had more difficulty assimilating the complex visual information from the desktop virtual crime scene environment. This disorientation or confusion was also supported by the Camtasia transcripts of the comments made by field dependent officers. Conversely, field independents appeared to have the ability to separate and extract the visual information contained in each node then accurately reassemble it in their drawings of the crime scene.

In examining disorientation depicted in the crime scene sketches and gender, it was found that 13 participants were male and 2 were female. However, the small number of females in the study (n = 4) because of the gendered nature of the policing occupation made this count meaningless. Disorientation affected participants from all three age groups. Four (26.6%) of these participants were between 21-35 years old; seven or (46.6%) were between 36 and 45 years old; and four (26.6%) were between 46 and 51 or more years old. Disorientation was also found in each of the three law enforcement experience groups. Four disoriented participants (26.6%) had between 1 to 10 years of prior law enforcement experience. Seven (46.6%) were between 11 and 20 years of prior law enforcement experience and four (26.6%) had between 21 to 30 or more years of prior law enforcement experience. These findings suggest that disorientation in the virtual crime scene was more strongly related to field dependent/field independent cognitive style than to other learner characteristics included in this study.

Research Question 4:
Is There a Difference in the Way Individuals with Differing Prior Experience or Knowledge Navigate a Virtual Crime Scene?

In examining prior knowledge or experience, there are several factors to consider which can contribute to the collective knowledge an individual has acquired. Individual differences in age, education level, computer experience, years of law enforcement experience, and investigative experiences all contribute to one's prior knowledge. Data on these variables were gathered and examined quantitatively. Multiple groups of law enforcement experience, age, and education levels were each collapsed into three separate groups for analysis. The seven levels of law enforcement experience gathered from the participant surveys were collapsed into group 1 (officers with 1 to 10 years of experience); group 2 (officers with 11 to 20 years law enforcement experience); and group 3 (officers with 21 or more years of law enforcement experience). The seven age categories on the survey were collapsed into group 1 (officers with ages ranging from 21 to 35); group 2 (officers with ages ranging from 36 to 45); and group 3 (officers with ages ranging from 46 to 51 or more). The six surveyed education levels were collapsed into group 1 (officers with high school or some college); group 2 (officers with an Associate or Baccalaureate degree); and group 3 (officers with a masters or higher degree).

One-way analyses of variance (ANOVAs) with test of homogeneity of variance were used to compare means of groups on the study's dependent variables for the independent variables of law enforcement experience, age, and education level. Independent samples *t*-tests were used to compare group means on the dependent variable for the independent variable of detective experience and computer experience. Each of these variables had only two groups of YES and NO.

Years of Prior Experience

Prior knowledge defined as years of law enforcement experience and how it might influence navigational patterns in a virtual environment was analyzed with one-way ANOVAs to compare group means on each navigational and time dependent variable. Years of law enforcement experience of the sample was collapsed into the following three experience groups:

1. Officers with 1 – 10 years law enforcement experience (n = 12),
2. Officers with 11 – 20 years of experience (n = 14), and
3. Officers with 21 – 30 or more years of experience (n = 4).

A one-way ANOVA was used to compare the means of each of the dependent variables across the three experience groups. The level of significance was set at p = .05 and possible trends were set at $.09 \leq p > .05$. No significant differences in navigational behaviors were found based on years of law enforcement experience.

However, when the time (in seconds) spent in each node was examined by one-way ANOVAs, three significant differences and one trend were found. ANOVA revealed significant differences in the amount of time the most experienced officers (21 – 30 or more years of law enforcement experience) spent exploring three specific nodes (node 5-kitchen scene, node 5B-bloody palm print on kitchen countertop and node 6F-bathroom still photograph). Statistical data for these one-way ANOVAs are shown in Table 16.

Table 16

Prior Law Enforcement Experience and Node Exploration Time in Seconds

Years of L.E. Experience	*N*	*M*	SD	Levene's Statistic	*df*	Sig. for Levene's	Between Groups *F*	*p*
Node 4B (Photo of victim's injuries)								
1 – 10 years	12	23.33	28.211	22.455	2, 27	.000	2.690	.086[T]
11 – 20 years	14	28.57	19.740					
21 – 30+ years	4	112.50	197.309					
Node 5 (Kitchen)								
1 – 10 years	12	144.00	80.599	1.723	2, 27	.198	4.971	.015[S]
11 – 20 years	14	219.79	130.888					
21 – 30+ years	4	339.50	103.178					
Node 5B (Bloody palm print on kitchen counter)								
1 – 10 years	12	23.33	27.231	.358	2, 27	.703	3.362	.050[S]
11 – 20 years	14	28.64	16.653					
21 – 30+ years	4	56.00	21.103					
Node 6F (Bathroom still photo)								
1 – 10 years	12	25.92	16.076	23.074	2, 27	.000	5.032	.014[S]
11 – 20 years	14	28.36	16.355					
21 – 30+ years	4	112.25	142.605					

[S] Statistically Significant at $p \leq .05$
[T] Trend at $.09 \leq p > .05$

In node 5 (kitchen), the ANOVA showed a significant difference among the experience groups in time spent exploring ($F = 4.971$; $df = 2, 27$; $p = .015$). The test of homogeneity of variances was not significant (*Levene statistic* = 1.723; $df = 2, 27$; $p = .198$). Post hoc Tukey tests using harmonic means for unequal groups identified a significant difference between officers with 21 – 30 or more years of law enforcement experience and those with 1 – 10 years of experience ($p = .013$), with the more experienced officers exploring longer. No significant differences were found between officers with 1 – 10 years and the 11 – 20 years of law enforcement experience groups ($p = .205$) or between the 11 – 20 and the 21 – 30 or more year of experience groups ($p = .152$).

A similar difference in favor of the most experienced officers was found in node 5B (bloody palm print on kitchen countertop) ($F = 3.362$; $df = 2, 27$; $p = .050$). The test of homogeneity of variances was not significant (*Levene statistic* = .358; $df = 2, 27$; $p = .703$). Post hoc Tukey tests using harmonic means for unequal groups identified a significant difference in exploration time between the 21 – 30 or more year group and the 1 – 10 year experience group ($p = .041$), but not between the 21 – 30 or more year group and the 11 – 20 years of experience group ($p = .091$) or between the 11 – 20 year group and the 1 – 10 year group ($p = .814$).

Police officers with 21 – 30 or more years experience spent a greater time in node 6F (bathroom scene) than both less-experienced groups ($F = 5.032$; $df = 2, 27$; $p = .014$). The test of homogeneity of variances was significant (*Levene statistic* = 23.074; $df = 2, 27$; $p = .000$). Post hoc Tukey tests using harmonic means for unequal groups identified significant time differences in favor of more experienced officers. Significant time differences were found between the 21 – 30 or more years and the 1 – 10 years experience groups (*p* = .016) and between the 21 – 30 year group and the 11 – 20 year group (*p* = .017), but not between the 1 – 10 year and the 11 – 20 year groups (*p* = .992).

A trend was also found in favor of the more experienced officers (21 – 30 or more years of experience) on node 4B (an embedded photograph of the victim's injuries). The more experienced officers spent much more time in node 4B (photo of victim's injuries) than the other two experience groups (*F* = 2.690; *df* = 2, 27; *p* = .086). The test of homogeneity of variances was also significant (*Levene statistic* = 22.455; *df* = 2, 27; *p* = .000). Post hoc Tukey tests using harmonic means for unequal groups revealed a trend in the exploration time between the more experienced officers (21 – 30 or more years of experience) and the 1 – 10 years experience group (p = .086), but no significant differences were found between the 1 – 10 years of experience and the 11 – 20 year experience groups (p = .980) or the 11 – 20 years experience and the 21 – 30 or more years experience group (p = .103).

Because of the small number of the most experienced officers (*n* = 4) in this sample, caution must be used in interpreting the results. Additional research using a larger sample should be conducted. In this study, the more experienced officers tended to take significantly more time to examine the evidentiary details of the kitchen, the bloody palm print on the kitchen countertop, the bathroom, and the victim's injuries than the other two experience groups. Key items of evidence were located within these particular nodes. It is possible that the older officers' greater level of experience may have influenced their attention to details and time taken to analyze the evidence contained in these nodes.

Age

One-way ANOVAs did not reveal any significant differences in navigational behavior among the three age groups. However, in regards to time spent in each node, ANOVAs identified significant differences on node 5 (kitchen scene) and node 6E (fingerprint collection movie) and a trend on node 6F (bathroom still photo). Statistical data for these ANOVAs are shown in Table 17.

Table 17

Age *and Node Exploration Time in Seconds*

Age	*N*	*M*	*SD.*	Levene's Statistic	*df*	Sig.of Levene's	Between Groups *F*	*p*
Node 5 (Kitchen)								
21 – 35 years	12	151.92	70.365	2.225	2, 27	.128	7.970	.002[S]
36 – 45 years	12	186.25	128.863					
46 – 51+ years	6	350.83	93.187					
Node 6E (Fingerprint collection movie)								
21 – 35 years	12	233.58	.793	44.628	2, 27	.000	44.628	.031[S]
36 – 45 years	12	164.75	103.488					
46 – 51+ years	6	234.83	2.787					
Node 6F (Bathroom still photo)								
21 – 35 years	12	29.75	14.277	8.605	2, 27	.001	2.650	.089[T]
36 – 45 years	12	25.00	18.911					
46 – 51+ years	6	83.33	119.234					

[S] Significant at $p \geq .05$
[T] Trend at $.09 \leq p > .05$

Older officers (46 – 51 or more years old) spent significantly more time exploring node 5 (kitchen) than the youngest group (21 – 35 years old) or the middle group (36 – 45 years old). The F ratio for this ANOVA test was significant beyond the .05 level chosen for this study ($F = 7.970$; $df = 2, 27$; $p = .002$). Post hoc Tukey tests using harmonic means for unequal groups identified significant time score differences between both the 46 – 51 or more year olds and the 21 – 35 year olds ($p = .002$) and between the 46 – 51 or more year olds and the 36 – 45 year olds ($p = .009$), but not between the 21 – 35 and the 36 – 45 year olds ($p = .715$).

The older police officers (46 – 51 or more year of age) also spent a significantly greater amount of time in node 6E (fingerprint collection movie) than the 36 – 45 year old officers, but not significantly more time than the youngest group (21 – 35 year olds). The test of homogeneity of variances was significant (*Levene statistic* = 44.628; df =2, 27; $p = .000$). One-way ANOVA revealed significant differences between groups ($F = 3.956$; $df = 2$; $p = .031$). Post hoc Tukey tests using harmonic means for unequal groups identified significant time differences between the 21 – 35 year old officers and the 36 – 45 year old officers ($p = .043$), but not between the 21 – 35 year old and the 46 – 51 or more year olds ($p = .999$). No significant difference was found between 46 – 51 or more year olds and the 36 – 45 year olds ($p = .125$).

A trend favoring the older officers (46 – 51 or more years old) was found in the exploration time of node 6F (bathroom still photo). Older officers spent more time in node 6F (bathroom still) than the other two age groups ($F = 2.650$; $df = 2, 27$; $p = .089$). The test of homogeneity of variances was also significant (*Levene statistic* = 8.605; df = 2, 27; $p = .001$). Post hoc Tukey tests using harmonic means for unequal groups revealed a trend in the exploration time between the older officers (46 – 51 or more years of age) and the middle age group (36 – 45 years old) ($p = .093$), but no significant differences were found between the older officers (46 -51 or more years) and the youngest officers (21 – 35 years old) ($p = .131$) or between the youngest officers (21 – 35 years old) and the middle age group (36 – 45 years of age) ($p = .974$).

The observed age group differences may be related to years of experience. However, because of the small number of older officers ($n = 6$) in this study, caution must be used in interpreting the statistical data. Further research using a larger sample is needed to validate these findings.

Education Level

Education level was eliminated as a variable for analysis in this study because the sample was too homogeneous to make an ANOVA analysis meaningful.

Detective Experience

Eighteen or 60% of the participants in this study had detective experience while 12 or 40% did not. Independent samples t-tests were conducted to see if detective experience had an influence on navigational behaviors, time spent in each node, the number of nodes accessed, the number of nodes revisited, and crime scene sketch Σscores. No significant differences were found for any of these variables between officers who had or did not have detective experience.

Computer Experience

The data revealed that this sample was fairly homogeneous in regards to computer experience in word processing, Internet use, computer programming experience and self assessed computer skill level. Computer gaming experience was the only variable on which the participants differed. Therefore it was the only computer experience variable examined for this study.

Independent samples t-tests were performed to assess the significance of any differences found on the navigational variables between officers with and without self-reported computer gaming experience. Levene's Test for Equality of Variances was performed to determine whether equal variance between groups was assumed or not assumed. The level of significance for the t-tests was set at $p = .05$, while possible trends were identified at $.09 \leq p > .05$. No significant differences between the groups were found for the navigational variables. Only one trend approaching significance was found regarding the time spent in node 4A (Movie clip on blood stains collected from victim's shirt). Participants with prior computer gaming experience spent a greater time watching this video clip. Table 18 shows statistical data on time spent in node 4A by computer gaming experience.

Table 18

Computer Gaming Experience

Computer Gaming Experience	*N*	*M*	SD	Levene's Test for Equality of Variance *F*	Sig.	*t*	*df*	Sig. (2-tailed)
Time spent in Node 4A (Movie clip on blood stains)								
Yes	18	112.67	24.864	4.800	.037	2.029	16.398	.059*
No	12	85.83	41.074					

* Equal variance not assumed (Pooled variances used)

Research Question 5:
Is There a Difference in Configural Knowledge Acquisition From a Virtual Crime Scene Among Individuals with Differing Experience?

Years of Prior Experience

This study found a significant difference in crime scene sketch Σscores in favor of officers with 20 or fewer years of law enforcement experience. Table 19 provides descriptive data on participants' years of experience groups and mean scores.

Table 19

Years of Prior Experience and Mean Crime Scene Sketch ΣScores

Prior Experience	*N*	*M* *ΣScore*
1 – 10 years	12	30.33
11 – 20 years	14	33.14
21 – 30+ years	4	17.50

One-way ANOVA revealed the significant difference between experience groups. The overall *F* ratio for this test was significant beyond the .05 level chosen for this study ($F = 3.922$; $df = 2, 27$; $p = .032$). Post hoc Tukey tests using harmonic means for unequal groups identified significant score differences between the 11 – 20 year and the 21 – 30 or more years of experience group ($p = .025$). A trend was found between the 1 – 10 year experience group and the 21 – 30 or more years of experience group ($p = .080$). However, no significant difference was found between the 1 – 10 and the 11 – 20 year experience groups (p = .752).

Due to the small number ($n = 4$) of the most experienced officers, caution should be used in interpreting the results of this ANOVA test. Further research using a larger sample is needed.

Age

One-way ANOVAs did not reveal any significant differences in crime scene sketch Σscores by age group.

Detective Experience and Computer Gaming Experience

Independent samples t-tests were run to compare the crime scene sketch Σscores for officers with and without detective experience, and also with and without computer gaming experience. There were no significant differences in scores based on prior detective experience. However, there were significant differences in crime scene sketch Σscores in favor of those with prior computer gaming experience. Table 20 shows the statistical data for crime scene sketch Σscores by prior computer gaming experience.

Table 20

Crime Scene Sketch Σscores for Officers with and without Computer Gaming Experience

				Levene's Test for Equality of Variance				
	N	*M*	*SD*	*F*	Sig.	*t*	*df*	Sig. (2-tailed)
Computer Gaming Experience								
Yes	18	33.94	8.285	2.804	.105	2.755	28	.010*
No	12	23.92	11.697					

* Equal variances assumed

A closer analysis of computer gaming experience revealed that officers with 11 – 20 and 1 – 10 years of law enforcement experience tended to have more prior computer gaming experience, while officers with 21 – 30 or more years law enforcement experience had no prior gaming experience. This difference is understandable in that officers with 1 – 20 years of law enforcement experience consisted of individuals who were exposed to computers at a very early age – called digital natives by Prensky (2001) – while the officers with 21 – 30 or more years experience were exposed to computers and computer games later in life – Prensky's (2001) digital immigrants. Table 21 presents prior gaming experience by law enforcement experience group.

Table 21

Computer Gaming Experience by Years of Law Enforcement Experience

		Years of Law Enforcement Experience		
Gaming Experience	*N*	1- 10	11- 20	21-30+
Yes	18	9	9	
No	12	2	6	4

Table 21 may help to explain why officers with 11 – 20 years of law enforcement scored better on the crime scene sketches than the more experienced officers with 20 – 30 or more year experience but not significantly better than the least experienced (1 – 10 years) law enforcement officer group. The familiarity with and ability to do well in the virtual crime scene by the younger officers with gaming experience was perhaps related to the fact that desktop VEs are closely related to computer games.

Research Question 6:
Is There a Difference in How Male and Female Police Officers Navigate a Virtual Crime Scene Environment?

Independent samples t-tests were performed to assess the significance of any differences found between genders on the navigational variables. While the number of female participants was very limited due to the gendered nature of the policing occupation, the inferential t-tests were added to the descriptive data as an exploratory step. Levene's Test for Equality of Variances was performed to determine whether equal variance between groups was assumed or not assumed for each t-test. The level of significance was set at $p = .05$. Possible trends were set at $.09 \leq p > .05$.

In this study, 14 significant navigational and time differences, as well as two possible trends were found between males and females. In general, females made more navigational moves left, right, up, and down. Females changed their perspectives more often than males by zooming in and out. Females also spent significantly greater time exploring specific nodes within the virtual crime scene than their male counterparts. Possible trends in favor of females were found in the time spent exploring two specific nodes (4A, the collection of blood samples from the victim's shirt movie, and node 6B, a still photograph of the knife). Table 22 presents the significant and trend navigational and time differences between genders.

Table 22

Gender Differences in Navigation Behaviors and Exploration Times

				Levene's Test for Equality of Variance				
	N	*M*	*SD*	*F*	Sig.	*t*	*df*	Sig. (2-tailed)
Total number of mouse clicks								
Male	26	218.19	85.166	.215	.646	-3.811	28	.001*[S]
Female	4	395.00	95.906					
Total cursor movements left								
Male	26	221.96	103.540	.428	.518	-3.180	28	.004*[S]
Female	4	402.75	123.373					

Table 22 (continued) *Gender Differences in Navigation Behaviors and Exploration Times*

	N	*M*	*SD*	Levene's Test for Equality of Variance *F*	Sig.	*t*	*df*	Sig. (2-tailed)
Total cursor movements right								
Male	26	211.42	89.246	1.221	.279	-3.618	28	.001* S
Female	4	393.25	122.851					
Total cursor movements up								
Male	26	172.04	80.732	2.409	.132	-2.720	28	.011* S
Female	4	297.50	120.467					
Total cursor movements down								
Male	26	162.04	75.370	2.197	.149	-2.519	28	.018* S
Female	4	270.50	112.530					
Total zoom in movements								
Male	26	20.12	17.079	.028	.868	-2.392	28	.024* S
Female	4	42.25	18.428					
Total zoom out movements								
Male	26	12.38	12.336	.383	.541	-2.534	28	.017* S
Female	4	28.75	9.032					

Table 22 (continued) *Gender Differences in Navigation Behaviors and Exploration Times*

	N	*M*	*SD*	Levene's Test for Equality of Variance *F*	Sig.	*t*	*df*	Sig. (2-tailed)
Total time on VR Task (in seconds)								
Male	26	1517.38	593.037	.833	.369	-2.946	28	.006* S
Female	4	2490.00	771.692					
Node 2 time in seconds								
Male	26	199.81	111.282	1.073	.309	-2.908	28	.007* S
Female	4	387.75	178.815					
Node 4 time in seconds								
Male	26	173.38	83.183	1.327	.259	-3.225	28	.003* S
Female	4	327.25	126.526					
Node 4A time in seconds								
Male	26	97.27	29.346	3.181	.085	-1.989	28	.057* T
Female	4	132.25	53.169					
Node 4D time in seconds								
Male	26	37.12	4.719	2.345	.137	-2.659	28	.013* S
Female	4	100.25	61.147					

Table 22 (continued) *Gender Differences in Navigation Behaviors and Exploration Times*

	N	*M*	*SD*	Levene's Test for Equality of Variance *F*	Sig.	*t*	*df*	Sig. (2-tailed)
Node 5B time in seconds								
Male	26	25.50	19.399	.457	.505	-3.133	28	.004* [S]
Female	4	60.50	30.028					
Node 6B time in seconds								
Male	26	17.85	12.376	1.090	.305	-1.870	28	.072* [T]
Female	4	31.00	18.019					
Node 6C time In seconds								
Male	26	87.15	45.990	9.876	.004	-2.806	25.152	.010** [S]
Female	4	112.50	1.000					
Node 6E time in seconds								
Male	26	202.04	77.161	3.699	.065	-2.111	25.036	.045** [S]
Female	4	234.00	.816					

* Equal variances assumed
** Equal variances not assumed
[S] Significant at $p \leq .05$
[T] Trend at $.09 \leq p > .05$

Research Question 7:
Is There a Difference in Configurational Knowledge Acquisition Between Male and Female Officers?

The scores given by each rater on the accuracy of the crime sketch floor plan, location and quantity of evidentiary details, and the completeness of the crime scene sketch for each participant was totaled to provide a sum (Σ) score. An Independent samples t-test was conducted to determine whether there was a significant difference between genders on the crime scene sketch Σscore. Equal variance was assumed based on a Levene's test. No significant gender difference in Σscores on the crime scene sketch was found ($t = -1.482$; $df = 28$; $p = .149$). This finding indicates that both males and females were equally able to acquire the survey or configurational knowledge needed to complete the crime scene sketch task regardless of differences in navigational routes or behaviors used.

Research Question 8:
Is There a Difference in the Way Law Enforcement Officers Interact with the Virtual Crime Scene and a Real World Crime Scene?

To answer this question, data captured by observation of participant navigational behaviors and review of each of the participants' comments as recorded by the Camtasia software were analyzed. Using these data sources, three primary areas of virtual/real world comparison emerged.

Virtual Crime Scene as Replication of Physical Reality

Participants reported the virtual crime scene to be very realistic and an excellent tool for training in crime scene investigation. For example subject 58 (male, 41– 45 years old, field dependent) stated, "It's very realistic. You could maneuver through the house like you were walking through it. The hotspots were cool. They help point out details. It was easy to use and easy to understand." Subject 58 also said "The pictures of the victim and wounds were very realistic. It was like walking through the crime scene. The clarity was very good, just like a real crime scene."

Subject 5 (male, 46-50 years old, field dependent) advised:

> I thought it was a good learning tool, with videos of how and why. Very interesting, you could move it around and look at everything. It gave a sense of being there, moving through the house by moving up and down and zooming in and out. I liked it. It was like a video game, you're in control and can move where you want to, look at what you want to, to spend as much time as you want to in rooms, rather than watching a movie.

Subject 56 (male, 36-40 years old, field dependent) said "It was very good. It would be useful training for crime scenes. It forces you to focus on details for a sketch, those items that are important." As subject 71(male, 46-50 years old, field dependent) toured the virtual crime scene he stated:

> I'm telling you now, I could have looked at pictures all day and not remembered the crime scene as well as I am right now! A directional arrow would have helped; something to show north, south, east and west…That is an outstanding teaching tool! I'm blown away! I'm overly impressed. That is how crime scene investigation should be taught until something better comes along.

As this subject moved through the crime scene he pointed out several items of evidence and attempted to reconstruct what he thought had occurred based on the evidence he observed.

Subject 25 (male, 51+ years old, field dependent) was actively engaged in the exploration of the virtual crime scene. He critiqued the crime scene and attempted to explain the significance of evidentiary items. Similarly, subject 49 (female, 31-35 years old, field independent) also noted important pieces of evidence and their location. She also attempted to formulate a scenario as to what may have occurred during the crime. Subject 18 (male, 36-40 years old, field independent) liked the virtual crime scene but said he had trouble estimating distance of the body from the furniture and wanted to see more of the house to get a better idea of the floor plan.

Number of Scene Walk-Throughs

Another aspect concerning whether there is a difference in how participants interacted with the virtual crime scene and a real scene was the number of walk-throughs or passes that participants made while exploring the virtual scene. The researcher, based on past experience as a detective and criminal investigations commander, has observed that officers and detectives investigating real crime scenes typically make at least three passes or walk-throughs of a real crime scene. The first pass is to orient and gain an overview of the scene. The second pass is generally slower and more methodical. Evidence is photographed, measured, sketched, processed, logged and collected. The third pass is to ensure the investigator has not missed anything. It is generally a quick tour of the scene. This walk-through pattern is typical in physical reality, or real-world, crime scene investigations.

In this study a complete pass or walk-through was operationally defined as the number of times participants viewed the five major nodes in the virtual crime scene. The major nodes were:

- Node # 2 (front entry/foyer)
- Node # 3 (dining room)
- Node # 4 (living room)
- Node # 5 (kitchen)
- Node # 6 (bathroom).

Moving through each of these major nodes allowed participants to maneuver through the entire crime scene one time. Camtasia software was used to capture each participant's movements and comments as they maneuvered through the virtual crime scene. For example, while exploring the virtual crime scene, subject 65 (female, 31-35 years old, field independent) said, "I was wanting to go through the whole house before I started looking at specifics."

The times and sequence of each participant's navigational movements were logged in an Excel spreadsheet for analysis. In this study, the number of complete passes through the virtual crime scene varied among participants. The majority of participants (23 or 77 percent) made two to three complete passes through the virtual crime scene environment, while five or 17 percent of the participants made four or more passes. Only two or 6 percent of the officers traveled through the virtual crime scene only once. Both of these individuals were field independent. Table 23 shows the number of passes by field dependent/field independent participants.

Table 23

Number of Passes through the Virtual Crime Scene by Cognitive Style Group

Passes	Field Dependent	Field Independent	Total
1	0	2	2
2	6	6	12
3	7	4	11
4	1	2	3
5	1	1	2
Total	15	15	30

The data on the number of walk-throughs of the virtual crime scene show that the majority of officers (77%) behaved similarly to the way they have been trained to interact with real crime scenes. Navigation behaviors and participant comments tended to support the idea that officers engaged the virtual crime scene exploration similarly to the way they would a real crime scene. Training in the virtual environment may support or reinforce investigative behaviors developed through real world training. Alternatively, real-world training behaviors may transfer to the virtual environment. In either case, similarity of behaviors in the real and the virtual environment appears to occur for both field dependents and field independents.

Note-Taking

An unexpected finding related to differences in officer interactions with the virtual crime scene as opposed to a real-world scene was in their note taking habits. Police officers are trained throughout their careers to observe and record the facts and details of their investigations in their field notes. When interviewing suspects, witnesses, and victims, officers generally take notes to document what was said. In this study, it was assumed that the officers exploring the virtual crime scene would either ask to take notes or automatically take them without asking. However, this study found that only 16 or 53 percent of the participants requested to take notes while 14 or 47 percent did not make such request. Of the 16 subjects who asked to take notes, only 13 of them actually took notes, meaning a total of 17 or 57 percent of the participants did not take notes.

This contradiction between the officers' training and real-world behavior and their behavior in the virtual crime scene prompted further investigation. Questioning of five note-takers and five non-note-takers found that those who took notes did it because of previous training. They said they always take notes when investigating crimes. They used their notes to refresh their memories, to document the facts and details accurately. Participant 54 (male, 26-30 years old, field independent) said he normally takes notes because of his training and to assist his memory. Participant 56 (male, 36-40 year old, field dependent) also indicated he took notes because of his training. He wanted to note some of the important things that he wanted to remember later. Participant 57 (41-50 year old, field dependent, male) said he was trained to take notes in the police academy, in the field training officer program, and by senior officers before he was assigned to patrol on his own. He said he took notes "(1) to refresh my memory if the need arise for a later date and (2) to help me draw a more complete diagram." Participant 58 (male, 41-45 year old, field dependent) said he took notes "for memory, to be able to go back and refer to them." This participant added:

> I was under the impression that the crime scene was probably going to be at least an entire house or good sized area and I thought for memory purposes, you know, to be able to go back and remember what was where and through the size and location of it. I thought it was going to be a benefit to have notes.

This same participant said it is common for him to take notes when looking at crime scenes and that he needs them for memory purposes. He asserted he may have to reconstruct the scene for court or use them to testify in court. Furthermore, he stated that note taking "has been part of [my] training from day one and not only on crime scenes, but…if you're out on a call of some kind or interviewing somebody, taking notes you know, so that you can go back and refer to them later."

When the five non-note takers were questioned, they indicated that they did not know they could take notes or that taking notes never crossed their minds. Some indicated that they thought they were to memorize the scene. Two indicated this was a new experience for them. They treated it like a video game or an exercise.

Participant 7 (male, 36-40 year old, field independent) said he did not understand the extent of what he was to do. He thought the virtual scene was "more of a show and tell kind of thing. Had [I] realized [I] would be drawing a sketch, [I] would have taken notes." He advised that he thought the task was rote memorization where he would have to remember details of the crime, not the layout of the residence.

Participant 74 (male, 36-40 year old, field independent) advised that he was not aware he could take notes. He didn't see a need in taking notes at the time. Note taking didn't occur to him. Participant 9 (male, 26-30 year old, field independent) said, "Oh, most of the time whenever I'm doing stuff, especially with computers, I associate it with a picture in my head and I do that a lot when I'm in real crime scenes as well." He said he was viewing the virtual crime scene from a patrol officer's perspective rather than from an investigator. He said "I tend to take snap shots of things in my head to associate where everything is."

Participant 7 (male, 36-40 year old, field independent) advised he was not aware he could take notes. He said he "normally does not take notes when he is working on the computer." He thought it was just an exercise and did not understand he was able to take notes. Participant 75 (male, 31-35 year old, field independent) said, "I was probably just focused on making sure I got the diagram correct." He also indicated he treated the virtual crime scene more like a video game. He said, "I just knew it was an exercise and that's how I treated it."

Participant 53 (male, 46-50 year old, field independent) stated:

> For me, doing it on the computer that way was just such a new experience, I really wasn't sure what I was getting into and I had never seen that house before…It took me the longest time just to figure out my way around the house…When I got to the end of the hallway, I thought I was going to click on the window and keep moving farther whether on another angle or not. It took me a while to realize that I had turned around and I was looking back again and I was doing some back and forth moving before I realized that I was just moving back and forth.

This same participant also advised that:

> I kind of came in here feeling like I was sort of a game show contestant, even though there was nothing to win from it, but it was going to be an unusual experience, a unique experience and it was going to be see if maybe somehow this can be implemented in the future and so I – I know that the piece of paper was off to the side, I knew I was to draw a map on it later, but again, the thought of taking notes on it never crossed my mind.

The comments from the note-takers and non-note-takers provided insight into how realistic the virtual crime scene was to them, and how prior experience or training may influence their behavior. Note-takers viewed the virtual environment as realistic. They took notes as they would during an investigation in the real-world. Their comments indicated that they relied on their previous training and work habits. Notes were taken to help them capture details of the crime scene accurately and to support or aid their memories.

Conversely, non-note-takers did not appear to view the virtual crime scene as real. It was seen as a new technology which was unfamiliar to them. Some saw it as an exercise or computer game rather than a learning tool. It is possible that some of these participants were distracted by the virtual presentation's bells and whistles or by navigational issues. During this distraction or disorientation, they appear to have forgotten prior training and experience.

Some indicated they were unclear of the task and were unaware they could take notes. This suggests that when distraction or disorientation occurs in a virtual environment, learners need immediate help to overcome the impediment. Adequate navigational training with clear, concise instructions, and continued support or guidance may need to be provided throughout the exploration of the virtual environment.

CHAPTER V

Conclusions, Discussion, and Recommendations

Summary of the Study

There has been an increased focus on using technology to assist in the education of learners. Recent advances in virtual reality (VR) technology have opened the door to the development of new non-traditional instructional methods, which have shown promise in preparing people for the work place and improving their job performance. Despite a growing body of literature supporting the success and acceptance of virtual reality technology, relatively little is currently known about the individual differences of users as they maneuver and learn within virtual environments. Waller (2000) asserted that "Computer-simulated environments hold promise for training people about real-world spaces. However little research has examined the role of user characteristics and abilities in determining the effectiveness of these virtual environments (VE's) for training spatial knowledge" (p. 3). Ausburn and Ausburn (2003) argued that past research tended to "focus on comparing instructional treatments and designs as main effects rather than on examining interactions between treatments and specific types of learners" (p. 2).

This study addressed the lack of information about learner characteristics and VEs. It used a research design that compared the behaviors of learners with different individual characteristics. The study examined the navigational behaviors and level of configurational/survey knowledge acquisition of individuals with different cognitive styles, gender, and prior experiences as they explored a desktop virtual crime scene environment. A mixed method research model combining quasi-experimental techniques and qualitative observations and questions was used in this study to examine two groups of law enforcement officers from a mid-sized police department in northeastern Oklahoma. The participants were divided into two cognitive style groups (field dependent/ field independent) and were exposed to the same desktop VR treatment of a crime scene, to see how they interacted with and learned from the technology. An extreme-group design was used to assign subjects to the two cognitive style groups based on their *Group Embedded Figures Test* (GEFT) scores. Gender, years of law enforcement experience, and levels of computer experience were self-reported by subjects. Navigational behaviors in the virtual environment were recorded through observation and Camtasia 6.0 screen capture software for quantitative and qualitative analysis of differences. Configurational or survey knowledge acquisition was measured by having subjects draw a crime scene sketch from memory, after they had completed interacting with the VR treatment. The sketches were assessed independently by three crime scene experts, and quantitative measures of inter-judge reliability were calculated.

Conclusions and Discussion

Several conclusions can be drawn from the findings of this study. Conclusions supported by the data include the following:

1. Navigational Behavior in a Desktop VE Is Individualistic Rather Than Occupational

Navigational behaviors in the virtual crime scene were found to be highly individualistic. Participants' navigational behaviors for this study were determined from direct observations by the researcher, analysis of the observation logs, analysis of the Camtasia video file for each participant, and analysis of quantitative and qualitative data. No general navigational patterns or systematic "occupational" navigation patterns were found. There was no evidence of any patterns that were "typical" of police officers. No two participants' navigational behaviors in the virtual crime scene were exactly alike. Movement through the virtual environment was related more to individual or personal preference differences than to the policing occupation. Navigational behaviors were not influenced by cognitive style (field dependent/field independent), age, prior law enforcement experience, detective experience, education level, or computer experience in this study.

2. Identification of Instructional Design Flaws in Virtual Environments Is Critical to Successful Navigation

Design flaws in the virtual crime scene used in this study caused several navigational problems. Data used to identify design flaws and their effects on learners came from direct observation by the researcher, analysis of the observation log, analysis of each participant's Camtasia video file, and content analysis of participants' statements and comments during and after navigating the virtual crime scene. Darken and Sibert (1996) discussed disorientation in wayfinding. They found when individuals are not given an adequate source of directional cues, disorientation can occur that inhibits both wayfinding performance and the acquisition of spatial knowledge. Disorientation also appears to inhibit learning in technology-based environments. Graff (2003) asserted that:

> The lack of ability to orient oneself within a web-based environment may cause an individual to experience disorientation. The more disoriented the user becomes, the more they must focus on navigation and less on processing the information content, which reduces the amount of learning that can take place. (p. 408)

VE design flaws may create navigational issues which can distract, confuse, and disorient learners. Participant disorientation was linked to the following VE design flaws in this study:

- A navigational hot spot to the bathroom was positioned at the beginning of the hallway near the kitchen. When subjects clicked on this hot spot, it transported them to the opposite end of the hall facing the location on which they had clicked. This confused and disoriented half of the participants.
- A similar flaw was found in the hot spot leading to the living room. It was located in the doorway between the dining room and breakfast nook. When participants clicked on this hotspot, they were transported through the breakfast nook and into the living room facing the direction they had been (dining room). This disoriented several participants. They thought they were moving from the dining room to the breakfast nook, not to the living room. Although each hotspot was tagged to display the location it would take learners to when the mouse hovered over the hotspot, very few of the participants used this navigational feature.
- An object movie of the suspected murder weapon (knife) was mounted vertically on a rotating device to allow for a 360 degree observation. This object movie was

linked to a panoramic view of the bathroom. The object movie of the knife confused several participants because it did not depict the knife in its original horizontal position on the bathroom counter top. This raises cautions about how to position and orient movable objects embedded in virtual environments.

- Discrepancies in the virtual environment such as different flowers in two scenes and out of place furniture or objects may have distracted and confused learners. Designers must ensure continuity between panoramic scenes.

Disorientation comments from participants in this study suggested several design considerations that may reduce the effects of disorientation on navigation. First, navigational hot spots should be positioned in a linear manner in each room that a participant may move through. When one clicks on a hot spot, it should transport them to the location of the hot spot, not to another area. This may enhance the sense of walking through the VE. Second, if an object movie is embedded within a panoramic scene, guidance and instructions should be given immediately to reduce any disorienting effect that may be encountered. Third, when shooting photos for panoramic scenes and photos or videos to be embedded into the panorama, designers should be careful not to move items from one scene to another. This will provide continuity of the virtual representation and reduce distraction and disorientation for users.

3. Tendency for Disorientation in a VE is Related to Cognitive Style

Field dependent participants in this study experienced greater navigational difficulties than field independents. They were more susceptible to distraction and disorientation caused by flaws in the navigational design of the VE. While this differential reaction to the spatial characteristics of a VE should be noted by instructional designers, it should also be noted that individual differences in visual field articulation and navigational disorientation did not have detrimental effect on learning performance outcome.

4. Cognitive Style Differences are More Influential on the Learning *Process* than on the Learning *Outcome* in the Virtual Environment

Data used to identify cognitive style differences in VE navigation and exploration and in learning outcome came from direct observation by the researcher, analysis of the observation logs, analysis of the Camtasia video files, analysis of quantitative data and analysis of crime scene drawings for each participant. Differences in the amount of time spent in specific VE nodes appeared to be linked to cognitive style differences in information processing. Cognitive style differences were observed in the crime scene drawings, but were primarily stylistic rather than substantive. There were no significant differences in crime scene sketch Σscores, indicating that field dependents and field independents both learned effectively from the VE despite differences in the ways they explored the virtual crime scene.

5. Prior Domain Knowledge and Experience May Not Significantly Affect Learning in VEs

Older participants with the most prior law enforcement experience (21 – 30 or more years) spent more time exploring and processing a few specific nodes in the virtual crime scene. Data used to identify age and prior experience differences was obtained from direct observation by the researcher, analysis of observation logs, and analysis of quantitative data. It is possible that the older officers' greater level of prior experience may have influenced their attention to details and time taken to analyze the evidence contained in those nodes. Several studies have supported relationships between prior domain knowledge and performance with various media formats. For example, Lawless, Schrader, and Mayall (2007) asserted that "One of the most prominent variables both in terms of number of studies, as well as findings indicating a significant influence on navigation, is prior knowledge" (p. 292). Similarly, Lawless and Kulikowich (1998) concluded that "One consistent finding supported by the literature examining traditional texts is that the more domain knowledge one has, the better one can employ strategies to competently process related text" (p. 53). Ford and Chen (2000) found greater experience in an area correlated with higher performance in the same or closely related area. Lazonder, Bremans, and Wopereis (2000) argued that "Domain expertise enhances search performance. Those with high domain knowledge tend to take less time completing search tasks and produce a greater number of correct solutions" (p. 576). Echoing this finding, Roy and Chi (2003) asserted that search skills improve with greater domain knowledge.

Findings of this study indicate the situation may be different in virtual environments. Contrary to most research literature on prior experience, the older participants in this study with more law enforcement and detective experience did not do as well on the crime scene sketch task as the younger less-experienced officers. In this study age, with the exception of being associated with spending a greater amount of time in a few nodes of the VE, greater prior law enforcement experience, and prior detective experience did not appear to influence navigation behaviors or to enhance the acquisition of configurational knowledge. Thus, variables other than prior domain experience or knowledge appear to be more important in performance in virtual environments.

6. Computer Gaming Experience Influences Performance in VEs

Younger officers with 20 or fewer years of law enforcement experience tended to have more computer gaming experience and did better on the crime scene sketch task. There are two possible reasons why those with computer gaming experience displayed superior performance on the crime scene sketch task. First, those with computer gaming experience may have been more comfortable with the technology and familiar with similar programs. The familiarity with and ability to do well in the virtual crime scene by the younger officers with more gaming experience was perhaps related to the fact that desktop VEs are closely related to computer games. Isdale, Fencott, Heim, and Daly (2002) asserted that "Computer games are a closer media relative of VE than film…The line between a VE and a highly interactive computer game may be simply a difference in interface devices" (p. 521). Schroeder (1997) noted similarities between Internet-based computer games and desktop VR systems. Calvert (2002) argued that "When a person directly experiences a media form and is able to control it, there is a one-to-one correspondence between what is done and what happens. This increased sense of personal involvement and presence in the VE game may also increase player identification with characters, their perceptions of the vividness of events, and their perceptions of self-efficacy" (p. 665). Second, individuals with prior computer gaming experience may have a better understanding of how to search and discover in a virtual environment than their non-gaming counterparts. Those with computer gaming experience have a better understanding of the "Virtual World Concept" described by

Ausburn and Ausburn (2010). Computer gamers are familiar with exploring vast areas or levels of a computer game to gather information, tools, points, or clues. Those with prior gaming experience understood that they were not just viewing a graphic representation of a scene, but were actually standing in the center of and interacting with the virtual environment. As a result of their prior gaming experience, they realized there was a large amount of informational items located 360^0 around them. It is also possible that they realized the individual nodes or "spheres of reality" (Ausburn & Ausburn) could be stand alone virtual environments or linked to other nodes which made up a larger virtual world or universe. Being able to comprehend this virtual world concept allowed those with computer gaming experience to know how to move through and between these nodes searching for the information they needed.

Despite superior crime scene sketch scores by individuals with prior computer gaming experience, one problem surfaced in this study regarding computer gaming experience and the transfer of knowledge from a real world environment to the virtual environment. Many of those with computer gaming experience tended to treat the virtual crime scene like a game rather than a real scene. They became so involved with "playing the game" that they failed to take notes to document their observations. This failure to document the crime scene was contrary to the way they had been trained and contrary to the way they would have reacted to a real world crime scene.

The findings of this study support a relationship between VEs and computer games. In VEs, unlike other media forms, prior technology experience (i.e. computer gaming) may be more important than prior domain knowledge to successful learning performance unless learners are carefully prepared through pre-immersion training.

Successful training may be able to overcome the detrimental effects of the overwhelming technology that can be problematic for non-gamers in virtual environments. In other words, pre-immersion training may help to level the technology playing field for the non-gamers and return prior domain knowledge to the prominent place it has typically had in the literature on learning performance.

7. There Are Gender Differences in Navigational Behaviors in VEs

Males and females navigated differently in this study's virtual crime scene, but there were no differences in learning outcomes. Data used to obtain gender differences were derived from direct observation by the researcher, analysis of the participant observation logs, and analysis of quantitative data. Females made significantly more navigational moves and spent much more time exploring the virtual crime scene environment, but had no difference in learning outcomes based on crime scene sketch Σscores. While findings related to gender in this study must be tentative due to the small number of females in the sample of police officers, differences in navigational behaviors in this study do support previous research literature regarding differences between men and women as they interact with virtual reality technologies (Ausburn, Martens, Washington, et al., 2009; Hunt & Waller, 1999; Jansen-Osmann, Schmid, & Heil, 2007; Lawton, 1994; Waller, Hunt, & Knapp, 1998a, 1998b). Much of the VR research that explores the effects of gender indicates that females have more difficulty navigating than males and may be more susceptible to disorientation in virtual environments and also tend to score lower on tests of spatial ability and mental rotation as measured by paper-and-pencil tests (Ardito, Costabile, & Lanzilotti, 2006; Ausburn & Ausburn, 2010;

Ausburn, Martens, Washington, et al., 2009; Lawton, 1994; Waller, Hunt, & Knapp, 1998a).

In this study, women made significantly more navigational moves and spent a greater amount of time exploring the virtual environment than their male counterparts. This finding supports previous research that concluded gender differences in navigational behaviors were due to females becoming disoriented, overwhelmed, or lost in space (Ausburn, Martens, Washington, et al., 2009; Hunt & Waller, 1999; Jansen-Osmann, Schmid, & Heil, 2007; Lawton, 1994; Waller, Knapp, & Hunt, 1998a, 1998b). Contrary to most VR research, however, this study found no significant differences in learning outcomes (i.e., crime scene sketch Σscores) between men and women. The fact that despite navigational differences, no differences in learning outcomes occurred indicates that both men and women were able to learn and benefit from their interaction with the virtual crime scene environment.

A possible reason why men and women in this study scored similarly on the crime scene sketch task may be related to exploration time. It appears that allowing participants to explore as long as they wanted may have helped females overcome any navigational difficulties they might have encountered. Once they were able to re-orient themselves within the virtual environment, they were able to return to various nodes for closer inspection of the scenic details. Similarly, Ausburn and Ausburn (2008a) reported that when "…students could take as much time as they wished to learn to operate the VR and to explore its contents; issues of overload [disorientation] may have disappeared and the supplantation-concreteness benefits of VR may have become more important" (p. 57). This raises questions in the researcher's mind regarding exploration time and navigation in VEs. Were the females truly lost and disoriented by the VE or were they merely being more thorough in their exploration of the VE? More research in this area is needed.

8. A Sense of "Presence" Can be Achieved in a Desktop VE

An unexpected finding surfaced during the course of this research that addresses a major issue in VE research. Evidence was found that participants felt a sense of "presence" as they interacted with the virtual crime scene used in this study. A great deal of research is currently being conducted on the concept of "presence" in virtual environments. Researchers are still not sure how or why the sense of presence is achieved by learners as they interact with VR/VEs. Ausburn and Ausburn (2010) argued "The most compelling and complex foundation for VR/VE effectiveness – and the most extensively studied – is a theoretical construct generally referred to as 'presence,' a phenomenon that seems to occur when many attributes of virtual reality come together effectively" (p. 2).

Presence, which is a shortened version of the term 'telepresence,' has been defined as:

> A psychological state or subjective perception in which even though part or all of an individual's current experience is generated by and/or filtered through human-made technology, part or all of the individual's perception fails to accurately acknowledge the role of the technology in the experience. Except in the most extreme cases, the individual can indicate correctly that s/he is using the technology, but at *some level* and to *some degree*, her/his perceptions overlook that knowledge and objects, events, entities, and environments are perceived as if the technology was not involved in the experience. (International Society for Presence Research, 2000)

According to Ausburn, Marten, Dotterer and Calhoun (2009) and Di Blas and Poggi (2007), it is "presence," or ability to give learners a feeling they have actually *been* somewhere rather than just seeing it, that gives virtual reality technology its power. Data used to determine participants' sense of presence in this study was obtained from direct observation by the researcher, analysis of each participant's Camtasia video file, and analysis of qualitative data from participant statements and comments during and after their interaction with the virtual environment.

For VEs to be effective as instructional technologies, learners need to feel like they are really "there" in the environment and not merely an observer. Achieving a sense of presence is very important for effective learning in a virtual environment. In this study participants were given a role to play as they interacted with the virtual crime scene. Participants were advised that they were officers assigned to assist the crime scene technician, who introduced the VE in a preliminary video clip, with his investigation. The tasks they were to complete were to *explore the scene* and *gather as much information as possible* in order to *draw a detailed crime scene sketch*. During and after their interaction with the virtual crime scene, several participants indicated voluntarily how realistic the crime scene was. They felt like they were really there. For example, one officer stated, "It's very realistic. You could maneuver through the house like you were walking through it. The hotspots were cool. They help point out details. It was easy to use and easy to understand." This same officer also said "The pictures of the victim and wounds were very realistic. It was like walking through the crime scene. The clarity was very good, just like a real crime scene."

Another officer advised:

> I thought it was a good learning tool, with videos of how and why. Very interesting, you could move it around and look at everything. It gave a sense of being there, moving through the house by moving up and down and zooming in and out. I liked it. It was like a video game, you're in control and can move where you want to, look at what you want to, to spend as much time as you want to in rooms, rather than watching a movie.

Participants were able to *walk* through the house and examine the evidence with the aid of the navigational interface (mouse). They tended to make several passes through the virtual scene similar to the way they would interact with a real crime scene. Some took notes because that was what they do at real crime scenes and it was how they had been trained. They reported that they wanted the notes to help refresh their memories and to help recall details they observed. This study also found that younger less-experienced officers tended to have prior computer gaming experience and scored better on their crime scene sketches. Those with computer gaming experience are familiar with assuming the role of a character in the computer game and are also more proficient and comfortable with navigating within virtual worlds. This may have helped them feel a sense of presence in the VE. The high fidelity, photo-realistic quality of the VR treatment may have also added to participants' sense of presence.

9. Real World Training Can Transfer to Desktop VE

The qualitative data in this study also indicated that prior training and experience may be re-enforced and transferred to the virtual environment. The skills developed in the virtual environment may also transfer to the real world. Evidence of the transfer of knowledge and skills surfaced in this study primarily from participant behaviors of note-taking and the number of crime scene walk-throughs. In addition, police officers' ability to recall evidentiary details and relative positions of evidentiary items transferred to their crime scene sketch of the virtual environment.

Note taking. In this study, 43% of the participants took detailed notes as they explored and investigated the virtual crime scene, while 57% of the participants did not take notes. The data indicated that the ability to transfer real world knowledge and skills to the virtual environment may be related to how learners perceive the VE. Participants in this study who took detailed notes tended to view the virtual crime scene as a real crime scene. Participants indicated in their statements that they treated the VE like a real crime scene and that they took notes because they have always taken notes at real crime scenes. Furthermore, they explained that note taking had become a habit because they had been trained to take notes throughout their careers. Participants advised that they use the field notes to accurately capture facts and details about the crime scene in order to refresh their memories, draw crime scene diagrams, write their police reports or to help them when testifying in court.

Even though the non-note-takers commented on how real the virtual crime scene was, they tended to view the VE as a game rather than a real crime scene. A few of the non-note-takers commented that the VE was a new experience or they did not know what to expect. This new technology experience may have distracted these individuals and prevented them from transferring previous note-taking knowledge to the VE. All of the non-note-takers commented that they normally take notes at real crime scenes, but in this instance, taking notes never crossed their minds.

In this study, those who viewed the VE as a real scene interacted with it similarly to the way they would interact with a real world crime scene. Those who viewed it as a game or a new and unfamiliar experience appeared to be enamored with the technology and forgot to rely on their previous note-taking training. The evidence in this study indicates learners may need more preparation time (pre-immersion training) and a clearer understanding of what to expect and what to do once they enter the VE. Sufficient pre-immersion training and clear instruction may help facilitate the transfer of real world knowledge to the virtual training environment.

Crime scene walk-throughs. The data in this study indicated that the majority of participants tended to walk through the virtual crime scene similarly to the way they would interact with a real world scene. The majority of participants in this study made two to three passes through the virtual crime scene as they conducted their investigations. This was consistent with how most police officers have been trained. The initial pass was typically at a moderate speed and appeared to be used to orient oneself to the environment. The second pass was generally slower. Participants took their time and examined the rooms and evidence more closely. The third walk-through tended to be quicker and appeared to be an effort to make sure they had not missed anything during their first two passes. The crime scene walk-through behaviors demonstrated by the participants in this study provided evidence of a transfer of prior experience and training to the virtual environment.

Crime scene sketch skills. Having participants draw a sketch of the virtual crime scene allowed participants to practice skills learned in the real world environment. Police officers in this study were able to hone their investigative, observation, memory and drawing skills as they investigated the virtual homicide crime scene. Skills developed in real world applications were able to transfer to the virtual crime scene learning environment. The virtual environment was able to help re-enforce participants' prior crime scene investigation training. These participants were able to acquire the necessary information from the virtual crime scene to successfully complete the crime scene sketch task used in this study. Observations made in the virtual environment were transferred to the real world crime scene sketch in this study. This suggests that skills can be transferred from the real world to the virtual environment and from the virtual environment back to the real world.

10. Pre-Immersion Training and Preparation are Important to Successful Navigation and Learning in VEs

Data on pre-immersion training and preparation was gleaned from analysis of qualitative data, direct observation by the researcher, and analysis of each participant's Camtasia video file. Participants were exposed to a non-treatment-related virtual environment (house scene) before entering the virtual crime scene. They were instructed to explore the non-treatment VE for as long as they wanted in order to familiarize themselves and become comfortable with the navigational interface tools, hot spots, and movement within the virtual environment. The majority of participants spent only a few minutes in the practice VE before indicating they were ready for the virtual crime scene. Shortly after they entered the treatment VR (virtual crime scene), it became apparent many of these participants needed additional time to practice. Most participants needed additional instruction and guidance regarding how to navigate. Many needed further clarification on the tasks they were to perform. These findings support the assertion of Ausburn and Ausburn (2010) that detailed and extensive training is necessary before learners enter a desktop VE to facilitate learning. Figure 10, illustrates Ausburn and Ausburn's pre-immersion training model for testing in future research.

Figure 10. Ausburn training model for learner pre-immersion in CTE desktop virtual environments. Copyright 2009, Floyd B. Ausburn.

11. Learners with Different Characteristics Can Learn from a Desktop VE

This study examined individual learner characteristics and how they may influence navigation behavior and acquisition of configurational or survey knowledge in a desktop VE. Individual characteristics consisted of field dependence/field independence cognitive style dimension, gender, and prior knowledge or experience. Prior experience encompassed participant's number of years in law enforcement, detective experience, age, education level, computer experience and prior computer gaming experience. Despite some definite gender differences in navigation behavior, all participants in this study regardless of their individual characteristics were able to explore and learn from the desktop VE. They were able to search for and gather the information needed to successfully complete the crime scene sketch task from memory. The findings of this study indicate that when given sufficient pre-immersion training, exploration time, and instruction, all types of learners can learn from a well designed VE.

Implications for Occupational and Career Education

Desktop virtual reality technology is capable of helping learners engage in highly interactive and complex learning opportunities. This technology makes it possible to transport learners to realistic workplace environments to practice skills or develop new skills and knowledge in their field of study. The virtual workplace is at learners' fingertips; all they need to do is click the mouse and enter.

Numerous career fields could benefit from this relatively inexpensive, versatile, and effective educational tool. Customized VR lessons could be developed to expose learners and industry professionals to a wide array of career experiences without placing them in harm's way. This technology allows learners to practice new skills or hone previously learned skills. Furthermore, findings from this study indicate that learners with a variety of characteristics can learn and benefit from well-designed virtual environments.

Implications for Law Enforcement Education

Law enforcement education and training has used VR in the form of driving and shooting simulators for several years. Most of these simulators are bulky and too expensive for many police departments. However, with recent advances in desktop VR technology that combine greater fidelity and presence with lower cost, most police departments could add this technology to their educational arsenal.

The findings from this study indicate that regardless of an individual's cognitive style, gender, or prior experience each participant was able to learn from the virtual crime scene environment. Officers in this study became immersed in the virtual crime scene. Many achieved a sense of presence or the feeling that they were really there. Similar virtual environments could be designed to allow police officers to practice their investigative skills, patrol tactics, interviewing skills, or develop skills for responding to terrorist threats and weapons of mass destruction. One's imagination is the only limitation to the types of desktop VEs that could be developed to aid in training individuals for the law enforcement profession.

Recommendations

Recommendations for Further Research

Additional research is needed regarding how individual learner characteristics may influence navigation behaviors and learning in virtual environments. This study examined only one dimension of cognitive style. Additional research on other cognitive style dimensions would help advance knowledge as to the role cognitive skills and characteristics play in interactions with VR/VEs.

More gender research with larger samples is needed to verify the findings of this study. Additional research will help provide a better understanding as to how and why females navigate differently and take more time in VEs. It may help to answer questions about whether females who interact with VEs are really disoriented or if they are being more thorough than males.

Future research needs to examine what is already known about VR/VEs in order to develop sound research-based guidelines for designing more effective virtual environments. From this research several operational and design elements surfaced that appear to affect VE performance. These are discussed below as tentative recommendations for practice. All these recommendations merit further research before they can become established instruction design and implementation guidelines for virtual environments.

Recommendations for Practice

Pre-immersion Training. Learners need adequate time to learn how to operate and maneuver within a virtual environment. It is recommended that a practice VE be used before learners are immersed in the treatment VE. Learners need a sufficient amount of time to practice and become comfortable with the navigational interface devices. Once they become proficient with navigating and operating the VE, they will be better prepared to focus on the learning task. If they are distracted or disoriented within the VE or have difficulty navigating, the level of learning may suffer. The pre-immersion training model proposed by Ausburn and Ausburn (2010) (see Figure 10) may provide guidance in developing successful preparation of learners for VE experiences. This model is recommended as a starting place for VE designers in planning pre-immersion training.

Task Clarification. Clear and specific instructions should be given to learners before they become immersed in a virtual environment. Additional task clarification may be necessary if learners become distracted or overwhelmed with the complexity of the VE. Once a learner has entered the virtual world, it is imperative that they know exactly what it is that they are supposed to do to avoid confusion and lack of engagement. It is recommended that VE designers give learners clear goals and purposes before placing them in a VE.

Navigational Aids and VE Design. Navigational aids in the form of verbal guidance or information, signage, arrows, a compass, maps, diagrams, or written instructions assist learners as they maneuver inside a virtual environment. Navigational aids to avoid disorientation or a feeling of “lost in space” can reduce anger, frustration, and anxiety which can impede learning. It is recommended that VE designers select and apply navigational aids with care and field-trial navigational interfaces as part of the VE production process.

To reduce disorientation for some learners, it is recommended that VE designers should consider embedding numerous navigational hotspots to create multiple routes of sequential exploration pathways. This would enhance the sense and flow of “walking through” the virtual scenic display. Embedded hotspots should depict the views that learners would expect to find at a particular location. When learners in this study clicked on some hotspots, they were transported unexpectedly to different locations. This confused, disoriented, and frustrated many of the participants. Disorientation interferes with an individual’s ability to learn. By reducing the effects of disorientation learning outcomes can be enhanced.

Conclusion

In summary, the data in this study suggests that the way one maneuvers through the VE may not be as important as what one is able to learn from their interaction with the virtual environment. When learners are able to take their time, move at their own pace and become comfortable with the navigational interface device, they can become deeply engaged in the exploration of the virtual environment. When learners perceive the virtual environment as real and achieve a sense of “presence” they appear to fully engage and interact with the virtual environment. They move where and when they want to as they examine the complex graphic details more thoroughly. There was evidence that learners were able to transfer their prior knowledge and skills from the real world to the desktop virtual environment. Evidence was also present which suggested that learners were able to transfer the new knowledge gained from the desktop virtual environment to real world applications.

When the participants’ learning or configurational/survey knowledge of was examined and assessed, the most exciting conclusion from this research surfaced. The data suggested that learners with a variety of different individual characteristics were able to learn from the desktop environment when provided with sufficient pre-immersion training, preparation, and time. The data indicated that it really did not matter whether the learner was field dependent/independent, male/female, young or old, possessed a master degree or a high school diploma. It did not matter whether the learner had prior computer experience or was a novice. It did not matter whether the learner had computer gaming experience or no computer gaming experience, a seasoned veteran law enforcement officer or inexperienced law enforcement officer. Regardless of each learner's individual characteristics, they were all able to learn and benefit from the VE. Each of the participants in this study were able to maneuver through the VE, search for and locate complex evidentiary details and then recall from memory the layout of the virtual environment, numerous evidentiary items, their position and location within the VE.

Information revealed in this study suggests that VR has strong potential for professional training and human resource development. Furthermore, that research should continue to discover the full possibilities of this potential.

References

Alexander, P. A., & Judy, J. E. (1988). The interaction of domain-specific and strategic knowledge in academic performance. *Review of Educational Research, 58*(4), 375–404. doi:10.3102/00346543058004375

Alomyan, H. (2004). Individual differences: Implications for web-based learning design. *International Education Journal, 4*(4), 188–196.

Anderson, R. C., & Pearson, P. D. (1984). A schema-theoretic view of basic processes in reading comprehension. In P. D. Pearson (Ed.), *Handbook of Reading Research* (pp. 255–291). New York, NY: Longman.

Andris, J. F. (1996). The relationship of indices of student navigational patterns in a hypermedia lab simulation to two measures of learning style. *Journal of Educational Multimedia and Hypermedia, 5*(3), 303–315.

Ardito, C., Costabile, M. F., & Lenzilotti, R. (2006, May). *Gender and virtual navigation: An exploratory study*. Paper presented at Advanced Visual Interfaces 2006, Venezia, Italy. Retrieved from ttp://www.informatics.man.ac.uk/~antonella/gender/files/papers/Gender%20and%20Virtual%20navigation%20exploratory%Study.pdf

Ausburn, F. B., Ausburn, L. J., Cooper, J., Kroutter, P., & Sammons, G. (2007, Spring). Virtual reality technology: Current status, applications, and directions for education research. *The Journal of the Oklahoma Association of Teacher Educators, 11*, 7–14.

Ausburn, L. J. (2004). Gender and learning strategy differences in non-traditional adult students' design preferences in hybrid distance courses. *Journal of Interactive Online Learning, 3*(2). Retrieved from http://www.ncolr.org/jiol/issues/PDF/ 3.2.6.pdf

Ausburn, L. J., & Ausburn, F. B. (1978). Cognitive styles: Some information and implications for instructional design. *Educational Communications and Technology Journal, 26*(4), 337–354.

Ausburn, L. J., & Ausburn, F. B. (2003, Spring). A comparison of simultaneous vs. sequential presentation of images in a visual location task to learners with visual and non-visual perceptual styles: A study of supplantational instructional design. *The Journal of the Oklahoma Association of Teacher Educators*, *7*, 1–20.

Ausburn, L. J., & Ausburn, F. B. (2004, Winter). Desktop virtual reality: A powerful new technology for teaching and research in industrial teacher education. *Journal of Industrial Teacher Education, 41*(4), 1–13. Retrieved from http://scholar.lib.vt.edu/ejournals/JITE/v41n4/ausburn.html

Ausburn, L. J., & Ausburn, F. B. (2008a). New desktop virtual reality technology in technical education. *I-Manager's Journal of Educational Technology, 4*(4), 48–61.

Ausburn, L. J., & Ausburn, F. B. (2008b). Effects of desktop virtual reality on learner performance and confidence in environment mastery: Opening a line of inquiry. *Journal of Industrial Teacher Education, 45*(1), 54–87. Retrieved from http://scholar.lib.vt.edu/ejournals/JITE/v45n1/pdf/ausburn.pdf

Ausburn, L. J., & Ausburn, F. B. (2010, December). *Spheres of reality: A conceptualization of desktop virtual environments in career and technical education and an implementation training model.* Paper presented at Career and Technical Education Research and Professional Development Conference, Las Vegas, NV.

Ausburn, L. J., & Brown, D. (2006, Winter). Learning strategy patterns and instructional preferences of career and technical education students. *Journal of Industrial Teacher Education, 43*(4), 1–27. Retrieved from http://scholar.lib.vt.edu/ejournals/JITE/v43n4/pdf/ausburn.pdf

Ausburn, L.J., Fries, C., Mahan, M., Martens, J., Sayman, D., Steele, D., . . . Washington, A. (2009). Gender and desktop virtual environments: Considerations for teaching and learning. In *Proceedings of the 7th Annual Hawaii International Conference on Education* (pp. 3294-3313). Retrieved from http://www.hiceducation.org/EDU2009.pdf

Ausburn, L. J., Martens, J., Dotterer, G., & Calhoun, P. (2009). Avatars, pedagogical agents, and virtual environments: Social learning systems online. *I-Manager's Journal of Educational Technology, 5*(4), 1–13.

Ausburn, L. J., Martens, J., Washington, A., Steele, D., & Washburn, E. (2009). A cross-case analysis of gender issues in desktop virtual reality learning environments. *Journal of Industrial Teacher Education, 46*(3), 51–89. Retrieved from http://scholar.lib.vt.edu/ejournals/JITE/v46n3/pdf/ausburn.pdf

Ayersman, D. J., & Minden, A. V. (1995). Individual differences, computers, and instruction. *Computers in Human Behavior, 11*(3–4), 371–390. doi:10.1016/0747-5632(95)80005-S

Blade, R. A., & Padgett, M. L. (2002). Virtual environments standards and terminology. In K. M. Stanney (Ed.), *Handbook of virtual environments: Design, implementation, and applications* (pp. 15–27). Mahwah, NJ: Erlbaum.

Bluck, J., Zona, K. A., & Rachul, L. J. (1999, May 3). NASA telemedicine: Improving health from a distance [Press release]. Retrieved from http://www.nasa.gov/centers/ames/news/releases/1999/99_27AR.html

Boling, E. (2000). Wayfinding—navigation by landmarks, routes and maps. Retrieved from http://www.indiana.edu/~iirg/ARTICLES/NAVIGATION/wayfinding.html

Bollman, B., & Friedrich, L. (n.d.). *Transfer of training in general VR environments.* Unpublished manuscript, Department of Information Technology and Electrical Engineering, Swiss Federal Institute of Technology (ETH), Zurich, Switzerland.

Calvert, S. (2002). The social impact of virtual environment technology. In K. M. Stanney (Ed.), *Handbook of virtual environments: Design, implementation, and applications* (pp. 663–680). Mahwah, NJ: Erlbaum.

Center for Inclusive Design and Environmental Access. (2010). Universal design New York: 4.1c Wayfinding. Retrieved from http://www.ap.buffalo.edu/idea/udny/Section4-1c.htm

Chen, S. (2002). A cognitive model for non-linear learning in hypermedia programs. *British Journal of Educational Technology, 33*(4), 449–460. doi:10.1111/1467-8535.00281

Chen, S.Y., & Ford, N. J. (1998). Modeling user navigation behaviors in a hypermedia-based learning system: An individual difference approach. *Knowledge Organization, 25*, 67–78.

Chi, M. T. H., & Ceci, S. J. (1987). Content knowledge: Its role, representation, and restructuring in memory development. In H. W. Reese (Ed.), *Advances in child development and behavior* (Vol. 20, pp. 91–142). San Diego, CA: Academic Press.

Conti, G. J. (2009). Development of a user-friendly instrument for identifying the learning strategy preferences of adults. *Teaching and Teacher Education, 25*, 887–896. doi:10.1016/j.tate.2009.02.024

Conti, G. J., & Kolody, R. C. (1997). Guidelines for selecting methods and techniques. In M. Galbraith (Ed.), *Adult learning methods* (2nd ed.). Malabar, FL: Krieger.

Conti, G. J., & Kolody, R. C. (1998). Development of an instrument for identifying groups of learners. In *Proceedings of the 39th Annual Adult Education Research Conference*. Retrieved from http://www.adulterc.org/Proceedings/1998/98conti.htm

Conti, G. J., & Kolody, R. C. (1999). The relationship of learning strategy preference and personality type. In *Proceedings of the 40th annual adult education research conference*. Retrieved from http://www.adulterc.org/Proceedings/1999/99conti.htm

Conti, G. J., Kolody, R. C., & Schneider, B. (1997). Learning strategies in the corporate setting. In *Proceedings of the 38th Annual Adult Education Research Conference*. Retrieved from http://www.adulterc.org/Proceedings/1997/97conti.htm

Corbin Design (n.d.). What is wayfinding? Retrieved from http://www.corbindesign.com

Creswell, J. W., & Plano Clark, V. L. (2007). *Designing and conducting mixed methods research.* Thousand Oaks, CA: Sage.

Darken, R. P. (1995). Wayfinding in large-scale virtual worlds. In J. Miller, I. Katz, R. Mack, & L. Marks (Eds.), *Conference companion on Human Factors in Computing Systems* (pp. 45–46). New York, NY: ACM.

Darken, R. P., & Peterson, B. (2002). Spatial orientation, wayfinding, and representation. In K. M. Stanney (Ed.), *Handbook of virtual environments: Design, implementation, and applications* (pp. 493–518). Mahwah, NJ: Erlbaum.

Darken, R. P., & Sibert, J. L. (1996). Wayfinding strategies and behaviors in large virtual worlds. In M. J. Tabuer (Ed.), *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems: Common ground* (pp. 142-149). New York, NY: ACM. Retrieved from http://www.sigchi.org/chi96/proceedings/papers/Darken/Rpd_txt.htm

Davies, R. (2004). Adapting virtual reality for the participatory design of work environments. *Computer Supported Cooperative Work: The Journal of Collaborative Computing, 13*(1), 1–33.

Di Blas, N. D., & Poggi, C. (2007). European virtual classrooms: Building effective “virtual” educational experiences. *Virtual Reality, 11*(2–3), 129–143. doi:10.1007/s10055-006-0060-4

Dochy, F., Segers, M., & Buehl, M. M., (1999, Summer). The relations between assessment practices and outcomes of studies: The case of research on prior knowledge. *Review of Educational Research, 69*(2), 145–186. doi:10.3102/00346543069002145

Dong, Y., & Lee, K. P. (2008). A cross-cultural comparative study of users' perceptions of a webpage: With a focus on the cognitive styles of Chinese, Koreans and Americans. *International Journal of Design, 2*(2), 19–30. Retrieved from http://www.ijdesign.org/ojs/index.php/IJDesign/article/view/267/163

Dotterer, G., Calhoun, P., Kroutter, P., Jennings, C., Burkett, R., & Braithwaite, P. (2008, December). *Preparing learners for desktop virtual reality training in career and technical education.* Poster session presented at ACTE Research and Professional Development Conference, Charlotte, NC.

Emory University Woodruff Health Sciences Center (2004, December 21). Researchers say virtual reality training is wave of the future for cardiovascular medicine [Press release]. Retrieved from http://whsc.emory.edu/press_releases2.cfm?announcement_id_seq=2959.

Eveland, W. P., & Dunwoody, S. (1998). Users and navigation patterns of a science World Wide Web site for the public. *Public Understanding of Science and Technology, 7*(4), 285–311. doi:10.1088/0963-6625/7/4/003

Faterson, H. F., & Witkin, H. A. (1970). Longitudinal study of development of the body concept. *Developmental Psychology, 2*(3), 429–438. doi:10.1037/h0029167

Feinberg, S., & Murphy, M. (2000). Applying cognitive load theory to the design of web-based instruction. In *Proceedings of the IEEE Professional Communication Society International Professional Communication Conference: Technology &*

teamwork (pp. 353–360). Piscataway, NJ: IEEE. Abstract retrieved from http://portal.acm.org/citation.cfm?id=504855

Fellenz, R. H., & Conti, G. J. (1989). *Learning and reality: Reflections on trends in adult learning* (Information Services No. 336). Retrieved from ERIC Database (ED315663)

Fiaola, A., & MacDorman, K. F. (2008, April). The influence of holistic and analytic cognitive styles on online information design. *Information, Communication & Society, 11*(3), 46–72. doi:10.1080/13691180802025418

Ford, N. (2000). Cognitive styles and virtual environments. *Journal of the American Society for Information Science, 51*(6), 543–557.

Ford, N., & Chen, S. Y. (2000). Individual differences, hypermedia navigation and learning: An empirical study. *Journal of Educational Multimedia and Hypermedia, 9*(4), 281–311.

Ford, N., & Miller, D. (1996). Gender differences in Internet perceptions and use. *Aslib Proceedings, 48*(7/8), 183–192.

Fraenkel, J. R., & Wallen, N. E. (2006). *How to design and evaluate research in education* (6th ed.). New York, NY: McGraw-Hill.

Garner, R., Alexander, P. A., Gillingham, M. G., Kulikowich, J. M., & Brown, R. (1991). Interest and learning from text. *American Educational Research Journal, 28*(3), 643-659.

Golbeck, J. (2002). *Cognitive load and memory theories*. Retrieved from http://www.cs.umd.edu/class/fall2002/cmsc838s/tichi/printer/memory.html

Governor, D. (1999). *Cognitive styles and metacognition in web based instruction.* (Education Specialist thesis, University of West Florida). Retrieved from http://www.members.cox.net/vogannod/THESIS.html

Graff, M. (2003). Learning from web-based instructional systems and cognitive style. *British Journal of Educational Technology, 34*(4), 407–418. doi:10.1111/1467-8535.00338

Gravetter, F. J., & Wallnau, L. B. (2007). *Statistics for the behavioral sciences*. Belmont, CA: Thomson Wadsworth.

Hansen, J. W. (1995, Spring). Student cognitive styles in postsecondary technology programs. *Journal of Technology Education, 6*(2), 1–12. Retrieved from http://scholar.lib.vt.edu/ejournals/JTE/v6n2/jhansen.jtev6n2.html

Hunt, E., & Waller, D. (1999). *Orientation and wayfinding: A review* (ONR Technical Report No. N00014-96-0380). Arlington, VA: Office of Naval Research.

International Society for Presence Research (2000). *The concept of presence: Explication statement.* Retrieved from http://ispr.info

Iowa State University News Service. (2006, May 8). The most realistic virtual reality room in the world. Retrieved from http://www.iastate.edu/~nscentral/news/06/may/c6update.shtml

Isdale, J., Fencott, C., Heim, M., & Daly, L. (2002). Content design for virtual environments. In K. M. Stanney (Ed.), *Handbook of virtual environments: Design, implementation, and applications* (pp. 519–532). Mahwah, NJ: Erlbaum.

Jansen-Osmann, P., Schmid, J., & Heil, M. (2007). Wayfinding behavior and spatial knowledge of adults and children in a virtual environment: The role of the environmental structure. *Swiss Journal of Psychology*, *66*(1), 41–50. doi:10.1024/1421-0185.66.1.41

Jul, S. (2001). *Locomotional structure in service of wayfinding: A partial design theory*. Retrieved from http://www-personal.umich.edu/~sjul/papers/structure.pdf

Kagan, J. (1965, August). Individual differences in the resolution of response uncertainty. *Journal of Personality and Social Psychology, 2*(2), 154–160. doi:10.1037/h0022199

Kagan, J., (1976). Commentary. *Monographs of the Society for Research in Child Development*, *4*(5, Serial No. 168), 48–52. Retrieved from http://www.jstor.org/stable/1166020

Kagan, J., & Kogan, N. (1970). Individual variation in cognitive processes. In P. H. Mussen (Ed.), *Carmichael's Manual of Child Psychology: Volume 1* (3rd ed., pp. 1273–1365). New York, NY: Wiley.

Kagan, J., & Messer, S. (1975, March). Some misgivings about the matching familiar figures test as a measure of reflection-impulsivity: Commentary reply. *Developmental Psychology*, *11*(2), 244–248. doi:10.1037/h0076501.

Kaplan-Leiserson, E. (2004). Augmented reality check. *Learning Circuits*. Retrieved from http://www.astd.org/LC/2004/1204_kaplan.htm

Kennedy, R. S., Kennedy, K. E., & Bartlett, K. M. (2002). Virtual environments and product liability. In K. M. Stanney (Ed.), *Handbook of virtual environments: Design, implementation, and applications* (pp. 543–553). Mahwah, NJ: Erlbaum.

Kim, K. S., & Allen, B. (2002, January). Cognitive and task influences on web searching behavior. *Journal of the American Society for Information Science and Technology, 53* (2), 109–119.

Korthauer, R. D., & Koubek, R. J. (1994). An empirical evaluation of knowledge, cognitive style, and structure upon the performance of a hypertext task. *International Journal of Human Computer Interaction, 6,* 373–390.

Kozhevnikov, M., & Hegarty, M. (2001). A dissociation between object manipulation spatial ability and spatial orientation ability. *Memory & Cognition, 29*(5), 745–756. Retrieved from http://mc.psychonomic-journals.org/content/29/5/745.full.pdf+html

Krafft, M. F. (2001). *Wayfinding*. Retrieved from http://www.ifi.uzh.ch/~krafft/papers/2001/wayfinding/html/node27.html

Lawless, K. A., & Kulikowich, J. M. (1998). Domain knowledge, interest, and hypertext navigation: A study of individual differences. *Journal of Educational Multimedia and Hypermedia, 7*(1), 51–70.

Lawless, K. A., Schrader, P. G., & Mayall, H. J. (2007). Acquisition of information online: Knowledge, navigation and learning outcomes. *Journal of Literacy Research, 39*(3), 289–306.

Lawton, C. A., (1994). Gender differences in way-finding strategies: Relationship to spatial ability and spatial anxiety. *Sex Roles, 30*(11/12), 765–779. doi:10.1007/BF01544230

Lazonder, A. W., Biemans, H. J. A., & Wopereis, I. G. J. H. (2000, April). Differences between novice and experienced users in searching information on the World

Wide Web. *Journal of the American Society for Information Science, 51*(6), 576–581.

Lee, M. W., Chen, S. Y., Chrysostomou, K., & Liu, X. (2009). Mining students' behavior in web-based learning programs. *Expert Systems with Applications, 36*, 3459–3464. doi:10.1016/j.eswa.2008.02.054

Liu, M., & Reed, W. M. (1994). The relationship between the learning strategies and learning styles in a hypermedia environment. *Computers in Human Behavior, 10*(4), 419–434. doi:10.1016/0747-5632(94)90038-8

Lowenfeld, V., & Brittain, W. L. (1970). *Creative and mental growth* (5th ed.). New York, NY: Macmillan.

Lu, J., Yu, C., & Liu, C. (2003). Learning style, learning patterns, and learning performance in a WebCT-based MIS course. *Information & Management, 40*, 497–507. doi:10.1016/S0378-7206(02)00064-2

Luo, G., & Peli, E. (2006, September). Use of augmented-vision device for visual search by patients with tunnel vision. *Investigative Ophthalmology & Visual Science*, *47*(9), 4152–4159. doi:10.1167/iovs.05-1672

Lynch, K. A. (1960). *The image of the city*. Cambridge, MA: The MIT Press.

MaKinster, J. G., Beghetto, R. A., & Plucker, J. A. (2002, June). Why can't I find Newton's third law? Case studies of student's use of the web as a science resource. *Journal of Science Education and Technology*, *11*(2), 155–172. doi:10.1023/A:1014617530297

Mandel, C. (2002, March 5). *3-D med school, hold the cadavers*. Retrieved from http://www.wired.com/print/medtech/health/news/2002/03/50829

McCauley-Bell, P. R. (2002). Ergonomics in virtual environments. In K. M. Stanney (Ed.), *Handbook of virtual environments: Design, implementation, and applications* (pp. 807–826). Mahwah, NJ: Erlbaum.

Merriam, S. B., & Caffarella, R. S. (1999). *Learning in adulthood: A comprehensive guide* (2nd ed.). San Francisco, CA: Jossey-Bass.

Monereo, C., Fuentes, M., & Sanchez, S. (2000). Internet search and navigation strategies used by experts and beginners. *Interactive Educational Multimedia, 1,* 24–34.

Moshell, J. M., & Huges, C. E. (2002). Virtual environments as a tool for academic learning. In K. M. Stanney (Ed.), *Handbook of virtual environments: Design, implementation, and applications* (pp. 893–910). Mahwah, NJ: Erlbaum.

Muhlhausen, J. (2006). Wayfinding is not signage: Signage plays an important part of wayfinding—but there's more. Retrieved from http://www.gscottdesign.com/learn.html

Parkinson, A., & Redmond, J. A. (2002). Do cognitive styles affect learning performance in different computer media? *SIGCSE Bulletin*, *34*(3), 39–43.

Pask, G. (1972). A fresh look at cognition and the individual. *International Journal of Man-Machine Studies, 4,* 211–216.

Pask, G., & Scott, B. C. E. (1972). Learning strategies and individual competence. *International Journal of Man-Machine Studies, 4,* 217–253.

Prensky, M. (2001). Digital natives, digital immigrants: Part 1. *On the Horizon*, *9*(5), 1–6. doi:10.1108/10748120110424816

Raubal, M., & Egenhoffer, M. (1998). Comparing the complexity of wayfinding tasks in built environments. *Environment & Planning B: Planning and Design, 25*(6), 895–913. doi:10.1068/b250895

Reiss, E. (2001). *Rediscovering wayfinding: How we move through physical spaces*. Retrieved from http://www.fatdux.com/resources/articles/rediscovering-wayfinding

Riding, R. J., & Cheema, I. (1991). Cognitive styles: An overview and integration. *Educational Psychology, 11*(3/4), 193–215.

Riding, R. J., & Sadler-Smith, E. (1992). Type of instructional material, cognitive style and learning performance. *Educational Studies*, *18*(3), 323–340.

Roy, M., & Chi, M. T. H. (2003). Gender differences in patterns of searching the web. *Journal of Educational Computing Research*, *29*(3), 335–348.

Rumetshofer, H., & Wöb, W. (2003). XML-based adaptation framework for psychological- driven E-learning systems. *Educational Technology & Society*, *6*(4), 18–29. Retrieved from http://www.ifets.info/journals/6_4/4.pdf

Santostefano, S. G. (1964). A developmental study of the cognitive control leveling-sharpening. *Merrill-Palmer Quarterly, 10*, 343–360.

Santostefano, S. (1978). *A bio-developmental approach to clinical child psychology: Cognitive controls and cognitive control therapy*. New York, NY: Wiley.

Santostefano, S. (1985). *Cognitive control therapy with children and adolescents*. New York, NY: Pergamon.

Santostefano, S. (1986). Cognitive controls, metaphors and contexts: An approach to cognition and emotion. In D. J. Bearison and H. Zimiles (Eds.), *Thought and emotion: Developmental perspectives* (pp.175–210). Hillsdale, NJ: Erlbaum.

Santostefano, S., & Paley, E. (1964). Development of cognitive controls in children. *Child Development*, *35*(3), 939–949.

Satalich, G. (1995). *Navigation and wayfinding in virtual reality: Finding the proper tools and cues to enhance navigational awareness* (Master's thesis, University of Washington). Retrieved from http://www.hitl.washington.edu/publications/satalich

Schroeder, R. (1997). Networked worlds: Social aspects of multi-user virtual reality technology. *Sociological Research Online*, 2(4). Retrieved from http://www.socresonline.org.uk/2/4/5.html

Schwarz, J. (2001, June 13). Lost in virtual space: Gender differences are magnified [Press release]. Retrieved from http://www.washington.edu/newsroom/news/2001archive/06-01archive/k061301.html

Sensen, C. W., Brum, J., Gordon, P., Hood, M., Lindahl, G., Schulman, M., . . . Unger, S. (2002). Establishment of the first Java 3D enabled cave: A white paper. Sun Center of Excellence for Visual Genomics, University of Calgary Health Sciences. Retrieved from http://www.visualgenomics.ca/images/stories/whitepaper.pdf

Seymour, N. E., Gallagher, A. G., Roman, S. A., O'Brien, M. K., Bansal, V. K., Andersen, D. K., & Satava, R. M. (2002, October). Virtual reality training improves operating room performance: Results of a randomized, double-blind study. *Annals of Surgery, 236*(4), 458–464. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1422600/?tool=pubmed

Shrock, S. A., & Coscarelli, W. C. C. (1989). *Criterion-referenced test development*. New York, NY: Addison-Wesley.

Somyürek, S., Güyer, T., & Atasoy, B. (2008, April). The effects of individual differences on learner's navigation in courseware. *Turkish Online Journal of Educational Technology, 7*(2), 32–40. Retrieved from http://www.tojet.net/volumes/v7i2.pdf

Stanney, K. M., & Zyda, M. (2002). Virtual environments in the 21st century. In K. M. Stanney (Ed.), *Handbook of virtual environments: Design, implementation, and applications* (pp. 1–14). Mahwah, NJ: Erlbaum.

Stroop, J. R. (1935, December). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*(6), 643–662.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science, 12*(1), 257–285.

Tan, D., Czerwinski, M., & Robertson, G. (2003). *Women go with the (optical) flow*. Retrieved from http://research.microsoft.com/~marycz/chi2003flow.pdf

Telepresence (n.d.). *Bloomberg Businessweek*. Retrieved from http://bx.businessweek.com/telepresence

University of Texas Robotics Research Group. (n.d.). *Industrial robots*. Retrieved from http://www.robotics.utexas.edu/rrg/learn_more/low_ed/types/industrial.html van der Bosh, A. E., Koning, A. H., Meijboom, F. J., Simoons, M. L., van der Spek, P. J., & Bogers, A. J. (2005, December 23). Dynamic 3D echocardiography in virtual reality. *Cardiovasc Ultrasound*, *3*(37*).* doi:10.1186/1476-7120-3-37

Vila, J. Beccue, B., & Anandikar, S. (2002). The gender factor in virtual reality navigation and wayfinding. In R. J. Sprague, Jr. (Ed.) *Proceedings of the 36th Hawaii International Conference on System Sciences (HICSS'03).* doi:10.1109/HICSS.2003.1174239

Waller, D. (1999). *An assessment of individual differences in spatial knowledge of real and virtual environments*. (Doctoral Dissertation, University of Washington). Retrieved from http://academic.research.microsoft.com/Paper/ 272289.aspx?viewType=1.

Waller, D. (2000, December). Individual differences in spatial learning from computer simulated environments. *Journal of Experimental Psychology: Applied, 6*(4), 307–321. doi:10.1037/1076-898X.6.4.307

Waller, D., Beall, A. C., & Loomis, J. M. (2004). Using virtual environments to assess directional knowledge. *Journal of Environmental Psychology*, *24*, 105–116. doi:10.1016/S0272-4944(03)00051-3

Waller, D., Hunt, E., & Knapp, D. (1998a). The transfer of spatial knowledge in virtual environment training. *Presence: Teleoperators and Virtual Environments*, *7*(2), 129–143. doi:10.1162/105474698565631

Waller, D., Hunt, E., & Knapp, D. (1998b, Nov 21). *Measuring spatial knowledge in a virtual environment: Distances and angles*. Paper presented at the 39th annual meeting of the Psychonomics Society, Dallas, TX.

Waller, D., Knapp, D., & Hunt, E. (1999). *Spatial representations of virtual mazes: The role of visual fidelity and individual differences*. Retrieved from http://depts.washington.edu/huntlab/vr/pubs/maze5.pdf

Wang, X., Liebscher, P., & Marchionini, G. (1988, January). *Improving information seeking performance in hypertext: Roles of display format and search strategy* (Tech Report HCIL-88-02). Retrieved from University of Maryland, Human-Computer Interaction Lab website: http://www.cs.umd.edu/localphp/hcil/tech-reports-search.php?number=88-02

Weller, H. G., Repman, J., & Rooze, G. E. (1994). The relationship of learning, behavior, and cognitive styles in hypermedia-based instruction: Implications for design of HBI. *Computers in Schools, 10*, 401–420. doi:10.1300/J025v10n03_09

Whitley, B. E., (1997). Gender differences in computer-related attitudes and behaviors: A meta-analysis. *Computers in Human Behavior, 13*(1), 1–22. doi:10.1016/S0747-5632(96)00026-X

Williams, M. S. (2008). *The effects of supraliminal bipolar primes on career and technical educators' viewing time, perceived confidence, and self efficacy of desktop virtual reality* (Doctoral dissertation). Available from ProQuest Dissertations and Theses database (UMI No. 1663052381)

Wilson, P. N., Foreman, N., & Tlauka, M. (1997). Transfer of spatial information from a virtual to real environment. *Human Factors, 39*(4), 526–530.

Witkin, H. A. (1967). A cognitive approach to cross-cultural research. *International Journal of Psychology, 2*(4), 233–250.

Witkin, H. A., & Asch, S. E. (1948). Studies in space orientation III: Perception of the upright in the absence of a visual field. *Journal of Experimental Psychology, 38*, 603–614. doi:10.1037/h005537

Witkin, H. A., Oltman, P. K., Raskin, E., & Karp, S. A. (1971). *A manual for the embedded figures tests*. Palo Alto, CA: Consulting Psychologists.

Witkin, H. A., Price-Williams, D., Bertini, M., Christiansen, B., Oltman, P. K., Ramirez, M., & Van Meel, J. (1974). Social conformity and psychological differentiation. *International Journal of Psychology, 9*(1), 11–29.

Witkin, H. A., Moore, C. A., Goodenough, D. R., & Cox, P. W. (1977, Winter). Field-dependent and field-independent cognitive styles and their educational implications. *Review of Educational Research, 47*(1), 1–64. Retrieved from http://www.jstor.org/stable/1169967

APPENDICES

APPENDIX A
PARTICIPANT OBSERVATION LOG

Sub	Node	MouseClick	Pan	Right	Left	Up	Down	ZoomIn	ZoomOut
Totals:		0	0	0	0	0	0	0	0

APPENDIX B

Subject I.D. Number ____________

Crime Scene Sketch Likert:
Rate the following questions regarding the subject's crime scene sketch using the following Likert scale and rubric:

A. The floor plan accuracy of the subject's crime scene sketch:		
1.	Extremely poor	Incomplete sketch of floor plan (1-2 rooms).
2.	Below Average	Somewhat complete floor plan (3-4 rooms).
3.	Average	Basic floor plan accuracy (5-6 rooms).
4.	Above Average	Depicted overall floor plan (6 rooms & hallway)
5.	Excellent	Complete and detailed floor plan with furniture.
B. The quantity and location of evidentiary details:		
1.	Extremely poor	0-3 items of evidence in right location.
2.	Below Average	4-6 items of evidence in right location.
3.	Average	7-10 items of evidence in right location.
4.	Above Average	11-15 items of evidence in right location.
5.	Excellent	16 or more items of evidence in right location-included furniture.
C. The overall completeness of the subject's crime scene sketch:		
1.	Extremely poor	Incomplete floor plan / lacked evidentiary detail
2.	Below Average	Incomplete floor plan /minimal evidentiary detail
3.	Average	Complete floor plan / minimal evidentiary detail
4.	Above Average	Complete floor plan / moderate evidentiary detail
5.	Excellent	Detailed floor plan / greater than 15 items in right position

APPENDIX C

The Influence of Field Dependence/Independence, Gender and Prior Experiences on Navigational Behavior and Configurational Knowledge Acquisition in a Desktop Virtual Reality Environment

DATA FORM

Collector's name ______________________________

Subject Number: ______________________________

1. Gender: ___________________________________
2. Age Range: ________________________________
3. Years of Law Enforcement Experience: _______
4. Education Level: ___________________________
5. Computer Use:
   - Word Processing ______________________
   - Browsing Internet _____________________
   - Playing Computer Games _______________
   - Computer Programming ________________
6. Level of Computer Experience: ______________
7. GEFT Score: ______________________________

---

8. Total time spent on learning task/computer program:___ minutes _____ seconds
9. Time spent in each node:

Node 1 –Intro Video	min. ________	sec.________
Node 2 (Foyer)	min. ________	sec. ________
2A) Foot Print 1	min. ________	sec. ________
2B) Foot Print 2	min. ________	sec. ________
Node 3 (Dining room)	min. ________	sec. ________
Node 4 (Living room):	min. ________	sec. ________
4 A: Victim evidence movie	min. ________	sec. ________
4 B: Victim angle 1	min. ________	sec. ________
4 C: Victim angle 2	min. ________	sec. ________
4 D: Victim angle 3	min. ________	sec. ________
Node 5 (Kitchen)	min. ________	sec. ________
5A: Wet blood collection movie	min. ________	sec. ________
5B: Palm on counter	min. ________	sec. ________
Node 6 (Bath room)	min. ________	sec. ________
6A: Knife-object movie	min. ________	sec. ________
6B: Knife-still	min. ________	sec. ________
6C: Dry blood collection-movie	min. ________	sec. ________
6D: Dry blood in sink-still	min. ________	sec. ________
6E: Fingerprint collection movie	min. ________	sec. ________
6F: Bath room-still	min. ________	sec. ________

10. Number of nodes revisited more than twice ___________________________________
____
____
____

11. Sequence of nodes visited: ____
____
____
____
____
____

12. Total cursor movements left: ____________________________
13. Total cursor movements right: ___________________________
14. Total cursor movements up: _____________________________
15. Total cursor movements down: ___________________________
16. Total number of zoom in movements: _____________________
17. Total number of zoom out movements: ____________________
18. Total number of mouse clicks: ___________________________
19. Total number of pan movements: _________________________

---

20. Total time drawing crime scene sketch: min. __ sec. ________
21. Likert score on crime scene sketch floor plan accuracy: ______
22. Likert score on quantity of evidentiary detail: ______________
23. Likert score on completeness of sketch: ___________________

APPENDIX D

The Influence of Field Dependence/Independence, Gender and Prior Experience on Navigational Behavior and Configurational Knowledge Acquisition in a Desktop Virtual Reality Environment

PARTICIPANT SURVEY FORM

Collector's name ____

Subject Number: ________________

1. Gender: Male: _______ Female ______

2. Age Range (Circle the most appropriate range):

   20-25 26-30 31-35 36-40 41-45 46-50 51 and older

3. Years of law enforcement experience: (Circle one)

   1-5 6-10 11-15 16-20 21-25 26-30 31 or more

4. Highest level of education attained: (Circle one)

   High School Some College Associate Baccalaureate Masters Doctorate

5. I use the computer for: (Circle all that apply)

   a. Word processing for work/school.

   b. Browsing the Internet for research or fun

   c. Playing computer games

   d. Computer programming

6. My experience with computers would best be described as: (Circle one)

   a. None

   b. Novice/Beginner

   c. Moderate/Average

   d. Advanced/Very experienced

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POLICE DEPARTMENT

INTEROFFICE MEMO

To: **Sworn Officers**

From: **Chief T. Wuestewald**

CC: **Sworn Personnel**
Date: **September 22, 2009**

Re: **Research Project**

In the fall, our own Paul Kroutter, will be conducting research for his dissertation at OSU. This research will examine how individual learner characteristics influence navigation and learning in virtual reality environments. The findings generated from this study may help researchers to predict performance in such a learning environment or allow them to adjust the environment to accommodate differences among learners. This research may benefit the department as we incorporate more high tech training programs.

Initially, Paul needs 75 sworn officers from this department to volunteer to assist with this research. Those who participate will be asked to take a short pen and paper test which will take approximately 20-30 minutes. Approximately one to two weeks after taking the written exam, 30 officers will be selected and assigned to one of two groups for further research.

In this second phase of the research, the 30 officers will be scheduled to explore a new desktop virtual reality crime scene curriculum and complete a short written task. The crime scene exploration and writing task will take approximately one hour of your time.

I would like to encourage you to volunteer and help Paul in this research study. Should you choose to help, you will be permitted to take part in this study while on duty. No overtime will be authorized for this project.

Okla. State Univ.
IRB
Approved 9/16/09
Expires 9/15/10
IRB# ED-09-122

The Influence of Field Dependence/Independence, Gender and Prior Experience on Navigational Behavior and Configurational Knowledge Acquisition in a Desktop Virtual Reality Environment

Participant Consent Information Sheet

This research is being conducted by OSU Doctoral Candidate Paul Kroutter to study the influence of information processing (cognitive) style, gender and prior experience on navigation and learning in a desktop virtual reality (VR) crime scene environment.

Specifically, this research will compare the navigational behaviors and learning effects of two different cognitive groups as they maneuver through a desktop VR crime scene program. After studying the VR crime scene, participants will be asked to complete a written exercise to see how well the presentation helped them learn about the scene.

By agreeing to participate in this research, you will be accepting and agreeing to the following:

You understand that your participation in this research is completely voluntary, that there are no special incentives for your participation, that there are no negative consequences for declining participation, and that you are free to withdraw your consent and participation at any time.

You understand that the purpose of this research is to help researchers to learn more about the influence of cognitive style, gender and prior experience upon knowledge acquisition and navigational behaviors in virtual environments.

You understand and agree to the following conditions regarding your voluntary participation in this research:

- Your participation will involve completing a short (approximately 20-30 minute) pen and paper assessment of your cognitive style dimension.
- Your participation may also involve viewing a computer presentation followed by the completion of a written learning activity which will take approximately one hour of your time.
- Information you provide will be coded with a personal number assigned to you and will be treated with complete confidentiality. The Principal Investigator will be the only one having access to the list with your name and code number. Once all data has been gathered and code numbers have been verified for accuracy, the list will be shredded.
- Information you provide will be secured at all times by the Principal Investigator.
- The data yielded from this research will be used solely for research and instructional improvement.
- Any data from this research used in preparation and publication of professional literature and reports will be anonymous and reported only in aggregate and/or in codes. No specific reference to your name or personal identity will be made at any time.
- All records of this research will be kept solely by the Principal Investigator and will be maintained under locked security.

You understand that if you have questions or concerns, you may contact the Principal Investigator, Paul Kroutter by phone at (918) 451-8399 or by email at paul.kroutter@okstate.edu. If you have questions about your rights as a research volunteer, you may contact Dr. Shelia Kennison, IRB Chair, 219 Cordell North, Stillwater, OK 74078, 405-744-1676 or irb@okstate.edu.

By removing this Consent Information Sheet and completing the Group Embedded Figures Test (GEFT) administered by the researcher, you understand you are agreeing to voluntarily participate in this research and to have the data you provide included in the study's data analysis and its reporting in the Principal Investigator's doctoral dissertation and in published professional research articles.

VITA

Paul Joseph Kroutter Jr.

Candidate for the Degree of

Doctor of Philosophy

Dissertation: THE INFLUENCE OF FIELD DEPENDENCE / INDEPENDENCE, GENDER, AND EXPERIENCE ON NAVIGATIONAL BEHAVIOR AND CONFIGURATIONAL KNOWLEDGE ACQUISITION IN A DESKTOP VIRTUAL REALITY ENVIRONMENT

Major Field: Education (Occupational Studies)

Biographical:

Education: Completed the requirements for the Doctor of Philosophy in Education (Occupational Studies) at Oklahoma State University, Stillwater, Oklahoma in December, 2010.

Completed the requirements for the Master of Science in Criminal Justice at Northeastern State University, Tahlequah, Oklahoma in May, 1981.

Completed the requirements for the Bachelor of Science in Criminal Justice at Northeastern State University, Tahlequah, Oklahoma in May, 1979.

Experience: Broken Arrow Police Department, 1981 - present
Northeastern State University Campus Police, 1979 - 1981
Rogers State University Adjunct Instructor 1984 to 2008
Tulsa Technology Center- School Board Member 2004 - present
OACP Law Enforcement Accreditation Commission, 2006 - present

Professional Memberships: Omicron Tau Theta, Oklahoma Criminal Justice Educators Association, RSU and Tulsa Community College Criminal Justice Advisory Board, Association for Career and Technical Education (ACTE), State (OSSBA) and National School Board Association (NSBA).

Name: Paul Joseph Kroutter Jr. Date of Degree: December, 2010

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: THE INFLUENCE OF FIELD DEPENDENCE / INDEPENDENCE, GENDER, AND EXPERIENCE ON NAVIGATIONAL BEHAVIOR AND CONFIGURATIONAL KNOWLEDGE ACQUISITION IN A DESKTOP VIRTUAL REALITY ENVIRONMENT

Pages in Study: 217 Candidate for the Degree of Doctor of Philosophy

Major Field: Education – Occupational Studies

Scope and Method of Study:

Little is known about the influence of individual learner differences on navigational behaviors and learning within a desktop virtual reality environment (VE). This mixed-methods exploratory study used orienting, navigating, and wayfinding theory, digital performance-recording technology, and expert judges to examine the influences of the individual characteristics of field dependent/field independent cognitive style, gender, and prior domain knowledge or experience on navigation behaviors and survey knowledge acquisition of 30 police officers in a virtual crime scene created for the study.

Findings and Conclusions:

Detailed analyses were made of navigational moves and post-VE-treatment drawings of the virtual crime scene. Based on descriptive statistics, independent sample t-tests, analysis of variance, qualitative data, inter-judge reliability coefficients, and rating scores on post-treatment drawings, several conclusions were drawn:

1. Navigational behaviors in a desktop VE is individualistic rather than occupational.
2. Identification of instructional design flaws in VEs is critical to successful navigation.
3. Tendency for disorientation in a VE is related to cognitive style.
4. Cognitive style differences are more influential on the learning process than on the learning outcome in a VE.
5. Prior domain knowledge and experience may affect learning in VEs less than in other media.
6. Computer gaming experience influences performance in VEs.
7. There are gender differences in navigational behaviors in VEs.
8. A sense of “presence” (“being there”) can be achieved in a desktop VE.
9. Real-world training can transfer to a desktop VE.
10. Pre-immersion training and preparation of learners are critical to successful navigation and learning in VEs.
11. Learners with different characteristics can learn from desktop VEs.

ADVISER’S APPROVAL: Dr. Lynna Ausburn