Cognitive and Environmental Factors Influencing the Process of Spatial Knowledge Acquisition within Virtual Reality Environments

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ABSTRACT

As the fidelity of virtual environments (VE) continues to increase, the possibility of using them as training platforms is becoming increasingly realistic for a variety of application domains, including military and emergency personnel training. In the past, there was much debate on whether the acquisition and subsequent transfer of spatial knowledge from VEs to the real world is possible, or whether the differences in medium during training would essentially be an obstacle to truly learning geometric space. In this paper, the authors present various cognitive and environmental factors that not only contribute to this process, but also interact with each other to a certain degree, leading to a variable exposure time requirement in order for the process of spatial knowledge acquisition (SKA) to occur. The cognitive factors that the authors discuss include a variety of individual user differences such as: knowledge and experience; cognitive gender differences; aptitude and spatial orientation skill; and finally, cognitive styles. Environmental factors discussed include: Size, Spatial layout complexity and landmark distribution. It may seem obvious that since every individual’s brain is unique - not only through experience, but also through genetic predisposition that a one size fits all approach to training would be illogical. Furthermore, considering that various cognitive differences may further emerge when a certain stimulus is present (e.g. complex environmental space), it would make even more sense to understand how these factors can impact spatial memory, and to try to adapt the training session by providing visual/auditory cues as well as by changing the exposure time requirements for each individual. The impact of this research domain is important to VE training in general, however within service and military domains, guaranteeing appropriate spatial training is critical in order to ensure that disorientation does not occur in a life or death scenario.

Keywords: Cognitive Factors, Environmental Factors, Individual User Differences, Spatial Knowledge Acquisition (SKA), Virtual Environments (VE)

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INTRODUCTION

The ability to ‘learn’ the environment before engaging in navigation is an area of interest for a variety of application domains ranging from military, to touring of real space for people with mobility problems (Egsegian et al., 1993, Wilson et al., 1996, Foreman et al., 2003). Although spatial training can be provided through maps and briefings of an environment, these methods only provide topological (survey) knowledge, which, whilst being more flexible, pays little attention to the details of routes and landmarks; and requires ‘mental construction’ of the environment, rather than direct experience and formation of procedural memory (Thorndyke, 1980; Golledge, 1991). Procedural learning has a distinct advantage over survey knowledge, as can be seen in the experiments of Thorndyke and Hayes-Roth (1982) where participants with procedural knowledge of an environment, estimated route distances significantly better than participants who had acquired just survey knowledge. Navigation therefore relies heavily on previously acquired visual information, e.g. the process of re-orientation during navigation in a previously visited environment (Montello, 2005), which relies on previously seen “visual references” in order to adjust bearings during navigation. Maps and other traditional navigational equipment cannot provide the same level of supporting information. VE training, therefore, promises to provide procedural knowledge through direct experience, and has caught the attention of a variety of researchers all attempting to discuss whether virtual training is more efficient than training through more traditional methods (Witmer et al., 1995; Goerger et al., 1998; Waller et al., 1998; Foreman et al., 2003), and even whether mobile GPS systems can effectively help people acquire spatial knowledge of their environment while on the move (Huang et al., 2012).

Learning in virtual environments relies on the ability of users to develop an understanding of space either through the use of relational memory, or by creating a cognitive map of the environment (Asthmeir et al., 1993; Cobb & d’Cruz, 1994; Silverman & Spiker, 1997; Clark & Wong, 2000; Riva & Gamberini, 2000; Kumaran & Maguire, 2005; Konkel & Cohen, 2009). There is some debate over which of the two methods is employed by humans during spatial learning. Cognitive maps, are in a sense ‘mental images’ of an environment, and, according to Kumaran and Maguire (2005) are more likely to be the dominant method of spatial memory, since the human hippocampus shows a bias towards spatial relations during navigational learning. Relational memory, on the other hand has been described as essentially a mental network of nodes representing memories that occurred at a given time. These memories could be visual, but could also be part of a larger array of information from other modalities. For example, when walking down a familiar street, you may be flooded with memories of things that happened last time you walked down that path, the music that was playing in a nearby cafe, the people you talked to, but also any associations this street may have to other streets (that may run parallel to this street for example). Therefore, relational memory rejects the idea of a mental map model, but instead argues that maps are formed by a series of memories from various modalities (Eichenbaum et al., 1999).

Although there is a significant debate over which of the two cognitive learning methods human beings utilise during environmental learning, both theories rely on direct experience with an environment (Thorndyke, 1980; Golledge, 1991; Witmer et al., 1995; Goerger et al., 1998; Eichenbaum et al., 1999). Navigation itself is made up of two separate and very distinct processes. The first of these processes is locomotion, which is the movement of a person within an environment. The second process is way-finding, which is the planning of routes that a person undergoes when trying to get to a specific destination (Montello, 2005). With self-directed locomotion (where the person is actively moving about in the environment, rather than being driven around), there is a tendency to acquire more spatial knowledge (Feldman & Acredolo, 1979). This tendency is reminiscent of the Action Perception loop, a very important
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