

The Use of Interactive Map Based Displays for Teleportation in Virtual Environments

David L. Jones, Brian Goldiez
Institute for Simulation and Training
Orlando, FL
david@mail.ucf.edu, bgoldiez@ist.ucf.edu

ABSTRACT

As technology advances, new ways to interact with systems become available to system designers. One such advancement that is being used in various virtual environments today is the technique of using “teleportation” to navigate through environments. Teleportation is defined as the movement from one location in an environment to a distant location instantaneously. As with most technological advances, this technique has tremendous potential benefits (reduced travel time, less chance for navigation error) if used correctly. On the other hand, like many new techniques and technologies, if used incorrectly, the drawbacks can be just as great (inaccurate mental map development, chance of being lost increased).

The purpose of the following paper is twofold. First, based on the current literature and experimentation, it lays out guidelines for the design and use of teleportation systems within virtual environments. Secondly, it introduces a new interactive map-based teleportation technique which should be useful when there is a need for accurate mental map development within the virtual environment. The proposed system should allow for a totally interconnected environment while not taking away from the spatial learning component which is essential in most virtual environments.

ABOUT THE AUTHORS

David L. Jones is pursuing his Master’s degree in Industrial Engineering with a focus on human-computer interaction (HCI) and usability. His primary research focus is on designing multimodal interactive systems. His background education focused on human factors and computer science. Past projects include usability evaluations for industry clients as well as government organizations. He has also been involved with usability evaluations of virtual environments. He is currently working on experimental determination of working memory various capacities and interference, and the resulting effects on dual task performance.

Brian Goldiez is the Deputy Director of the Institute for Simulation and Training at the University of Central Florida. In his thirty years in the modeling and simulation field he has been involved in a variety of aspects of simulation including flight models and computer simulations, computer graphics, and systems level research issues in M&S such as software development, integration methods and distributed simulation. Mr. Goldiez current research activities include usability analysis of augmented reality systems and investigation of modeling methodologies. Mr. Goldiez is currently pursuing his doctorate in modeling and simulation at the University of Central Florida.

The Use of Interactive Map Based Displays for Teleportation in Virtual Environments

David L. Jones, Brian Goldiez
Institute for Simulation and Training
Orlando, FL
david@mail.ucf.edu, bgoldiez@ist.ucf.edu

INTRODUCTION

As virtual environments become more and more common throughout different industries, various ways of navigating the spaces are being designed and implemented to make the user experience more efficient. One such navigation method that has great potential to save traversal time in virtual environments is the use of teleports to instantaneously move people across large spans of the virtual environment. Although this transportation method has apparent potential advantages, if used incorrectly and not well designed, there can be great disadvantages associated with it as well. One such disadvantage is the loss of spatial awareness that is encountered when users teleport from one place to another. Methods of teleportation need to be designed to preemptively and instantaneously give users spatial information that is normally gained through natural navigation from the origin to the destination.

The following paper first gives a background on the use of virtual environments and explains some of the problems currently associated with the use thereof. It then explains how teleportation is currently used, citing good and bad examples, and explains why current teleportation methods may add to the problems which are already apparent in virtual environments. In order to better explain what information is lost when teleporting, methods of spatial knowledge acquisition are described and an overview of how current research is working to mitigate the problems associated with the use of teleportation is presented. The paper concludes by explaining how people gain spatial knowledge through the use of maps, which lends support to the use of interactive map based teleportation systems, such as the one described at the conclusion of this paper, in order to mitigate many of the problems associated with the used of teleportation in virtual environments.

BACKGROUND ON VIRTUAL ENVIRONMENTS

Virtual environments (VEs) have proven to be a very useful tool for studying different models of spatial knowledge acquisition. They provide flexible environments that can be quickly changed to study the methods that people use to acquire spatial knowledge. They also give researchers the ability to add and take away potential navigational cues to study the effectiveness of them.

Along with the study of spatial knowledge acquisition techniques, VE's are employed for a wide spectrum of real-world task and spatial training. In training applications, VE's allow people to explore and train in environments that are not practical, possible, or safe to train in the actual real world setting. Some examples of such situations are the training of military or police units in hostile situations, firefighter training, and space training for astronauts (Witmer et al., 1996). Each of these situations are both very dangerous and expensive to train in the real environment but can be safely controlled in a VE setting.

The use of VE's that will be primarily focused on throughout this paper is that of spatial training in virtual environments and the transfer of that training to real-world environments. An early study of wayfinding in immersive VE's was performed by Regian and Shebilske (1992). This study showed that people would learn efficient routes of travel in virtual environments, even if they were low quality representations of the real world.

When studies of wayfinding in VE's are compared with studies of real world wayfinding, many of the same environmental factors are shown to influence navigation in each environment (Barlow, 2001). This point leads to the idea that spatial representations of virtual environments can be transferred to real world environments. A study by Witmer, Bailey, and Knerr (1996) supported the idea that virtual environments with adequate representation of the real world space can be an effective training tool for learning complex

routes in the real world environment. In this study, participants studied route directions in a VE, in the actual building, or through verbal directions and photographs. Participants were then tested on their route knowledge in the real world building. The results showed that the type of route rehearsal did not have a significant effect on the configurational knowledge of the building, which supports the idea that VE's can be used to train complex routes when the real world site can't be used. These findings have been supported in multiple other studies as well (Ruddle et al., 1997; Koh et al., 1999; Arthur and Hancock, 2001, Wilson, Foreman, & Tlauka, 1997; Witmer et al., 1996).

PROBLEMS WITH VIRTUAL ENVIRONMENTS

Although virtual environments have proven on numerous occasions to be a useful tool for acquiring spatial information of real world locations, they are not without flaws. One of the most dominating problems with VE systems since the development of such systems has been the disorientation that accompanies their usage (Durlach & Mavor, 1995; Psootka, 1995). The disorientation that is associated with the use of VE systems has been attributed to both inadequate design such as missing cues or poor organizational structure, as well as user shortcomings such as low spatial ability (Stanney and Salvendy, 1994 and 1995).

Cutting (1997) has listed many of the cues required for distance estimation in real world and virtual environments. A lack of natural cues is not limited to distance perception in VE systems. Another missing cue that has been noted in the literature, which may lead to a decrement in spatial knowledge transfer to the real world, is the lack of proprioception (the sense of motion) in VE's (Grant & Magee, 1998). The use of joysticks, pointing devices, or data gloves to direct navigation is not natural and doesn't afford proprioceptive feedback to the user. Grant and Magee (1998) found that when a proprioceptive feedback (walking interface) device was used to direct movement in the virtual environment users performed better when later finding objects in the real world environment. This suggests that the lack of proprioceptive feedback in VE systems may lead to a degraded transfer of spatial knowledge to the real world.

TELEPORTATION IN VIRTUAL ENVIRONMENTS

The above mentioned limitations of virtual environments to serve as spatial orientation systems for real world environments stem from a lack of natural cues in the VE. Another action that is sometimes available in virtual environments which is not natural in the real world is the discontinuity of movement that is associated with hyperlinks or the use of teleports in the virtual environment.

Teleports and hyperlinks are not always a bad idea in VE's, but when used improperly can lead to users being confused and instantaneously lost in the environment. Some examples of when hyperlinks and teleports are suitable to use include when they are used to take a user back to a starting location after making a mistake, or to set up a scenario for a user to participate in, or any other time when the act of navigation is not an important action for the user to take part in. In those cases, teleportation and the use of hyperlinks can be very convenient.

Problems arise when VE designers implement hyperlinks and teleports into scenarios where it is important for users to be involved in the navigation of the environment. Situations where current teleportation techniques are improperly used include any situation where the main goal of the system is to train users on the spatial organization of the environment in order to transfer this knowledge to real world situations. One documented case of poor use of this teleportation function is the speech-interactive virtual environments for ship familiarization, which has been developed by the Naval Research Laboratory (Wauchope, et al., 2003). The teleport function investigated gives no information on how the user has been taken to the location or even where the location is in reference to the entire ship or other rooms, and could lead to disorientation and a decrement in the overall goal of the system which was to train users on the spatial layout of the ship.

WHY TELEPORTATION ADDS TO PROBLEMS IN VIRTUAL ENVIRONMENTS

To resolve the problems that accompany teleportation in VE's, the reason for the problems must be first understood. The problem of disorientation caused by hyperlinks in VE navigation can be compared to disorientation in hypertext environments such as the World Wide Web. In hypertext environments this problem stems from users developing a wrong or

incomplete conceptual model of how information is structured and linked within the hypertext system (Elm & Wood, 1985). It is believed that there is a similarity between hyperlink movements and teleportation. In virtual environments where teleportation is used to jump to distant nodes of space, the user develops a wrong or incomplete conceptual map of the physical space that he is navigating in.

In spatial navigation that uses hyperlinks or teleportation to connect distant spaces in a physical space, two different levels of disorientation may occur during teleportation. The first level of disorientation occurs in regard to the user's overall position within the entire VE. At this level of disorientation the user does not know where he/she is in reference to other rooms within the environment. This type of disorientation is very similar to that of the disorientation that is developed using hypertext systems. In both situations, this level of disorientation causes people to be lost in reference to where they just came from and within the global structure of the environment.

Another level of disorientation, which is not present in hypertext situations, occurs in the virtual environment. This type of disorientation occurs at more of a local or room level. When users teleport to different areas within a VE they do not know where they are located and which direction that they are facing within the particular room that they are in. For this reason, users must first orient themselves within the local space and then proceed to orient themselves at a more global level. Both of these tasks lead to wasted time and an opportunity for the user to create a poor conceptual map of the space in which they are navigating.

There are multiple causes for the disorientation that occurs when teleports are used in VE's. One of the primary causes for disorientation is the lack of visual continuity (Ruddle, et al., 2000). In normal navigation in VE's and in the real world visual continuity is almost 100%. When teleports are used, many times this visual continuity can drop to nearly 0%. When there is no anchoring image to allow a user to draw a connection between the node that they traveled from and the one that they traveled to, users typically get lost and must take time to regain their bearings. This very point has been demonstrated in a study where participants took a significantly longer time to re-orient themselves after teleporting between points in space when compared to participants who continuously traveled between the same two locations (Bowman, et al., 1997).

Poor spatial relationships between hyperlink locations and destination locations may also lead to disorientation during hyperlink traversal. Directional cues, which are explained by Ruddle et al. (2000) as the difference between a persons implied direction of travel and actual direction of travel when they use hyperlinks, in many cases, is poorly implemented. Users expect that the direction that they are facing when they teleport is the direction that they will travel to get to the destination node. When this is not the case, the user's conceptual map of the space may become distorted.

A problem that adds to the above-mentioned shortcomings of hyperlinks in VE's is the use of unidirectional links (Ruddle et al., 2000). With such links users become frustrated because they get lost within the environment and have no way to undo the actions that they have done to get there. Not only will this lack of an undo function lead to users becoming frustrated and disoriented, it will eventually lead to users not using the hyperlinks for a fear that they will be taken to an unknown location that they can't find their way out of. In a sense, unidirectional hyperlinks could lead to users who are afraid to use the technology that is available to them.

HOW PEOPLE GAIN SPATIAL KNOWLEDGE THROUGH NAVIGATION

To better understand what information is lost when teleporting, models of spatial knowledge acquisition can be studied. Although, currently, there is no universally accepted model of spatial knowledge acquisition, there are a few that stand out and are well accepted.

The most widely accepted model of spatial knowledge acquisition during navigation has been the Landmark-Route-Survey (LRS) model (Colle and Reid, 1998, Siegle and White, 1975). This model defines three different spatial knowledge representation types. Landmark knowledge can be described as descriptive information of noticeable places within an environment. Route knowledge consists of knowledge of mentally defined routes between locations. Finally survey knowledge can be defined as spatial knowledge in the form of a mental map of an environment. These mental maps are thought to be metric representations of locations and objects that are in the environment (Colle and Reid, 1998).

Siegel and White (1975) suggest that the different knowledge that is gained from an environment is gained in sequence. First, knowledge is gained about

landmarks that are visible. Next, landmarks are located in reference to each other. This relationship between landmarks allows people to develop and learn routes throughout the environment. Over time, with support from the procedural knowledge that has been gained, a mental map of the environment can be constructed. This mental map is considered survey knowledge of the environment and contains metric representations of locations and objects.

Although the LRS model of wayfinding is the most widely accepted, there are theories that build upon it and contradict Siegel and White's suggestion that different types of spatial knowledge is gained sequentially. Colle and Reid (1998) describe the dual-mode model, which proposes the idea that survey knowledge of local regions can quickly be gained.

The dual mode model assumes that there are two modes of spatial knowledge acquisition. The two modes described in this theory are the gaze viewing mode and the route tour mode. Unlike the LRS model, the two proposed modes in the dual mode model can operate at the same time and can both operate at any user experience level.

The gaze viewing mode is utilized when people acquire a spatial representation of the current local area. A local area can be defined as anything in the spatial span, which can be seen from the observer's viewpoint. By rotating the head or body, an observer can create an exocentric spatial map of this local area. The spatial knowledge acquired in this mode is referred to as direct imagery, or "a reconstruction of the three-dimensional perceptual space acquired from viewing objects within the spatial span" (Colle and Reid, 1998). The spatial knowledge that is gained in this mode is metrically coded and appears to represent Euclidean angular directions and distance.

The route tour mode is engaged when an observer is moving throughout a larger region of space. In this mode, participants don't gain the knowledge of object positions that are gained in the gaze viewing mode. Instead, they gain topologically coded knowledge of how to get from one place to another by connecting different decision points (landmarks) and turns. The information gained in this mode is more egocentric and cognitively constructed than gaze view knowledge. By employing the gaze view and the route tour modes, users can quickly gain survey knowledge about local areas while simultaneously connecting that knowledge to create a cognitive map of the larger region.

HOW TELEPORTATION PROBLEMS ARE CURRENTLY BEING MITIGATED

The additional disorientation that is associated with teleportation can lead to major problems in an environment that has already proven to be more disorienting than the real world, especially when spatial training is important in the task that is being performed. For this reason, people have been working on ways to make the process of teleportation in virtual environments a smoother process which will not lead to such disorientations.

Ruddle et al. (2000) mention the idea of adding useful previews, which provides localized information that allows the content and location of the destination node to be viewed before teleportation. This idea and the potential usefulness of it were mentioned above. Previews when combined with additional (and accurate) directional cues, and minimization of directional offset will lead to users creating a better conceptual map of the space that they are navigating. However, preview and directional cues can only do so much. In the end, users will still not gain the survey knowledge of the physical space that they would by actual navigation through the environment.

Another technique that has been mentioned by Ruddle et al. (2000) is extending the time required to traverse hyperlinks. By extending the time requirements of hyperlinks, it is speculated that users would have more time to plan and think about the link that they are making. Their research showed that time delays did, in fact decrease the detrimental effects that the use of hyperlinks had on participants spatial knowledge. However, even with time delays introduced, users still developed less accurate spatial knowledge while using hyperlinks than they did using conventional VE's and conventional navigation methods.

Although studies have made attempts to decrease the detrimental effects of teleportation on spatial knowledge acquisition, teleportation still seems to impede the acquisition of survey knowledge of spaces that are being navigated. For this reason, other methods of teleportation will need to be developed in order to facilitate this very specialized type of spatial knowledge acquisition. The remainder of this paper explains how map based teleportation systems could be implemented in order to supplement the survey knowledge information that is lost when teleporting.

HOW PEOPLE GAIN SPATIAL KNOWLEDGE WITH MAPS

The use of maps has proven useful in the development of survey knowledge of spatial information in other settings. Past studies (Hirtle and Hudson, 1991; Thorndyke and Hayes-Roth, 1982) have shown that configurational knowledge of an environment can be quickly created by studying maps without navigation of a novel space. A study by Lloyd (1989) even showed that only a few minutes of map study lead to a more accurate configurational knowledge of a space than years of navigation in the environment. Although it was noted by Thorndyke and Hanes-Roth (1982) that the survey knowledge gained from maps is different than that gained from navigation of space, they both consist of knowledge of the global environment and not just landmarks within it.

The survey knowledge that is gained from maps has been described as a more geocentric knowledge of space when compared to the egocentric survey knowledge that is gained from navigation. According to studies performed by Aretz and Wickens (1992) and Darken and Peterson (2002) this may only be the case when north-up maps are used. These studies support the idea that forward-up map configurations can be useful for egocentric navigation tasks.

AN IMPROVED INTERFACE FOR VE TELEPORTATION

As explained above, current VE teleportation systems consist of a limited number of interconnected nodes within the environment that are typically connected one-to-one with other nodes. The interface of such systems consists of portals within the virtual environment that transport users from one end of the connection to the other.

There are two key problems that such systems lead to. The primary dilemma that must be resolved is the development of poor mental maps of the VE space that so often accompanies the use of current teleportation systems. The second dilemma is the lack of convenience that can result from a portal based interface. The development of interactive maps to interface with teleportation systems is a possible solution to both of the aforementioned drawbacks of current systems.

Advantage of Interactive Maps

The use of maps to gain survey knowledge of space could be leveraged to replace the information that is lost when teleports are used to navigate in VE's. Since the spatial knowledge that is lost during teleportation is on the level of route and survey knowledge, a map interface could be used to supplement the user's knowledge of the environment.

Interactive Maps Used To Reduce Disorientation

As was stated before, there are two different levels of disorientation that occur when users teleport from one place to another in current teleportation methods. The first level of disorientation occurs at the global level and leads to users being disoriented within the whole of the environment. This level of disorientation leads to users not knowing where they are in reference to where they came from. The map based interface for teleportation can give users an instantaneous indication of the relationship between the start point of teleportation and the destination. By requiring users to look at a map and interact with it when teleporting, users can take note of the direction and distance of the destination from the starting location whenever they teleport. Requiring users to always interact with the map interface when teleporting also forces them to learn the configurational knowledge of the environment that they lose by not navigating from place to place.

The other level of disorientation when teleporting is used occurs at a local (room) level. When users teleport to different areas within a VE they do not know where they are located and which direction that they are facing within the destination room. This lack of local orientation cues requires the user to first orient themselves within the room before orienting themselves within the global environment. This level of disorientation adds to an opportunity to become lost within the global environment and creation of a poor conceptual map of the environment.

Allowing users to choose the initial viewpoint direction within the room that they are to be teleported to may alleviate the local disorientation that is caused by teleportation. By implementing a point and drag interaction to select the teleport destination (point) and the direction that is initially faced (drag) users are given an instantaneous indication of both where they are teleporting and what direction in reference to other rooms and the teleport start location they will be initially facing. This could reduce the time and mental effort required for users to orient themselves within the VE when teleportation is used.

By allowing users to select the position on the map that they want to be teleported to as well as the direction within the room that they would like to initially face within the room both levels of disorientation can be resolved. By allowing users to choose which room that they want to teleport to, users will know where the destination is in reference to the start point of the teleport. This will allow users to effectively teleport without the use of previews (Ruddle et al., 2000). As stated before, the use of dragging to select the initial direction that the user is to face when teleported will resolve the problem that is caused by rotational offset, which is described by Ruddle et al. (2000).

Added Convenience of Interactive Maps

Another advantage of the map-based interface for teleportation is that it is external from the VE and can be used to access any node from any location. The fact that it is external from the VE means two things. First, graphical space within the VE is not required to present hyperlink locations to users. Second, it allows the teleportation function to be available at all times or through some variable action, such as a user directed on demand display or from an intelligent agent. By allowing the user to teleport to any destination at any time allows the VE to be fully connected, while not producing a messy network of "spider's web" connectivity which has been described as unmanageable in current teleportation systems (Ruddle et al., 2000). The map-based interface for teleportation in VE's essentially allows for the ultimate connectivity of the environment without adding the level of complexity that current teleportation methods add.

Proposed Interface Summary

The proposed teleportation system that has been explained and supported above is an interactive map-based system. This system will be separate from the VE and consists of a map of the total VE through which users will interact with to be transported to distant locations within the environment instantaneously. With this system, the interactive map can be presented as a virtual map within the VR system which can be pulled up on command, or on supplemental systems such as PDA's.

A point-and-drag method is used to interact with the system. Pointing to the map at any point will set the users position to that location within the environment and dragging will set the initial direction that the user will face. Such an interaction system will reduce both the local and global levels of disorientation that are common with current teleportation methods while

adding the convenience of a totally interconnected environment.

This teleportation method is distinctly different from methods that are used in current systems and should prove to be useful in reducing disorientation as well as proving to be a more convenient interaction technique.

CURRENT RESEARCH

User studies are being planned to compare the spatial knowledge acquisition of users using current teleportation techniques to those using the proposed map-based system. In these studies, mental map accuracy, time required traveling to locations, and subjective measures from users will be used to compare the two methods.

Further study is needed to determine which teleportation mechanisms best enhance human performance in VE's. Research is being planned to investigate user controlled maps that have dynamic zoom with increasing detail as well as user directed orientation in the teleported space. Coupled with the impact on human performance is parallel research to study methods for implementing teleportation features in a variety of devices, including PDA's. Additionally, investigations will consider where to locate the interactive map to minimize divided attention as well as how to deal with tradeoffs between map and displayable screen size for optimal human performance.

ACKNOWLEDGEMENTS

This research was sponsored, in part, by the Office of Naval Research under grants N00014-02-1-0927 and N00014-03-1-0677. The authors appreciate their support. The views expressed in this paper, though, are those of the authors and do not necessarily reflect the views of the sponsors.

REFERENCES

- Aretz, A. J., & Wickens, C.D. (1992). The mental rotation of map displays. *Human Performance*, 5(4), 303-328.
- Arthur, E. J. & Hancock, P. A. (2001). Navigation Training in Virtual Environments. *International Journal of Cognitive Ergonomics*, 5(4), 387-400.
- Barlow, T. (2001). Acquisition of Route Knowledge Through Navigation in a Virtual Environment.

- International Journal of Cognitive Ergonomics, 5(3), 279-295.
- Bowman, D. A., Koller, D., & Hodges, L. F. (1997). Travel in immersive virtual environments: an evaluation of viewpoint motion control techniques. Proceedings of the Virtual Reality Annual International Symposium. (VRAIS'97), Albuquerque, NM, pp. 45-52.
- Colle H. A. & Reid G. B. (1998). The Room Effect: Metric Spatial Knowledge of Local and Separated Regions. Presence: Teleoperators and Virtual Environments, 7 (2), 116-129.
- Cutting, J. E. (1997). How the eye measures reality and virtual reality. Behavior Research Methods, Instruments, & Computers, 29 (1), 27-36.
- Darken, R.P., & Peterson, B. (2002). Spatial Orientation, Wayfinding, and Representation. In Stanney, K.M. (Ed.), Handbook of Virtual Environments.
- Durlach, N.I., & Mayor, A. S. (1995). Virtual Reality: scientific and technological challenges. Washington, DC: National Academy Press.
- Elm, W & Woods, D (1985). Getting lost: A case study in interface design. Proceedings of the Human Factors Society 29th Annual Meeting, pp. 927-931.
- Hirtle, S. C., & Hudson, J. (1991). Acquisition of Spatial Knowledge Routes. Journal of Environmental Psychology, 11, 335-345.
- Lloyd, R. (1989). Cognitive maps: Encoding and decoding information. Annals of the Association of American Geographers, 79.
- Potka, J. (1995). Immersive training systems: Virtual reality and education and training. Instructional Science, 25, 405-431.
- Regian, J. W., & Shebilske, W. L. (1992). Virtual Reality: An instructional medium for visual-spatial tasks. Journal of Communication, 42 (4), 136-149.
- Ruddle, R. A., Payne, S. J., & Jones, D. M. (1997). Navigating buildings in "desk-top" virtual environments: Experimental investigations using extended navigational experience. Journal of Experimental Psychology: Applied, 3 (2), 143-159.
- Ruddle, R. A., Howes, A., Payne, S. J., & Jones, D. M. (2000). The effects of hyperlinks on navigation in virtual environments. International Journal of Human-Computer Studies, 53, 551-581.
- Schaefer, W.A. (2001). Using Interactive Maps for Navigation and Collaboration. Student poster in Extended Abstracts of the Conference on Human Factors in Computer Systems (CHI 2001) (pp. 453-454). Seattle, Washington.
- Stanney, K. M. & Salvendy, G. (1994). Effects of diversity in cognitive restructuring skills on human-computer performance. Ergonomics, 37, 595-609.
- Stanney, K. M. & Salvendy, G. (1995). Information visualization: assisting low spatial individuals with information access tasks through the use of visual mediators. Ergonomics, 38, 1184-1198.
- Stoakley, R., Conway, M. J., & Pausch, R. (1995). Virtual reality on a WIM: Interactive Worlds in Miniature. Paper presented at the proceedings of ACM SIGCGI '95, Denver, CO.
- Siegel, A. W. and White, S. H. (1975). The development of spatial representations of large-scale environments. In H. W. Reese (Ed.), Advances in child development and behavior: 9-55. New York: Academic Press.
- Thorndyke, P. W., & Hayes-Roth, B. (1982). Differences in spatial knowledge acquired from maps and navigation. Cognitive Psychology, 14, 560-589.
- Wauchope, K., Everett, S., Tate, D., & Maney, T. (2003). Speech-Interactive Virtual Environments for Ship Familiarization. 2nd International EuroConference on Computer and IT Applications in the Maritime Industries (COMPIT '03), Hamburg, Germany, pp. 70-83.
- Wilson, P. N., Foreman, N., & Tlauka, M. (1997). Transfer of spatial information from a virtual to a real environment. Human Factors, 39 (4), 526-531.
- Witmer, B. G., Bailey, J. H., & Knerr, B. W., & Parsons, K.C. (1996). Virtual spaces and real world places: Transfer of route knowledge. International Journal of Human-Computer Studies, 45, 413-428.