Wayfinding Affordances are Essential for Effective Use of Virtual Environments for Instructional Applications

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Abstract

Virtual environments (VEs) are becoming increasingly popular as a delivery medium for instruction. However, to leverage the unique affordances of such environments for learning, VE designers need to incorporate wayfinding mechanisms that aid users in navigating the environment into their designs. This paper discusses six wayfinding affordances to assist VE users in constructing mental models in virtual environments, information that useful to both VE designers and to educators who use VEs to teach.

Keywords: Affordances, anchored instruction, cues, avatar perspectives, decision making, dynamic route descriptors, landmarks, problem solving, situated cognition, virtual environments, wayfinding

Introduction

Rapidly approaching the end of the first decade of the 21st Century, educational researchers, theorists and technologists are prolifically generating ideas about the best approaches to solving the problems of the American education system in order to produce the human capital necessary for this country to maintain its lead in a high-tech global economy. While many of these theories converge rather than conflict, the sheer mass of new data and knowledge often make these varied and disparate contributions seem at odds. Ed Coughlin, senior vice-president of the Metiri Group, a California-based consulting firm finds that “While most educators agree that attributes like collaboration, creativity, and personal accountability are important traits for students to possess now and in the future, turning rhetoric into action is a hurdle most districts fail to leap” (cited in Dillon, 2006, p. 25). Instructional technologies that encourage collaboration, critical problem-solving, action, and context are those that seem to be best equipped to meet this need for a new kind of literacy, described well by Naomi Dillon, associate editor of the American School Board Journal:

> Today, literacy is more than just decoding text. It’s about making sense of everything in the human world, whether it is the images displayed on computer screens and televisions, the ethical questions imbedded in stem-cell research, or the impact of global warming. But in an era of information overload, it’s also about finding meaning and applying it for maximum benefit—employing, yet again, those all-important thinking skills. The catch-all phrase for this has become digital age literacy. (Dillon, 2006, p. 24)

A variety of communications technologies have been deployed to address this imperative, technologies ranging from text-based learning management systems to fully immersive three-dimensional worlds that situate learners in contexts other than the traditional classroom so that they might conceptualize better (Dede, Nelson, Ketelhut, Clarke, & Bowman, 2004; Jones, 1999; Orey & Nelson, 1997) and transfer further (Brown, Collins, & Duguid, 1989; Cognition and Technology Group, 1990; Harmon & Jones, 2001) knowledge that is acquired by the learner. These goals of improved conceptualization and transfer are based solidly upon principles of situated cognition or anchored instruction.

As early as the 1800s, pragmatists such as Dewey (1925; 1938) argued that instruction that was anchored in an authentic context provided better learning. More recently, Jean Lave and Etienne Wenger (1991) have more specifically spelled out principles of situated cognition, citing the role of interaction with other actors in a knowledge domain or communities of practice as a significant component of situated learning. Based upon these theories, Virtual Environments (VEs), seem to offer great promise in producing citizens who are 21st Century or “digital age” literate. The term VE as used in this paper broadly refers to a range of immersive digital worlds constructed for learning, including digital games, simulations, or multi-user virtual environments (MUVEs), technologies of interest to educational researchers as a means to deeply engage learners and promote “digital age literacy”. It is suggested, however, that in addition to consideration of the instructional goals that shape the design of a VE for learning, designers must also consider the users’ ability to find their way within the environment. On one hand, if a user cannot intuitively navigate within a VE, the instructional objectives might not be achieved. On the other, wayfinding within a VE is a process of problem-solving or critical thinking in and of itself. Thus consideration of wayfinding affordances when designing VEs can assist designers both in reducing navigational obstacles to learning and in better incorporating wayfinding techniques into their overall instructional goals. From this synthesis of existing literature on wayfinding in real-world and virtual environments, six wayfinding affordances are presented for designers to consider when constructing VEs for instruction.

Wayfinding in Real and Virtual Realms

Since human beings first began traversing the surface of planet Earth, they have utilized *wayfinding* techniques to help them navigate from one place to another (Passini, 1999, p. 88). Long before the advent of digital computers and graphical virtual environments, people employed wayfinding methods to get around the physical world (Lynch, 1960; Murakoshi & Kawai, 2000). More recently, Passini (2000) has defined wayfinding as, “the cognitive and behavioral abilities associated with purposefully reaching a desired physical destination” and sees wayfinding as a unique set of problem solving behaviors focused on "operating in an architectural, urban or geographic space" (p. 88). Wayfinding in these contexts is comprised of three principle cognitive processes:

1. Decision making and the development of a plan of action to reach a destination.
2. Decision execution, transforming the plan into behavior at the appropriate place(s) along the route.
3. Perception and cognition (information processing), providing the necessary information to make and execute decisions (Passini, 2000).

These processes typically result in the wayfinder formulating a mental model or cognitive map of the region which aids in problem-solving and decision-making (Chen & Stanney, 1999; Elvins, Nadeau, & Kirsch, 1999; Gommel, 1995; Murakoshi & Kawai, 2000).

Moreover, contemporary research seems to indicate that wayfinding techniques learned in the physical world can also be employed to help humans successfully navigate VEs (Darken & Sibert, 1996; Murray, Bowers, West, Pettifer, & Gibson, 2000; Passini, 2000; Vinson, 1999). Vinson (1999) asserts that wayfinding is crucial for successful VE navigation because VEs “require the user to navigate, navigation . . . is difficult, and disorientation is upsetting” (p. 2). Disorientation is particularly disruptive in environments designed for learning when it becomes an obstacle to knowledge construction. The challenge for the VE designer is to provide navigational affordances without cluttering the information landscape.

Much of this discussion of wayfinding affordances and indeed the use of VEs for situating learning comes from the work of J. J. Gibson (1950; 1979) whose oeuvre spans the fields of ecological psychology, visual perception, design, and ergonomics. Gibson has coined the term “affordances” to refer to the interactive possibilities inherent in either an object or an environment (Gibson, 1950). Ecological psychology views humans and animals as players in a complex environmental system and postulates that behavior cannot be fully understood without conceptualizing its role within the larger system or situation (Gibson, 1979). Thus, wayfinding affordances necessarily involve a systems approach, which sees the context, both social and material, and the interactions within it as the basis for knowledge construction, problem-solving, and decision-making. While wayfinding affordances other than those discussed here do indeed exist, this paper addresses the integral role of six affordances which promote successful VE navigation and decision-making: landmarks, topographical and spatial elements, depth cues, audio cues, and avatar perspective (see Table 1). These six affordances apply most readily to the broad definition of VE as previously stated and omit affordances that apply more specifically to Virtual Reality, such as dynamic route descriptions afforded by eye-tracking mechanisms in VR headsets (Chewar & McCrickard, 2002; Shneiderman, 1998).

Table 1. Six Wayfinding Affordances

Affordance	Description	Application	Suggestions for Designers
Landmarks	Stationary visual cue	Virtual maps of real places	Use landmarks that reflect reality
Topographical spatial elements	Perspective or depth of field	Architectural rendering, virtual spaces	Create different ways to view scenes
Depth cues	Dimensional presence	Creditability in large virtual spaces	Project determines 2 or 3D
Dynamic route descriptions	Map through virtual space	Visual route through complex environment	Use cartographic tools from real world
Audio cues	Sensory input	Warnings, clues and hazards	Use sparingly-too much distracts
Avatar perspective	Sense of being there	3D Virtual environments, simulations	Make avatars connect with user, use avatar as informational source

Note: None of the affordances has greater priority than any other in all situations and contexts. Use of each will depend on the instructional goals in each context.

Landmarks

Individuals confronted with wayfinding problems in real-world urban settings have been observed to construct “cognitive maps” in order to find their way (Sternberg, 1999, p. 242). Research conducted by Vinson (1999) indicates that navigators of large VEs must also construct cognitive maps of their virtual environment in order to navigate successfully. Just as in the case of real-world settings, VEs need to incorporate landmarks as aids to navigation. According to Vinson, such landmarks should resemble their real-world counterparts as closely as possible. However, a crucial problem with creating sufficiently information-rich landmarks is that they tend to be computationally expensive. Accordingly, VE designers are constrained as to the level of detail such landmarks can convey to the user. Vinson has defined a set of guidelines to assist the VE designer in addressing this problem. These guidelines focus on the placement, number and information content of VE landmarks. Appropriately designed landmarks should convey position and orientation information, and facilitate "acquisition and application of spatial knowledge" (Vinson, 1999, p. 8). Although Vinson (1999) provided a set of design guidelines for creating effective landmarks in VEs, his study did not present quantitative or case study data supporting his suggestion that such landmarks can help users transfer their real-world wayfinding abilities to the problem of navigating in a VE. Further research is necessary to test the significance of these design guidelines. Furthermore, landmarks are only one type of VE wayfinding affordance. Other research indicates that navigational elements that facilitate an understanding of the topographical structure of VEs are also crucial.

Topographical and Spatial Elements

Darken and Sibert (2004) addressed the need to facilitate the VE navigator's conceptualization of the entire virtual space. These authors asserted that landmarks alone are not sufficient to facilitate efficient wayfinding in VEs; topographical elements are also essential. Such elements can help the user acquire "survey knowledge" (Sternberg, 1999, p. 243) or the "bird's eye view" that Darken claimed to be "the key to successful wayfinding in any environment" (Darken, 1995, p. 46). Darken and Sibert stated that current VEs provide very poor support for efficient navigation and assert that real-world wayfinding methodologies should be implemented in VEs. In furtherance of this goal, they present a set of design principles for augmenting wayfinding in VEs. When implemented by the VE designer, these principles may assist the navigator with organizing and interpreting the spatial structure and information hierarchy of a VE. These design principles also stress the importance of simple, optimally placed, directional cues that can assist users in the construction of their own navigation paths or maps. Based on their observations of subjects navigating large VEs, Darken and Sibert offered a number of conclusions regarding the importance of topographical information for successful wayfinding. These conclusions included the following:

1. "When not given an adequate source of directional cues, disorientation will inhibit both wayfinding performance and spatial knowledge acquisition.
2. A large [virtual] world with no explicit structure is difficult, if not impossible, to search exhaustively.
3. Path following is a natural spatial behavior.
4. A map allows for optimizations to be made to [VE] search strategies" (p. 13).

Darken and Sibert (1996) provided detailed quantitative and case study data in support of their hypothesis and concluded that both landmarks and topographic information are essential for successful wayfinding in VEs. Nevertheless, other types of cues may further aid navigation. "Depth cues" and the type of 3D information such cues convey can be crucial for successful wayfinding in VEs (Komerska & Ware, 2003).

Depth Cues

The role of depth cues in guiding or misdirecting the VE navigator is presented by Komerska & Ware (2003) in an article published by the Data Visualization Research Lab. The author presents research indicating that rendering all landmarks and visual cues in 3D is not optimal for every wayfinding task in VEs. In some situations, cues rendered in 2D or "2½D" are more appropriate because they can convey essential information to the navigator in a more concise manner than a 3D object. The author discusses the five following depth cues and their implications for wayfinding in VEs.

1. Occlusion. The most important depth cue, occlusion refers to the fact that an object which is closer to the viewer may partially block or obscure an object that is farther away.
2. Shadows and shape form shading. Shadows and shaped shading help to emphasize the apparent distance between objects and indicate that objects can be grasped or moved.
3. Perspective. Derived from basic 3D geometry, perspective constitutes three related depth cues: linear perspective, texture gradients, and size gradients.
4. Structure from motion. Structure from motion cues result from the rotation of 3D objects with the result that the objects are easier to perceive. These cues also provide the phenomenological impression of spaciousness that is a crucial aspect of most VEs.
5. Stereo. Stereo refers to the ability of the brain to use the difference between the images in the two eyes to obtain information about distance in the environment. Stereo cues tend to be of less relevance than structural or motion cues in VEs (Komerska & Ware, 2003).

Komerska & Ware assert that effective inclusion of these cues in the virtual landscape will result in a more meaningful information display and an environment that can be navigated in a more natural way. All human beings live in a world of three-dimensions. Humans are surrounded by and interact with 3D objects. Accordingly, comprehension of data displays in VEs can be improved when these displays incorporate a 3D structure. In addition, providing 3D wayfinding affordances in VEs can facilitate navigation by allowing humans to utilize intuitive real-world wayfinding skills they already possess. However, in some virtual environments, navigational elements rendered as 2D or what Komerska & Ware calls “2½D” objects can more effectively convey crucial navigational data than 3D objects. VEs should be laid out as 2D grid systems so that visual occlusion cues can be fully integrated into the landscape. When these cues are absent or incorrectly placed, navigators can quickly become disoriented and lost. In contrast, research has shown that textual elements should consistently be rendered as 2D objects. Text rendered as 3D is often difficult to read and may be confused with navigational elements in the environment.

In a related article, Chalmers, Ingram, and Pfranger (1996) encourage designers not to clutter their VEs with too much information or an over-abundance of objects. Chalmers states that the primary goal of the designer should be to create a VE which can be easily navigated and explored. The designer should incorporate landmarks and visual cues into the environment to the extent that these help to focus the user's attention on important or interesting aspects of the virtual world. In addition, the degree of detail displayed by a 3D object should increase as the viewer approaches the object. At the same time, the focus of the user's attention should be closely tracked by the VE to avoid cluttering the display with unnecessary information. Pop-up menus and text boxes or other similar devices can be used to temporarily increase the volume of information provided to the user upon close inspection of an object. Finally, the authors state that VEs should provide feedback to the user in the form of dynamic updates to the virtual environment to facilitate search and navigation.

Audio Cues

Saue (2000) presents a model for using audio cues as aids to wayfinding in VEs. Saue's model addresses not only the volume and position of audio cues in a virtual environment, but their timing and duration as well. The concept of “temporalization” (Saue, 2000, p.2) is introduced as a methodology for controlling the timing and duration of audio cues. Saue states that audio cues are well suited as wayfinding affordances in VEs because both audio and virtual environments share an immersive, user-centered view point which is at once interactive, multisensory and three-dimensional (Saue, 2000). A key problem with audio cues is that sound tends to be dynamic, changing with the orientation of the listener. As a result, audio cues alone are not sufficient wayfinding affordances. However, the dynamic nature of sound does allow audio cues to assist in accurate navigation within a VE. Although audio cues do not permit precise comparisons between quantitative data elements displayed in a VE, Saue's assertions that audio cues do play an important role in wayfinding are well grounded in every-day experience. In addition, Saue provides examples of speculative VEs in which audio cues could fulfill a pivotal role in search and navigation.

Avatar Perspective

The point of view afforded an avatar, the graphical representation or “surrogate persona” (Dede, 1995, p. 46) of the user maneuvering in a VE, can also contribute significantly to the wayfinding performance of its user. Avatars are usually afforded one of two perspectives: the first person, by which the user is *immersed* in the VE, or the third person, by which the user views both her avatar and the VE as an *external observer* (Amorim, Trumbore, & Chogyen, 2000, p. 166). These differing points of view can have a significant impact on the user’s spatial processing in the environment. Amorim, Trumbore, and Chogyen (2000) describe the difference perspectives as follows:

> In third-person imagery, the subject is engaged in more of a ‘gaze tour’ and extrapolates the content of the visual scene faced by the imaginary avatar through attention shifting onto the VE [virtual environment]. Otherwise, in first-person imagery the subject has to imagine the changing visual scene with his displacement and must reconstruct the spatial configuration missing in the visual scene (p. 166).

In a first person perspective, users view the environment directly through the eyes of the avatar and typically do not see their own avatars themselves, only the avatars of others present in the VE. From this perspective, much of the users’ field of vision can be limited, particularly as most movement controls in VE avatars are limited to bodily turning to the left or right rather than turning only the head or shoulders while still moving forward at ground level. The peripheral vision to which users are accustomed in the natural world is also typically reduced in a VE and focused instead on what is directly in front of the avatar rather than to the sides. These restrictions could impede wayfinding since they limit the amount of visual stimuli that a user assimilates in constructing a cognitive map of the VE. Nevertheless, when an avatar is endowed with additional movement affordances, such as the ability to fly, wayfinding in the first person perspective can be greatly enhanced. “Flying” allows the user to rise above ground level and get a bird’s eye view, a perspective which allows the user to gain survey knowledge of the VE. However, as Murray, Bowers, West, Pettifer, and Gibson (2000) discovered, users felt uncomfortable using the flying affordance in the context Cityscape, a VE representing a realistic city. They surmise that this discomfort may not have occurred in a more fantastic environment. Consequently, these researchers suggest including mechanisms that encourage such movement: “vehicles such as hot-air balloons, or familiar architectural features such as lifts” (Amorim, et al. 2000; Murray et al., 2000, p. 441).

The third person perspective is characterized by the user viewing the avatar “out of body” as a third person. Some VEs provide this view from over the avatar’s shoulder; in others the perspective comes from above, with the user looking down on the avatar. In many VEs, the user can control this “camera angle” and alternate between an over-the-shoulder or bird’s-eye view of the avatar. These angles have obvious implications for wayfinding given the ways that they afford the various perspectives necessary to building spatial knowledge of the VE. When minimizing disorientation is a goal in VE design, designers should consider such user controls given the wayfinding abilities they afford.

Conclusion

Inhabitants of complex, three-dimensional worlds need wayfinding techniques to move about the complex environments, complete their projects, and attain their objectives. These users rely on the presence of cues, landmarks and other affordances in the environment as aids to navigation. When these aids are ill-placed, poorly designed or absent, wayfinding becomes exceedingly problematic if not impossible. The virtual worlds created with computers will not provide the type and number of real world wayfinding aids to which users are accustomed unless designers plan for and provide them. Accordingly, to function successfully and efficiently in VEs, designers must ensure that adequate wayfinding affordances are present. This paper has presented a number of techniques for incorporating essential wayfinding affordances into VEs. While the approaches discussed here are interesting and innovative, much more research is needed to determine how each of these affordances impact the user’s spatial processing. How effectively VEs are designed and used will almost certainly depend to a large degree on how well researchers come to understand the transfer of real world skills to these constructed worlds.

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