Limitations of Signs as Navigation Aids in Virtual Worlds

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Abstract
Virtual worlds continue to increase in popularity as a medium for teaching, training, and recreation. However, traveling in virtual worlds is a challenge for many who visit them. Previous research has shown that signs can be effective aids to assist virtual world users in the navigation process for some navigation tasks. In this paper, we explore limitations of signs as navigation aids in virtual worlds. Specifically, we report the results of an experiment to determine the impact of increasing the amount of information on signs and the results of removing signs from intersections in a virtual world. Our findings indicate that for navigation tasks with a small number of target locations, sign users outperform map users. With eight or more target locations, map users outperform sign users. Additionally, the performance of sign users began to degrade significantly when more than two signs were missing from the world.

1. Introduction
Virtual reality and virtual worlds have become increasingly important for teaching, training, business, and entertainment purposes. Virtual worlds have been constructed to teach about history and culture [25, 50], to help train children about the barriers faced by those with disabilities [29], and to allow for “an alternative consumer experience” in contrast to the traditional experience of printed advertisements [15]. Educators have begun to recognize the potential for online virtual worlds [12] developing learning games [45], laboratory activities [32], and spaces where the avatars of faculty and students can meet for discussions and lectures [5]. Applications have been developed to prepare soldiers for peacekeeping efforts in foreign countries [23] and to treat soldiers with symptoms of Posttraumatic Stress Disorder [46]. Other virtual worlds have been constructed recently to train Civil Support Teams how to respond appropriately to radiological threats [21] and to visualize automobile traffic flows [42].

While the application areas for virtual worlds are numerous, recreational users of virtual worlds far outnumber all others. Massively multiplayer online role-playing games (MMORPGs) like Everquest and World of Warcraft allow players to interact with other users as they complete tasks together in virtual worlds that are constantly changing even when players are offline [39]. These virtual gaming worlds “are separate universes with their own rules, culture, ethics, economy, and politics” [2], offering to many a highly addictive opportunity to live in a fantasy setting different from anything that could be experienced in the real world. In 2008, World of Warcraft had over ten million subscribers with several hundred thousand playing the game at any given time [24, 43]. Still other virtual worlds, such as Club Penguin, provide safe environments for children to interact online with other children. Massively multiplayer online worlds, like Second Life, exist for more social and economic purposes. Second Life users can buy and sell land and other goods creating virtual economies that support shopping, advertising, virtual tourism, and even speculation on real estate [1, 18, 20, 24, 49]. Research on consumer learning indicates that “a virtual experience may extend product knowledge, affect brand attitude, and influence purchase [decisions]” [15]. Furthermore, some researchers predict that “Virtual Worlds offer the next advancement in information dissemination and communication” and companies are “realizing the potential of Virtual Worlds” [17].

Clearly, the possibilities for virtual worlds are vast. However, as with other emerging technologies, users do experience usability problems with these worlds that limit their effectiveness. For example, a noted drawback of educational virtual worlds is the difficulty users experience when learning to interact with and navigate in these environments [22]; others have also commented on the challenge of learning their way around in MMORPG worlds [4]. This problem of user navigation in virtual worlds is well known as most users find it more difficult to acquire spatial knowledge in a virtual world than in the real world [30], with males outperforming females on many spatial tasks [41]. Researchers have investigated a number of approaches to help make virtual world navigation more natural for users, such as increasing the user’s field of view of the world and incorporating physical body
movement into the navigation process [40, 48]. However, these approaches require computer hardware that most virtual world users currently do not have available, leading the designers of virtual worlds to incorporate aids (such as maps) into the application to assist users with navigation.

Navigation difficulties can have a significant impact on the effectiveness of virtual worlds; simply put, if users cannot find their way to a destination, they cannot use the world for the desired purpose. Imagine visiting a virtual museum and not being able to locate the exhibit of interest, or searching for a piece of property you own in a virtual world with no success. Navigation problems leave users exhausted and frustrated and can substantially impact their desire to use the world again.

In this paper, we focus on the issue of supporting user navigation in virtual worlds. Specifically, we describe our research into the design of effective signage to assist users as they find their way through virtual worlds. In section two, we provide background information and discuss previous research. Section three describes an experiment we conducted to explore limitations of signs as navigation aids in virtual worlds, and section four presents the results of this experiment. Section five describes our conclusions and discusses future research directions.

2. Background

Virtual world applications frequently require users to travel throughout the world to locate destinations of interest. Travel is supported through a number of means, such as walking, riding, and teleporting [2]. While many virtual worlds, such as Second Life, allow users to teleport directly to general locations, users must still navigate their avatar to the specific places of interest in that location. For example, our university has a Second Life representation with models of several campus buildings. Second Life users can teleport directly to our virtual campus; however, once there they must navigate in and around the buildings on campus to locate destinations of interest. This process of finding a path to or between locations of interest is called “wayfinding.”

Darken and Sibert [13] describe three categories of wayfinding tasks in virtual worlds: naïve search, primed search, and exploration. In a naïve search, the user has a destination of interest in mind, but does not know anything about the structure of the world, so he or she is unable to travel directly to that destination. In a primed search, the user knows the location of the destination of interest, and an exploration task is one in which the user has no destination of interest. Naïve searches and exploration tasks are often similar to users from a route planning standpoint; both may require that the world be searched exhaustively. Depending on the size of the world, exhaustive searches can be frustrating and time consuming. In the real world we typically avoid naïve searches of unfamiliar environments. Rather, we attempt to locate information about the environment to allow us to travel directly to destinations of interest. For example, suppose you visit a university for the first time. Since you have never been there before, you do not know the layout and have no idea how to get to certain places within the university. Suppose you were looking to meet someone inside a particular building. One strategy you might employ to locate the building would be to exhaustively search the university until you find the location of interest. However, most people do not enjoy searching, as it can be frustrating, strenuous, and time consuming. Instead, at places like a university newcomers are often given access to maps so that navigation can be more effective.

To classify navigation aids, we will use terminology introduced by Passini [27] to describe different types of wayfinding strategies in the real world. The first, a search strategy, is used when no information is available about the world. The second, an access strategy, is used when information is available. Strictly speaking, Passini applies these terms to the presence or lack of environmental information that could be used to form route decisions. In this paper, we use the terminology somewhat more broadly to classify navigation aids as those that are helpful for naïve searches (the search strategy aids), and those that allow us to change a navigation task to a primed search by accessing information about the world (the access strategy aids).

Search strategy navigation aids have been thoroughly studied and include landmarks [8, 28, 31, 36, 38, 44] and trails that mark a user’s path [34]. Generally speaking, as the amount of visual information in a virtual world increases, a user’s ability to navigate effectively increases as well [16]. Landmarks are a fundamental component of wayfinding as they help to remind us where we have been and provide visual cues that can lead us to where we want to go. However, these types of aids do not indicate the best route to a destination. They only serve to help us orient ourselves as we move about. For example, the tower shown in Figure 1 is an obvious distinct physical landmark.

Access strategy navigation aids include maps [7, 13, 14, 33, 37], signs [9, 10], directions or route recommendations [35], tools that create trails to desired destinations [47], and markers that point the way to locations of interest [6]. Access strategy aids
allow us to identify an appropriate path to a chosen destination, hopefully alleviating the need to search the world exhaustively. Maps have been the most thoroughly studied of the access strategy navigation aids, and are often provided in some form to users of virtual worlds. For example, the Second Life interface provides users with a dynamic map that always rotates so that the up direction on the map is forward for the user (see upper right of Figure 1). However, some real world studies indicate that people actually prefer signs to maps [3, 26]; but in both these studies the maps were static and only provided in fixed locations. In virtual worlds, maps can be made dynamic, constantly available to the user and always indicating location and direction of view.

Figure 1: The Second Life interface (www.secondlife.com)

In a previous research project, we compared signs to maps as navigation aids in a virtual building [9]. Our motivation for this research was due in part to the real world studies that indicated a preference among subjects for signs over maps, and the fact that maps had been so frequently studied as navigation aids in virtual worlds. We wanted to know how signs could compare to maps as users traveled about in a virtual world. In the study, subjects searched a virtual office building four times for six spheres in one of three conditions: no aid, map, and signs. Not surprisingly, subjects were significantly faster and located the spheres in significantly less distance with the aid of either signs or a map, than the subjects who searched the building in the no aid condition. When comparing only the signs and map conditions, we found that there was no difference in the distance traveled between these groups; however, the map users took slightly, but significantly, longer to complete the task. The map provided to subjects in our study was dynamic in that it constantly updated to show the user position and orientation information. However, after reviewing the literature [14, 33], we elected to implement a north-up (non-rotating) map because we believed that our task was global in nature (we wanted subjects to find the shortest path connecting all of the spheres).

It is likely that the increased time taken by subjects in the map condition was due in part to the time required to plan a route; subjects in the sign condition only needed to read and follow the signs. However, some of the time difference may also have been due to the mental rotation task required of subjects in the map condition since the map did not rotate such that up on the map was always forward for the subject (as is the case in Second Life). In a follow-up research project, we compared signs to rotating maps, as well as adding a condition for testing the effectiveness of these aids for an ordered navigation task [10]. An ordered navigation task is one in which the order that targets are visited is predetermined for the user. For example, if users want to purchase virtual furniture for a virtual building, the virtual furniture store must be visited before the furniture can be placed in the building. Similar to the previous study, subjects searched a virtual office building four times for six spheres in one of two conditions: map and signs. Each subject did this process twice, once in an unordered navigation task and once in an ordered navigation task. We found that for both tasks, subjects located the targets while covering significantly less distance when using signs as opposed to a map.

These results were somewhat surprising, particularly for the unordered navigation task. Wayfinding research frequently identifies two strategies that individuals use for successful navigation: route and survey strategies [19]. The distinction between the strategies is related to the type of information that the individual uses when navigating through an environment. Specifically, when using route information, individuals tend to focus on landmarks and left/right turns, as if they are at street level. The sign condition in the current study forces individuals to rely on this strategy. The second wayfinding strategy is using survey knowledge. Survey knowledge provides individuals with a third person perspective or overview of the entire environment, a “bird’s eye view” of the world. Individuals in the map condition were required to rely on this strategy when navigating through the virtual environment. Signs tell users the shortest path to travel to find the targets; with maps, users must plan their own route. Thus, it might be expected that in the ordered task the map users would travel further since the shortest route may not always have been obvious on the map. Sign users only had to follow the signs to travel the most effective route. However, in an unordered collection of targets, signs do not tell users...
the best route to travel to visit all of the targets. Signs only tell the best route from the current point to each of the targets individually. It seems likely that subjects could end up traveling quite inefficiently as they collect the targets (moving from one side of the world to the other) if they have no survey knowledge of the overall structure of the world. Additionally, individuals in this condition would be more likely to become disoriented. Again, though, we did not find this to be the case in our study. A possible explanation is that the world was not large enough for inefficient routes by sign users to be significantly detrimental to performance. Also, the amount of information on the signs was relatively small and easily processed. This is not always the case, however, in the real world. Imagine signs at an airport or in a hospital. It is not uncommon for 10 to 20 destinations to be listed on these signs. For designers of virtual worlds, it would be useful to know at what point the amount of information on signs begins to make them less effective. Thus, our first research question for the current study is:

**Research Question 1**: How does the number of locations of interest on a sign impact the effectiveness of signs as navigation aids?

It may also be the case that the number of signs in a virtual world is insufficient. In the real world, signs may not be placed at every intersection leaving us with incomplete information (or we might miss a sign as we are traveling). Furthermore, in a large virtual world it may be impractical to produce a complete set of signs for every intersection that lead to all destinations of interest. Thus, our second research question for the current study is:

**Research Question 2**: How does the removal of signs from intersections affect a user’s ability to navigate?

We feel this work is significant because it will provide further guidelines for the design of effective signs as navigation aids for users of virtual worlds. Specifically, it will begin to answer questions regarding possible shortcomings of signs and appropriate contexts in which signs and maps are sufficient as navigation aids.

### 3. Experimental Design

An experimental methodology similar to that described in our earlier studies [9, 10] was used to investigate the research questions introduced in the preceding section. Subjects first visited a small virtual building (see left side of Figure 2) to practice with the navigation interface (a PC joystick) and to become familiar with the navigation aid (either signs or a dynamic forward-up rotating map). Subjects navigated the practice building twice to collect the spheres. There were two spheres to locate the first time and four spheres the second. The spheres could be collected in any order. Subjects then navigated the larger building (shown on the right of Figure 2) six times collecting spheres. These six trials required subjects to collect a different number of spheres each time (two spheres, four spheres, six spheres, eight spheres, 10 spheres, and 12 spheres); however, the order that subjects collected these spheres was counterbalanced between subjects to minimize the possible effects of practice on the results of the study. Again, for each individual trial, subjects were allowed to collect the spheres in any order. Time and total distance traveled were recorded for each visit to the larger building.

![Figure 2: Layout of the virtual buildings used in the experiment](image)

At the conclusion of the first part of the experiment, subjects in the signs condition were then required to collect six spheres in a virtual building five more times. The spheres were in the same locations for each of these trials; however, for the first trial one sign was removed from the building. For trial two, two signs were removed from the building, then four signs were removed, and on the last trial 16 signs were removed.

### 3.1. Subjects

Thirty-four subjects (29 males and five females) were recruited to participate in the experiment predominantly from college level Engineering and Computer Science courses. However, two females and one male dropped out of the experiment due to weariness or sickness. This left 16 subjects in the map condition and 15 in the sign condition. The average
The age of subjects was 20.6 (sd = 2.90). All subjects either volunteered for the experiment or received extra credit in their course. None of the subjects participated in our previous experiments.

3.2. Test Environment

Subject testing took place in a computer laboratory at the University of the Pacific. Up to five subjects at a time were run through the experiment on computers that were clones of each other. These computers contained dual core 2.33 GHz processors, 2 GBs of RAM and had a 20 inch wide-screen (1.6 aspect ratio) display. The subjects were separated by at least two seats in the laboratory so as not to distract each other during testing. Subjects were provided with a 67.5º field of view into the virtual world, and kept aware of their progress through a heads up display (HUD) on the right of the screen (see the right side of Figures 3 and 4). The spheres disappeared from the HUD as they were collected, and from the map in the map conditions.

3.3. Navigation Aids

Similar to our previous experiment, subjects in the map condition were provided with a dynamic rotating map such that the up direction corresponded to the user’s direction of view into the virtual world (see lower left of Figure 3). A dynamic rotating map eliminates the need for the user to mentally rotate the map to determine the appropriate direction to turn at each intersection. The map was also augmented with a you-are-here (YAH) marker (the orange triangle with blue dot that indicates direction of view, which can be clearly seen in Figure 2). The map constantly moves and rotates around the YAH marker to show position and orientation in the world.

Subjects in the signs condition were provided with signs that hung from the ceiling and indicated the shortest path to the spheres (see Figure 4). Following the suggestions of Butler et al. [3] and Corlett et al. [11], ambiguity in the signs was minimized as much as possible and they were provided at each decision point along the paths between the spheres. Signs were not provided at every intersection, but only those intersections that required a change in direction along the designated paths. In the second part of the experiment, signs were removed from some of these locations (as described earlier).

4. Results

The data was analyzed using an analysis of variance (ANOVA) for each of the dependent variables (time and distance traveled) for both parts of the experiment. Main effects and interactions are reported only if they are significant at the $\alpha = 0.05$ level.

4.1. Increasing the Number of Targets

A two-way ANOVA with number of targets as the within subject factor and condition (signs or map) as the between subject factor was used to analyze the data from the first part of the experiment. When evaluating time (in seconds) as the dependent variable, a main effect of number of targets was observed, $F(5, 29) = 262.70, p < .001, \eta = .90$, with it taking participants more time to locate the spheres as the number increased. There was also a main effect of condition, $F(1, 29) = 5.51, p < .05, \eta = .16$, with participants assigned to the dynamic rotating map condition ($M = 127.88, SE = 6.95$) locating the spheres more quickly.
than the participants assigned to the signs condition \( (M = 150.92, SE = 7.18). \) These main effects were qualified by a number of targets by condition interaction, \( F(5, 29) = 12.79, p < .001, \eta = .31 \) (see Figure 5). Consistent with our previous experiment, there was little difference between conditions when the number of spheres to collect was six or less. However, map users outperformed sign users when the number of targets were eight \( (t[29] = 2.80, p < .01), \) ten \( (t[29] = 2.03, p < .05), \) or twelve \( (t[29] = 3.93, p < .001). \)

### 4.2. Removing Signs

A one-way ANOVA with trial as a within subject factor was used to analyze the data from the second part of the experiment, when signs were removed across trials for participants assigned to the signs condition only. When evaluating time (in seconds) as the dependent variable, a main effect of number of signs removed was observed, \( F(4, 14) = 9.73, p < .001, \eta = .41, \) with it taking participants more time to locate the spheres as the number of signs removed increased (see figure 7). Post hoc analyses revealed that removing only one sign was significantly different relative to removing eight or sixteen signs. Additionally, removing two signs led to significantly faster times relative to removing four, eight or sixteen signs. Removal of one or two signs did not lead to significant time differences; this is also true for removing eight versus sixteen signs.

When evaluating distance traveled (in feet) as the dependent variable, a main effect of number of signs removed was observed, \( F(4, 14) = 11.10, p < .001, \eta = .44, \) with participants traveling greater...
distances to locate the spheres as the number of signs removed increased (see figure 8). Post hoc analyses revealed a similar pattern to differences in time. Specifically, removing one sign was significantly different relative to removing eight or sixteen signs. Additionally, removing four signs led to significantly shorter distances traveled relative to removing eight or sixteen signs. Removal of one or two signs did not lead to significant differences in distance; this is also true for removing eight versus sixteen signs.

![Figure 8: Mean distance traveled (in feet) to locate the targets as the signs were removed.](image)

5. Conclusions

Our earlier studies showed that in some situations signs can be effective as aids for participants as they navigate virtual worlds in search of target locations. In the present study, we sought to identify some of the limitations of signs as navigation aids for users of virtual worlds. The results suggest that signs may become less effective than maps as navigation aids when the number of targets exceeds six. Subjects in the rotating map condition significantly outperformed sign users in time taken and distance traveled for 8, 10, and 12 targets. Thus, when there are fewer targets, individuals relying on route knowledge may perform equally well as individuals relying on survey knowledge. However, as the number of targets increase, eight targets in the current study, processing an increased amount of route knowledge may make the task more difficult. When relying on survey knowledge, or maps, the increase in information that requires processing is minimal. These findings suggest that when the number of unique locations in a virtual world is greater than six, survey knowledge, or maps, might be preferable to route knowledge, or signs, as navigation aids.

The results from the second part of our study indicate that removal of one or two signs from key intersections is not particularly detrimental to subject performance. However, as the number of removed signs increased, subject performance began to degrade significantly. As suggested in previous research [19], use of route knowledge, or signs, may lead to an increased likelihood of becoming disoriented. Thus, as the number of signs that were removed increased, participants were more likely to become disoriented, even though they had navigated this environment in previous trials. This might suggest that for signs to be effective navigation aids, designers of virtual worlds do need to take care to place them at nearly all intersections along paths between destinations of interest. Otherwise, subjects could start to become lost as they travel about.

There are two important limitations of this study, in regards to the sample, which deserve mention. First, nearly all the subjects were male and thus the conclusions drawn may only be applicable to males, particularly given what is known about navigation differences between male and female users of virtual worlds [36, 40, 41]. Second, the average age of subjects was 20.6 years, so the conclusions may only be relevant for college age users of virtual worlds. Future research should include a much larger and more diverse sample so that age and gender effects can be explored.

Additional research is also necessary to compare signs and maps to other access strategy navigation aids, such as spoken or written directions, and virtual worlds augmented with arrow markers that point towards destinations of interest. Various navigation aids may also be more or less useful in different types of virtual worlds. As already indicated, the size of a world may impact the effectiveness of a navigation aid. Also, multi-story buildings can make navigation aids considerably more complex as subjects must consider multiple levels of information to locate their destinations of interest.

As the number of application areas for virtual worlds continues to grow, the need to make these worlds usable by those who visit them becomes increasingly important. If users cannot navigate effectively, their willingness to use a virtual world will likely diminish. Thus, the design and implementation of navigation aids deserves careful consideration by the developers of these worlds. Our long term goal with this research is to be able to provide concrete guidelines about the most effective navigation aids for virtual worlds of all types.
6. Acknowledgements

This work was funded in part by the School of Engineering and Computer Science at the University of the Pacific. We would like to thank Christopher N. Chapman for his comments which, in part, encouraged this study. We would also like to thank the students who participated in our experiment as test subjects.

7. References


Innovation and Technology in Computer Science Education (ITiCSE 2007), June 25-27, 2007, Dundee, Scotland.


