Using an Eye Tracker to Compare Active versus Passive Navigational Aids in a Virtual Desktop Environment

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Abstract

Virtual environment navigation can be improved through the use of a navigational aid. In this study two different navigational aids, one active aid and one passive aid, were tested. An eye-tracking apparatus was used to collect fixation data on each navigational aid, in addition to task performance data and user preference data. It was hypothesized that participants using the passive navigational aid would perform better than the active navigational aid and that there would be significant differences in the amount of fixations on the passive and active aids. The results revealed that there was no significant difference in the amount of fixations on passive and active aids. However, participants with the passive navigational aid completed the task significantly quicker. Of the three hypotheses of this study, the results showed evidence of only the first hypothesis. This study could be replicated with more participants to determine if there is further evidence for the other two hypotheses.

1 Introduction

Navigation of an environment consists of traveling from one point to another within that environment. When traveling, people often employ the use of navigational aids, such as a map or a GPS. These aids provide information about the user's environment, which can help them navigate. In this study, two different types of navigational aids, active and passive aids, are compared in a virtual environment.

An eye-tracker is used to gather quantitative data on how people use the different navigational aids. Eye trackers can collect data such as eye fixation points, fixation durations and scan paths, all of which can provide us with information on how an individual uses a navigational aid. One study has demonstrated how an eye tracker can be used to compare different navigational aids; Vembar et al. revealed that participants will sometimes only fixate on the navigational aid to get them through the environment (Vembar et al., 2004) To combat this bias, our study requires users to complete a search task in addition to using the navigational aid.

Our study has three hypotheses:

> H1: Participants receiving passive navigational aids will perform significantly better than participants receiving active navigational aids.
>
> H2: There will be a significant difference in the percentage of fixation durations between participants receiving active navigational aids than participants receiving passive navigational aids.
>
> H3: There will be a significant difference in the number of fixations on the navigational aid between participants receiving active navigational aids than participants receiving passive navigational aids.

2 Background

In order to navigate through an environment one would first need to be able to find one's way, a term called wayfinding. Ishikawa et al. describe wayfinding in three different steps; orientation, planning a route, and execution of the planned route (Ishikawa et al., 2008). In order to perform these tasks one requires some form of spatial knowledge, route or survey knowledge, about their environment. Route knowledge is the knowledge required to successfully travel from one place to another (Golledge, 1991). Survey knowledge is the understanding of the overall layout of an environment (Rossano, West, Robertson, Wayne & Chase, 1999).

Darken and Sibert have shown that the tasks for navigating in real life are similar to the tasks for navigating in a virtual environment (Darken & Sibert, 1996). This has led to the idea that navigational aids are also useful in virtual worlds, which has been demonstrated by researchers (Darken & Sibert, 1996; Wuheng, Baihua, Duanyang, 2009). Many different types of navigational aids have been implemented in virtual environments, including maps (Wuheng et al., 2009), 2D and 3D pointers (Burigat & Chittaro, 2007), and worldlets (Elvins, Nadeau, & Kirsh, 1997).

Of particular interest is a study by Li et al. comparing a GPS to a dual scale exploration aid. The GPS is considered to be a passive aid, while the dual scale exploration aid is considered to be an active aid (Li et al., 2013). A passive navigational aid provides the user with some form of spatial knowledge needed to navigate through an environment (Wu, Zhang, Hu, & Zhang, 2007). Conversely, the active navigational aid supports the acquisition of spatial knowledge (Li et al., 2013). One type of navigational aid in particular, a trail, was shown to improve spatial knowledge in users (Ruddle, 2005), categorizing it as a passive aid. A trail promotes spatial knowledge by providing users with information on where they have already been. Li et al. theorize that the active aid is better suited when the user will enter the environment multiple times because the active aid promotes the learning of spatial knowledge (i.e. the user is actually learning the environment). They also theorize that the passive aid will be better suited when the user will only need to enter the environment one time, or when the user does not necessarily need to learn the environment (Li et al., 2013).

This study compares the effectiveness of two navigational aids, active and passive, in an industrial virtual environment.

3 Methodology

3.1 Virtual Environment

The virtual environment that participants navigate is that of an automotive manufacturing facility (Figure 1). Participants navigated this environment with one of three conditions: control condition provided no navigational aid, active condition provided an active aid, and passive condition provided a passive navigational aid. The active aid consisted of a map with a pointer followed by a trail of red arrows indicated exactly where in the environment participants have already been (Figure 2). The passive aid consisted of the same map with a "you are here" pointer as well as a path indicating exactly where participants needed to go (Figure 3).

Figure 1: *Virtual environment of an automotive manufacturing facility*

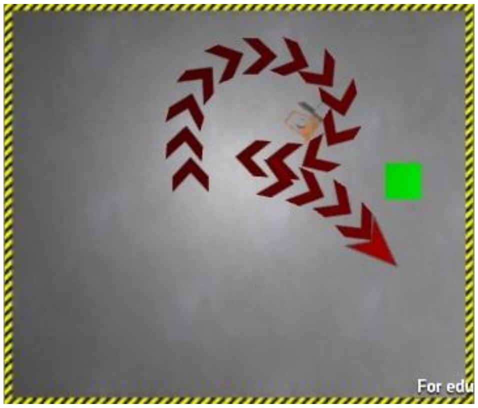

Figure 2: *Active navigational aid*

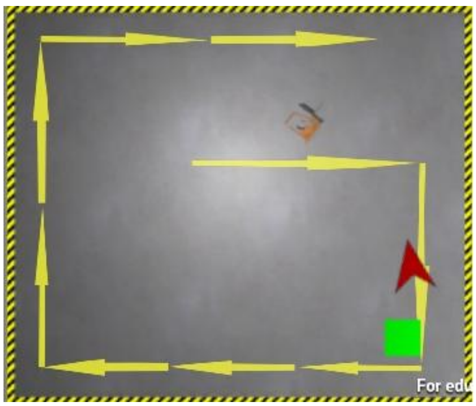

Figure 3: *Passive navigational aid*

3.2 Apparatus

Participants interacted with the virtual environment through the use of a standard desktop computer with mouse and keyboard. Participants were seated approximately 30 inches in front of a 22'' monitor (Figure 4 and Figure 5).

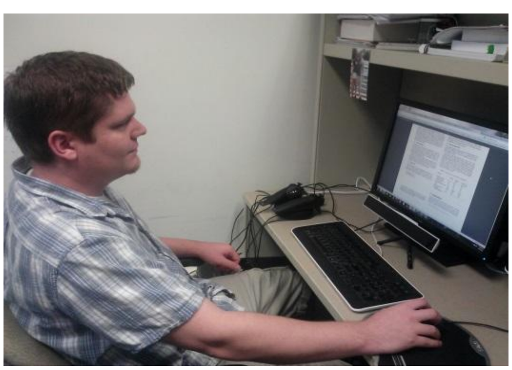

Figure 4: *Experiment set-up with GP3 eye-tracker*

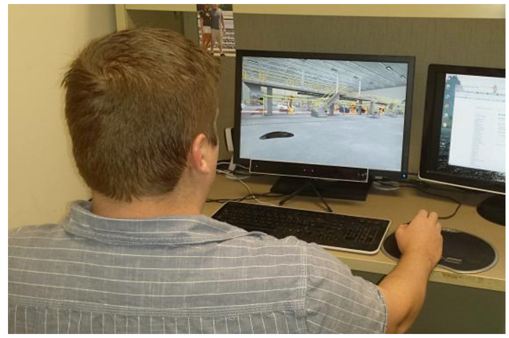

Figure 5: *Participant view of experiment set-up*

The desktop computer ran the Windows 7 OS. Eye movements of both eyes were recorded using the non-invasive GazePoint (GP3) eye tracker sampling at 60Hz (Figure 6). Participants were asked to remain as still as possible while performing the tasks. The spatial resolution of the GP3 (from .5 to 1 degree) allowed the team to determine fixations.

Figure 6: *GP3 eye-tracker attached to monitor*

3.3 Participants

Twenty-three participants from the Clemson community took part in the experiment. Eight of these participants were excluded from data analysis due to error in the eye-tracking results.

Therefore, the study included fifteen participants, 10 females and 5 males, ranging from 22-32 years of age, with a mean age of 27 years. They had normal to corrected normal vision. All but three participants had experienced virtual environments in which they must navigate. Additionally, all of the participants that reported having experience with virtual environments also reported using navigational aids in a virtual environment.

3.4 Experimental Design

The independent variable, type of navigational aid that participants received (e.g., passive, active, or none), was manipulated between individuals randomly assigned to conditions. The dependent variables that were measured are mean completion time (measured in seconds) and mean number of oil spills identified. The mean completion time did not include the time that participants spent in the tutorial.

Other dependent variables include eye movement parameters such as the mean percentage of fixations on the navigational aid and the time of fixation durations on the navigational aid. The fixations on the navigational aid were captured anytime a fixation occurred on the portion of the screen that housed the navigational aid. The mean percentage of fixation durations was calculated by dividing the mean number of fixations on the navigational aid by the total number of fixations that occurred during the simulation. This did not include fixations that occurred during the tutorial. The time of fixations on the navigational aid were captured by recording the mean amount of time participants spent fixating on the portion of the screen that housed the navigational aid. The percentage of time spent looking at the navigational aid was then calculated by dividing the fixation durations by the amount of time participants spent in the environment. Statistical analysis was done using two-sampled t-tests with an alpha level of .05.

3.5 Procedure

Before beginning the experiment, each participant was provided with information on the study and given the option to participate or not. After receiving participant consent, the eye-tracker was then calibrated to the participant and began recording data. Next, the participants all went through a tutorial for the virtual world where they learn to how to use the controls to navigate the virtual environment. This tutorial environment is a simpler environment than the one where participants were tested, but they both follow the same navigational mechanics.

Once participants completed the tutorial, they then entered the virtual factory. In order to keep participants from only using the map with path and pointer, participants were asked to perform a search task while traveling through the environment. The users were asked to find all of the oil spills on the floor of the virtual factory, while making their way from the entrance of the factory to the exit.

Once the participant completed the task, they were then given a basic demographic survey and a questionnaire (Likert scale) about the virtual environment and their overall experience to gather user preference data.

4 Results

Data between the active, passive and control groups was analyzed through the use of two-sampled t-tests. An alpha level of .05 was used for all statistical tests.

Results revealed no significant difference between the mean number of oil spills found in the active (M=9.00,SD=1.22) compared to the control condition (M=8.60, SD=1.34), $t(7)=.49$, $p=.638$, the passive condition (M=9.60, SD=.894) compared to the control condition (M=8.60, SD=1.34), $t(6)=-1.39$, $p=.215$, or the active (M=9.00, SD=1.22) compared to the passive condition (M=9.60, SD=.894), $t(7)=-0.88$, $p=.406$. A box plot of the results can be seen below (Figure 7).

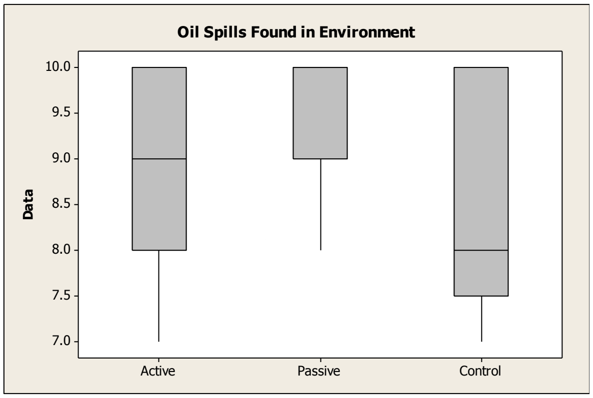

Figure 7: *Box Plot of Number of Oil Spills found in Virtual Envrionment for each Condition*

The percentage of fixations on the navigational aid approached significance in the active (M=.207, SD=.103) compared to the control condition (M=.087, SD=.065), *t*(6)=2.21, *p*=.069. However, no significant difference was detected in the mean percentage of fixations on the navigational aid in the passive (M=.147, SD=.106) compared to the control condition (M=.087, SD=.065), *t*(8)=1.08, *p*=.311, or the active (M=.207, SD=.103) compared to the passive condition (M=.147, SD=.106), *t*(7)=.91, *p*=.395. A box plot of the results can be seen below (Figure 8).

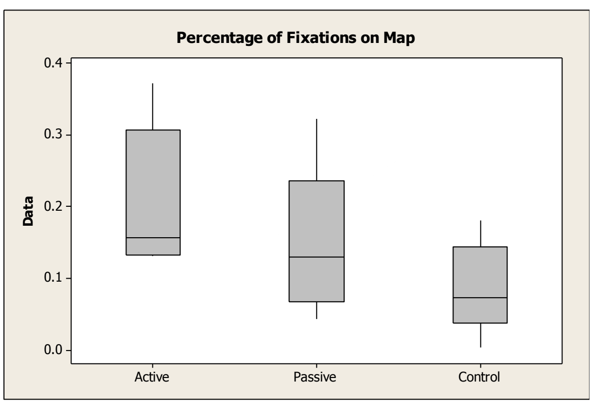

Figure 8: *Box Plot of Percent of Fixations on the Navigational Aid*

A significant difference was revealed in the percentage of fixation time on the navigational aid for the active (M=.186, SD=.091) compared to the control condition (M=.074, SD=.048), *t*(8)=2.45, *p*=.040. However no significant difference was found in the active (M=.186, SD=.091) compared to the passive condition (M=.139, SD=.109), *t*(8)=.74, *p*=.481, or the passive (M=.139, SD=.109) compared to the control condition (M=.074, SD=.048), *t*(8)=-1.24, *p*=.249.

A significant difference was also found in the mean completion time (measured in seconds) for the active (M=254.7, SD=40.7) compared to the passive condition (M=193.5, SD=36.6), *t*(8)=2.50, *p*=.037.

The active (M=254.7, SD=40.7) compared to the control condition (M=173.5, SD=78.0) approached significance with *t*(8)=2.06, *p*=.073. And no significant difference was found for the passive (M=193.5, SD=36.6) compared to the control condition (M=173.5, SD=78.0), *t*(8)=-0.52, *p*=.618. A box plot of these results can be seen below (Figure 9).

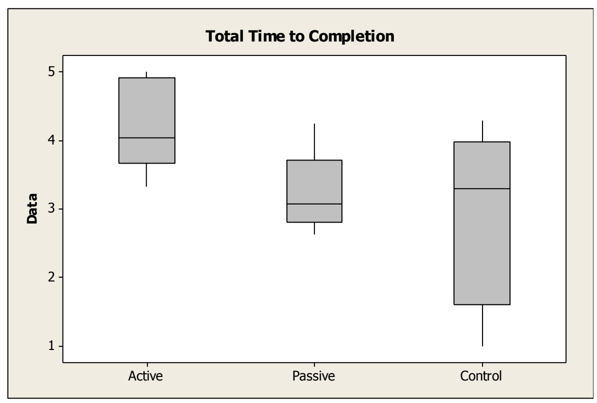

Figure 9: *Box Plot of Total Completion Times (min)*

A summary of the data results can be seen in Figure 10. An asterisk (*) next to a number denotes statistical difference in that category. A plus ($^{+}$) next to a number denotes approaching significance.

Condition	Average Total Time to Completion (sec)	% Time Looking at Navigational Aid	% Fixations on Navigational Aid	Average Oils Spills Found (10 total)
Active	254.7*+	19%*	21%+	9.0
Passive	193.5	14%	15%	9.6
Control	173.5	8%	9%	8.6

Figure 10: *Summary Table of Results*

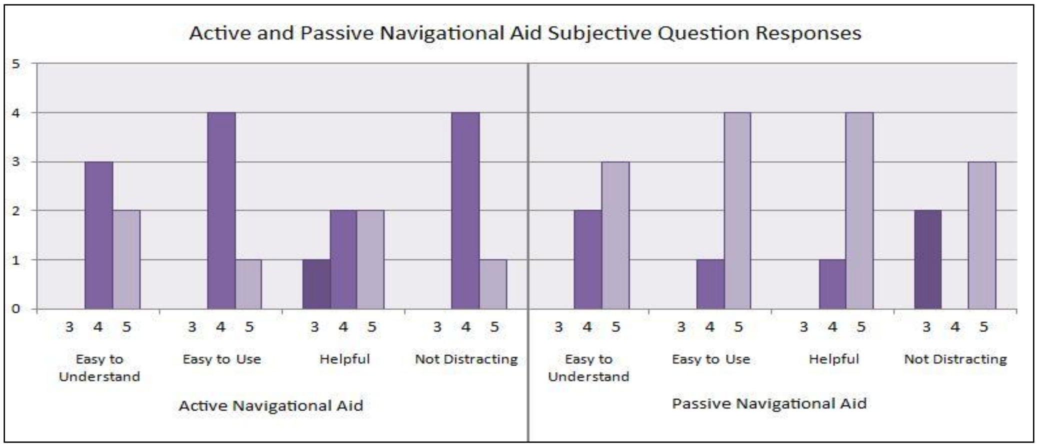

Figure 11: *Subjective Question Responses for Active and Passive Aids*

Lastly, results from the Likert scale questionnaire showed little difference between the active and passive navigational aids (Figure 11). Overall, the passive navigational aid received slightly higher scores in the categories of "Easy to Understand," "Easy to Use," and "Helpful," but was rated lower in the "Not Distracting" category.

5 Discussion

Due to the fact that there was a significant difference between the passive and active conditions in terms of the mean completion time, we failed to reject the first hypothesis. Li et al.'s theory that the passive navigational aid is better for one time use environments (Li et al., 2013) is supported by this finding. While the results were not significant, the mean completion time for participants in the active condition was higher than for participants in the control condition. It is possible that participants spent a longer time in the environment with the active navigational aid because this aid encouraged the participants to spend more time exploring the environment. A future study could be run with more participants to find evidence to support this theory.

The data rejects the second hypothesis because there was no significant difference found in the percentage of fixation durations for the active compared to the passive conditions. There was also no significant difference in the percentage of fixation durations for the passive compared to the control group. This suggests that participants spent no more time looking at the bottom right of the screen with a navigational aid than they did without a navigational aid. We believe this is the case because participants without a navigational aid had no navigational aid blocking their view from the environment. Consequently participants in the control conditions had more screen to view the environment with. This could have been prevented had the control condition had a solid block on the bottom of the screen, just as the active and passive conditions had a block on the bottom of their screens. Other fixes would be to make the navigational aids transparent, or to have the navigational aids placed out of the participants' view of the environment.

The results reject the third hypothesis due to no significant differences being found in the passive compared to the active condition in terms of the mean percentage of fixations on the navigational aid. Because there were also no significant differences for the active and passive compared to the control conditions, this suggests that participants were no more likely to fixate on the navigational aid than they would have been to fixate on the bottom right of the screen. These results are probably due to the same problem that was mentioned above.

The results of the questionnaire provided no significant evidence for a user preference between the active and passive navigational aids. Participants rated the passive navigation aid slightly better than the active, but not enough to prove significant. It is interesting to note that all of the participants who used the passive aid reported being familiar with that specific type of navigational aid, whereas the active aid was unfamiliar to some participants. This familiarity could potentially have influenced the participant's subjective responses. Again, this study could be replicated with additional participants to see if familiarity with a specific navigational aid influenced the user's performance with that aid.

6 Conclusion

This study failed to reject the first hypothesis that participants receiving passive navigational aids will perform significantly better than participants receiving active navigational aids. These results provide supporting evidence for Li et al.'s theory that the passive navigational aid is better suited when the user will only enter the environment once. Further research could be done to provide evidence to support the theory that the active navigational aid encourages exploration of a virtual environment.

Although the results rejected the second and third hypotheses, replications of our study could be done in the future to correct the placement of our navigational aids, and to provide supporting evidence for our hypotheses.

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