

Effects of Plane Mapping on Sound Localization in a Virtual Auditory Environment

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Abstract. Virtual auditory environments (VAEs) can be used to communicate spatial information, with sound sources representing the location of objects. A critical factor in this type of immersive system is the degree to which the participant can interact with the virtual environment. Our prior work has demonstrated that listeners can successfully locate virtual spatialized sounds, delivered over headphones, in a VAE using a mouse and screen to navigate the virtual world. The screen indicates the avatars position on the vertical plane. The present study seeks to determine the effects of plane mapping on listener performance. In the horizontal-plane interface, the listener used a WACOM tablet and pen to navigate the VAE on the horizontal plane. Results suggest that there is no significant performance difference when locating a single sound source. In the multi-source context, it was observed that the time taken to locate the first sound was significantly larger than the time taken to locate the remaining sounds.

1 Introduction

Digital sounds can be processed, creating auditory cues that convey spatial information within a virtual auditory environment (VAE). In this type of environment, locations are indicated by sound sources. To increase immersion, a user needs to explore this VAE as naturally as possible. A challenge in developing VAEs is choosing the proper mediation through which the user will interact with the environment. An interface that allows the listener to easily explore the world, while minimizing potential perceptual overhead is desirable.

Generally speaking, most people are familiar with using a mouse interface and receiving locational feedback through a standard computer monitor. On the surface, one might assume that using a mouse driven interface to navigate a VAE is ideal since it is inexpensive, does not present calibration issues, can be used by virtually any computer application, and requires little training to be used by most people. On the other hand, the use of a mouse and screen also requires the perceptual overhead of mapping horizontal mouse movements to vertical locations on the screen.

The present experiment assessed the effects of horizontal to vertical plane mapping on the listener's ability to find a virtual sound source. Listener performance was assessed as they searched for sounds in an interface that required

plane mapping and compared to an interface that did not require such mapping. In the non-mapping interface, the listener navigated the environment by moving a pen on a WACOM tablet (on the horizontal plane) while absolute position was indicated by the pen's location on the tablet.

2 Methods

An experiment was designed to determine the performance effects of using a mapping vs. a non-mapping interface during a search task in a VAE. The VAE was comprised of acoustic sources arranged along a circle in an otherwise anechoic environment. In the search task, listeners were asked to find a sound source by moving to the location of that source. Participants moved through the VAE by physically moving the pen on the WACOM tablet or by using the mouse to change position, presented on a vertical display. Henceforth, the mouse and vertical screen display will be referred to as the mouse mediation and the WACOM tablet and pen will be referred to as the tablet mediation. A training task was used to acclimate participants to each mediation. During training, each user practiced locating a single sound source as quickly as possible. Next, in the test phase, listeners were presented with four sound sources and asked to locate each in a prescribed sequence.

2.1 Procedure

In the training and test phases, each trial began with a source (or sources) positioned randomly along a fixed circle placed horizontally on the ear-level plane and the participant positioned in the center of that circle. Participants moved to the sound source and were notified with a diotic auditory cue when they arrived within a fixed radius of the source. Training continued until a participants current and past four search times had a standard deviation of 2.5 seconds or less.

Four sound sources were used in the test phase of the four-source environment. At the beginning of a trial, participants were cued with the source they should search for. Then, all four sources were presented and the participant began their search. Upon successfully locating the first source, the sources were turned off, the second cue was presented, and all sources were turned back on. This sequence continued until all four sources were cued and located. Once a participant finished the test and training phases for one modality, they repeated for the alternate modality.

The four sources were selected from a publicly available database of audio recordings [1]. Recordings of a typewriter, street crowd, brook, and electronic sounds, as might be heard in a piece of computer music were selected.

Eight paid volunteers participated in the experiment. These students were chosen from the undergraduate Performing Arts Technology Program at the University of Michigan. Half began using the mouse mediation while the other half began using the tablet mediation.

3 Results

3.1 Training

The scatter plot in Figure 1 displays the mean search times, once optimality was reached, for each subject. The mouse-first subjects are labeled “M-subject Number” and tablet-first subjects are labeled “T-subject Number”. The mouse interface search time is on the x-axis and the tablet mediation search time is on the y-axis. The 45 ° diagonal line indicates where each subject’s time would be plotted if there were no difference between either mediation. During optimal performance, listeners took significantly more time to search in the mouse mediation than the tablet mediation [$F_{1,78}=4.14$, $p<0.05$].

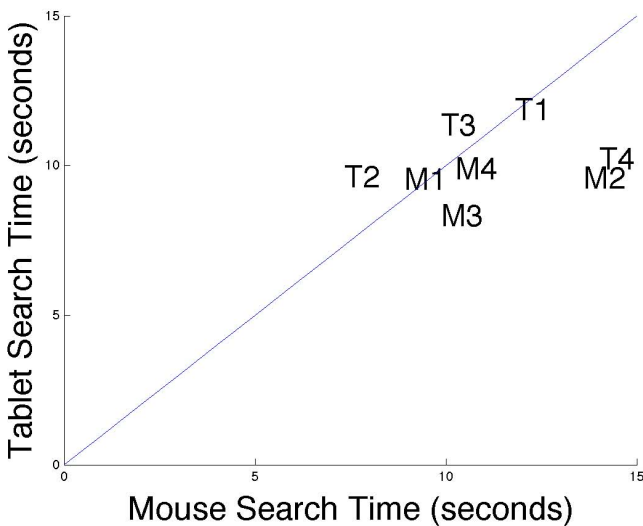


Fig. 1. Mean search times are shown for mouse-first (M-subject number) and tablet-first (T-subject Number) subjects during the training phase

3.2 One Source Context

Figure 2 shows the mean search times for each subject while searching for one source in the single-source environment. There was no significant difference observed as an effect of mediation type [$F_{1,318}=0.84$, $p=0.33$].

3.3 Four Source Context

Figure 3 shows the mean search times for each subject while searching for the first source in the four-source environment. Search time for one source in the four-source environment was significantly higher than the single-source condition

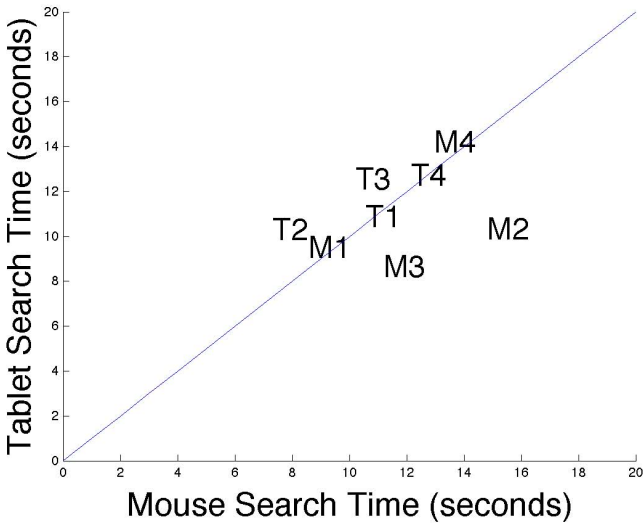


Fig. 2. Single-source environment search times for mouse-first (M-subject Number) and tablet-first (T-subject Number) subjects

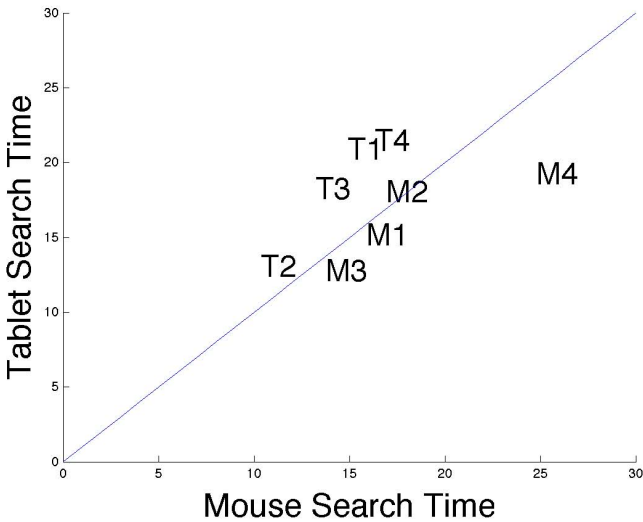


Fig. 3. Search times for the first source within the 4-source context for mouse-first (M-subject Number) and tablet-first (T-subject Number) subjects.

[$F_{1,638}=70.58$, $p<0.01$]. Collapsed across subjects, no significant difference was observed as an effect of interface type [$F_{1,318}=0.21$, $p=0.65$]. It should also be noted that tablet-first subjects had a significantly lower search time with the mouse mediation than the tablet mediation [$F_{1,158}=4.92$, $p<0.05$].

4 Discussion

The present work examined the effect of plane mapping on a listener's search time while looking for a sound in a VAE, with and without competing sources. Overall, training and testing results suggest that search performance is not affected by mediation type.

During training, it was observed that listeners needed significantly more time when using the mouse mediation, however, once the listener performed more trials in the one-source and four-source context, the increase in time for mouse mediation was not observed.

It was also observed that listeners needed significantly more time to search for one source in the four-source context than in the one-source context. This finding suggests that competing sources in the background may create a distraction for the listener, perhaps making the task a bit more challenging. This observation could also be attributed to the subjects' need to spend additional time orienting to the environment.

Tablet-first listeners performed significantly better using the mouse interface than with the tablet interface, in the four-source context. This could possibly be due to the four-source task presenting more of a challenge, which resulted in better performance with the more familiar interface.

The key finding of our experiment is that overall, there is no significant difference in search time for listeners interacting with a VAE using mouse mediation or tablet mediation. Once the participants are adequately trained, they appear to use both interfaces equally as effectively.

Reference

1. Begault, D.: 3-D sound for Virtual Reality and Multimedia (2000)