Gunzelmann, G., Douglass, S., Khooshabeh, P. (2008). Learning to Orient Using a Map Display: Evidence from Eye Tracking. In C. Holscher (Ed.), *Spatial Cognition 2008: Poster Proceedings*. (Report #016-08/2008, pp. 85-88). Bremen, Germany: Transregional Collaborative Research Center SFB/TR 8 Spatial Cognition.

Learning to Orient Using a Map Display: Evidence from Eye Tracking

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Abstract. Eight individuals participated in an experiment requiring them to identify the position of a viewer on a map given the viewer's egocentric perspective of the space. Performance data indicated that response times decreased significantly over the course of the experiment, but accuracy did not improve. An analysis of eye tracking data showed that the speedup in participant performance was primarily a reflection of participants shifting attention between the two perspectives of the space less often. This finding suggests that the improvement resulted from reduced efforts to verify the hypothesized relationship between the views, but that identifying corresponding features remained as a significant challenge.

Keywords: Orientation; Frame of Reference; Eye Tracking; Sequence Analysis.

1 Introduction

Maps provide a nearly ubiquitous tool for aiding in navigation and route planning. A substantial literature exists documenting the utility and challenges associated with using maps in a variety of contexts to support human spatial reasoning (e.g., [1], [2], [3]). Practicing using maps to guide spatial reasoning can lead to improved performance in a variety of task contexts, in terms of both accuracy and response time.

In the experiment presented here, we examine learning that takes place as individuals perform an orientation task requiring them to establish correspondence between egocentric visual information about a space and an allocentric map of the same space. In addition to traditional performance measures, we collected eye point of regard (POR) data to evaluate the solution process in detail to identify changes resulting from learning. In the next section, the experiment methodology is described briefly, followed by the results of the experiment, in terms of overall performance and changes in eye movements as experience with the task increased.

2 Experiment Methodology

Participants performed an orientation task requiring them to identify the location of a viewer based upon that viewer's egocentric perspective of a space. In each trial, a circular space containing 10 objects was shown. On the left, a view of the space was presented from the perspective of a viewer standing on the edge of the space facing the center. On the right was a map of the space, which indicated the locations of all 10 of the objects. A small green object indicated the center of the space on both views. Participants responded by clicking on the location on the edge of the map where they thought the viewer was located. A sample trial is shown in Figure 1.

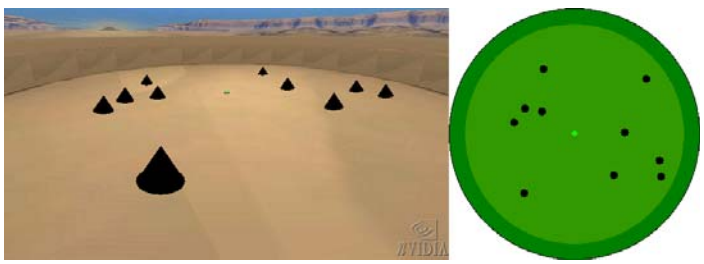

Fig. 1. Sample trial from the experiment. On the left is an egocentric perspective of the space, with a map of the space on the right. Participants were asked to identify the location of the viewer on the map, based upon the egocentric perspective shown. In this trial, the viewer is located in the 30 degrees to the left from the bottom of the map.

Participants completed a total of 576 unique trial conditions, which varied in terms of several factors including the misalignment of the map and factors associated with the arrangement of the objects in the space. A drop-out procedure was used such that if a participant made an error on any particular trial during the experiment (i.e., a response >30˚ from the viewer's actual location), that trial condition was repeated later in the experiment, but with a different randomly-generated set of object locations. There were 8 participants (6 male, mean age 28.5) in the experiment, which was broken into 2 hr sessions, one per day. Participants required from 2 to 4 sessions to complete the study, depending on performance and were compensated for their time at the rate of $10/hr. Calibration of the eye tracking equipment was performed at the start of each session, and opportunities for recalibration were given every 20 trials throughout the experiment. In the results presented next, we focus on the impact of practice on performance, focusing on changes in observed eye movement sequences that can be associated with learning that is taking place.

3 Results and Discussion

Throughout the experiment, data were collected on response time and accuracy for each trial, in addition to the eye POR data. Increased experience with the task did not influence accuracy $F(28,196)=0.83$, $p>.70$[1] (p-values are Greenhouse-Geisser adjusted). However, there was a significant speedup in performance across the experiment, $F(22,176)=8.24$, $p<.001$, which is illustrated in Figure 2. The decrease in response times is quite large. For the last 100 correct responses, average response time was 9.85 seconds, compared to 18.25 seconds for the first 100 correct responses.

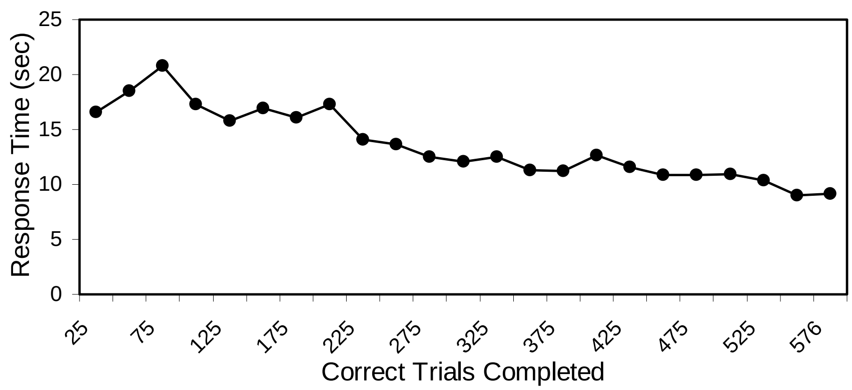

Fig. 2. Performance results for empirical study, showing average response time for sets of 25 correct responses, showing a steady decrease in response times across the experiment.

Although the performance data show evidence of improvement in the participants, they do not provide insight regarding why performance got faster. However, we can add key evidence about what was being learned by examining changes in the sequences of fixations generated by participants as experience with the task accumulated. Figure 3 presents two measures derived from the eye tracking data. The first is the average number of fixations directed to a particular view (the visual scene or the map) during a single period of looking at that view (i.e., consecutive fixations – a “dwell”). The second measure is the average number of such dwells per trial.

The data in Figure 3 illustrate two potential sources of learning in the experiment. The first, fixations per dwell, provides an indication of how difficult it was for participants to (1) extract meaningful spatial information about grouping and organization from one view and (2) identify the corresponding information in the other view. The data indicate that learning had a relatively modest impact on this measure, and the effect was only marginally significant, $F(22,154)=2.13$, $p<.10$. Alternatively, the impact of learning on the number of dwells is much larger. Increased practice led to a decline in the average number of dwells per trial, $F(22,154)=5.05$, $p<.01$. For both measures, however, the analysis revealed a significant linear trend in the data, $F(1,7)=19.55$, $p<.01$ for the number of dwells and $F(1,7)=18.51$, $p<.01$ for the average dwell length. A subsequent test of the slopes of

[1] This analysis is based upon the proportion correct for the first 29 sets of 25 trials for each participant. Because of the drop-out procedure, some participants had no data beyond this point. Including data from subsequent blocks would artificially decrease accuracy, since the participants with the lowest error rate would no longer be contributing data to the analysis.

the effects showed that they both differ significantly from zero as well, t(7)=4.42, p<.01 for number of dwells and t(7)=4.30, p<.01 for dwell length.

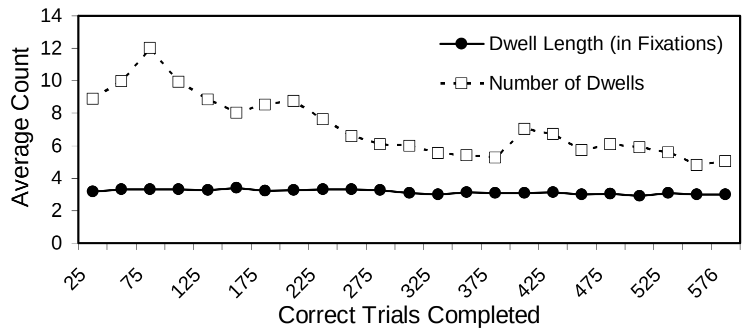

Fig. 3. Eye tracking results for average number of dwells and dwell length for the experiment.

The decrease in the number of dwells provides evidence that participants were becoming more efficient at verifying the correspondence of features between the two views. The small decrease in the average dwell length suggests that searching for features and executing the matching process may have improved, but only to a small degree. Together these results suggest that participants were using the same basic process throughout the experiment (i.e., cycling between views to identify corresponding features and refine an estimate of the viewer's location), but that fewer iterations through the cycle were required with practice. More detailed analyses, follow-on experiments, and computational cognitive modeling will be used to address and validate these conclusions in more detail as the research progresses.

Acknowledgements

The views expressed in this paper are those of the authors and do not reflect the official policy or position of the Department of Defense or the U.S. Government. This research was sponsored by the Air Force Research Laboratory's (AFRL) Warfighter Readiness Research Division and by grant 05HE06COR from the Air Force Office of Scientific Research (AFOSR). Peter Khooshabeh's participation was sponsored by an AFRL internship administered by the Oak Ridge Institute for Science and Education.

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