Roles of Additional Information for Wayfinding in Virtual Environment

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Abstract

Although variety of artificial information such as a roadmap and a car-navigation system are available, our primary information for wayfinding is cognitive map, namely internal representation of an environment. Since an allocentric cognitive map is learned through exploring the environment with egocentric view, transformation from observer-centered frame of reference to world-centered frame of reference is necessary. We simulated wayfinding in a real-world environment by a maze in a virtual-reality display system. We investigated effects of additional information to egocentric view during exploration of the environment on performance of cognitive map acquisition. Performance was evaluated by accuracy of learned cognitive. The results showed that with addition of landmarks on the maze there was not only statistically significant improvement of acquired cognitive map but shorter time to take for learning. It was also found that when information about heading direction was presented with egocentric view, performance was significantly better than when no additional information was presented. These results suggest that transformation from observer-centered frame of reference to world-centered frame of reference requires information about observer's orientation besides temporal change of egocentric view.

Key words: Wayfinding, Egocentric information, Allocentric information, Virtual environment, Cognitive map

1. Introduction

When we find a way in an environment, we use both an egocentric information and an allocentric information. The egocentric information for wayfinding is a real-time change of sight from our point of view. While we are moving, we estimate our own speed and direction of heading by an optical-flow field, namely a velocity field created by our self-motion, as well as by information from a vestibular and a somatosensory systems (see Ohmi, 1996 for review). We can also detect locations of obstacles as irregularities of optical-flow field (Gibson, 1979). Therefore we can move around the environment safely with avoiding obstacles as long as we can see them.

However, obstacles in the environment may or may not be visible depending on spatial relationship between them and us. Therefore, we must maintain a mental representation of spatial relationship among these objects in the environment in order to find a way in real-world environment (Weisman, 1981). This maintained mental representation is the allocentric information for wayfinding. The representation is also entitled as a cognitive map, since it is supposed to be like a bird's-eye view of the environment.

It has been believed that we learn an exocentric representation of environment by integrating egocentric views perceived while traversing an environment (Passini and Proulx, 1988). A Landmark-Route-Survey model (LRS model) is the most well-accepted model for describing how the allocentric representation of environment is acquired from the egocentric information (Siegel and White, 1975; Thorndyke and Hayes-Roth, 1982). When we encounter an unfamiliar environment at the first time, we acquire descriptive information about a few landmarks (Landmark stage). Then, by using these landmarks as markers, we develop information about specific route (Route stage). This information is sets of paths and turns to reach specific destinations. Finally, we learn cognitive map, or survey map, of the environment and are able to take, for example, a short cut easily (Survey map stage). It has been assumed that these representations are acquired successively as we experience the environment.

Although the LRS model is a powerful conceptual tool, it is also claimed that its assumption about successive stage of acquisition of spatial representation is too restricted. There are many experimental studies to show that we can acquire some allocentric representation even after short exploration of an environment (Evans, 1980; Foley and Cohen, 1984; Taylor and Tversky, 1996; Colle and Reid, 1998). We reported last year that observer created either an egocentric or an allocentric representation of environment as a working memory for wayfinding (Ohmi, 1998).

When we navigate through a familiar environment, an allocentric information in cognitive map has to be integrated with an egocentric information in a view. It has not been clear, however, how the acquired allocentric information interacts with the egocentric information to help our wayfinding.

In the real world, we not only develop the allocentric representation of the environment from the egocentric information through exploration, but also have access to plenty of artificial allocentric information such as roadmap and car-navigation system. Therefore it is practically more important to understand roles of the allocentric information for wayfinding in real-world environment. exploring virtual maze. It was suggested that landmark information during exploration of virtual maze was not useful for memorizing route.

In this research, we investigated effects of additional allocentric information to egocentric view during exploration of the environment on performance of navigation in virtual environment. In Experiment 1 and Experiment 2, a real-world environment was simulated by a maze in a virtual-reality display system. We investigated effects of landmark information on acquisition of route information and learning of wayfinding. In Experiment 3, effects of heading information on acquisition of cognitive map were investigated.

2. Experiment 1

Method

In Experiment 1, we investigated how a landmark information contributed on performance of route memorization in a virtual maze. Observer explored the maze with following route instructed by experimenter and was asked to report memorized route after exploration by drawing it on a map of the maze. Figure 1 depicts observer's egocentric view during exploration. The view was transformed according to location of observer in the maze.

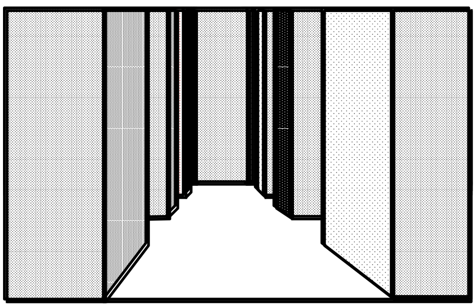


Figure 1 Egocentric view of the maze

Two kinds of virtual maze were used. The maze with landmark had nine walls marked with different color. The maze with no landmark had the same configuration but without any colored wall.

The virtual maze was created by a real-time graphical simulation application (WalkThrough Pro, Virtus) on a personal computer and was presented on the computer monitor.

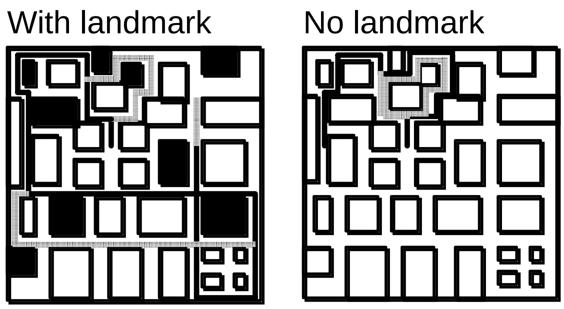
Eight undergraduate students participated as an observer. Five mazes with different shapes were presented with or without landmark. Sequence of presentation was in random order.

Result

Figure 2 depicted a typical memorized route for the maze with or without landmark. Solid line is an explored route and dotted line is a memorized route. There was no significant improvement of memorized route by adding landmarks on the maze. Results from other observers also showed that memorization of route was not significantly better when landmark was presented while exploring virtual maze. It is suggested that landmark information during exploration of virtual maze was not useful for memorizing route information.

Figure 2 Explored and memorized route of virtual maze

3. Experiment 2



Method

In Experiment 2, we investigated effect of landmark information on performance of wayfinding in a virtual maze. Shape of the maze in this experiment was more regular compared with that used in Experiment 1. Observer navigated from designated starting point to the goal in the virtual maze following route instructed on a map.

Two kinds of virtual maze were used. The maze with landmark had nine walls marked with different color. The maze with no landmark had the same configuration but without any colored wall. Figure 3 depicted examples of maze used in the experiment.

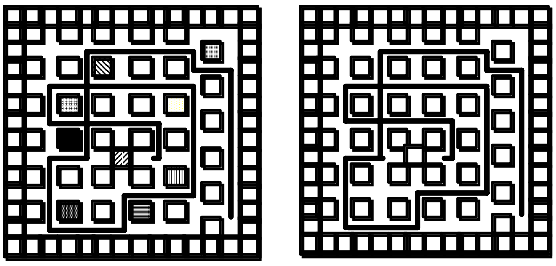


Figure 3 Example of virtual maze

The virtual maze was created by a real-time graphical simulation application (WalkThrough Pro, Virtus) on a personal computer and was presented on the computer monitor.

Observers navigated the mazes for eight consecutive trials. Their performance was accessed by navigation time from starting point to goal.

Eight undergraduate students participated as an observer. Five mazes with different shapes were presented with or without landmark. Sequence of presentation was in random order.

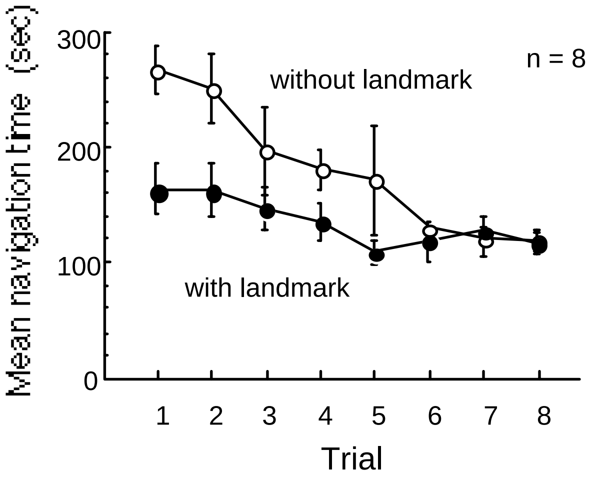
Result

Measured values of navigation time from the starting point to the goal were averaged for each trial among eight observers and five different mazes.

These averaged values were depicted with standard deviation in Figure 4. It is shown from Figure 4 that mean navigation time is significantly shorter when landmark was presented in the maze than when there was no landmark. It is also shown that navigation time became shorter as observer explored the maze more. Although this learning effect is shown when landmark was presented, the effect is much clearer when there was no landmark. Navigation time reached asymptote after several consecutive trials, and there was no difference between with landmark and without landmark conditions. Learning of route occurred much quicker when landmark was presented than when it was not presented.

Results showed that learning of wayfinding was significantly better when landmark was presented while navigating virtual maze. It is suggested that landmark information during navigation improved performance of wayfinding even though it did not contribute for route memorization.

Figure4 Change of averaged time to navigate with or



without landmark

4. Experiment 3

Method

In Experiment 3, we investigated effect of heading information on acquisition of cognitive map. Observer was instructed to draw acquired cognitive map after viewing video clip taken from car driven in residential area.

There were three viewing conditions. In the first condition (+direction), compass was presented as heading information. In the second condition (+direction & distance), information about traveling distance was presented as well as compass. In the third condition (no aid) no such aiding information was presented.

Five underground students participated as an observer. Observers viewed the same video clip and drew acquired map for three times for each condition.

Result

Figure 5 is a typical example of acquired cognitive map drawn by one observer after each nine combination of three viewing conditions and three trials. Acquired cognitive map was better when heading information was presented while exploring environment.

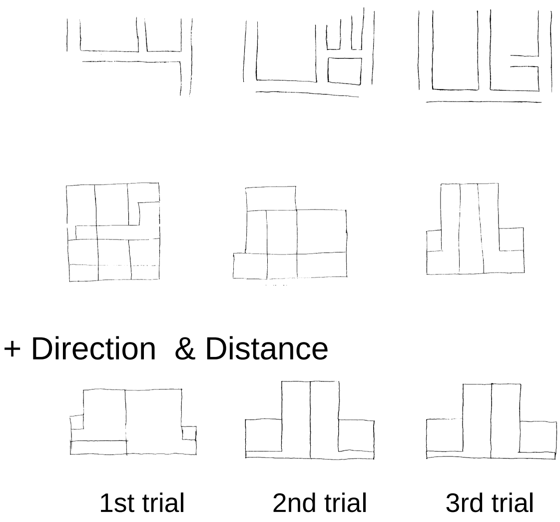


Figure 5 Typical example of drawn cognitive map

In order to estimate resemblance of each drawn map with actual one, each drawing was estimated with seven-point scale by five estimators. Figure 6 shows average point for each trial for each viewing condition. Solid circle is a data for +direction & distance condition. Open square is a data for +direction condition. Open circle is a data for no aid condition.

Quality of acquired map improved by viewing video clip more times only when direction and distance information about heading was presented. It is suggested that heading information during exploration improved learning of cognitive map.

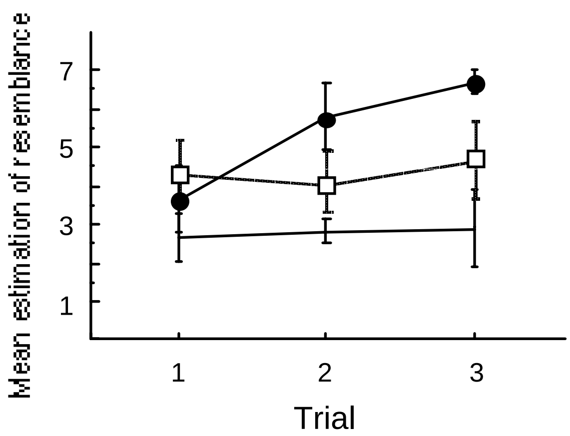


Figure 6 Mean estimate of resemblance of cognitive map with actual one

5. Discussion

We investigated roles of additional information on wayfinding in virtual environment. Experimental results showed that adding more information was beneficial for performance of wayfinding that based on change of an egocentric view. Although it sounds trivial, we found that the role were different for different additional information. We added landmark information in Experiment 1 and Experiment 2. We added heading information in Experiment 3.

Landmark information during exploration of virtual maze improved both performance and learning of wayfinding. On the other hand, landmark information did not contributed for observer’s memorization of route in the maze.

It is understandable that addition of landmarks substantially improves performance of wayfinding since route following becomes much easier with appearance and disappearance of landmarks. Temporally changing egocentric views have to be integrated for acquiring cognitive map. During this process views are converted from observer-centered frame of reference to world-centered frame of reference. Integration of egocentric views should be easier and quicker when landmark information is concurrently presented because it helps to determine relationships among egocentric views. Therefore landmark information plays substantial roles for development of allocentric representation of environment, namely cognitive map. It suggests that landmark stage of LRS model is connected with survey map stage more directly rather than indirect connection through route stage.

Heading information during exploration in environment improved learning of cognitive map. It showed that addition of two-dimensional information of direction and distance was especially beneficial and it facilitated conversion of information from observer-centered frame of reference to world-centered frame of reference. On the other hand, this learning effect was not shown by adding one-dimensional information of direction. Since quality of acquired cognitive map was significantly better with addition of direction information, each heading information seemed to have different role for development of allocentric representation of environment.

Since both landmark and heading provide orientation of observer, our results suggest that the process for developing allocentric representation of world from temporally changing egocentric information requires information about observer's orientation. In this research orientation was obtained either by observer's relation with landmarks or by observer's heading information. We have found that sensation of self-motion plays important role for development of cognitive map

(Asakura, Ohmi & Suzuki, 1999). More investigation is on the way to reveal contribution of human orientation on cognitive map acquisition.

We previously reported that ability to acquire allocentric representation of environment was quite different among observers (Ohmi, 1998). In that experiment many observers could not draw cognitive map at all. Although those observers were involved in Experiment 3 of this research, they learned substantially reasonable map representation when heading information with direction and distance was presented concurrently. It suggests that navigation-aid system with heading information such as a car-navigation system could be most useful for helping those observers to learn cognitive map of environment instead of navigation aid during driving car.

6. Conclusion

1. Learning of wayfinding is faster with addition of landmark information.

2. Acquisition of cognitive map is better with addition of heading information.

3. Transformation from observer-centered frame of reference to world-centered frame of reference requires information about observer's orientation besides temporal change of egocentric view.

Acknowledgment
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