How Egocentric and Exocentric Information are used to Find a Way in Virtual Environment?

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Abstract

When we move around an unfamiliar environment, we use an exocentric information such as a road map or a car-navigation system to help our wayfinding performed upon a real-time egocentric information. It has not been thoroughly understood, however, how the exocentric information interacts with the egocentric information in order to achieve an appropriate wayfinding. We simulated the wayfinding in a real-world environment by a maze with the egocentric view in a virtual-reality display system. We investigated effects of a concurrent or prior exocentric information on performance of a task to reach a goal of the virtual-reality maze. The results showed that although the concurrent exocentric information improved performance in general, there was no statistically significant improvement of performance by presenting position of the observer superposed on the exocentric view as implemented in the car-navigation system. It was also found that when false exocentric information was presented concurrently, performance was significantly worse than when no exocentric information was presented. It would simulate a situation of losing ourselves in real-world environment. On the other hand, performance to reach a goal of a maze did not depend on whether prior presentation of the maze was egocentric or exocentric for both the maze with many landmarks and that without any landmark. It suggest that we create a common representation of environment as a working memory for wayfinding.

Key words: wayfinding, egocentric information, exocentric information, cognitive map, virtual environment

1. Introduction

Wayfinding is a natural and essential activity for us performing in real-world environment. We use both an egocentric and an exocentric information to find a way in the environment. The egocentric information for wayfinding is a real-time change of sight from our point of view. We estimate speed and direction of our own 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). Three-dimensional locations of obstacles and openings are detected as irregularities of optical-flow field (Gibson, 1979). Therefore we can find our way in the environment by avoiding obstacles and entering openings as long as we can see these objects. Depending on distance and direction, however, obstacles and openings in the environment may or may not be visible from our point of view. 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 exocentric 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 suggested that we learn an exocentric representation of environment by integrating egocentric views perceived while traversing an environment (Passini and Proulx, 1988). There has been a Landmark-Route-Survey model (LRS model) to describe how the exocentric 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 stage). It has been assumed that these representations are acquired successively depending on amount of experience we have with the environment.

Although the LRS model is a powerful conceptual tool, it is also claimed that its assumption about successive acquisition of spatial representation is too restricted. There are many experimental studies to show that we can acquire some exocentric representation even after short exploration of an environment (Evans, 1980; Foley and Cohen, 1984; Taylor and Tversky, 1996; Colle and Reid, 1998). It has not been clear, however, how the acquired exocentric information interacts with the egocentric information to help our wayfinding performance.

In the real world, we not only develop the exocentric representation of the environment from the egocentric information through exploration, but also have access to plenty of artificial exocentric information such as road map and car-navigation system. Therefore practically it is more important to understand how the exocentric information and the egocentric information are used to find a way in real-world environment.

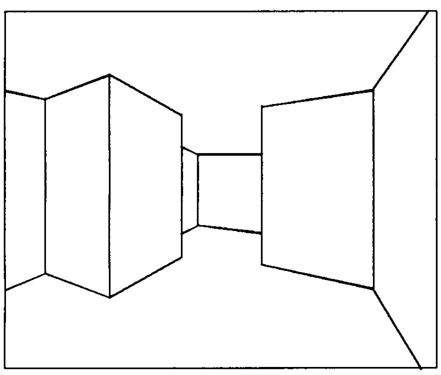
One experimental difficulty of this kind of experimental research is that once an observer has learned a particular real-world environment, it can not be used again, and we are going to run out of available environment sooner or later. Since we can create virtual environment as many times as we need, this is not a problem for virtual-reality display system. Therefore, we simulated the wayfinding in a real-world environment by a maze with the egocentric view in a virtual-reality environment. We investigated effects of (a) a concurrent exocentric information and (b) a prior egocentric and exocentric information on performance of a task to successively finding a way in virtual environment.

2. Experiment 1

Method

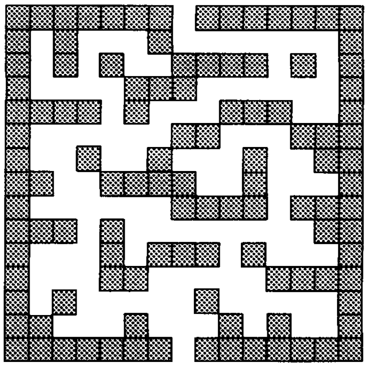
In the first experiment, we examined how an concurrent exocentric information contributed on performance of wayfinding within a virtual maze. Vantage point of the observer was located inside the maze. Therefore, observer's view was an egocentric one. It simulated a sight which observers saw when they were located on corridor of the maze (Figure 1).

Figure 1. Egocentric view of the maze



The egocentric view was transformed according to location of observer in the maze with real time. Observer's task was to navigate from a starting point to a goal of the maze. A top view of the maze was presented concurrently as an exocentric information of the maze (Figure 2) while observers were finding their way to the goal. We assessed observer's performance by elapsed time to navigate from the starting point to the goal.

Figure 2. Exocentric view of the maze



There were four experimental conditions for presenting exocentric information in the experiment.

1. Top view of the maze was presented with location and direction of movement ofobserver. It depicted a display of car-navigation system.
2. Top view of the maze was presented.
3. No exocentric view was presented.
4. Top view of the other maze was presented.

If exocentric information contributed on wayfinding with egocentric view, time to navigate in Condition 2 should be shorter than that in Condition 3. If presenting observer's location in exocentric display was beneficial for wayfinding, time to navigate in Condition 1 should be shorter than that in Condition 2. If false exocentric information disturbed performance of egocentric wayfinding, time to navigate in Condition 4 should be longer than that in Condition 3. Therefore, we would expect following relationship among time to navigate for each condition; time for Condition 1 < time for Condition 2 < time for Condition 3 < time for Condition 4.

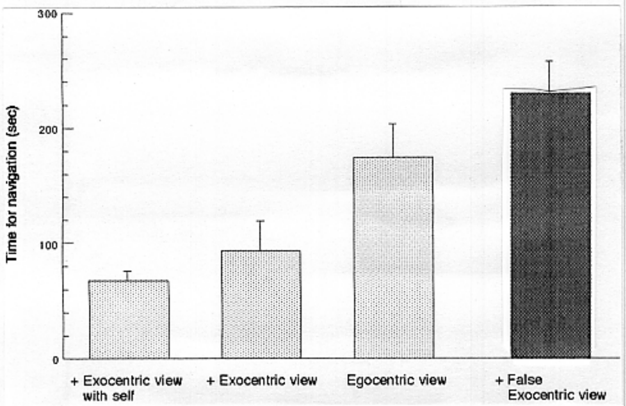
The virtual maze was created by a real-time graphical simulation application (WalkThrough Pro, Virtus) on personal computer (Power Macintosh 8600, Apple) and was presented on the computer monitor. Since the maze was composed of featureless vertical wall, there was no landmark cue for wayfinding within the maze. Observers were instructed to move from the starting point to the goal as fast as possible. They had control of their speed and direction of movement in the virtual maze with mouse. They were allowed to refer the exocentric information freely during wayfinding whenever it was available. If they could not reach the goal within five minutes, the trial was terminated.

Four undergraduate students and the author participated as an observer, five different mazes were presented for each experimental condition. Sequence of presentation was in random order.

Results

Measured values of elapsed time to navigate from the starting point to the goal were averaged for each experimental condition among five observers and five trials. These averaged values were depicted with standard deviation in Figure 3.

Figure 3. Averaged time to navigate with or without exocentric information



The leftmost bar (denoted as '+ Exocentric view with self') was a mean time to navigate for Condition 1. The second bar from the left (denoted as '+ Exocentric view') was a mean time to navigate for Condition 2. The third bar from the left (denoted as 'Egocentric view') was a mean time to navigate for Condition 3. The rightmost bar (denoted as '+ False Exocentric view') was a mean time to navigate for Condition 4. As we expected, elapsed time to navigate from the starting point to the goal became shorter when there supposed to be more contribution of exocentric information on egocentric wayfinding. It supported the notion that exocentric information such as map or car-navigation system was useful for wayfinding with egocentric view. Time to navigate with concurrent exocentric information was almost a half compared with that without exocentric view and the difference was statistically significant. Therefore we can conclude that the improvement of performance of wayfinding in the featureless maze by exocentric information was substantial.

Although performance was improved by superposing location and direction of movement of observer on the exocentric view, the amount of improvement was not statistically significant. It would suggest that the car-navigation system was useful for finding our own position relative to landmarks in environment rather than for facilitating performance of wayfinding with egocentric view.

It was also found that when false exocentric information was presented concurrently, performance was significantly worse than when no exocentric information was presented. Observers reported that even after they realized that the presented top view was false one, they could not ignore impression they got when they first saw the top view. It would mimicked a situation of losing ourselves in real-world environment. Actually one observer lost his way in three trials in Condition 4 and could not finish the task within time limit.

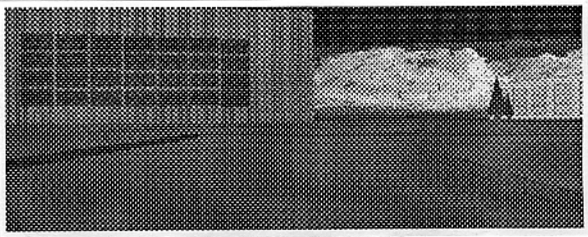
3. Experiment 2

Method

In the second experiment, we examined how an prior egocentric and exocentric information contributed on performance of egocentric wayfinding within a virtual environment. Vantage point of the observer was located inside the environment. Observer's view simulated a sight which was seen when observer was located in the environment. The virtual environment was composed of roads, buildings and other scene. It was a simulated scenery of commercial park where our laboratories were located.

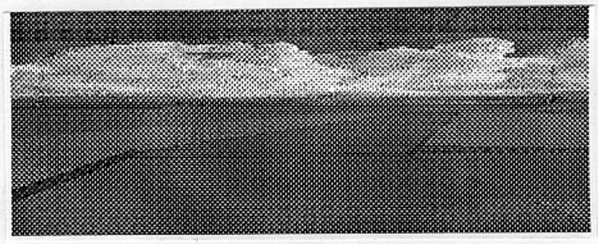
There were two kinds of virtual environment. In the virtual environment with landmarks, many buildings were shown as well as roads in the environment (Figure 4). These buildings were supposed to serve as landmarks for egocentric wayfinding.

Figure 4. Virtual environment with landmarks



In the virtual environment with no landmark, only roads in the environment were shown (Figure 5). Since there was no building, there was no landmark for egocentric wayfinding in this environment.

Figure 5. Virtual environment with no landmark



Before the experiment a prior exocentric or egocentric information of the environment was presented. A top view of the environment, namely a map of simulated commercial park, was presented as an exocentric information of the environment. A video clip taped from a car driven on the road of the commercial park was presented as an egocentric information of the environment. Subjects were required to memorize the prior information as precise as possible.

The egocentric view of the virtual environment presented during experiment was transformed according to location of observer in the environment with real time. Observer's task was to navigate from a designated starting point to a designated goal in the virtual environment with egocentric view. We assessed observer's performance by time necessary to navigate from the starting point to the goal.

For egocentric wayfinding with landmarks, egocentric prior information was supposed to be more beneficial than exocentric prior information. Since observers were able to remember landmarks in the environment while watching egocentric preview, they could easily find the way during wayfinding by matching current landmark with remembered one. On the other hand, for egocentric wayfinding with no landmark, this advantage of egocentric preview diminished. Since exocentric preview gave more comprehensive information about the complex of environment, exocentric prior information could be more useful than egocentric prior information in this case. Therefore we would expect that observer's performance for egocentric wayfinding with landmarks was better with egocentric preview than with exocentric preview. We would also expect that observer's performance for egocentric wayfinding with no landmark with exocentric preview was better than or similar with wayfinding with egocentric preview.

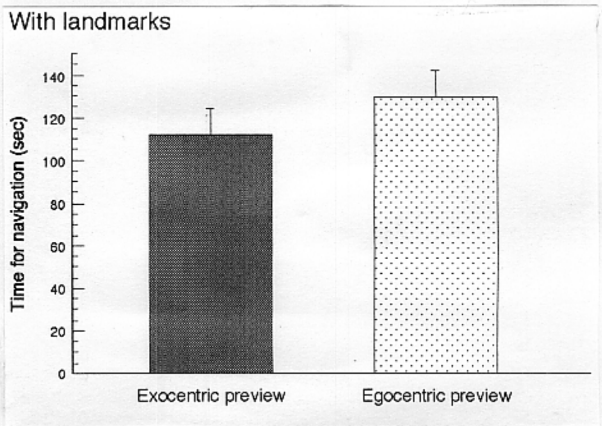
The virtual environment was created by a real-time graphical simulation application (WalkThrough Pro, Virtus) on personal computer (Power Macintosh 8600, Apple) and was presented on the computer monitor. Observers were instructed to move from a designated starting position to a designated goal as fast as possible. They had control of their speed and direction of movement in the virtual environment with mouse. If they could not reach the goal within five minutes, the trial was terminated.

Ten undergraduate students participated as an observer. There was one trial for each combination of prior information (egocentric vs. exocentric) and wayfinding (with landmarks vs. with no landmark). Different part of the whole environment was used for each combination. Sequence of presentation of four combinations was counterbalanced among observers.

Results

Measured values of elapsed time to navigate from the starting point to the goal in virtual environment with landmarks were averaged among ten observers. These averaged values were depicted with standard deviation in Figure 6.

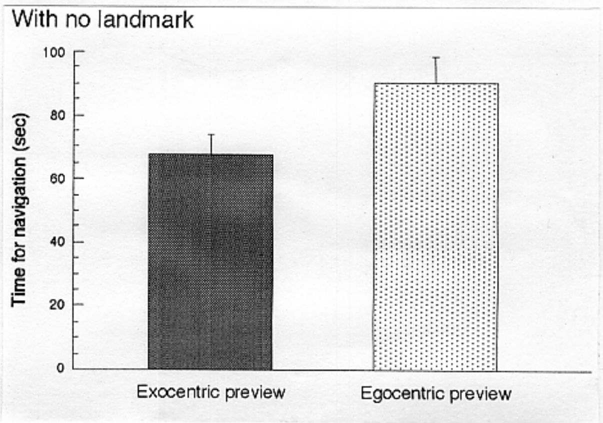
Figure 6. Time to navigate in virtual environment with landmarks



The left bar (denoted as 'Exocentric preview') was a mean time to navigate with exocentric preview of the environment before wayfinding task. The right bar (denoted as 'Egocentric preview') was a mean time to navigate with exocentric preview. Although the results showed that performance was a little better with exocentric preview than with egocentric preview, the difference was not statistically significant. Therefore, on the contrary to our expectation observer's performance of wayfinding was similar with egocentric preview and with exocentric preview.

Measured values of time for wayfinding in virtual environment with no landmark were averaged among ten observers. These averaged values were depicted with standard deviation in Figure 7.

Figure 7. Time to navigate in virtual environment with no landmark



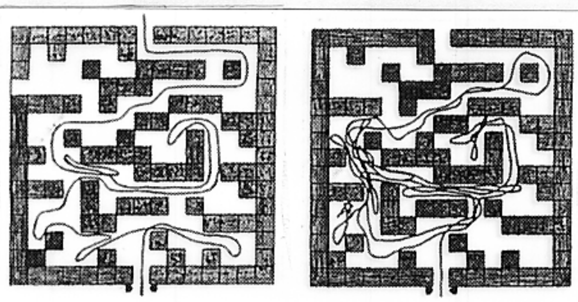
The left bar (denoted as 'Exocentric preview') was a mean time to navigate with exocentric preview of the environment before wayfinding task. The right bar (denoted as 'Egocentric preview') was a time to navigate with exocentric preview. As we expected observer's performance was better with exocentric preview than with egocentric preview, although the difference of performance between these two preview conditions was not statistically significant. Therefore, observer's performance of wayfinding with no landmark was also similar with egocentric preview and with exocentric preview.

The results of this experiment showed that performance to find a way in virtual environment both with many landmarks and with no landmark did not depend on whether prior presentation of the environment was egocentric or exocentric. We propose that subjects would create a common representation of environment from both egocentric and exocentric prior information and used the representation as a working memory for wayfinding. When we asked observers how they memorized prior information, half of them reported that they tried to draw mental map. Other half reported that they remembered route of landmarks. Interestingly enough their preference of 'map' or 'route' did not depend on whether preview of the environment was an egocentric or an exocentric one. This observation seemed to support our proposition that we individually had a preferred representation of environment.

4. Discussion

The results of Experiment 1 revealed substantial improvement of performance of wayfinding in the featureless virtual maze by exocentric information. Typical loci of wayfinding in the maze of an observer were shown in Figure 8.

Figure 8. Typical loci of wayfinding in the maze



The left graph is a locus when top view of the maze was presented as an exocentric information. Although the observer entered dead end a few times, he found the way out without difficulty by referring the top view. The right graph is a loci when exocentric information was not presented. The observer entered the same dead end many times without realizing that corridor did not afford exit. The observer seemed to have difficulty to determine on which corridor he was located. On the other hand, performance of wayfinding did not improved significantly by superposing location of the observer on the top view. These results suggest that the exocentric view like ordinary road map is enough to inform current location to the observer and car-navigation system may be useful for finding our own position relative to landmarks in environment. Although car-navigation system has became so popular in these days, its usefulness for wayfinding is rather skeptical (Dingus et al., 1997; Srinivasan and Jovanis, 1997). Car-navigation system should be assessed as an aid for facilitating learning process of exocentric representation of the environment.

Concurrently presented false exocentric information significantly disturbed performance of wayfinding. Observer's report that even after their realization of false top view they could not ignore their first impression of the view reminds deterioration of driver's performance after receiving unrealistic traffic information (Kantowitz et al, 1997). One reason to create large-scale virtual environment is for training machine for people like firefighter to familiarize inside of building before actual rescue operation. It has been reported that transfer of spatial knowledge obtained by virtual-environment training to real-world situation is feasible but not necessary seamless (Witmer et al., 1996; Bliss et al, 1997; Darken and Banker, 1998; Waller et al., 1998). One problem of virtual-environment training is that it is rather likely for observers to lose their way during training because of less than perfect set of information given to the observer. Since it is an inherited disadvantage of virtual environment, mechanism how we lose ourselves during wayfinding should be studied in virtual environment as well as in real-world environment.

The results of Experiment 2 revealed performance of wayfinding in virtual environment did not depend on whether prior knowledge of the environment was obtained as an egocentric form or as an exocentric form. It suggests that observers create a similar spatial representation of environment from observation of both egocentric and exocentric prior information and use the common representation as a working memory for wayfinding.

It should be noted that observers can be grouped by a preference of type of representation. Almost half of observers memorized prior information as set of paths and turns from a starting point to a destination. They developed information about specific route, that is a route representation. They created the route representation even when prior information was exocentric for which creating a survey map representation seemed much easier. Other half of observers memorized prior information as a survey map. They created the survey map representation even when prior information was egocentric for which creating a route representation seemed much easier.

Their preference of route representation or survey map representation also did not depend on whether they found their way in the environment with many landmarks or in the environment with no landmark. Finally the performance of wayfinding did not differ significantly for both groups. This finding suggests that we individually have a preferred representation of environment and do not necessary develop survey map representation in order to achieve wayfinding in environment.

5. Conclusion

We investigated effects of a concurrent or prior information on performance of wayfinding in the virtual environment.

1. The concurrent exocentric information improved performance of wayfinding. But there was no statistically significant improvement of performance by presenting position of the observer superposed on the exocentric view. When false exocentric information was presented concurrently, performance was significantly worse than when no exocentric information was presented.

2. Performance of wayfinding did not depend on whether prior presentation of the environment was egocentric or exocentric for both the environment with many landmarks and that with no landmark. It suggested that observer created a common representation of environment from both egocentric and exocentric previews as a working memory for wayfinding.

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