Book chapter

Ruddle, R.A. (2001) *Navigation: am I really lost or virtually there?* In: Harris, D. (ed) Engineering Psychology and Cognitive Ergonomics - Volume Six : Industrial Ergonomics, HCI, and Applied Cognitive Psychology. Ashgate , pp. 135-142.

In D. Harris (Ed.) *Engineering psychology and cognitive ergonomics (volume 6)*, 135-142, 2001.

Navigation: Am I really Lost or Virtually There?

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Abstract

Data is presented from virtual environment (VE) navigation studies that used building- and chessboard-type layouts. Participants learned by repeated navigation, spending several hours in each environment. While some participants quickly learned to navigate efficiently, others remained almost totally disoriented. In the virtual buildings this disorientation was illustrated by mean direction estimate errors of approximately 90°, and in the chessboard VEs disorientation was highlighted by the large number of rooms that some participants visited. Part of the cause of disorientation, and generally slow spatial learning, lies in the difficulty participants had learning the paths they had followed through the VEs.

Introduction

Large-scale spaces are those in which it is not possible to resolve all the information required for efficient navigation from a single position if a human's-eye viewpoint is used. In large-scale virtual environments (VEs), navigation has been researched for approximately 10 years. Anecdotal evidence from early studies indicated that people became disoriented very easily, and this sometimes persisted when they were provided with a map to aid their navigation (Henry, 1992).

Subsequent studies have shown that people are not inherently disoriented in VEs. The mental models that people develop when they navigate VEs are similar in structure to the models that people develop in the real world (e.g., May, Péruch, & Savoyant, 1995). People can learn the shortest route between locations in VEs and, if given sufficient time, can also develop accurate survey-type knowledge (Ruddle, Payne, & Jones, 1997). The primary difference, therefore, between real and virtual environments is the rate at which people develop spatial knowledge (e.g., see Grant & Magee, 1998; Richardson, Montello, & Hegarty, 1999; Witmer, Bailey, Knerr, & Parsons, 1996), and the cause lies somewhere in the reduced interface and environment fidelity of VEs (Waller, Hunt, & Knapp, 1998). Examples of the reduced interface fidelity include the lack of physical movement that is required to travel around VEs, with an associated reduction in kinaesthetic feedback, and the impoverished field of view (typically 50° - 90°). Important factors of environment fidelity include the amount of visual detail (e.g., features that can be used as landmarks) and the omission of non-visual sensory information.

The present article illustrates the magnitude of the problems that people encounter when they navigate in VEs. New data is provided from existing studies that used two different types of layout: (i) virtual buildings (Ruddle et al., 1997; Ruddle, Payne, & Jones, 1998), and (ii) chessboard-type environments (Ruddle, Howes, Payne, & Jones, in press).

Virtual Buildings

The data reported here are from Experiments 2 and 3 of the 1997 study, and Experiment 2 of the 1998 study. The environments used in these experiments were virtual buildings and, although they only existed in a virtual form, they had the sort of structure that is frequently encountered in the real world. This consisted of a regular network of corridors, off which lay a large number of rooms. The 1997 experiments investigated the effects of adding local landmarks (see Figure 1) to VEs, and the 1998 experiment investigated the effect of providing global orientation information in the form of a compass. A repeated measures design was used, with each participant navigating equivalent VEs (or sections of VEs) both with and without supplementary aids.

Methodology

Participants had to learn the location of several target rooms that were identified using 3D models of characteristic furniture. Learning was performed in a series of navigation sessions (9 sessions (1997) or 8 sessions (1998)), that were each structured using a *day at the office* metaphor. With this metaphor, a participant started and finished each session at the same location (the Lobby) and, during the session, visited all the target rooms in a specific order that changed between sessions. In the first two sessions the participant was guided by the experimenter along the shortest route between the rooms. In the remaining sessions, the participant had to find their own way. In all of the sessions, the path that participants followed was continuously recorded. In some of the sessions, and always in the final session, participants estimated the direction and straight-line distance between the target rooms, performing a set of estimates each time they arrived at one of the targets.

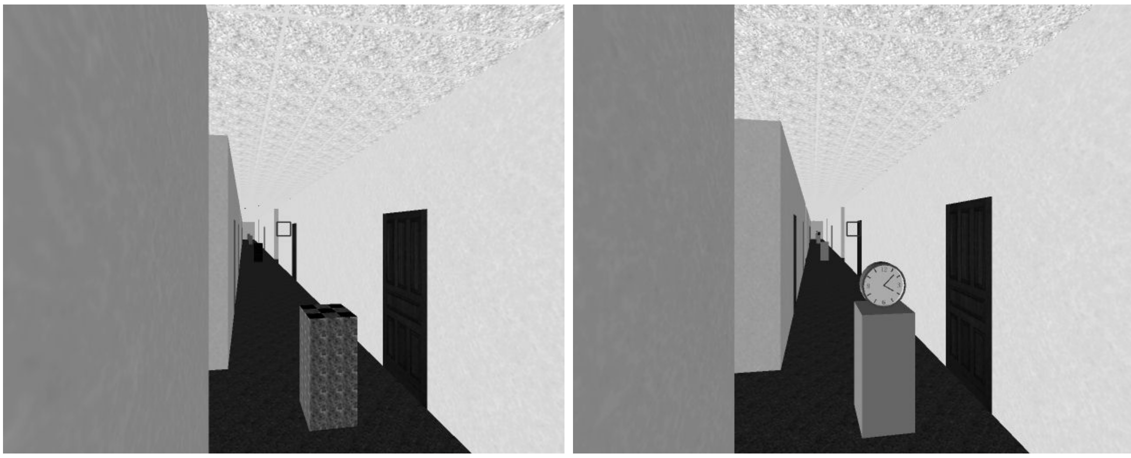

Figure 1 A virtual building with abstract landmarks (left) and everyday objects as landmarks (right)

Results and Discussion

In all three experiments, the provision of navigational aids (landmarks or a compass) had little effect on the accuracy of participants spatial knowledge when compared with the control (no aid) condition. The only statistically significant effect was a 16% reduction in the distance that participants travelled when everyday objects were used as landmarks (Experiment 3, 1997). The data reported here refer to the percentage extra distance travelled (*PE-distance = 100 * (distance travelled - minimum possible distance) / minimum possible distance*) and mean direction estimate error in the final session in each experiment, averaged over the aid and control conditions. These data measured participants' performance once they had already spent a considerable amount of time (1-2 hrs) navigating a VE.

In all three experiments, participants' mean direction estimate error was highly correlated with their PE-distance data (r = .86, p < .01 (1997, Experiment 2), r = .66, p < .01 (1997, Experiment 3), and r = .92, p < .01 (1998, Experiment 2)). The PE-distance metric was a direct measure of participants' navigational performance, whereas the direction metric measured participants' sense of orientation. The correlation between the two show that direction estimates, which take only a few minutes to perform, can be used to estimate the overall accuracy of a person's spatial knowledge.

The PE-distance and direction estimate data for the experiments are shown in Figure 2, with the data for the two 1997 experiments combined because they used the same structures of virtual building and experimental procedure. In each case the participants are ranked according to the magnitude of their direction estimate errors.

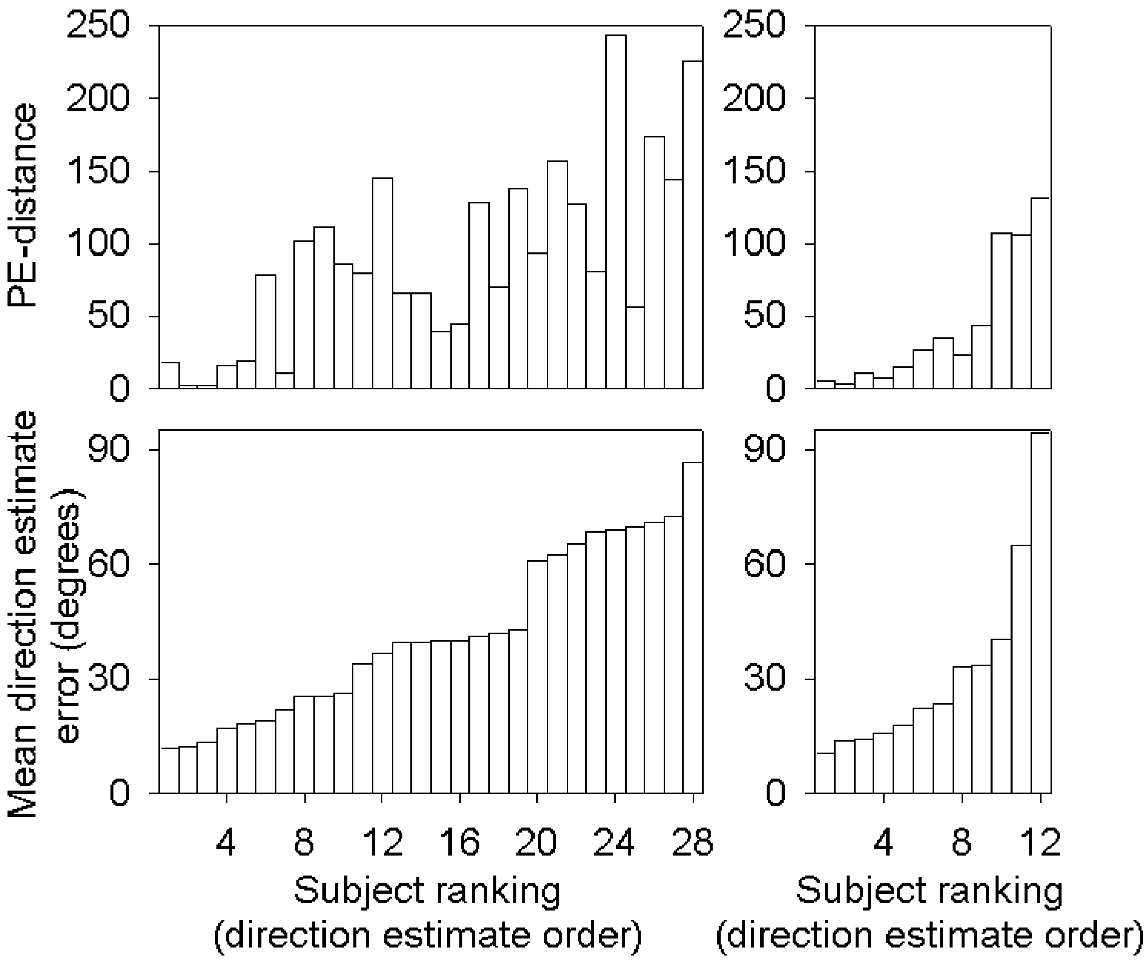

Figure 2 Mean direction estimate error and PE-distance data for the final navigation session of the 1997 (left) and 1998 studies (right)

The pattern of data was similar in all the experiments and show large variations in the rate at which different participants learned spatial knowledge. Some participants quickly developed near-perfect knowledge, but others learned extremely slowly. Even after several hours of navigational experience, these latter participants were often unable to find their own way between different places and, mathematically, were almost completely disoriented (random guesses for the direction estimates would produce a mean error or 90°). Thus, although it is true to say that, on average, people learn spatial knowledge substantially more slowly in VEs than in the real world, this is statement is also an over-generalisation. VEs seem to magnify the differences that exist between individuals to the extent that a minority of participants were unable to learn the layout of environments that had only moderately complex layouts (e.g., a 4 x 4 grid of corridors) and, there can be little doubt, would be straightforward for anyone to learn in the real world.

Chessboard-type Environments

VEs with a chessboard-type structure were used to study the effects of different spatial and temporal attributes of hyperlinks on navigation (Ruddle et al., in press). The data reported here, however, are from the control conditions of Experiments 1 and 2 of the study, where participants navigated conventional versions of the VEs. In these versions, the rooms were connected by doors that opened automatically when a participant approached.

Methodology

Each participant performed an extended practice in a 12-room VE, and then repeatedly navigated 16-room, test VEs. Each room contained a 3D model of a different everyday object, placed on a 1 metre high plinth (see Figure 3). Participants were informed that there was only one instance of each object. For consistency with the hyperlink conditions, each object was turned on like a light when a participant entered the object's room, and turned off when the participant exited. This meant that participants had to enter each room to see its contents.

In the test VEs, participants repeatedly searched for eight of the objects, which had been designated as targets. In the first two searches, a participant searched for the objects in *any order*. As the participant had no prior knowledge of the environment's layout the first search was *uninformed* search, whereas the search was an *informed search*. In the subsequent searches the participant had to find the objects in a *specific order*. Only the data for the any-order searches are reported here.

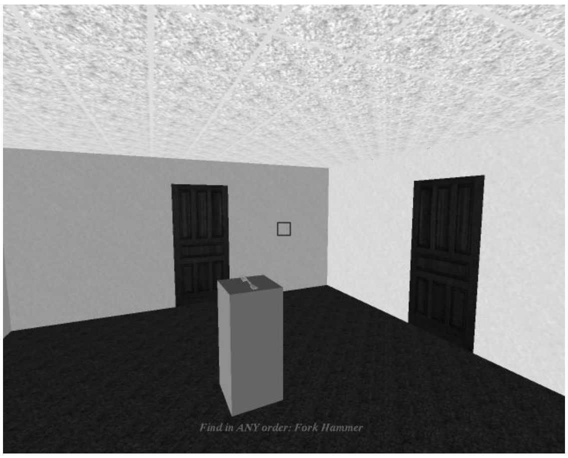

Figure 3 View inside a room in a chessboard-type VE

Results and Discussion

For the purposes of the present article, the data for the control (conventional VE) conditions of Experiments 1 and 2 have been combined, because these conditions were identical in the two experiments. Participants' performance was measured in terms of the number of rooms that they entered in each search.

In the any-order searches, some participants deliberately backtracked to over-learn an environment's layout. The intention of these participants was, presumably, to reduce the amount of time they took in the specific-order searches but there was little correlation between the percentage of backtracking that participants performed and the number of rooms they subsequently entered in the specific-order searches (r = -.02, p > .05 (uninformed), and r = .12, p > .05 (informed)). In other words, backtracking was a deliberate, but often ineffective, strategy.

The largest number of rooms entered by any participant was 95. On this (informed) search, and including backtracking, the participant found six of the targets after entering 13 rooms, had some difficulty finding the seventh target (entering 11 additional rooms), and then had a real epic finding the eighth target (see Figure 4). In total, the participant passed through one of the two rooms that was adjacent and connected to the final target on 16 occasions, and spent 14 mins performing the search as a whole. Although real-world searching behaviour has not been studied using chessboard environments, it is inconceivable that people would search as inefficiently as they did in the VEs. However, the difficulty that some participants encountered in the virtual chessboard layouts did echo the findings of the virtual building studies.

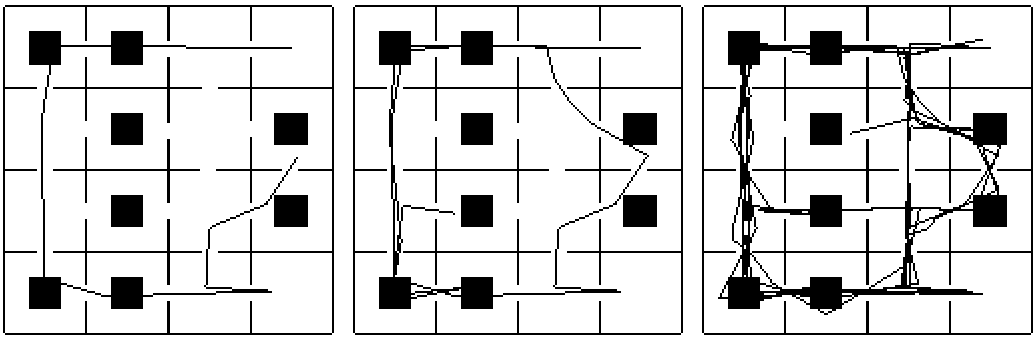

Figure 4 Path followed during the 95-room, informed search. The target objects were in the rooms indicated by the black squares.

General Discussion

In the chessboard study, each room was uniquely identified by an object and participants were informed that there was only one instance of each object. Therefore, when a participant repeatedly encountered a particular object, there can be no doubt that they knew they were repeatedly entering the same room. Two explanations can be offered for the performance and behaviour of participants who navigated inefficiently. The first is that these participants had little memory for the paths they had travelled through the VE and, as a result, repeatedly travelled along the same path instead of going through doors that, up to then, had remained unopened. The second is that the participants travelled in a straight line whenever possible instead of "exploring" because the former required less effort in terms of input to the user interface. Given the time taken by the slowest searchers, the first explanation is more likely. This explanation is supported by the data from the virtual building studies, where informal observation indicated that aids such as landmarks helped participants identify where they were (e.g., beside the clock) but only had a modest (or no) effect on the rate at which participants could connect together the different locations to begin to form an accurate mental model.

For large-scale VEs to have wide, practical use, users must be able to navigate with ease. However, the data in the present article show that a substantial minority of people have great difficulty developing spatial knowledge of VEs, and seem to be largely unaffected by variations in environment fidelity such as an increase in the amount of visual detail that is present. Other solutions must be developed, particularly those that promote learning in terms of paths rather than just individual places.

Acknowledgements

Part of this work was supported by grant GR/L25449 from the Engineering and Physical Sciences Research Council.

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