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Construction of a spatial mental model from a verbal description or from navigation in a virtual environment

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Introduction

A very common everyday experience is the construction of spatial mental representations from navigation, inspection of maps, or even from verbal descriptions. The construction of a spatial representation from a verbal description has been extensively studied, and the characteristics of the representation as well as the processes involved in this construction have been clarified. These spatial representations are usually called spatial mental models, in reference to the Johnson-Laird theory of mental models (1983). Over the last few years, a number of studies have investigated the processes and cognitive abilities involved in the construction of these mental models. Many studies have shown that these representations preserve the spatial relationships between the elements of the described environment (e.g. Schneider and Taylor 1999). One question of recent interest has been to investigate the involvement of working memory in the construction of such representations, and a specific involvement of the visuo-spatial working memory has been evidenced, as well for survey as for route descriptions, even if to a different extend (e.g. De Beni et al. 2005). It has also been shown that imagery instructions help subjects to form a spatial model, and that they then specifically rely on their visuo-spatial working memory to construct their model (Gyselinck et al. 2006). There are many other means to construct a spatial representation of an environment, and the development of new techniques of virtual reality provides new tools to explore the spatial representations. Some studies have compared the spatial mental representations constructed in various ways; learning from a map and reading a verbal description (e.g. Tlanka et al. 2005); navigating in a real environment and learning from a map (Richardson et al. 1999); navigating in a real environment and navigating in a virtual environment (Waller 2000; Chabanne et al. 2003). Results usually show that the representations constructed are comparable. A question is to characterize the mental representations individuals construct when they are immerged in such a virtual environment, and then to examine the processes and cognitive abilities involved in the construction of a spatial model from virtual navigation. The aim of the study reported here is to compare the representation constructed from navigation in a virtual environment with the representation constructed by processing a verbal description of the same environment. Given that gender differences have been found to play a role in many visuo-spatial tasks (Voyer et al. 1995), this variable has been taken into consideration in this study.

Method

Participants

A total of 32 students (20 female and 12 male) from the University René Descartes, France, participated voluntarily in exchange for course credits.

Materials

A virtual environment was built with Virtools Dev 3.0 software. A town was constructed on the basis of photos

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of Paris, France. All the classical elements of a town were shown, such as buildings, shops, traffic lights, garbage containers, trees, other cars, etc., and usual motor noise and town noise were also heard. An itinerary has been registered, that follows a road with turns and crosses. Ten specific areas or landmarks can easily be distinguished (such as a train station, the town hall, a parking, etc.). The corresponding verbal description of this route was constructed on the basis of the navigation in the environment, and then registered by a single speaker to be presented to subjects. This verbal description adopted a route perspective and the landmarks were described with some of their visual details.

Twenty-four sentences describing the spatial relationships between the landmarks were constructed. A false and a true version of each statement were prepared. Among the statements, 11 referred to relationships explicitly stated in the description (paraphrases) and 13 implied an inference, because the landmarks considered had not been related explicitly in the description. A pilot study was run with a previous version of the material which conducted to minor changes in the virtual environment and corresponding verbal description, and a better control of the statements.

Procedure

Subjects were randomly assigned to the virtual environment or to the verbal description (10 females and 6 males in each group). They were told that a friend was driving them to the train station, and they were instructed to remember how to get there in order to be able to find their way in the town. In the virtual condition, the computer-generated virtual environment was projected onto a wall with a video projector. In the verbal condition, subjects had headphones to listen to the description. Two presentations of the itinerary were made. At the end of the presentation, landmarks were presented in a random order to facilitate their identification. In the virtual condition, pictures of the elements of the virtual city were presented together with a verbal label, and in the verbal condition, only the labels were presented. Subjects had then to verify statements, which were presented in a new random order for each subject, so that half of the statements presented to each subject were false and half false. Finally, subjects had to draw a map of the route.

Results

Verification accuracy

Only the analysis of verification accuracy is entirely reported here. An omnibus analysis of variance (ANOVA) was conducted on the verification task data with the type of statements (paraphrase, inference) as a within-subjects variable, and presentation (virtual, verbal) and sex (female, male) as between-subjects variables. Figure 1 shows the mean percentage of correct responses for the verification test in the virtual and verbal conditions as a function of the type of statement and sex. The main effect of presentation was not significant ($F < 1$), nor was the main effect of sex, but the effect of type of statements was significant ($F(1, 28) = 14.58$, $P < 0.001$), showing that subjects verified more easily paraphrase statements than inference statements. The interaction between presentation and statement was significant ($F(1, 28) = 20.29$, $P < 0.001$), showing that whereas subjects who were presented a verbal description verified more easily paraphrase statements than inference statements (71.9% vs 50.6%), the reverse was true for subjects who navigated in the virtual city (58.6% vs 63.8%). Both effects were significant ($F(1, 28) = 15.3$, $P < 0.001$ and $F(1, 28) = 7.33$, $P < 0.025$). In addition, the interaction between sex and type of statements was also significant ($F(1, 28) = 11.57$, $P < 0.005$), showing that whereas women outperformed men on paraphrase statements (70.0% vs 60.6%), the reverse effect was observed for inference statements (52.3% vs 62.2%). The effect was significant for paraphrases ($F(1, 28) = 11.44$, $P < .001$), but only marginal for inferences ($F(1, 28) = 3.26$, $P = 0.08$). The interaction between presentation, sex and type of statements was not significant ($F(1, 28) = 1.69$).

Sketch maps

The quality of the maps drawn by the subjects was evaluated according to the number of crossings encountered, the number of buildings included, and accuracy of relationships between the landmarks and the geometrical structure. Overall, the maps drawn by subjects presented with the virtual environment and by subjects presented with the verbal description did not differ, except for the first crossing, which was more often forgotten in the virtual condition than in the verbal condition.

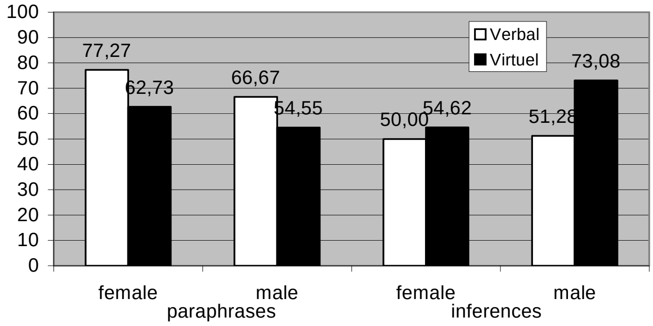

Fig. 1 Mean percentage of correct verifications in verbal and virtual conditions as a function of sex and type of statements

Discussion

The experiment conducted here aimed at verifying whether a spatial representation constructed from the immersion in a virtual environment differed from a representation constructed from a verbal description of the same environment. A verification test has been chosen to assess the construction of a spatial mental model, making a distinction between paraphrase and inference statements. In addition, the gender differences have been considered. The data show that, overall, the representations built in the two conditions do not differ. Learning from a virtual environment or from a verbal description might then appear equally valid to acquire spatial information. The way the relationships between landmarks have been encoded is however important, as evidenced by the difference of performance obtained when we consider paraphrase and inference statements. Paraphrases statements were indeed better verified by subjects of the verbal condition than inference statements, which is not surprising because the former correspond to relationships explicitly described whereas the latter had to be reconstructed. What is more surprising, however, is the fact that the reverse was found in the virtual condition. We could have expected paraphrase and inference statements to be equally well verified. It would then be interesting to analyse more precisely the specific statements to which these subjects answer accurately. Another puzzling result is that women performed better than men for paraphrase statements and that the reverse tended to be true for inference statements. We can consider that paraphrases are more closely linked to some verbal ability and to route orientation strategy typical in women (Lawton 1994). Inference sentences on the reverse require a bird's eyes perspective and a survey representation more typical of men. As visuospatial storing capacities have proven important to consider in the construction of spatial mental model from verbal descriptions (e.g. Gyselinck et al. 2006), it would be interesting to consider them also in the case of virtual environment.

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