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Planning optimal paths: A simple assessment of survey spatial knowledge in virtual environments

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Abstract

In spatial cognition studies several cognitive factors were analysed in order to identify the aspect that could constitute the basis for the capacity of organising spatial knowledge into survey maps.

This study presents a method for evaluating spatial ability, based on the capacity of obtaining a survey-type spatial knowledge organisation, in a recently explored virtual environment. The ability to plan optimal paths in virtual environments was examined in 40 female adult subjects. Spatial evaluation deriving from navigation of a simple virtual environment was compared with classical spatial survey tasks (wayfinding, pointing and sketch maps) performed after the active exploration of a complex virtual environment.

Results show that there is a relationship between planning optimal paths and other spatial tasks related to survey representation.

These findings highlight how the navigation-supported learning capacity results in a predictive factor for individuals' assessment of spatial ability.

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Keywords: Spatial cognition; Virtual reality; Survey map; Planning in advance; Individual ability

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1. Introduction

Virtual reality-based environments offer an interesting opportunity for the study of spatial cognition (Morganti, 2003; Péruch & Gaunet, 1998; Tlauka & Wilson, 1996). Flexibility is one of the major virtues of this type of synthetic environment: the layout of the environment can be systematically manipulated and different kinds of interactions can be designed in order to create suitable experimental conditions. Furthermore, virtual environments allow monitoring and recording the behaviours through which an explorer gains spatial knowledge for further evaluation.

Moreover subjective involvement at a personal level in a highly interactive system, such as a virtual environment, allows people to experience the cycles of perception and movement that are the basis for the construction of mental representations of space. In fact, being active has been acknowledged as a key factor for spatial learning in ecological conditions.

Like many studies carried out in natural and virtual environments, it is necessary to control the influence of individual differences in the ability to orientate themselves in space (Lawton, Charleston, & Zieles, 1996; Malinowski & Gillespie, 2001). In particular, there is evidence that variability between subjects in spatial task performance is higher in virtual than in natural spaces (Bliss, Tidwell, & Guest, 1997; Klatzy, Loomis, Beall, Chance, & Golledge, 1998; Waller, Hunt, & Knapp, 1998; Witmer, Bailey, Knerr, & Parsons, 1996). By comparing exploration in natural and virtual environments, studies have concluded that most of the abilities involved in learning in a natural world, are also needed for learning in a virtual world, but the latter presents additional demands. Consequently, the need to create an evaluation tool specific for virtual environment application is deeply felt in order to get reliable data (Belingard & Péruch, 2000; Richardson, Montello, & Hegarty, 1999; Waller, 2000, 2005).

Up to now several different methodological approaches have been used in the assessment of an individual's navigational abilities and different tools have been developed, such as auto-evaluation questionnaires (Lawton, 1994; Pazzaglia & De Beni, 2001), evaluation of general cognitive level (Juan-Espinosa, Abad, Colom, & Truchaud, 2000), mental rotation tasks (Just & Carpenter, 1985; Casey, 1996) or specifically suited visual-spatial tasks (Colom, Contreras, Shih, & Santacreu, 2003; De Vega, 1994; Denis, 1996; Poli, 2000; Shah & Miyake, 1996). Given the moderate correlation shown between the results of these kinds of evaluation tools and the navigational ability in a virtual environment, the problem in designing an effective assessment tool is still open (Bailey, 1994; Darken, 1995; Richardson et al., 1999; Waller, 2000).

Even if the specific factors investigated in the previously mentioned studies can be considered very influential in spatial performance, if taken one by one they do not allow for the definition and prediction of global ability to perform complex spatial tasks. In our opinion, a more promising way could be to derive navigational ability from the types of spatial representations that an individual is able to produce in order to adaptively interact with space within a given activity. Our methodological proposal is therefore primarily based on a conceptual framework about spatial representations.

It is a largely shared opinion that spatial knowledge of large-scale environments is organised in two types of mental representations or cognitive maps, route and survey maps (Chown, Kaplan, & Kortenkamp, 1995; Golledge, 1990, 1999; Kitchin & Freundschuh, 2000). The characterisation of these maps has been debated, but it is generally agreed that in route maps the environment is represented in a viewer-centred, egocentric frame of reference that reflects the person's navigational experiences, while in survey maps distant places are linked together to form an integrated global overview of the entire environment.

Cognitive maps are useful for a wide variety of purposes, but fundamentally for wayfinding. In this activity, the representations serve to aid navigation within the mapped environment in order to reach a target. In contrast with route maps, survey maps are more flexible and effective, as they offer the choice of alternative paths to connect distant places, for example in the creation of shortcuts.

In order to predict how an individual will be able to perform a spatial task, it is therefore interesting to discover if, when needed, they are able to organise information in a survey representation.

From an experimental point of view it is possible to investigate survey knowledge by using typical spatial tasks, such as sketch maps, pointing and wayfinding tasks.

Sketch map tasks are considered effective for externalising survey maps, as they require the production of an external representation based on a birds-eye perspective (Billinghurst & Weghorst, 1994). Some difficulties arise in that sketching maps requires drawing abilities and it is difficult to interpret the results. Another drawback of sketch map tests depends on how difficult it is to quantitatively evaluate the drawings. A distinction has to be made between distortions that result from limited knowledge and ones that depend on difficulties in producing externalisation (Foreman & Gillet, 1997). To avoid these problems, another distinctive feature of survey maps, hierarchical organisation, can be used. Different studies have shown that knowledge about large-scale environments is represented in terms of macro-regions, defined by anchor points (Golledge, 1987), or "centroids", reciprocally linked by spatial relationships, containing in turn other connected micro-regions, according to a part-whole relation. Thus, the primary elements of the representations are portions of space limited by visual barriers and gateways (Chown et al., 1995); examples include walls and doors of buildings or hills and paths in a valley. In a building, a significant part of the hierarchy is a cluster of rooms connected with corridors that give access to the cluster itself. Aggregates of clusters constitute the layout of the building. Accordingly we have decided to consider hierarchies as a main factor to be reflected in sketch maps.

Pointing is another task extensively used in spatial knowledge evaluation. Participants are generally asked to indicate, by lines in the air, the position of an unseen distant target point, usually from different vantage positions. According to several authors only external pointing trials are able to highlight survey knowledge (Carassa, Geminiani, Morganti, & Varotto, 2002; Gaunet, Vidal, Kemeny, & Berthoz, 2001). This kind of pointing requires an explorer moving along a route pointing towards a target, that is not located along the travelled route. Pointing performance appears to become easier through repeated exploration sessions; corroborating the hypothesis that performance depends on the gradual creation of survey knowledge (Ruddle, Payne, & Jones, 1997). Even though pointing in virtual reality with a restricted visual angle might be considered a sound survey task, the latter could greatly jeopardise the ability of assessing directions (see for example Montello, Richardson, Hegarty, & Provenza, 1999).

Finally, a wayfinding task can be used to investigate the capacity of organising knowledge in a survey map, under specific conditions. For example, if the individual is asked to find the shortest route to a target point, not previously travelled, a wayfinding task constitutes the most ecologically valid spatial task. Not all wayfinding tasks necessarily require a survey ability; the easier they are the more likely it is for them to be correctly executed by simply resorting to a type of route representation. In wayfinding behaviour surveys representation allows two fundamental spatial activities; on one hand subjects can check their position within the entire environment during navigation (Chen & Stanney, 1999; Darken, 1995; Heth, Cornell, & Alberts, 1997; Thorndyke & Goldin, 1983); on the other hand it allows planning in advance new paths, (shortcuts included) connecting distant landmarks especially if they are not visible at the same time (Carassa & Geminiani, 2002). Several studies showed that a fairly good knowledge of the environment is necessary in order to get a good survey representation which is normally obtained after a long stage of familiarisation or, within the experimental field, through an intensive exploration of the whole environment.

In conclusion, all these standard survey representation tests appear to be quite difficult to achieve at experimental level, even in virtual reality environments.

For these reasons we chose to introduce a new task, to specifically investigate the individual capacity of organising spatial information in a survey map through quick exploration of a virtual environment. In particular, we have designed a task able to investigate survey representation: *planning in advance.* This method evaluates the capacity to plan in advance new shortcuts connecting distant landmarks (planning optimal paths). The experimental hypothesis is that the capacity of *planning in advance* optimal paths is related to classical survey tasks performance, i.e., wayfinding, pointing and sketch map tasks.

If this proves to be sound from the experimental viewpoint, the planning in advance task will thus become a quicker and more effective test to experimentally evaluate survey maps.

2. Methods

Three different virtual environments were employed in this study.

A small virtual environment was used in training, which has the same architectural and interactive features of the virtual environments used in the experiment.

Two virtual environments were used for the experimental work. The first was designed to assess the ability of *planning in advance* optimal paths. The second was aimed at evaluating performances in three survey tasks (wayfinding, pointing, and sketch map). This environment was previously developed for an experimental work in the same research field (Carassa et al., 2002).

The virtual reality environments were all developed at the Virtual Reality Lab of the Psychology Department of the University of Padua using Superscape 5.6 software.

The virtual environment used for the assessment of planning ability was created by reproducing the original plan of a virtual environment already used in other spatial cognition research (Stanton, Wilson, & Foreman, 2002); consisting of four, differently coloured rooms ($8 \times 6.5 \times 2.5$) each of which has a door leading to a small entrance (6.1×6.1), from which it is possible to access different linking paths among rooms. In the ex-novo created environment the originally open linking paths have been transformed into closed corridors among room-entrances. The plan of the environment, the room dimensions and the spatial relations between them were not modified. The virtual environment plan is depicted in Fig. 1. The numbers shown in the figure indicate corridors length.

This environment allowed us to place or remove exploration obstacles during experimental sessions in order to create different travel paths suited to experimental needs (see

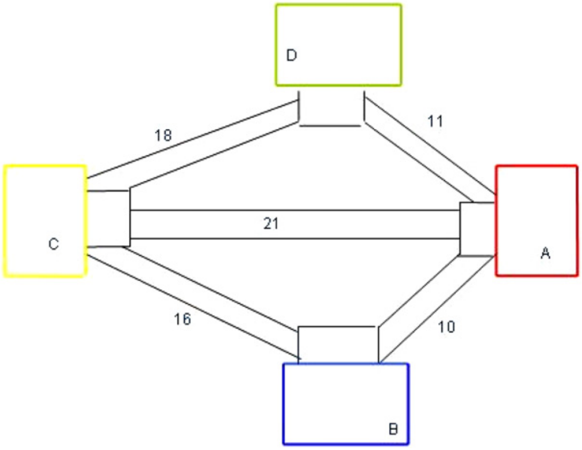

Fig. 1. Virtual environment for planning phase.

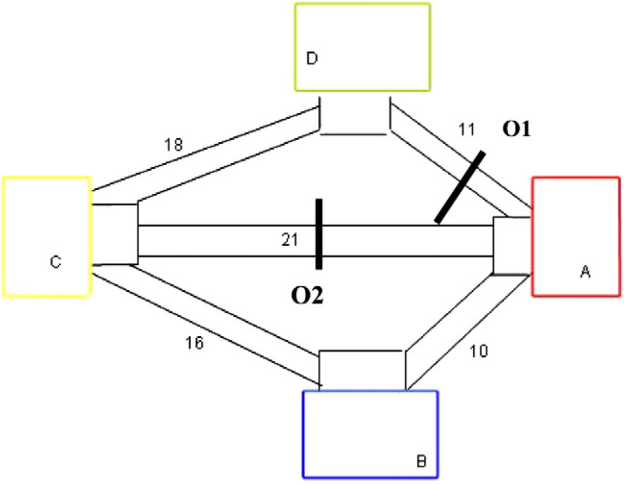

Fig. 2. Obstacle position in second planning session.

Fig. 2). As in the other virtual reality experimental environment described below, doors were closed after exploration.

The environment used for survey task sessions was a two floor closed environment with a T shape plan. It was completely empty and there were no landmark objects visible, neither from the internal nor external parts of the environment. The virtual environment plan is depicted in Fig. 3. Some doors were permanently closed within the environment; participants were allowed to test all the doors and to enter all the rooms. Doors to the outside were permanently closed.

Both virtual environments were run on a PC Pentium II, 400 MHz and explored in an immersive way by the Virtual Research V8 Head Mounted Display with 60° horizontal angle. The translation on the horizontal axis within environments was controlled by a joystick,

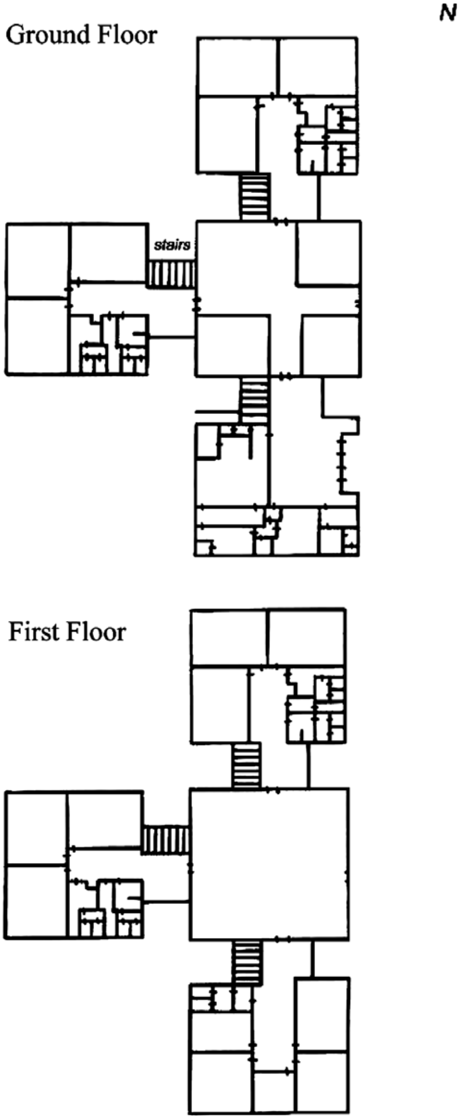

Fig. 3. Virtual environment for survey phase.

where the rotation was performed by a rotating head via the Inter-Trax Intersense gyroscopic sensor.

2.1. Participants

Forty students from the University of Padova took part in the experiments as volunteers; in order to avoid sex differentials in spatial cognition abilities (Foreman, Sandamas, & Newson, 2004; Voyer, Voyer, & Bryden, 1995), all of them were female. None of them had previously visited the two virtual environments used in this research.

2.2. Procedure

The experimental plan consisted of a first training phase in which participants had the opportunity of learning an ad hoc virtual environment through immersive interaction.

A *planning in advance* phase followed, in which participants were evaluated on route planning or navigation task performance.

Finally all the participants were involved in a typical survey assessment phase in which they were requested to explore the two floor closed environment and to perform spatial tasks.

The planning and the survey phase were both divided into a learning session, in which participants had to explore the environment and a test session, in which participants were requested to perform survey spatial tasks.

2.2.1. Training phase

Participants could freely learn to move themselves within a small open-air virtual environment. The main aim of this environment was to provide a virtual place in which participants could rapidly acquire movement skills afforded by a joystick and understand how to calibrate the rotational movements supported by head mounted tracker. In fact, during the experimental phases, interferences in spatial cognition due to technological interfaces have to be avoided.

The environment had the same architectural and interactive features of the virtual environment used both in the planning in advance and in survey assessment phases (that will be described below). The training environment was in fact developed by replacing in a new context the same corridors, doors and stairs present in the experimental environments.

So doing, participants could be trained to navigate in an experiment-like environment without learning the experimental environment's spatial layout.

The maximum time provided for training was 15 minutes. Participants were considered ready to start the assessment phase when they showed the ability to move smoothly and efficiently otherwise they were excluded from the experiment.

2.2.2. Planning in advance phase

After the training phase, participants were individually tested on their spatial abilities.

In the learning session they were requested to explore the virtual environment, and in the test session they were requested to perform different wayfinding tasks within the same environment.

The starting point both for learning and for test session was room C. In the learning session participants were allowed to navigate the external corridors in order to explore all the rooms. The route leading to the central corridor was forbidden. In this phase participants were requested to focus on the entire environment, trying to understand positions of rooms. They were also encouraged to stop and rotate angles during the exploration in order to enhance the construction of environmental knowledge.

Two different test sessions (described below as 1 and 2) were planned. In both test sessions the central corridor, that connects C with A, was opened. In this way participants were given the possibility of making shortcuts and to find new paths between rooms.

1. Starting from C participants were requested to reach three different target rooms (A, B, D) through the shortest route. (Note that the C–A path had never been explored

before). For each trial participants received 2 points if they were able to reach the target room in the shortest time, 1 point if they reached the target room and 0 points if they were unable to reach the room. Therefore the first test session global score was 0–6 range.

2. The aim of the second session was to assess the ability to find the only possible route, after having tried to navigate the shortest way between target rooms A and C. For that reason two obstacles, O1 between D and A, O2 between C and A, were placed as depicted in Fig. 2. Starting from C, participants were guided towards the obstacle placed between A and D, and were informed that eventually this obstacle would be kept and that they would find another obstacle in the environment. In this way, we were able to discover which route a participant would plan in advance: first, the shortest but blocked route (C–A) or the feasible one (C–B–A).

For this second test session participants received 1 point if they went directly to C–A corridor, which was the shortcut in the first session, ignoring the fact it was blocked, 1 point if they went to B (restarting from C) and 1 point if they travelled from B to A. No points were given if participants went directly to D starting from C. On the basis of this scoring participants obtained a 0–3 range scoring:

- 3 points if they tried the shortcut and, after having encountered the obstacle, they were able to choose the correct way (C–B–A) remembering the known obstacle in (A–D);
- 2 points if they were able to choose the correct way (C–B–A) remembering the known obstacle in (A–D), without trying the shortcut;
- 1 point if they reached room B directly but they were not sure about the correct path;
- 0 point if they did not plan in advance one of paths described above.

Route plan performances in both test sessions were analysed and evaluated on a 0–9 range.

2.2.3. *Survey assessment phase*

In the first learning session participants were physically and psychologically free (Carassa et al., 2002; Gaunet et al., 2001) to explore the entire two floor virtual environment for 15 min. They were previously recommended to pay attention to the layout of the environment. After exploration, the test phase consisted of different survey-type spatial tasks: to sketch a map of the explored environment, to execute pointing and wayfinding tasks.

In the sketch map task participants were requested to draw a map of the environment.

For maps, cluster organisation was assessed. Given the layout of the environment (see Fig. 3), a cluster consists of two rooms at least; a bathroom and a staircase grouped around a central corridor. Three independent judges evaluated the presence of clusters in the map, providing that at least two judges agreed on the evaluation.

In the wayfinding tasks, participants were requested to follow the virtual guide through a complex path within the environment and to come back through the shortest way (optimal wayfinding).

Original criteria, specifically developed for the virtual environment were used to evaluate wayfinding performances. Optimisation score was calculated giving 1 point for each of the following actions:

1. The participant reaches and stops on the target floor.
2. The participant reaches and stops in the target corridor.
3. The participant reaches and stops in the target room.
4. The participant performs optimal wayfinding without exploring other building areas.

According to this evaluation participants were able to obtain a 0–4 range score.

For the pointing tasks, participants had to follow a virtual guide through a path within the environment and at the end of the path they were requested to indicate an unseen target place in the environment. Participants executed 4 pointing trials, in 2 of them they were requested to point towards a place that was inside the previously travelled path; in the other 2 trials participants had to point towards a place that was outside the path. The angular difference between the facing (pointing) direction and the actual direction of target point was noted for each participant.

According to Carassa et al. (2002) only external pointing trials are able to highlight survey knowledge. For pointing tasks, the angular error between indicated and the target point were evaluated.

Spatial ability in the planning assessment phase has been correlated with performances on the standard spatial task provided in the survey phase.

3. Results

The score of all tasks is depicted in Table 1.

In the planning in advance task, the mean score was 4.52 (SD = 2.34). The frequency of distribution of the scores is depicted in Fig. 4.

The score analysis in the planning in advance task revealed that the first and second planning sessions are significantly correlated (Spearman's Rho = 0.352, $p = 0.026$).

In the sketch map task, 14 participants out of 40 sketched a clustered map.

In the wayfinding task the average score was 3.3 (SD = 1.89). The frequency of distribution is depicted in Fig. 5.

In external pointing, mean angular error was 64.77 (SD = 27.38), whereas in internal pointing mean angular error was 69.21 (SD = 22.95).

In order to assess the relationship between the planning in advance task and survey tasks, a comparison has been made between the presence of clustering in maps and the performances in planning task and other survey tasks. In the planning task participants with clustered maps performed better than the others (Mann-Withney adjusted $z = -2.68$ $p = 0.007$). In wayfinding tasks participants with clustered maps did slightly better (Mann-Withney adjusted $z = -1.74$ $p = 0.082$). In pointing tasks participants with clustered maps performed significantly better but only in external pointing (Student T test = 2.06, df = 37, $p = 0.046$).

Our findings showed significant correlations between planning scores and wayfinding scores (Spearman's Rho = 0.354, $p = 0.025$) and between planning scores and external pointing errors (Spearman's Rho = −0.314, $p = 0.048$); no correlation was found between planning scores and internal pointing and between wayfinding score and external pointing errors.

4. Discussion

The aim of the experimental work presented was to investigate the planning in advance as a spatial task that makes it possible to evaluate the survey-type organisational ability of

Table 1
Score in planning in advance, sketch map, wayfinding, internal and external pointing

Participant	Sketch map	Planning	Wayfinding	External pointing	Internal pointing
01	No cluster	4	0.50	34.40	119.50
02	Cluster	9	1.00	68.80	78.75
03	Cluster	5	2.00	94.80	45.75
04	No cluster	4	1.00	75.80	49.25
05	No cluster	3	0.00	113.80	71.25
06	Cluster	2	2.00	37.80	27.25
07	No cluster	6	2.50	65.00	70.00
08	No cluster	7	1.00	44.80	96.00
09	No cluster	4	0.50	77.80	120.50
10	No cluster	9	4.00	73.80	37.50
11	No cluster	4	1.50	49.20	72.25
12	No cluster	3	1.50	40.60	92.50
13	Cluster	6	3.00	59.60	52.75
14	No cluster	2	1.50	90.20	72.75
15	Cluster	7	3.50	23.60	55.50
16	Cluster	4	2.50	39.20	47.50
17	No cluster	3	3.00	85.80	91.75
18	Cluster	7	3.00	47.60	87.50
19	No cluster	3	3.00	115.00	65.00
20	No cluster	1	0.50	133.80	57.00
21	No cluster	0	1.00	83.80	87.25
22	Cluster	9	4.00	47.00	82.75
23	Cluster	7	1.50	34.60	76.00
24	No cluster	4	2.00	27.40	39.75
25	Cluster	5	3.00	33.40	45.75
26	Cluster	4	1.50	57.00	95.00
27	No cluster	2	1.00	99.20	82.50
28	No cluster	5	1.00	69.20	63.75
29	No cluster	3	2.50	26.40	64.00
30	No cluster	6	3.00	59.60	54.00
31	Cluster	8	1.00	42.00	81.50
32	No cluster	6	3.00	42.20	44.50
33	No cluster	7	1.00	80.20	64.00
34	No cluster	3	0.50	63.00	88.00
35	No cluster	2	3.00	98.60	61.75
36	No cluster	4	3.00	72.40	36.75
37	–	1	0.50	63.00	42.25
38	Cluster	7	1.50	97.80	69.25
39	Cluster	3	2.00	35.80	63.25
40	No cluster	2	0.50	86.80	116.50
	Tot cluster	$M = 4.52$	$M = 3.3$	$M = 64.77$	$M = 69.21$
	14	SD = 2.34	SD = 1.89	SD = 27.38	SD = 22.95

For planning in advance performances were analysed and evaluated on a 0–9 range score. For sketch map a cluster was individuated were two rooms at least, a bathroom and a staircase grouped around a central corridor were represented. For wayfinding performances were analysed and evaluated on a 0–4 range score. For pointing, the angular difference between the facing (pointing) direction and the actual direction of target point was noted.

spatial data of a previously explored environment. In our view, given the distinctive features of survey maps, the ability to plan in advance new paths – shortcuts in particular – is only possible with the survey-type competence offered by this kind of representation.

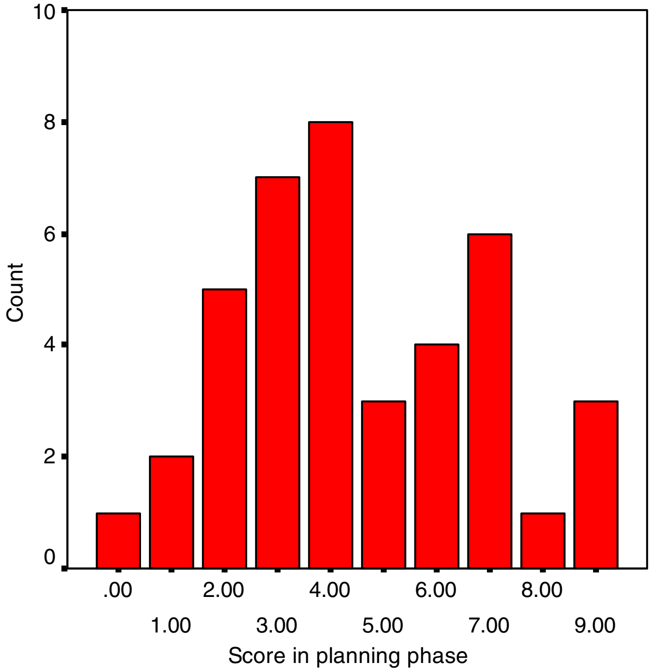

Fig. 4. Cases distribution in planning phase.

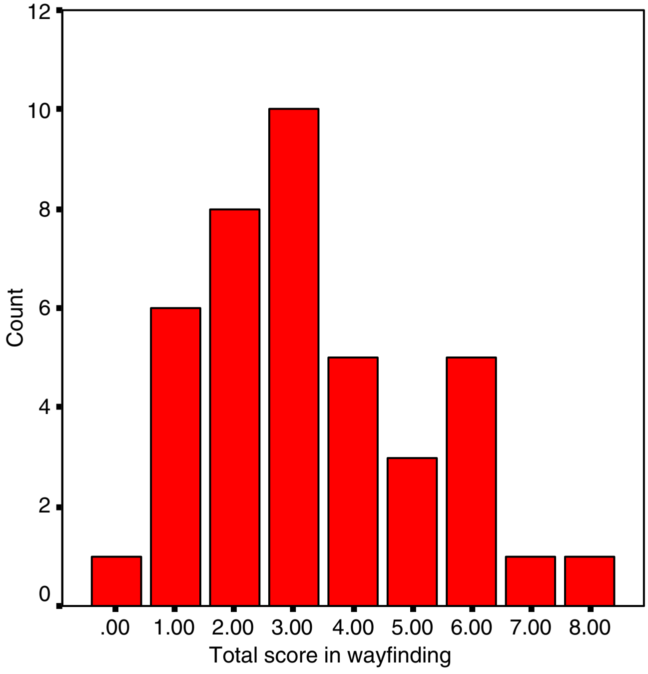

Fig. 5. Cases distribution in wayfinding task.

The theoretical assumption for our experimental work was that sketch map skills rely on survey representation of spatial knowledge, therefore sketch map tasks are undisputable evidence of survey maps.

Our results show that the ability to sketch a map is related to better performances in survey tasks; in particular, the presence of clusters in maps is associated with better performances in the planning in advance task. Moreover planning in advance correlates with external pointings, but not with internal ones, with the wayfinding task.

As regards the pointing task, we have highlighted the difference between external and internal pointing, by considering the former only as an effective indicator of a survey map (Carassa et al., 2002; Gaunet et al., 2001). Our results corroborate this idea by showing that clustered maps and optimal planning exclusively correlate with external pointing.

An unexpected finding was that the presence of clusters in maps is slightly related to performances in wayfinding tasks. We regard that a possible explanation of this can be found in the spatial characteristics of the explored environment: in fact, the lack of landmarks renders the environment barely distinguishable. For this reason, even if relying on a survey type representation, participants could have difficulties in individuating the wayfinding starting point within the environment.

Some forms of wayfinding, (as when a shortcut is taken in the environment using the world as an external memory) are performed as well by using simpler forms of representation (i.e., route maps). However, assessing the layout of the environment, in order to infer new paths for future action, does require a survey map. Our approach was therefore to design an environment in which participants, engaged in specific types of wayfinding, were challenged to use their knowledge in order to perform optimal planning.

In short, the performances in the *planning in advance* correlate with all survey tests, while performances in wayfinding and external pointing do not. The overall data indicate that two kinds of tests can differentiate between the use of survey maps: sketch maps and *planning in advance*.

From a methodological point of view, a comparison between the two tests suggests that the task of *planning in advance* in order to reach a target place is a more ecological task with regard to sketching maps. Our choice was to create a VE where participants could be engaged in a planning test, considering that virtual reality affords the investigation of spatial cognition under conditions resembling real life. Learning is the result of active exploration, planning is accomplished through navigation. These aspects make it possible to overcome some limitations of current research: the confliction between the need to study spatial cognition in conditions that allow experimental control and the need to create situations which have ecological validity. In the former case research is conducted in artificial, impoverished laboratory conditions, in the latter it requires to investigate spatial behaviours in complex and unpredictable real environments. Virtual reality permits us to create complex environments that are open to both experimental control and unfolding interaction.

In our experimental setting, as in everyday life, spatial expertise is obtained by exploring new environments within goal-oriented activities: a high-level spatial explorer is the one who has the ability to perform actions that allow her to update survey maps during exploration.

According to the distinction between decision making process and decision execution process in wayfinding introduced by Chen and Stanney (1999), a significant aspect of spatial ability is the skill not only to plan in advance but also to implement it in action within an unknown environment. The interaction with the virtual reality could easily highlight both capacities in a rigorously monitored experimental study. In virtual reality simulations, in fact, it will be possible to manipulate all the environment characteristics, like for example, the time of exploration, the speed of navigation, the largeness of the space covered, and further, to keep under control the contingencies involved in the experiment, the so-called variable interferences, like the variations of luminosity or distracting factors due to experimental measurements. Moreover, researchers have the possibility to manipulate environmental features to investigate the strategies utilised by the participant in the exploration of complex and different environments.

As we have pointed out in Section 1, in order to obtain significant data, a specific tool is needed, able to preliminary differentiate spatial performance capacities in people involved in virtual environments experiments (Richardson et al., 1999; Waller, 2000, 2005).

We have proposed an environment where it is possible to acknowledge the acquisition of a survey map after a brief exploration, in a simple and straightforward way.

In particular the present study addressed experimental conclusions previously stated from Richardson et al. (1999) who underlined the necessity to preliminary evaluate individual differences in spatial navigation skills within a virtual environment. To do that, the authors have in fact used a smaller virtual environment. They also hypothesised that good performance in spatial tasks undertaken in an easier environment would be equal even in a more complex virtual environment. The results of our research support this point of view, demonstrating that a small virtual environment can be a useful tool in the study of individual differences in spatial cognition.

Besides research application in the field of spatial cognition, the VE *planning in advance* test here presented can also contribute to develop guidelines for the creation of useful tools in neuropsychological rehabilitation. Generally, a virtual reality-based evaluative and rehabilitative protocol will make patients able to create new personalized and self-made cognitive strategies in order to improve their autonomy also in unfamiliar environments. Actively interacting with VR, in fact, patients should be able to create representation of actions and in consolidating their ability to represent space by generalizing what they have learned to not simulated environments. Locally, using VE it is possible to provide patients with ‘‘ecologically-like’’ situations that could enhance more efficient goal oriented planning behaviours in rehabilitative tasks performances. Among this intervention area, virtual reality-based *planning in advance* can be applied in evaluation and treatment of spatial knowledge in general, topographical disorientation and visuo-attentive deficits such as neglect syndrome (Morganti, 2004).

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