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EXTENDED ABSTRACT

A virtual reality based tool for the assessment of "survey to route" spatial organization ability in elderly population: preliminary data

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Introduction

It is a largely shared opinion that spatial cognition is the human capacity of orienting oneself in and to cope with everyday environments. It is by actively interacting with an environment, in fact, that an agent is able to organize spatial knowledge in a route (egocentric) and survey (allocentric) map in order to effectively use it for exploration (Carassa et al. 2002). According to recent studies spatial coping ability appears to be declining with age in healthy elderly population. (McCaddon et al. 2001). Moreover, several studies in neuropsychology showed how one of the main consequences of cognitive decline is pronounced in the capacity to explore new environments, execute wayfinding in familiar contexts and use landmark for orienting themselves in complex situations.

Despite the agreement in defining spatial cognition as specifically grounded in context and enacted in an active coping with the environment, up to now most of the evaluation tools for topographical orientation introduced laboratory methodologies in order to understand how people explore spaces. Analyzing literature, we can find several spatial tests—such as autoevaluation questionnaires (Vecchi et al. 1999; Pazzaglia and De Beni 2001), mental rotation tasks (Just and Carpentere 1985) or specifically suited spatial-memory tasks (Della Sala et al. 1999)—that unfortunately do not allow an immediate and direct interaction generally possible in the daily environment.

It constitutes an important bias for the evaluation of everyday spatial impairments especially in elderly population and/or in neurological patients, often making to wish the introduction of a more ecological evaluation. Thus, in fact, it is possible to observe exploration strategies of people and to individuate the specific environment elements the agent utilizes during navigation in complex spaces. Unfortunately the use of an agent observation in daily contexts (in order to investigate the explorative behaviors strictly related to the interaction with the specific characteristics of the environment), generates many questions about the reliability and interpretation of the collected data.

Actually the problem in designing an effective assessment tool that links a reliable evaluation methodology with a more situated observation of human spatial behaviors appears to be still open.

We propose to integrate classical evaluation tools with computer-based interactive ones, such as virtual reality, in order to evaluate complex environments exploration capacity by observing the types of spatial representations that a patient is able to produce in order to adaptively interact with space within a given activity. Virtual reality (VR) environments, in fact, provides a representation of dynamic nature and these interactive environments constitutes the essential connection between the use of laboratory simulations and the possibility of evaluating the type of explorative interactions acted during an exploration (Morganti 2003). Within these structures humans can actively act explorative behaviors "as they are" in daily

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environment according to the sense of presence they feel in virtual reality simulations (Morganti and Riva 2006). By this way, the utilization of VR environments allows an extreme flexibility in the creation and modification of the assessment environments creating complex simulations the most possible equivalents of the structures present in reality. Besides, the use of VR allows an effective and objective registration of all the varying spatial behaviors avoiding interference due to experimenter intervention.

According to this vision, we aim in examine the "survey to route" spatial cognition ability in elderly population through the introduction of the VR-Maze and VR-Road Map assessment tools (Morganti et al. 2007). With the introduction of these tools, in fact, we will able to test participants' ability to effectively explore a complex environment in an egocentric way by using a survey type map. The procedure we propose is based on classical paper and pencil tests generally used for spatial cognition assessment that are presented to subject in a classical survey perspective. With the introduction of VR we integrate this assessment with the possibility to actively explore space in a egocentric perspective providing subjects with a ecological-like context.

We hypothesize that this ability will decrease in elderly population showing how spatial cognition, as well as other cognitive ability, is declining in old age.

Methods

Materials

The VR-Maze Test is an originally developed virtual reality tool based on Wisc-R Maze subtest customized to match the requirements of interactive evaluation purposes. The tool was developed with 3D Game Studio software by which the virtual version of 5 mazes, explorable both in immersive and desktop modality was created.

The VR-Road Map Test is the originally developed virtual reality version of the Road Map Test in which the paper and pencil version (that shows a stylized city map within which patients have to describe a designed route) is turned in a simulated and actively explorable city. No landmark objects were provided as navigation aid and all the buildings have the same texturization.

For both the VR systems, the possibility to track user's spatial behaviors is provided. A file containing the x, y, and z coordinates of a given participant every 600 ms within the VE was produced for each environmental exploration session. An application to read these files and provide a pictorial representation of the participants' movements within a two-dimensional plan of the environment is provided with the tools.

Participants

In this study we evaluated the VR-Maze-Test as well as the VR-Road-Map Test over seven age groups ($n = 120$). Neuropsychological examination was performed by each subject included to exclude deficits in cognitive domains. Neuropsychological examination included memory functions, executive functions attention, representation of body and visual exploration. The average age was 53.55 years of age (20–29 years, $n = 20$; 30–39 years, $n = 10$; 40–49 years, $n = 15, n = 19$; 50–59 years $n = 32$; 60–69 years, $n = 19$; 70–79 years, $n = 5$), including 83 females and 37 males. Sixty subjects were included in each country, Italy and Germany. Education was monitored differently for the two countries, 0.83% of the German group had less than 9 years of school education, 9.17% had 9 years of school education, 13.33% had 10 years of school education, 25.83 had 13 years of school education. It's the authors' opinion, that education is not influencing the ability for topographic orientation.

Procedure

Before starting the test, a 10-min training session was run to familiarize participants with the procedure and train them with the use of devices for navigating in VR. In the VR-Maze Test participants were requested to first perform the paper and pencil version of the maze, and then to find the right way into the equivalent VR version of the maze. In the VR-Road Map Test participants are requested to follow the designed route into the virtual environment using the paper and pencil version of the test as a guide map. Performance time and errors are recorded for each of the five VR mazes and for the VR-Road Map Test.

Results

As a first step in data analyses, we found a highly significant correlation between the age and the ability to accomplish the VR-Mazes Tests (<0.0001) as well as the ability to accomplish the VR-Road Map Test (<0.0001). These results were consistent over the cohorts. A second correlation over continuous aging and the ability to perform the tests also showed a highly significant negative correlation ($r = -0.607$, $P = <0.0001$).

Over the cohorts the average of items performed correctly decreased from 30.45 mean in the first cohort to 5.25 means for the last cohort. Data analyses over the differences between cohorts was performed with non-parametric statistics (Kruskal–Wallis test) and revealed highly significant decrease.

As a second outcome, the time subjects needed to perform the tasks was measured. Here again a highly significant correlation between age and the outcome was detected. The older subjects needed more time to perform the tasks. ($r = 0.6972$, $P = <0.0001$).

Conclusions

Further analysis of the data may reveal further results on functions that may be linked to topographic orientation. However, it seems clear, that the ability to navigate in virtual reality decreases with aging in healthy subjects. These results appear to be congruent with recent studies that show how there is a cognitive decline in old age specifically focussed on working memory and topographical orientation. Moreover, it is possible to highlight how by introducing a VR tool for the assessment of spatial cognition, we were able to observe participants' explorative behaviors that they act "as they were" in a daily context. We test spatial ability in a different way from the classical paper and pencil assessment that proposes tasks in an allocentric perspective. This possibility allowed us to conclude that older subjects could present impairments in exploration of new and/or complex environments that is not easily detectable with classical evaluation methodologies.

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