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The virtual reality Walking Corsi Test

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ABSTRACT

We compared the performance of men and women on a modified and a virtual version of the Walking Corsi Test (WalCT). The WalCT is a large version of the Corsi Block-Tapping Task that requires learning a path and then recalling it. It has been proved to measure topographical memory. The main aim of the study was to compare the effects of real and virtual reality learning environment on the acquisition of spatial information. A secondary aim was to detect the presence of gender-related differences in the two environments. Specifically, we expected that men would perform better in both environments. Eighty college students (40 men) were assigned to real or virtual environments and had to learn four different paths. Gender differences emerged in both environments: men outperformed women in both the real and the virtual reality environment. Results did not show difference in virtual and real environment supporting the equivalence of the two tests to measure topographical memory. Gender-related differences are interpreted in light of Coluccia and Louse's model, according to which men outperform women when tasks require a high visuo-spatial working memory load and the different spatial strategy used by men and women.

1. Introduction

Humans and other animals move through their environments in order to get to places with food or shelter and other resources; they also have to avoid threats and dangers such as predators, assaults and other risk factors. It appears clear that spatial navigation is crucial in everyday life. This ability is influenced by individual variables (i.e., gender, age and familiarity), differences in environmental features (presence and density of landmarks, regularity of street configuration) and differences in types of knowledge acquisition (real navigation vs. map learning) (e.g., Nori & Piccardi, 2011).

In everyday life, people learn and remember spatial relations in different ways: by directly moving through the environment (primary learning), by indirectly observing and studying a map (secondary learning) or by using language to exchange information about space (e.g., Gras, Gyselinck, Perrussel, Orriols, & Piolino, 2013). The question then arises of what specific effects the various modalities of acquiring spatial information have on the characteristics of the spatial representations generated (e.g., Piccardi, Risetti et al., 2011; Denis, Pazzaglia, Cornoldi, & Bertolo, 1999). Recently, thanks to the greater opportunities for studying spatial cognition provided by technological innovations, "real" and virtual environments have been compared to assess whether acquiring spatial information in virtual reality involves the same ability. Chrastil and Warren (2012) pointed out that moving in a virtual reality setting is quite different from walking around in a real environment. Also, desktop virtual reality involves physical hand movements, whereas actual walking provides qualitatively different motor, proprioceptive and vestibular information. Furthermore, virtual environments cannot be completely comparable to learning an environment from a map, which requires no physical movement. Thus, some authors consider virtual reality as secondary learning and others as primary learning (for a review see, Chrastil & Warren, 2012). In any case, comparisons between real and virtual navigation have led to contrasting results. For example, some studies concluded that in virtual navigation people also use most of the abilities involved in real navigation (e.g., Morganti, Carassa, & Geminiani, 2007; Waller, 2000, 2005) but others did not (e.g., Hegarty, Montello, Richardson, Ishikawa, & Lovelace, 2006). To our knowledge, most of the studies comparing virtual and real environments did not use the same environmental setting or

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expose the same sample to the same environment (for a review see, Chrastil & Warren, 2012). To further investigate this issue, we decided to compare the same environment in both real and virtual navigation.

Neuropsychologists have been interested in assessing navigational memory for many years and the topic has been widely studied over the past four decades by researchers concerned with the neurobiological bases of learning and memory (Parsons, Courtney, Dawson, Rizzo, & Arizmendi, 2013). Some of this research has focused on assessing navigational performance in the Walking Corsi Test (WalCT) (e.g., Piccardi, Risetti et al., 2011). This test (Piccardi et al., 2008) is a large version of the Corsi Block-tapping Task (Corsi, 1972). It requires learning and then recalling a path. The WalCT evaluates memory storage of a sequence of places in a defined area. Subjects are required to move to a series of places based on their memorized location. In previous studies, Piccardi and co-workers demonstrated that the WalCT measures a different spatial component (i.e., topographical memory) than the Corsi Test (Piccardi et al., 2008, 2013, 2014). Indeed, the authors found that brain-damaged patients affected by topographical disorientation failed on the WalCT but not on the Corsi Test (Bianchini et al., 2010; Piccardi et al., 2010; Piccardi, Iaria, Bianchini, Zompanti, & Guariglia, 2011). Nemmi and co-workers (2013) supported these results in an fMRI study that showed partially segregated neural systems for the WalCT and the Corsi Tests. A large cerebral network spanning from visual occipital to parietal to frontal areas was activated during the learning of both tests; but activation of the right lingual gyrus, calcarine sulcus and dorsolateral prefrontal cortex was specifically associated with learning in the WalCT, and activation of the left inferior temporal gyrus, lingual and fusiform gyrus and middle occipital gyrus with learning sequences in the Corsi Test. In the present study a virtual reality version of the WalCT (VR-WalCT) was developed to assess human navigational ability. In order to rule out the presence of navigational representations based on idiothetic and vestibular information, we used the VR-WalCT. In this environment vestibular and proprioceptive information about linear and angular movements is unavailable. Indeed, in a virtual environment, such as the one used in the present study, the only type of information available about self-motion is visual. If the VR-WalCT is able to show differences with respect to the WalCT, it could be useful for investigating other aspects of navigational memory with another tool. On the contrary, even if the VR-WalCT shows no differences from the WalCT it could allow analyzing navigational memory with tool that might also be useful in small environments, such as schools and hospitals as well as implemented in f-MRI experimental setting. Recently, some modified versions of the WalCT have been developed: the M-WalCT (Piccardi et al., 2014), in which a larger version of the WalCT was developed; the L-WalCT (De Nigris et al., 2013), in which the administration procedure was changed; and the Magic Carpet (Perrochon, Kemoun, Dugué, & Berthoz, 2014), in which both the administration procedure and materials were different. The L-WalCT and the Magic Carpet, but not the M-WalCT, are the same size as the WalCT. The M-WalCT is larger; it was developed by increasing the layout size and the number of squares to make the array more complex and more similar to the external environment. Results obtained with the M-WalCT are in line with those obtained with the WalCT (Piccardi et al., 2008). The L-WalCT, instead, looks like the WalCT and provides the same results as investigating patients' performance with the WalCT. The only difference is the absence of movement by the participants after they have seen the examiner walks the path on the carpet and their subsequent reproduction of the path, without moving through it how in the M-WalCT, but using a luminous pointer to reproduce the path. Differently, the Magic Carpet only measures visual memory in a large space: participants observe a set of tiles that are lit by a computer. In this case, they have no movement information, just a sequence of individual lights no binding among them. This last adaptation failed to find the same navigational effects found in clinical studies when the traditional WalCT was used (Bianchini et al., 2010; Bianchini, Di Vita et al., 2014; Bianchini, Palermo et al., 2014; Piccardi et al., 2010; Piccardi, Iaria et al., 2011; Piccardi, Risetti et al., 2011). The VR-WalCT could be an advantageous alternative in which participants receive both visual and motion information by means of an avatar. The latter shows the path and allows exploration of a virtual space that maintains the dimensions of the real environment in a virtual environment. Further, navigation in virtual environments is considered realistic enough to activate the same mechanisms as those activated during navigation in real environments at both behavioral and neural levels (Aguirre, Detre, Alsop, & D'Esposito, 1996).

The main aim of our study was to analyze the effect of differences in learning spatial information in two different environments (real vs. virtual) by using WalCT vs. VR-WalCT tasks. Another aim was to determine whether gender-related differences were present in the two experimental settings. Indeed, it has been reported that men are more proficient than women in virtual environments (e.g., Billen, 2001; Czerwinski, Tan, & Robertson, 2002; Goeke, König, & Gramann, 2013; Waller, Hunt, & Knapp, 1998) because they use different navigational strategies (see Grön, Wunderlich, Spitzer, Tomczak, & Riepe, 2000).

2. Methods

2.1. Participants

We enrolled 80 college students (40 women: mean age = 23.97 yrs, S.D. = 3.61 yrs; mean education = 15.65 yrs, S.D. = 2.17 yrs and 40 men: mean age = 25.65 yrs, S.D. = 5.66 yrs; mean education = 15.05 yrs, S.D. = 1.82 yrs). They were recruited at the Department of Psychology of Bologna University and at the Department of Life, Health and Environmental Science of L'Aquila University, Italy. Specifically, 20 women and 20 men were randomly assigned to the WalCT or the VR-WalCT learning condition. In a preliminary interview no participants reported neurological or psychiatric diseases. Moreover, we asked participants how many times they had played videogames to analyze the relationship between past experience and proficiency in the VR-WalCT. The study was approved by the local Ethics Committee of both departments. All participants gave their written informed consent in accordance with the Declaration of Helsinki.

2.2. Experimental material

We used an enlarged version of the WalCT (Piccardi et al., 2008), that is the M-WalCT (7×6 m; used in Piccardi (Piccardi, Risetti et al., 2011; Piccardi et al., 2014) in which 18 squares (3×3 cm) are placed on a carpet (25×60 cm) in a scattered array (Fig. 1a). To induce route acquisition, the four cardinal points (i.e., north, south, east, west) are indicated outside the carpet. The walls are completely covered with curtains that hide all external landmarks (i.e., doors, heaters, etc.). In this learning condition, participants had to learn four different 8-step sequences. The examiner demonstrated each sequence by walking on the carpet and stopping on each square for 2 s (see Fig. 1b).

The VR-WalCT virtual environments were created using an open source program, Blender (available at www.blender.org), starting from the measures and features of the M-WalCT and programmed in the Blender Game Engine to manage movements and collect experimental data. This choice made an easy integration with Blender Game Engine for the interactive part. Furthermore, the