Improving spatial abilities with a 3D immersive environment. A pilot study

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Abstract
Spatial thinking deals with three-dimensional shapes, contents or information. Various activities in everyday life as well as in many scientific domains require understanding 3D information based on 2D representations. This task is challenging as it entails to mentally manipulate and/or rotate the 2D content. Evidence in the literature suggests that experience, training, or playing 3D games can improve spatial abilities. New technologies such as the 3D immersive environments are novel educational resources that should be considered. The pilot study reported here was conducted to investigate if training spatial ability, namely mental rotations, transfers on spatial standardized tasks (MRT and VVT). A 3D immersive spatial cognition trainer (SCT) with haptic interaction was developed to enable users to practice 3D manipulations through 4 levels of increasing difficulty. Sixteen 4th year medical students were randomly assigned to 2 conditions (training vs no-training). Unexpectedly, the no-training control group substantially improved their mental rotation ability performance. Findings could be explained by the short training duration, as well as a possible cognitive overload when manipulating 3D models for the training group.

250 mots

Keywords: serious game, spatial ability trainer, 3D spatial ability

Introduction

Spatial thinking in three dimensions is necessary in everyday life as well as in numerous scientific domains such as engineering, chemistry, architecture and medicine. For example, medical specialists often have to infer the 3D structure of a patient's anatomy based on 2D views (X-ray) and their knowledge of anatomy (Hegarty, Keehner, Cohen, Montello, & Lippa, 2007). The transition between 2D and 3D information is challenging, as it relies strongly on mental representations and transformations of spatial information. This 2D to 3D transition requires translation of 2D elements on which rotations are applied into 3D efficient and effective information. This task requires participants to use some forms of mental rotation processes. Evidence in the literature suggests that spatial abilities can be improved by different forms of experience, by training, or by playing video games. In relation to experience, activities like manipulating 3D content or playing 3D games positively influence spatial ability. For example, playing Tetris over a 12-week period led to a general improvement in mental rotation. This was then transferred to other spatial tasks, and was stronger over time than the effect of repeated spatial test testing (Terlecki, Newcombe, & Little, 2008). Moreover, technologies such as virtual reality or 3D immersive environments offer new forms of games. Immersive 3D environments may support learning of specific spatial skills as they provide learners the opportunity to manipulate 3D elements in a 3D working environment. This pilot study will address the issue of training transfers on spatial standardized tasks. With regard to the mental rotation ability, we expected the 3D immersive training condition would lead to significant improvements as compared to the no-training condition.

Method

Sixteen 4th year medical students aged between 22 and 28 years old (*M*age = 23.75, 9 females) of the Uniklinik RWTH Aachen, Germany, voluntarily participated in the study. They were randomly assigned to one of the two conditions varying in the training performed: a) training (*n*= 8), and b) no training – control (*n*= 8).

The instructional material consisted of a 3D immersive spatial cognition trainer (SCT) application, developed in collaboration with University of Lyon 1. Standard spatial ability questionnaires were used as transfer task material. They included the mental rotation test (MRT - Vandenberg & Kuse, 1978) versions A, B and C and the visualization of viewpoints test (VVT - Guay & Mc Daniels, 1976). The MRT-A was assessed prior to the experiment to provide a baseline measure of participants' spatial ability. All participants completed the MRT B and C and the VVT after training.

This SCT application is a 3D real-time simulation software build on the Unity3D framework (http://unity3d.com/) using two haptic devices (Geomagic Touch ©, formerly Sensable Phantom Omni (Massie & Salisbury, 1994). The interaction with the haptic device is implemented through a custom plug-in the authors developed. Two haptic end-effectors devices enable the user to select, move and rotate objects within the virtual 3D environment in order to solve different configuration puzzles. The haptic end-effectors provide force feedback on the users' hands, allowing them to feel virtual objects in 3D environments.

The SCT consists of 3D jigsaw puzzles with 4 levels of increasing difficulty (Figure 1). Level 0 allows the participants to get acquainted with haptic manipulation. Participants have to rebuild a simple puzzle configuration based on a model depicted in a 2D capture. In level 1, the 2D capture configuration is more complex and involves more 3D objects. In levels 2 and 3 the 2D captures' perspective is shifted. To achieve these levels, participants have to consider this perspective shift.

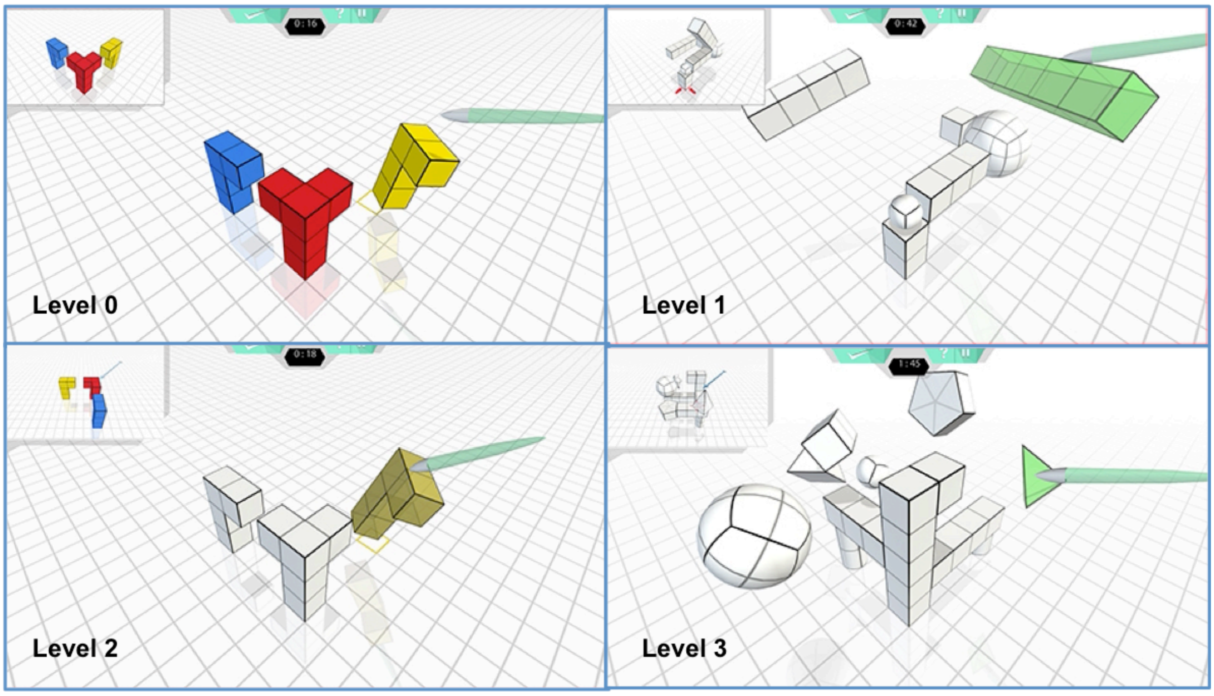

Figure 1: The 4 levels of the SCT

First results and discussion

Spatial scores obtained prior and after the training session were analyzed (table 1). Contrary to expectations, only 1 participant was able to perform the SCT 4-level during the training session. The other 8 participants completed only the two first levels. With similar mental rotation ability (MRT-A) prior to examination (t (15) = 1.621, p = .222), performance in mental rotation of the control group improved substantially (MRT-B) whereas there was no significant change in the training group (F(1, 13) = 6.76, p = .002). There was no difference in VVT test between groups (t (15) = 0.017, p = .898).

Table 1 Mean (and SD) of the spatial ability measures

	SCT training group		***No-training control group***	
	Mean	SD	Mean	SD
MRT – A	12.25	6.29	13.22	4.86
MRT – B	13.00	6.34	15.44	5.57
MRT – C	8.38	4.50	10.33	4.5
VVT	12.20	8.06	14.27	7.80

Findings suggest that training of a mental rotation task with a 3D immersive environment caused no real transfer to standardized measures. There are several possible explanations. Cognitive overload is known issue with 3D models manipulations (Huk, 2006) when learning with dynamic visualizations. By analogy, the complex mental operations required to achieve the 3D immersive game may have been too resource-demanding. Moreover, the short duration of training (1hr) may partially explain why explicit benefit of SCT training was not noticeable. Additionally, a plausible explanation for the control group spatial improvement may be due to the test-retest effects on the MRT. However, with such a small sample size, caution must be applied and more research is needed to draw strong conclusions. Findings from a larger sample size study will be presented at the Earli conference.

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