The role of visuo-spatial abilities in learning three-dimensional anatomical structures from animation

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Abstract. The study investigated how displaying orientation references (internal axes, external character or none) in learning of two anatomical three-dimensional structures from animation affect performance on subsequent spatial judgment tasks. Learners' visuo-spatial abilities in mental rotation and perspective-taking were also measured. The results showed no main effect of the orientation references on the accuracy of spatial judgments accuracy. However, participants who studied the material with the presence of orientation references, either internal or external, performed the spatial judgment tasks more quickly than did their control counterparts. There was no significant difference in the spatial ability measures for any of the orientation reference conditions. Nevertheless, visuo-spatial abilities affected the accuracy performance differently for the two tasks, suggesting different processing strategies.

Keywords: Animation; spatial ability; learning 3D information, functional anatomy learning.

Introduction

Functional anatomy is a complex visuo-spatial instructional domain, challenging to learn because it involves spatial reasoning and depends on information spatially distributed within the anatomical three-dimensional body space. So once the structure is understood in one plane, the learner has to mentally operationalize it in the other anatomical planes, in order to get a complete overview of the functional structure. To complete this task, the learner may apply mental rotations on the structure or mentally adopt a new perspective away from his current observation point. Animation of a 3D object is believed to support learners in the construction of a mental representation of a 3D object or structure, as it provides a continuous series of points of view of the object/structure in the three spatial dimensions. It has been demonstrated that the presence of orientation references close to, or embedded in, the visuals may help learners disambiguate the anatomical structures positions and locations when they learn with animations (Stull, Hegarty & Mayer, 2009; Ziemek, 2010). The building of such an accurate mental representation, however, depends heavily on learners' spatial abilities when learning from external visualizations (Hegarty & Waller, 2005; Höffler, 2010; Stull et al., 2009). The role of spatial ability in learning with animations is currently disputed by two hypotheses. The *compensating hypothesis* (Mayer & Sims, 1994) claims that low-spatial-ability learners, when learning from animation, may be better supported because animation provides the explicit external representation of the content-to-be-learnt, and thus can compensate learners' low spatial abilities. On the other hand, the *ability-as-enhancer hypothesis* (Hegarty & Sims, 1994) predicts that high-spatial-ability learners are better equipped to process animations. Learning with animation will then lead to high-spatial learners giving better performances. Therefore, a number of questions arise: Could the presence of different orientation references, namely internal or external, foster functional anatomy learning through animations of 3D objects/structures? Could it support the building of mental representations of these 3D elements? And how would these specific orientation references interact with learners' visuo-spatial abilities?

Study

This study investigated the effects of three *orientation references* (internal standard orthogonal axes, external human-like avatar, none-control) in the learning of anatomical structures with animations. In particular, we examined how the presence of the orientation references could support the building of mental representations of 3D structures and improve subsequent judgment performances. The participants' spatial abilities on the performance were also explored.

Hundred and forty-eight 1st year kinesiology students aged between 18 and 22 years old (65 women) of the University of Lyon 1, France, voluntarily participated in the study. The learning material consisted of 3D animations depicting two anatomical structures, the scapula and the larynx. This study compared three conditions varying in the type of orientation reference provided: 1) internal XYZ axes embedded in the structure, 2) external avatar of a character providing orientation of the body and 3) no orientation reference. Two types of visuo-spatial abilities were measured. Mental rotation ability was assessed with the MRT (Vandenberg & Kuse, 1978) and perspective-taking ability was measured with a French adaptation of the PTSO test (Hegarty & Waller, 2004). Two tasks were designed to investigate the building of mental representations of 3D structures and consisted of the judgments of relative a) structures' rotations (task 1) and b) structures' positions (task 2) within the tri-dimensional body space.

Main results

The main results showed that compared with the control condition, providing orientation references, either standard axes or avatar, had no overall effect on the two tasks of judgment accuracy performance (F (2, 138) = .806, p = .449, partial η^2 = .012). The analyses of the response time on performance showed a significant effect of the conditions when the effect of the spatial abilities was controlled for (F (2, 128) = 4.011, p = .02, partial η^2 = .059). Providing internal axes (p = .043) or an external avatar (p = .007) as orientation references decreased by 2 seconds, on average, the response time necessary to perform the anatomical tasks as compared with learning without any orientation references.

Table 1: Pearson Correlations between the tasks and the spatial ability measures

	Structure's rotation (task 1)		Structure's position (task 2)	
	Scapula	Larynx	Scapula	Larynx
Axes (n= 48)				
MRT	.375 *	.414 **	.468 **	.571 **
PTSO	-.204	-.124	-.293 *	-.209
Avatar (n= 54)				
MRT	.331 *	.487 **	.498 **	.443 **
PTSO	-.215	-.304 *	-.107	-.079
None (n= 42)				
MRT	.510 **	.461 **	.561 **	.555 **
PTSO	-.493 **	-.164	-.372 *	-.180

N.B. ** correlation is significant at the .001 level, * correlation is significant at the .005 level, PTSO values measure an angular deviation from the correct angle. The minus symbol should thus not be considered.

Regarding the learners' visuo-spatial abilities, the correlation analyses (Table 1) revealed significant and positive correlations between MRT spatial ability and performances on the accuracy measures of both tasks and for both materials (scapula and larynx). Globally, high-MRT learners performed better on both anatomy tasks than learners with low MRT abilities. The results of the PTSO correlation analysis were not conspicuous. More precisely, in the structure relative positions task (task 2), significant correlations were found between PTSO and accuracy in the internal axes ($r = .29$, $p < .001$) and control conditions ($r = .37$, $p < .001$), but not in the avatar condition ($r = .11$, $p = .426$).

Discussion

The presence of orientation references, either external or internal to the structures, did not lead to better accuracy (rotations' or positions' judgments) in learning of functional anatomy. In contrast, the findings regarding the response time still suggest that providing orientation references, either internal or external, during the learning phase helped the students perform both judgment tasks more quickly than their control counterparts. Thus, orientation references may scaffold the encoding of the structure spatial relationships. The correlations between visuo-spatial abilities and performance suggest that specific spatial abilities, especially mental rotation and perspective-taking abilities, play a different role when processing dynamic visualization. Indeed, our results showed that the mental rotation ability supports the *enhancer hypothesis* (Hegarty & Sims, 1994), since high-MRT-ability learners performed higher than low-MRT learners, irrespective of the materials and tasks. On the contrary, the correlations between PTSO and accuracy support the *compensating hypothesis* (Mayer & Sims, 1994), since in the avatar condition the avatar presence as orientation reference during learning seemed to help the low-PTSO learners reach a performance close to that of high-PTSO learners. Altogether, these findings suggest that the role (enhancer versus compensating) of animation should be considered in relation to the spatial ability factors processed and/or assessed in the visualizations, and not globally, as spatial abilities interact with the type of orientation references and the type of tasks.

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