Paper presented at the Conference of the European Association for Research on Learning and Instruction (Earli), 2013. August 27-31, Munich, Germany.

Supporting the processing of 3D objects in different orientations with animation: The case of functional anatomy

Sandra Berney[a], Mireille Bétrancourt[a] & Gaëlle Molinari[b]
[a]University of Geneva, Switzerland
[b]Distance Learning University, Switzerland

Abstract. Animation is widely used in instructional materials to represent dynamic systems changing continuously over time. Another use of animation is to provide a continuous series of points of view of an object in the three spatial dimensions. Such animated 3D visualization is believed to support learners in the construction of a mental representation of the 3D object, which is particularly important in domains like functional anatomy. Is animation really helpful for this purpose? How should animations be designed in order to support learners with various spatial abilities? This paper reports two experimental studies conducted with university students learning functional anatomy. The first study compared animated instructional material depicting the structure and behavior of the scapula with a static version of the same content. Learning tasks included the recognition of parts, rotations and orientations of the scapula. The second study investigated the effect of displaying orientation references (internal axes, external character or none) in learning the 3D structure of two anatomical objects, with expected effects of learners' visuo-spatial abilities in mental rotation and perspective-taking. The results of the first study showed no main effect of the conditions on performances, although the animation group was locally more accurate in performing some rotation tasks. Moreover, visuo-spatial abilities affected the performance differently for the two versions, suggesting different processing strategies. The findings of both studies (second study currently under analysis) will be discussed in terms of interaction between design features and learners' abilities.

Introduction

The two studies reported in this paper focus on the use of animation in a specific learning domain, functional anatomy, in which animation is used to provide a direct visualization of an anatomical structure in the three dimensions. The use of animation to provide 3D visualization is rarely studied in the multimedia literature, even though current practice indicates that instructional designers believe a continuous animated presentation of the different viewpoints can facilitate the construction of a mental representation of the structure (Hoyek et al., 2009). However, novice learners or learners with low visuo-spatial abilities reported feeling lost when manipulating such 3D visualizations. Using interactive 3D visualizations of anatomical objects, Stull, Hegarty and Mayer (2009) showed that providing axes to indicate orientation reference could compensate for the difficulties experienced by low spatial learners.

On the basis of the previous findings, we conducted two experimental studies to investigate three questions: First, is animation helpful to learn anatomical 3D structures and their behavior compared to a series of static frames of the different viewpoints? Second, does providing orientation reference features in animated 3D visualizations facilitate processing and memorization? Finally, what is the impact of visuo-spatial abilities, and particularly mental rotation and perspective-taking abilities?

Study 1 – Animated vs. static visualizations

Participants and Design - Forty-nine students (9 women and 40 men) starting their sport sciences education degree at the University of Lyon voluntarily participated in the study. They were randomly assigned to one of two learning conditions depending on the format of the instructional material, static (n= 27) or animated (n = 22).

Instruction material. - The learning material consisted of a 3D visualization developed by Icap (University of Lyon) depicting the structure of the scapula with labeling on 6 of its features in four different orientation views: front view, 60° (medial view), 180° (posterior view) and superior view (above). Two versions of the material were designed: a) an animated version and b) a static version, which presented simultaneously the different views as small-scale images (see Figure 1).

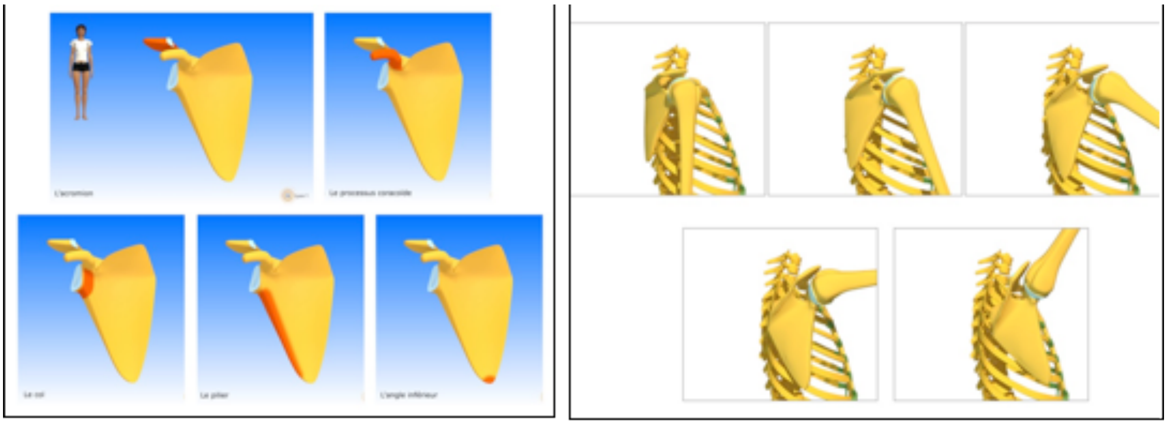

Figure 1. Snapshot of the static condition of the learning material of the structure and the movement of the scapula. **a)** Snapshot of the static condition presenting the scapula and its features in the standard anatomical view (0°), **b)** static condition of the scapula shoulder flexion movement in the lateral view.

Procedure. – After reading a brief text presenting general information about the scapula , participants studied the instructional material twice (animated or static depending on the condition) then completed one task involving the identification of features of the scapula (feature identification task) and two tasks involving the recognition of the degree of rotation of the structure (rotation task) or its orientation compared to those of a reference character (orientation reference task). Additional cognitive measures assessed mental rotation abilities (MRT; Vandenberg & Kuse, 1978), field dependence-independence (GEFT; Oltman, Raskin, & Witkin, 1971) and subjective workload.
Main Results. - A MANOVA revealed no significant difference between conditions overall on performance (Wilks' λ =.91, $F(3,45)$ =1.34, n.s). However, a significant global effect of mental rotation abilities (MRT) was found (Wilks' λ = .69, $F(3,43)$ =6.23, p <.001) with high MRT students outperforming low MRT students. There was also a significant interaction between conditions and MRT clustering on performance (accuracy) for the feature identification task, $F(1,45)$ = 5.46, p = .02. Low MRT students performed better in the animated condition than in the static condition, whereas the reverse pattern was found for high MRT students (figure 2).

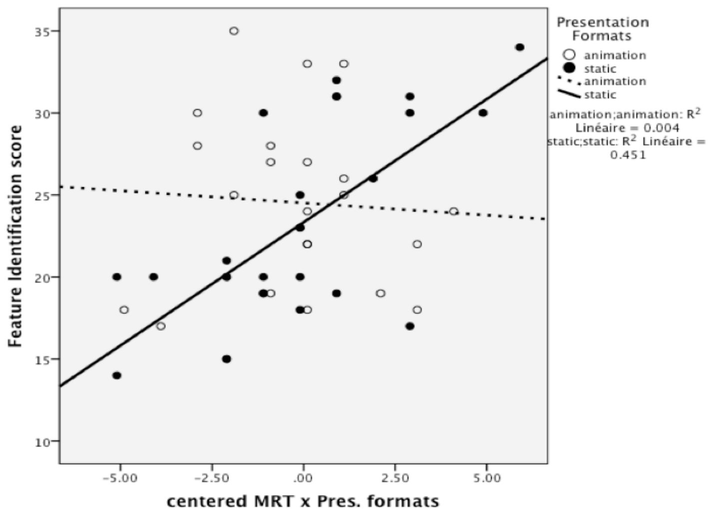

Figure 2. Feature Identification score as a function of MRT in interaction with presentation formats

There was no effect of field dependence-independence (GEFT). After controlling for MRT and GEFT effects, a marginal interaction between structure tasks and conditions emerged, $F(1,45) = 3.71$, $p = .06$. In the scapula *rotation task*, students in the animation condition performed better than students in the static condition, whereas the opposite pattern was found for performance on the *orientation reference* task.

Discussion. - The results of the first study confirmed the impact of visuo-spatial abilities when learning 3D structures, which interacted with the format of the visualization provided (animation or static frames). Further, after controlling for visuo-spatial abilities, the effect of the format varied depending on the task. This suggests that animation triggers specific strategies that are more or less helpful depending on the task to be performed when mentally processing the rotation of a 3D structure, and particularly whether the task involved internal reference (rotation) or external reference (character).

Study 2 – Type of orientation reference

To further investigate the impact of frame of reference, a second study was conducted. With a similar material (3D animated visualization of two anatomical structures, the scapula and the larynx), this study compared three conditions varying in the type of orientation reference provided: 1) axes: internal XYZ axes embedded in the structure, 2) avatar: external picture of a character providing orientation of the body and 3) control: no orientation reference. Two tests assessed visuo-spatial abilities: mental rotation with the MRT as in the first study and perspective taking measured with a French adaptation of the PTSO (Hegarty & Waller, 2004).

After studying the material, students had to perform two tasks involving recognition of the structure in different orientations suggesting either a rotation or a perspective taking strategy. We expected that the two conditions including orientation reference will help students learn the material, especially students with low visuo-spatial abilities. Moreover, we expected that students with high perspective-taking abilities will benefit more from a condition with external orientation reference rather than with an internal orientation reference, while students with high mental rotation abilities will perform better when studying with an internal rather than external orientation reference.

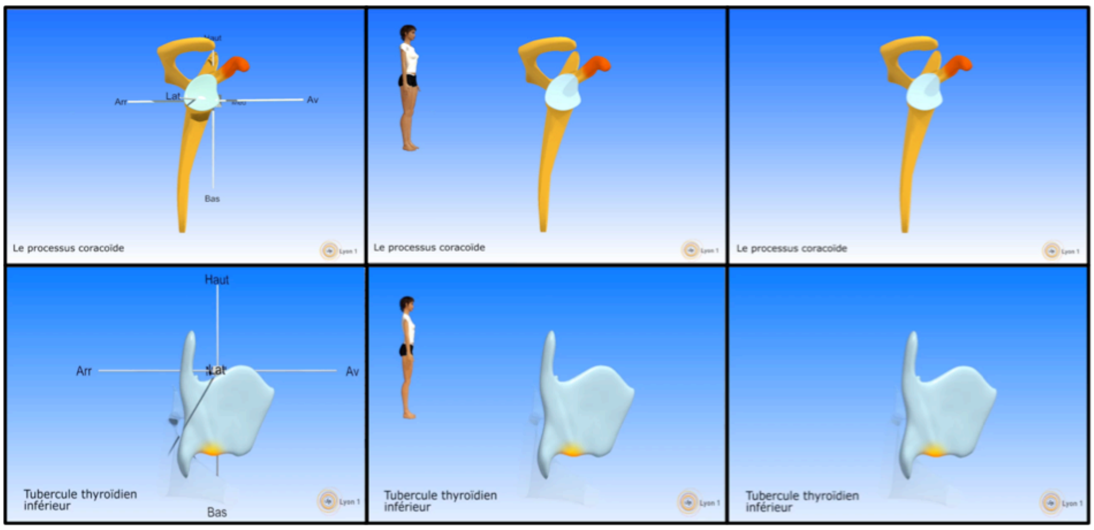

Figure 3. Snapshot of the 3 conditions of the learning material of the scapula structure (top raw) and the larynx cartilage structure (bottom raw). The left column presents the *axe* condition with the canonical axes embedded in the structure, the middle column presents the *avatar* condition, where the human-like character stands for the orientation reference, and the right column shows the control condition, without orientation reference.

Participants

Hundred and forty-eight 1st year students aged between 18 and 22 years old (65 women, 83 men, M = 18.8, SD = 0.815) enrolled in 1st year kinesiology degree at the University of Lyon 1, France, voluntarily participated in the study.

Results

Response accuracy

Compared to the control condition, providing orientation references, either orthogonal axes or avatar, had no effect on the tasks accuracy performances $F(2, 138) = .806$, MSE = 33.48, $p = .449$, partial $\eta^2 = .012$). Analyses revealed a significant interaction between task and material, $F(1,138) = 48.035$, MSE = 680.59, $p < .001$, partial $\eta^2 = .258$. Accuracy was high with the larynx material ($M_{Task\ 1} = 32.00$; $M_{Task\ 2} = 23.95$) than with the scapula material ($M_{Task\ 1} = 20.49$; $M_{Task\ 2} = 16.86$) for both tasks (Fig. 2). The main effects of tasks and material were also significant (task: $F(1,138) = 155.642$, MSE = 4768.68, $p < .001$, partial $\eta^2 = .530$; material: $F(1,138) = 352.34$, MSE = 12058.10, $p < .001$, partial $\eta^2 = .719$).

Response time

The effect of condition on response time was significant $F(2, 138) = 3.859$, MSE = 42539223.4, $p = .02$, partial $\eta^2 = .053$). Pairwise comparisons showed that participant in the avatar condition answered signifiantly faster than participants in the control condition (control: M = 11142.78, SD = 518.53; avatar: M = 9285.20, SD = 456.06).

Spatial abilities and performance

There was no significant differences between the learning conditions for none of the spatial ability measures ($F(1,123) = 1.459$, $p = .237$), neither between genders ($F(1,123) = 1.779$, $p = .236$).

The correlation between MRT and PTSO spatial ability measures was low and not significant (Pearson's r (137) = -.130, $p = .131$), providing support to the claim that these measures assess two different and separated dimensions of spatial abilities.

Correlation analyses between spatial ability MRT and performances on the accuracy measures of both post-tests and both materials are presented in Table 1.

Table 1 . Correlation between score to each spatial test and score to the tasks for each material and each learningcondition.

Pearson Correlation	***Structure relative Rotations (PT1)***		***Structure relation position (PT2)***	
	Scapula	Cartilage	Scapula	Cartilage
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
Control (n= 42)				
MRT	.510 **	.461 **	.561 **	.555 **
PTSO	-.493 **	-.164	-.372 *	-.180

Globally, the higher the MRT scores, the better the performance to all tasks, regardless the condition. Surprisingly, there were negative correlations between PTSO and accuracy scores for the two types of task, some of which being significant. These correlations would suggest that the more participants have difficulties to imagine transforming their actual perspective, the better they performed the task. We are still working in understanding the meaning of such result.

We are currently performing ANOVAs with orientation reference (avatar, axes, control) and MRT (respectively PTSO) spatial ability scores (high vs. low) as independent variables for each type of task.

Altogether, the findings of the two studies will be used to deepen our understanding of the interplay between spatial abilities, design features and strategies used by learners to make sense of animation.

References

Stull, A.T., Hegarty, M., & Mayer, R.E. (2009). Getting a handle on learning anatomy with interactive three-dimensional graphics. *Journal of Educational Psychology*, *101*(4), 803–816.

Hoyek, N., Collet, C., Rastello, O., Fargier, P., Thiriet, P., & Guillot, A. (2009). Enhancement of mental rotation abilities and its effect on anatomy learning. *Teaching and learning in medicine*, *21*(3), 201-6.