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Using 3D animation for learning functional anatomy

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Abstract. Learning functional anatomy requires the building of a dynamic mental representation to understand the structure and its behavior. Animation, often used to represent dynamic systems, can also be used to depict the configuration of a 3D structure, as it provides direct visualization of change across the viewpoints. This paper reports a study comparing two versions of a visual instructional material (animated or static) in learning the structure and behavior of the scapula. Results showed no effect of the conditions on performances, though locally the animation group was more accurate in performing some configuration tasks. Moreover, visuo-spatial abilities affected the performance but the interaction with the instructional version depended on the task.

Keywords: dynamic visualization; spatial abilities; anatomy learning; 3D representation

Introduction

Learning functional anatomy, from textbooks and anatomical charts, requires the learner to mentally manipulate the anatomical structure to imagine its spatial orientation to gain further understanding of its dynamic behavior. The building of such an accurate mental representation depends heavily on learner's spatial abilities, as they have to (re)create a dynamic mental model (Stull, Hegarty & Mayer, 2009). External visualizations, such as 3D animations, may bring an adequate solution to fill in the spatial difficulties encountered with static learning (Guillot, Champely, Batier, Thiriet & Collet, 2007; Hoyek et al., 2009), though they may be hard for novices to process. However, learning with external visualizations does not necessarily lead to better understanding, partially because of the intricate interplay of visuo-spatial abilities when learning (Hegarty, Kriz & Cate, 2003).

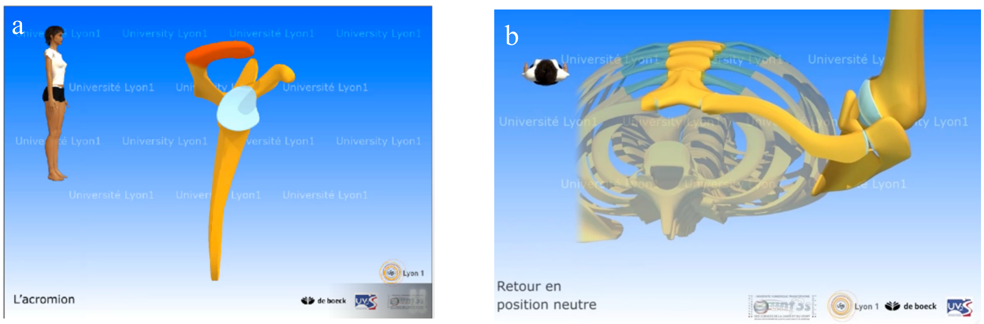

Figure 1: a) structure configuration: the scapula and its acromion process (in orange) in a 60° Y view and b) structure behavior/movement: superior view of the scapula movement during shoulder flexion

Animated visualizations can serve various instructional functions, such as a) conveying the configuration of a system or structure (Figure 1a) and b) the structure behavior or its movement (Figure 1b). The present research investigates the effect of two learning conditions (animated versus static visualizations) on the building of mental representations of structure and movement when learning functional anatomy of the scapula. We assumed that animation could help understanding the scapula behavior by directly showing the movement. Animation could also support the construction of a mental representation of the scapula structure within the anatomical 3D space of the body by providing transitions between the viewing perspectives.

Method

Participants and Design

Forty-nine 1st year students enrolled in the physical education degree at the University of Lyon 1, France, voluntarily participated in the study. They were randomly assigned to one of two learning conditions: a static visualization (*n*= 27) and an animated visualization conditions (*n*= 22).

Instruction material

The learning material developed by Icap Université Lyon 1 consisted of two 3D animations: a) the structure of the scapula and 6 of its features (acromion process, inferior angle, coracoid process, lateral border, spine, neck), and b) the scapula movement during shoulder flexion, that is when the arm is moving from the standard position (arm along the body) upward to the front. In both animations, four anatomical orientation views were sequentially presented: *0° view* (scapula posterior surface), *60° view* (Y view of lateral scapula), *180° view* (anterior surface), and *superior view.* In addition, in the structure material, a small character acted as a permanent spatial anatomical reference. Two versions of theses materials were designed; a) an animated visualization version and b) a static visualization version, which presented simultaneously the main small-scale images of each views. Both learning conditions material had the same duration.

Knowledge tests

Students' learning was assessed with 3 *structure* and 2 *movement* tasks. The *structure* tasks consisted of 1) a ***feature identification*** task assessing the recall of features' name and anatomical relative location; 2) a ***rotation of the scapula*** task assessing the understanding or recognition of various scapula rotations within the anatomical space; and 3) an ***orientation reference*** task for the recognition of the scapula position with regard to the orientation reference character. *Movement* tasks involved 4) a ***movement identification*** task for the recognition of dynamic excerpts of dis/similar phases of the shoulder flexion movement; and 5) a ***movement order*** task assessing the understanding of the scapula movement during shoulder flexion by ordering five static images of different motion states.

Procedure

Participants had an initial 2-minute study phase of scapula general information (a 86-word text coupled with a scapula labeled picture), followed by the instructional *structure* material and its 3 tasks. Then, the *movement* material was presented followed by its 2 tasks. All learning material was presented twice. Additional cognitive measures assessed mental rotation abilities (MRT, Vandenberg

& Kuse, 1978) and dependence towards the field (GEFT, Oltman, Raskin, & Witkin, 1971), from which high and low groups were defined by a quick cluster analysis.

Results

Findings revealed no overall advantage when learning with animated visualizations. Performance of the 2 groups did not differ on *structure* (Wilks' λ (λ) = .91, $F(3, 45) = 1.34$, *n.s*) nor on *movement* tasks (λ = .97, $F < 1$, *n.s*). However, significant global effects of mental rotation abilities (MRT) were found on the overall *structure* (λ = .69, $F(3, 43) = 6.23$, $p = .001$), and *movement* performances (λ = .82, $F(2, 44) = 4.61$, $p = .015$). Moreover, low MRT students performed better on the *feature identification* task when learning with animation ($M = 24.07$) compared to static learning ($M = 20.11$), whereas the reverse pattern was found for high MRT students ($M_{static} = 28.10$; $M_{animation} = 25.22$; $F(1, 45) = 5.46$, $p = .024$, partial $\eta^2 = .10$). No effect of field dependency (GEFT) and interaction effect were found.
Accurate items. A significant interaction between *structure* tasks and MRT clustering showed a quadratic trend ($F(1, 45) = 5.71$, $p = .021$, $\eta^2 = .11$). *Feature identification* and *orientation reference* tasks had an unusual but specific pattern (low MRT scores > high MRT scores), whereas the *scapula rotation* task presented an opposite trend (low MRT scores < high MRT scores).
Error items: Compared to the static learning group, students in the animated learning condition made fewer errors, when a) recalling the neck characteristic in the *feature identification* task ($M_{animation} = 1.31$; $M_{static} = 2.33$; $F(1, 47) = 4.35$, $p = .042$, $\eta^2 = .53$), b) comparing previewed canonical images in the *scapula rotation* task ($M_{animation} = -.37$; $M_{static} = .30$; $F(1, 47) = 6.23$, $p = .016$, partial $\eta^2 = .11$), and c) comparing items differentiated by a 90° vertical rotation in the *scapula rotation* task ($M_{animation} = -.33$; $M_{static} = .27$; $F(1, 47) = 4.84$, $p = .033$, $\eta^2 = .09$).

Discussion and future research

Overall, findings suggest no differences in performances across the learning conditions concerning the building of a mental representation of a 3D structure, as learners from both conditions performed equally on the *structure* and *movement* tasks. Explanations might be that a) the mandatory 2-minute learning phase upset the follow-up learning, b) information from both instructional materials was equivalent and/or c) tasks were not competitive enough to reveal differentiated performances. In line with the literature, we found that the building of mental representation of a 3D structure was largely influenced by learners' spatial abilities, particularly mental rotation abilities. The influence of the mental rotation levels on the *structure* performances differed across the tasks, suggesting that the tasks might not all rely on the same spatial abilities. The follow-up analyses revealed an interesting result regarding rotations. The animation group made fewer errors of rotation judgment with items where the scapula's view was 90° vertically rotated. Whereas both learning groups watched the same anatomical views, the difference lies in the motion. The animated learning group watched the scapula horizontally turn from 0° to 180° and then vertically to the superior view, while the static group saw sequentially the 4 frames. This result may suggest that the *structure* animation could help learners build the mental representation of the 3D scapula. Complementary research is needed to verify this hypothesis.

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