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Effectiveness of Three-Dimensional Digital Animation in Teaching Human Anatomy in an Authentic Classroom Context

Nady Hoyek,[1*] Christian Collet,[1] Franck Di Rienzo,[1] Mickael De Almeida,[2] Aymeric Guillot[1,3]
[1]*Centre de Recherche et d'Innovation sur le Sport-Laboratoire de la Performance Motrice, Mentale et du Matériel, Université Claude Bernard Lyon 1, Villeurbanne, France*
[2]*Innovation Conception et Accompagnement en Pédagogie-Domaine Rockefeller, Médiathèque Paul Zech, Lyon, France*
[3]*Institut Universitaire de France, Paris, France*

Three-dimensional (3D) digital animations were used to teach the human musculoskeletal system to first year kinesiology students. The purpose of this study was to assess the effectiveness of this method by comparing two groups from two different academic years during two of their official required anatomy examinations (trunk and upper limb assessments). During the upper limb section, the teacher used two-dimensional (2D) drawings embedded into PowerPoint® slides and 3D digital animations for the first group (2D group) and the second (3D group), respectively. The same 3D digital animations were used for both groups during the trunk section. The only difference between the two was the multimedia used to present the information during the upper limb section. The 2D group surprisingly outperformed the 3D group on the trunk assessment. On the upper limb assessment no difference in the scores on the overall anatomy examination was found. However, the 3D group outperformed the 2D group in questions requiring spatial ability. Data supported that 3D digital animations were effective instructional multimedia material tools in teaching human anatomy especially in recalling anatomical knowledge requiring spatial ability. The importance of evaluating the effectiveness of a new instructional material outside laboratory environment (e.g., after a complete semester and on official examinations) was discussed. Anat Sci Educ 00: 000–000. © 2014 American Association of Anatomists.

Key words: gross anatomy education; computer assisted learning; animations; 3D digital animations; spatial ability; students' performance; assessment; kinesiology program

INTRODUCTION

Teaching tools and techniques are permanently evolving. Several studies have already been conducted to compare new and traditional teaching methods in various topics. Mixed results have been found. Schwann and Riempp (2004) and Bodemer et al. (2004) provided evidence of the effectiveness of interactive dynamic visualizations when learning how to tie knots and how mechanical systems work respectively. In contrast, using dynamic media was less effective on learning meteorology (Lowe, 2004) and ecosystems (Zahn et al., 2004).

Teaching human anatomy has been considerably changing during the last decade. Until recently, teaching human anatomy in French medical schools consisted of drawing human anatomical structures on the board during lectures. During practical laboratory sessions dissection and/or prosection courses were given. The Brizon and Castaing booklets (1953a,b,c) had been extensively used as references for the study of the musculoskeletal system. Such documents included two-dimensional (2D) black and white drawings of the anatomical structures with their descriptions. Thiriet (1982) in doctoral dissertation questioned the pedagogical usefulness of such 2D-figures and plates. He underlined that 2D-figures elicited a high workload to encode and visualize. They require a clear representation and mental rotation of

*Correspondence to: Dr. Nady Hoyek; Centre de Recherche et d'Innovation sur le Sport-Performance Motrice, Mentale et du Matériel (P3M); Université Claude Bernard-Lyon I-UFR STAPS; 27–29 Boulevard du 11 Novembre 1918-69 622 Villeurbanne Cedex, France. E-mail: nady.hoyek@univ-lyon1.fr

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each anatomical structure. He further argued that students with poor scores on human anatomy examination probably had poor spatial abilities as well (Thiriet, 1982).

Practically, human anatomy describes geometrical shapes in a three-dimensional (3D) space. These are described statically or dynamically. Thus, understanding this kind of knowledge requires creating clear mental images. A large body of research provided evidence that spatial ability is one of the main key-components of being successful in anatomy and surgery learning (Rochford, 1985; Garg et al., 2001; Risucci, 2002; Wanzel et al., 2003; Keehner et al., 2004; Hegarty et al., 2007). Guillot et al. (2007) found a significant correlation between anatomy examination results and two spatial ability tests: the Group Embedded Figure Test (GEFT) evaluating the degree of field dependence–independence (Witkin et al., 1971) and the Mental Rotation Test (VMRT) evaluating spatial abilities in rotating 3D-objects in space (Vanderberg and Kuse, 1978). The effect of mental rotation training on student's anatomy results was also investigated (Hoyek et al., 2009). Mental rotation training enhanced learning procedures only for anatomical information requiring spatial ability. A reciprocal advantage of learning anatomy on students' spatial ability has been recently proved (Lufler et al., 2012; Vorstenbosch et al., 2013). Accordingly, participation in anatomy courses increases students' spatial ability. There is thus no doubt that understanding human anatomy and spatial cognitive operations share common processes.

Several studies on teaching human anatomy have already compared new teaching methods (i.e., interactive computer based teaching, 3D computer animated graphics, or 3D videography) to traditional ones (i.e., dissection, prosection, 2D images, or drawing the anatomical structure on the board). We noticed that two main procedures for comparison were used: (1) some investigators assessed students' perception regarding the use of new teaching methods with questionnaires; (2) others compared the outcome of 3D to traditional methods based on students' examination results.

Moorman (2006) and DiLullo et al. (2006) showed that most students were enthusiastic about digital video clips created to present dissection guidance. Khalil et al. (2005) found similar survey results. Students perceived computer-based teaching as being a better strategy than paper-based static material.

Interestingly, mixed results were reported when directly comparing teaching methods for teaching motor skills related to surgery and dissection. Hanna et al. (1998) compared 2D and 3D imaging in elective laparoscopic cholecystectomy for symptomatic gallstone disease. Roach et al. (2012) evaluated 3D-videographic e-learning modules of skin flap procedures compared to classical 2D-video recordings. Both studies evidenced that 3D-technology does not better contribute to enhance surgical skill acquisition than 2D-video recordings. This may be explained by the fact that surgery requires complex motor skills that are not easily transferred through 3D multimedia instructional tools. Furthermore, instruction videos and tutorials replacing or supplementing dissection courses did not seem to enhance students' scores both in cadaver practical laboratory test and in written examination (Granger and Calleson, 2007; Theoret et al., 2007; Mahmud et al., 2011). This was probably due to knowledge transfer to practical laboratory test, which is believed as being easier after dissection and prosection exercises. Unfortunately, knowledge transferability was not discussed in most studies dealing with anatomy education.

In addition to skills related to surgery and dissection, some investigators compared different teaching methods on theoretical knowledge acquisition. Khalil et al. (2005) compared computer-based interactive and paper-based static instructional materials without reporting any significant difference during immediate recall of anatomical information. In line with such findings, Saxena et al. (2008), Hopkins et al. (2011, and Tan et al. (2012) did not find any beneficial pedagogical effects of videos, 3D stereoscopic models or 3D-models on anatomy examinations, respectively.

Conversely, Nicholson et al. (2006) reported that a 3D-computer-based teaching enhanced medical students' learning of human ear anatomy. They explained that improvement might have been due to greater level of interactivity and suitability of the 3D-model to the topic complexity. Furthermore, Abid et al. (2007) replaced the classical "blackboard" techniques (drawing the anatomical structure on the board with a chalk during lectures) by an interactive CD-ROM containing 3D anatomy graphics. Students from the 3D group performed better in anatomy examinations.

We identified four reasons for such confounding results. First, some topics like ear anatomy (Nicholson et al., 2006) or organogenesis (Abid et al., 2007) require more spatial ability to be learned efficiently. Thus the use of 3D interactive graphics may be more beneficial compared to canine skull study (Khalil et al., 2005). Second, learning human anatomy is influenced by the interaction between the learner's spatial ability and the dynamism and interactivity of the instructional tool (Nguyen et al., 2012). For instance, only learners with high spatial abilities might benefit from dynamic animations. Thus, some minimal level of spatial ability would be required for comprehension from dynamic animations. On the other hand, low spatial ability learners would benefit more from static image. Third, different learning contexts and times were used in the literature. Apart few experiments conducted in an actual classroom context (Hanna et al., 1998; Granger and Calleson, 2007; Saxena et al., 2008; Mahmud et al., 2011), most studies did not provide adequate learning time in laboratory paradigms to observe significant improvements. Training sessions usually ranged from 45 minutes to 1 hour and most participants were volunteers, however, without incentive to perform well. Fourth, few studies looked into the appropriateness of their teaching methods to the type of assessed anatomical knowledge, and whether a positive transfer was favored or not.

The aim of the current study is to test the effectiveness of using 3D digital animations in teaching human anatomy. This study was conducted in a real classroom context on a large sample size, which is the main novel feature. We compared the effectiveness of using 3D digital animations versus 2D-plates and figures embedded in PowerPoint® slides on two types of anatomy questions (general and spatial anatomy knowledge). Students using 3D digital animations were expected to score better than students using PowerPoint slides on the anatomy questions requiring spatial abilities only.

METHOD

Participants and Educational Context

A total of 391 students attending the required human anatomy course took part in the study. We conducted a quasi-experimental design by comparing two groups from different classes. The 3D group was made of 190 students (63 women, 127 men, mean age = 19.5 years, range = 18–21 years) from the 2011–2012 first-year kinesiology program at Lyon 1 University. The 2D group was made of 201 students (71women, 130 men, mean age = 19.5 years, range = 18–21 years) from the 2009–2010 first-year kinesiology program. The 3D and 2D groups were essentially different classes on two different academic years. We controlled that none of the students had learned anatomy in advance. Students repeating the class were excluded from the analysis. During the first lesson, all participants completed a questionnaire about their previous academic years. We checked that both groups had similar characteristics including mental rotation ability assessed by the Vandenberg and Kuse Mental Rotation test (VMRT: Vandenberg and Kuse, 1978) and scientific high-school diploma the year preceding the enrollment in the anatomy course. Scores on the VMRT ranges from 0 to 24. The VMRT score was an inclusion criterion only; participants scoring between 8 and 14 were enrolled in data analysis. The local committee for human research approved this study.

Curriculum Design

All participants attended the same number of lessons, given by the same lecturer, and followed the same curriculum of human musculoskeletal system. The overall anatomy course consisted of 15 lecture-sessions (30 hours) and 10 laboratory practical skill-training sessions (20 hours). During lectures, the lecturer gave relevant information to the lecture's content in a one-way method of communication. However, 2 minutes of questions were provided every 15 minutes in order to increase active participation and engagement. On the other hand, laboratory practical sessions consisted of problem-based-learning and team-based-learning exercises. No dissection or prosection experience was included in the course. All participants were given exactly the same written reference materials (lecture notes) as study guidelines. They all had access to their respective instructional multimedia tools directly using an online server.

Description of the Instructional Multimedia Tool Used for Both Groups

3D digital animations for teaching human anatomy were created for kinesiology students in Lyon 1 University. According to Ainsworth and VanLabeke (2004) classification, these animations are time-singular representations. QuickTime® player, version 7.7.4 (Apple Inc., Cupertino, CA) allows slow motion forward or backward playing or playing different animations simultaneously. Multimedia tools were the same for both groups during trunk section. However, different multimedia tools were used during the upper limb sections: while students in the 3D group used the animations, 2D-figures and drawings embedded in PowerPoint slides were used for the 2D group. It is noteworthy to clarify that the 3D group did not utilize the PowerPoint slides used by the 2D group. Our 3D digital animations are without any verbal accompaniment. They last from 3–5 minutes each. The only interaction with the animation was that students could play them at their own pace, make pauses, rewind, forward, and check the lecture notes. The 3D animations are available on the university web site (Anatomie 3D Lyon 1, 2014).

Assessment

At the end of the upper limb and trunk teaching periods, both groups were evaluated using the same assessments. Twenty true/false statement questions covered each of the upper limb and trunk sections. A 20 minutes period was given for each assessment. Anatomy teachers subdivided the questions in both assessments into two categories: general anatomy knowledge questions, and specific questions requiring spatial ability operations (e.g., mental rotation and mental imagery) before answering. Some of the questions on the upper limb are given as examples in Appendix 1. Participants intended to do their best, as these tests were a specific part of the final anatomy examination, they represent 25% of the overall mark of the students.

Survey

At the end of the semester, all participants used a four-point Likert scale (1 = strongly agree; 2 = agree; 3 = disagree; 4 = strongly disagree) to answer a general survey regarding: the course rhythm, the amount of homework time, the importance of the learned knowledge, the strength of the link between the lectures and the laboratory practical courses. Only two questions related to the upper limb section were asked. In the first one, the participants had to state their perceived satisfaction with the instructional strategy used in the upper limb section during their respective lessons (2D or 3D). Accordingly the question was: "The multimedia material (PowerPoint and 3D digital animations for the 2D group and 3D group, respectively) was useful in understanding of anatomy of the upper limb". The second question was related to the amount of personal homework: "Too much time was devoted at home for the study of the upper limb".

To sum up, almost the same conditions were applied to both groups (curriculum, teacher, lecture note, number of lessons, assessment, survey). We controlled that the only difference between the two groups was related to the multimedia used only during the upper limb section. Table 1 shows a comparison between the two groups.

Data Analysis

The number of correct responses on both upper limb and trunk tests was collected for each student. Three different dependent variables were then taken into account: overall test scores, questions requiring spatial abilities sub-scores and general knowledge questions sub-scores. To compare groups' scores, we used a three-way ANOVA with Group (3D, 2D), Type of question (general knowledge questions, questions requiring spatial ability) and Section (upper limb, trunk) as main factors. Post-hoc comparisons were carried out using Bonferroni correction. Finally, to analyze students' answers self-evaluation with the likert scale, we performed a Chi-square analysis to compare the percentage of responses. The level of significance was set at $P \leq 0.05$. All analyses were performed with SPSS 18.0 software package (SPSS, Chicago, IL).

RESULTS

We first observed a main effect of Group (F (1,1,356) = 191.690, $P < 0.001$, $\eta^2 = 0.14$), Type of question (F (1,1,356) = 603.604, $P < 0.001$, $\eta^2 = 0.44$) and section (F (1,1356) = 656.485, $P < 0.001$, $\eta^2 = 0.48$). We also observed a significant two-way interaction between Group

Table 1.

Comparison Between Resources Utilized by Both 2D and 3D Groups

Resources	2D Group	3D Group
Upper-limb		
Multimedia tool	PowerPoint®	3D animations
Number of sessions	5 lectures + 3 practical sessions	
Lecture notes	Same	
Assessment	Same	
Trunk		
Multimedia tool	3D animations for both groups	
Number of sessions	5 lectures + 3 practical sessions	
Lecture notes	Same	
Assessment	Same	
Teachers	Same	
Curriculum	Same	

This table shows that the only difference between these two groups was in the multimedia tool used during the upper limb sections

and Section (F (1,1356) = 136.603, $P < 0.001$, $\eta^2 = 0.1$). Post-hoc tests with Bonferroni corrections did not show any score difference between 3D group and 2D group on the overall upper limb examination ($P > 0.05$). Conversely, students in the 2D group outperformed the 3D group on the trunk examination ($P < 0.001$).

Furthermore, we observed a significant three-way interaction between Group, Type of question and Section (F (1,1356) = 55.136, $P < 0.001$, $\eta^2 = 0.04$). Surprisingly, 2D group outperformed 3D group on both the trunk's general knowledge questions ($P < 0.001$) and spatial ability questions ($P < 0.001$).

On the other hand, post-hoc tests with Bonferroni corrections did not show any score difference between 3D group and 2D group on the upper limb's general knowledge questions ($P > 0.05$). Conversely a significant difference was found for upper limb's questions requiring spatial abilities ($P < 0.001$), with 3D group scoring better than 2D group. These results are shown in Figure 1A. All means and ±SDs are shown in Table 2.

Students' Self-Report

The chi-square test revealed no difference when comparing students' self-report scores on the instructional multimedia tool usefulness question ($X_2 = 4$, $df = 3$; $P = 0.26$). However, when looking separately at answers' distribution for negative (strongly disagree vs. disagree) and positive responses (agree vs. strongly agree), a significant group difference was found (Fig. 1B). Accordingly, 3D group students were both more positive (strongly agree) and less negative (strongly disagree) than the 2D group regarding the usefulness of the material: (1) the 2D group 'strongly disagreed' more than 'disagreed' ($X_2 = 13$; $df = 1$; $P < 0.001$); (2) On the other hand, the 3D group 'strongly agreed' more than 'agreed' ($X_2 = 4$; $df = 1$; $P = 0.04$). Finally, no significant difference was observed when comparing students' self-report of homework time ($X_2 = 4$, $df = 3$; $P = 0.29$).

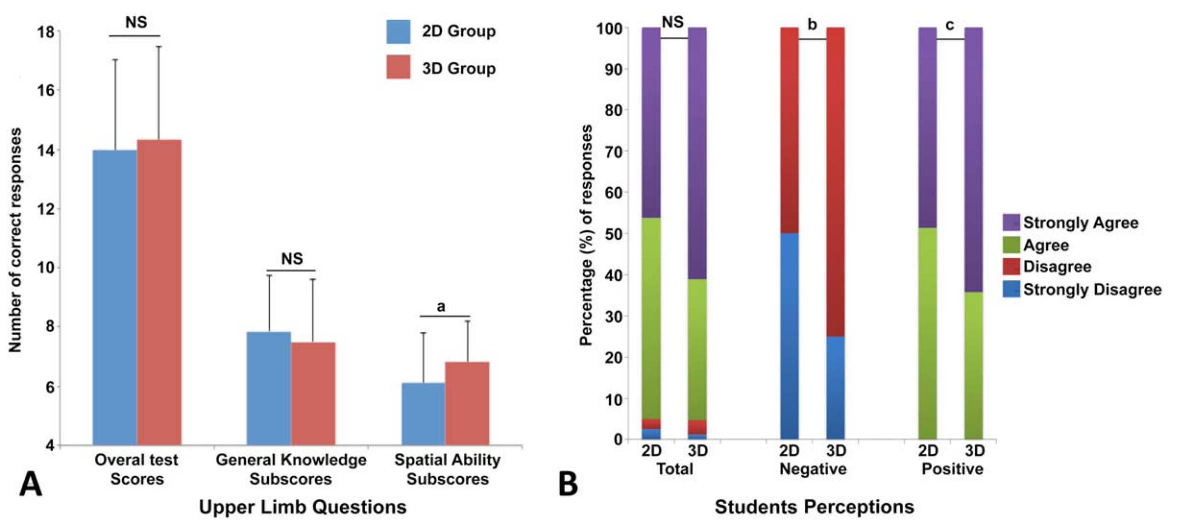

Figure 1.

General results at the anatomy examination and self-perception of 3D benefits. **A** Upper limb anatomy examination scores. No significant group difference was found on the overall test and on general knowledge questions. The 3D group outperformed the 2D group on questions requiring spatial ability; NS, non significant; $^{a}P < 0.0001$; **B** Students' perceptions of the benefits of the 3D teaching tool. While no significant group difference was found when comparing individual scores, students from the 2D group reported more frequently strongly disagreeing than 3D students, who conversely reported more frequently strongly agreeing with the fact that the material (animation/PowerPoint®) was useful; NS: non-significant; $^{b}P < 0.05$; $^{c}P < 0.001$.

Table 2.

Results of Students' Assessments for Both 3D and 2D Groups

Type of questions	Group	Mean (±SD)	*P*-value
Upper limb			
Overall score	3D2D	14.31 (±3.13)13.96 (±3.06)	>0.05
General knowledge	3D2D	7.50 (±2.11)7.86 (±1.88)	>0.05
Spatial ability	3D2D	6.81 (±1.39)6.09 (±1.67)	<0.001
Trunk			
Overall Score	3D2D	8.02 (±2.39)11.83 (±2.53)	<0.001
General knowledge	3D2D	5.01 (±1.96)7.57 (±1.80)	<0.001
Spatial ability	3D2D	3.00 (±1.09)4.25 (±1.29)	<0.001

P-values of the post-hoc tests with Bonferroni corrections are presented in the last right column. 2D-group outperformed 3D-group on the trunk assessment (both groups used the animations for this section). 3D-group outperformed 2D-group on the spatial ability question during upper limb assessment (3D animations and 2D figures were used by 3D-group and 2D-group, respectively, during this section).

DISCUSSION

The present study was designed to investigate whether using 3D digital animations was effective to facilitate the acquisition of anatomy knowledge, and more specifically for spatial anatomy questions. We addressed all comparisons against a group who learnt upper limb human anatomy using 2D images. The main strength of our experiment is that it was conducted under actual learning conditions. Thus, it was one of the few studies administered and controlled in a class instead of a laboratory paradigm.

First, students perceived 3D digital animations as being a good multimedia tool for learning human anatomy, as shown by previous studies (Khalil et al., 2005; DiLullo et al., 2006; Moorman 2006). Such pattern of result was quite expected as students are now well accustomed to digital technologies in daily life activities.

Comparing the anatomy upper limb examination outcome in the two groups, revealed that using 3D digital animations was more useful than traditional 2D-drawings embedded in PowerPoint slides. However this result was only observed for some specific questions requiring the use of spatial abilities. Accordingly, 3D group did not outperform 2D group on the overall final examination scores. In contrast, 3D group outperformed 2D group on questions requiring spatial ability. This result was observed despite that participants had similar spatial ability level at the beginning of the semester. This is in line with findings by Abid et al. (2007) and Nicholson et al. (2006). We confirm that some topics, namely the functional musculoskeletal anatomy, require more spatial ability to learn effectively and thus the use of 3D digital animations was beneficial.

Recalling human anatomy information relies on several types of knowledge and abilities. Some declarative knowledge questions (see Appendix 1: left column; e.g.: The pronator quadratus muscle is the only pronator of the forearm) do not appear to directly benefit from the use of 3D digital animations. In contrast, the use of animations might be significantly effective when considering questions requiring spatial ability, visualization, or mental rotation before answering (see Appendix 1: right column; e.g.: The movements of the scapula during shoulder flexion are: upward rotation, anterior tilting and elevation). Our 3D digital animations enhanced the ability to better understand such dynamic information. Unlike Nguyen et al. (2012), our spatial anatomy questions required both anatomical knowledge and implicit spatial operations before answering. Our questions are relevant and essential for the required anatomy knowledge. Conversely, Nguyen et al. (2012) questions required pure spatial ability and could even be answered without any anatomical knowledge.

Comparing two separate groups of students, one in the 2009–2010 academic year and the other in the 2011–2012 academic year was one of the biggest challenges of this study. One may argue that the two student groups were not comparable. Differences in terms of academic potential or motivation might exist. However, by comparing the trunk assessment scores in both groups, the 2D group outperformed the 3D group even though the learning conditions were the same during this section. This result was not expected and its' discussion is difficult and might be speculative especially under actual learning condition. However, what is interesting and essential in our study is that despite this difference on the trunk assessment, the upper limb assessment showed the opposite result. This makes the difference seen in the upper limb examination even more convincing in favor of 3D animation.

Results from the current study suggest that teaching anatomy with 3D animations offers some advantage on questions requiring spatial ability. First, 3D digital animations are likely to enhance students' spatial ability and increase their capacity to imagine the rotation of anatomical structures in different planes, thus facilitating the visualization of bones, muscles, joints, and attachments from different perspectives. Second, 3D digital animations helped students forming a clearer mental representation of the anatomical structures, and contributed to improve learning and understanding of their verbal and graphical knowledge. Third, animations may also have contributed to a better understanding of space and topographical relationships between anatomical structures. Fourth, in our 3D digital animations, the students were always encouraged starting with a very simple mental image of the anatomical structure. These were progressively complicated before being fully described and depicted. Practically, 3D digital animations provide sense and logic to some complex anatomical knowledge by combining appropriate verbal description (given by the lecturer) and visually animated information. According to Mayer's principles of cognitive load (Mayer, 2009) learners can grasp more if dual channels (auditory and visual information) are presented simultaneously. Fifth, 3D digital animations specify spatial organization of elements and how they change with time, a configuration that was hard to perceive in the 2D group (Betrancourt et al., 2001). Movements and changes are not directly visible with the static 2D images they have to be inferred (Hegarty, 1992).

However, caution should be taken before generalizing that all animations are more effective than static 2D images. Some animations can be very challenging for learners, especially because of the amount of information to be processed or its transient nature (Tversky et al., 2002; Ainsworth and Van Labeke, 2004). The wealth and transient information that must be processed can lead to cognitive overload, inaccessible information and task failure (Mayer and Moreno, 2003). Furthermore, an illusion of comprehension (Lowe, 2003) may occur when processing animation, especially when learners study them in a passive mode, without being totally engaged in the learning activity (Hegarty et al., 2003). This was not the case in our 3D animations because students had the possibility to accelerate, decelerate, stop, reverse or repeat parts of the animations. This allows learners to cut out the visual information flow into chunk events (Lowe and Boucheix, 2010). This segmentation will then alleviate the animation processing. In line with Schwan and Riempp (2004) study, such simple interactive features may accelerate the process of learning. Instead of being distracted by perceptually salient but not necessarily thematically relevant aspects of a display (Lowe, 2004), interactivity helped students distributing their attention and cognitive resources to relevant parts of the 3D digital animations. Caution should however be taken before generalizing the positive effects of interactive media. Accordingly, interactive dynamic displays are not necessarily more efficient, at least not for all students (Hegarty, 2004). To be effective, interactive displays require, in addition to motivation, metacognitive skills (Hegarty, 2004).

LIMITATIONS

Despite taking the actual learning conditions into account, we should underline the main limitations of our study. First, our animations were not always constructed with respect to the cognitive load theory (Mayer and Moreno, 2003). Some of them presented a big amount of pictorial information that was not easily processed by students, which disabled them in building connections between pictorial and verbal representations. Second, our 3D digital animations were produced before studying how students may cognitively process them (see Chandler, 2004; Lowe, 2004). Third, in a class-learning context some parameters like students' personal homework could not be easily controlled. The only data we have regarding the amount of homework is the students' self-report that showed no difference between the two groups. Even previous study failed to make a link between students' performance and the amount of personal homework time (Guillot et al., 2007). Future studies should better control this specific factor. Fourth, we did not include the VMRT scores among the dependent variables. That would have allowed interesting data analysis especially for observing how mental rotation ability varies between 2D and 3D groups. VMRT scores were simply taken as an inclusion criterion. Fifth, a more useful survey would have included multiple questions exploring how the students used our learning materials.

CONCLUSIONS

A first innovative finding is related to the selective usefulness of our 3D digital animations as they contributed to enhance acquisition of anatomy knowledge for specific topics and anatomy questions requiring spatial ability. Thus, although we cannot conclude that our animations are the best instructional tools for teaching human musculoskeletal anatomy, we recommend anatomy teachers to mix different teaching methods (new and traditional) in order to induce the desired transfer of knowledge. A second innovative aspect of the present study is that it was administered in a class-learning context. Our students directly benefited from the 3D animations during their required anatomy courses, with the main data collected being a part of their official final examination. Unlike laboratory-based experiments where the timelines are short, sufficient time was given for knowledge retention in our paradigm.

Finally, we encourage anatomy teacher to use 3D animations mainly because: 1. when constructed with respect to the cognitive load theory, 3D animations facilitate the comprehension of spatially demanding anatomical knowledge; 2. the students and the teachers usually appreciate them. The next step for developers and teachers is to construct new interactive and friendly multimedia tools.

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NOTES ON CONTRIBUTORS

NADY HOYEK, Ph.D., is an associate professor in Lyon 1 University, and a researcher in the Centre de Recherche et d'Innovation sur le Sport, Villeurbanne, France. He teaches human anatomy to first year kinesiology student and is specialized in the impact of spatial ability on learning.

CHRISTIAN COLLET, Ph.D., is a full professor in Lyon 1 University, and a researcher in the Centre de Recherche et d'Innovation sur le Sport, Villeurbanne, France. He teaches neurosciences and is specialized in mental and motor imagery abilities.

FRANCK DI RIENZO, Ph.D., is an assistant professor in Lyon 1 University, and a researcher in the Centre de Recherche et d'Innovation sur le Sport, Villeurbanne, France. He

teaches neurosciences and anatomy and is specialized in mental and motor imagery abilities as well as statistics.

MICKAEL DE ALMEIDA, M.Sc., is pedagogical assistant in the Innovation Conception et Accompagnement pour la Pédagogie Département, Université Claude Bernard Lyon 1, Lyon, France. He is specialized in knowledge assessment techniques.

AYMERIC GUILLOT, Ph.D., is a full professor in Lyon 1 University, and a researcher in the Centre de Recherche et d'Innovation sur le Sport, Villeurbanne, France. He teaches neurosciences and is specialized in mental and motor imagery abilities.

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APPENDIX
Examples of General Knowledge and Spatial Anatomy False/True Statements

General anatomy knowledge questions	True	False	Spatial ability anatomy questions	True	False
The biceps brachii is a supinator of the forearm	☐	☐	When the humerus is medially rotated the deltoid tuberosity moves from a lateral to an anterior to medial position	☐	☐
The infraspinatous fossa is located in the anterior surface of the scapula	☐	☐	The ulnar styloid process is lateral during supination	☐	☐
The glenohumeral joint has a loose capsule that is lax inferiorly	☐	☐	In a front view the clavicle appears like an italic S, while on a superior or inferior view it appears linear	☐	☐
The pronator quadratus muscle is the only pronator of the forearm	☐	☐	The movements of the scapula during shoulder flexion are: upward rotation, anterior tilting and elevation	☐	☐