A comparison of animated versus static images in an instructional multimedia presentation

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Daly CJ, Bulloch JM, Ma M, Aidulis D. A comparison of animated versus static images in an instructional multimedia presentation. Adv Physiol Educ 40: 201–205, 2016; doi:10.1152/advan.00053.2015.—Sophisticated three-dimensional animation and video compositing software enables the creation of complex multimedia instructional movies. However, if the design of such presentations does not take account of cognitive load and multimedia theories, then their effectiveness as learning aids will be compromised. We investigated the use of animated images versus still images by creating two versions of a 4-min multimedia presentation on vascular neuroeffector transmission. One version comprised narration and animations, whereas the other animation comprised narration and still images. Fifty-four undergraduate students from level 3 pharmacology and physiology undergraduate degrees participated. Half of the students watched the full animation, and the other half watched the stills only. Students watched the presentation once and then answered a short essay question. Answers were coded and marked blind. The “animation” group scored 3.7 (SE: 0.4; out of 11), whereas the “stills” group scored 3.2 (SE: 0.5). The difference was not statistically significant. Further analysis of bonus marks, awarded for appropriate terminology use, detected a significant difference in one class (pharmacology) who scored 0.6 (SE: 0.2) versus 0.1 (SE: 0.1) for the animation versus stills group, respectively (P = 0.04). However, when combined with the physiology group, the significance disappeared. Feedback from students was extremely positive and identified four main themes of interest. In conclusion, while increasing student satisfaction, we do not find strong evidence in favor of animated images over still images in this particular format. We also discuss the study design and offer suggestions for further investigations of this type.

3-dimensional; animation; cognitive load

The value of using computer-generated animations for teaching has been appreciated for >20 yr (8). Interestingly, in their 1994 publication, Lilienfeld and Broering (8) stated that “reality is the best glue to which information sticks.” Although the “reality” they refer to concerns embedding clinical scenarios within teaching sessions, we believe that the same could be said for multimedia presentations in the form of medical animations [i.e., anatomic accuracy (the reality) should be preserved]. This general view is supported by a study (4) that used interactive animations to teach molecular chemistry. The findings show that students can often be misled, and misconceptions can be reinforced, if animations are not designed within the confines of a structured learning framework. Intuitively, it may seem that three-dimensional (3-D) models/animations would be a better teaching tool than static images or diagrams. A combination of handheld models and computer software has been shown to enhance student understanding of protein structure-function relationships (7). Computer-generated models of chemical structure alone enhanced comprehension in students ranging from primary school to higher education (5), and biology students can use interactive 3-D visualization for protein folding (using the “Foldit” computer game). Therefore, many students are arriving at university with experience in using computer-based animation and 3-D visualization.

We have noted that many medical animations currently present on YouTube.com are very artistic but often bear little relation to reality. While our animations are partly artistic, they are set within an anatomically accurate 3-D scene, which will provide a clearer context and reduce misconceptions. We have not yet tested that assertion but have used this presentation style to test the effectiveness of animation versus static images. A recent study (13) has shown that certain animation styles may not improve learning but simply create an “illusion of understanding.”

The multimedia principle (10) that learning is improved by combining words and pictures is widely accepted, and there is a wealth of research data to back this up (2). However, it has also been shown that using simple, rather than complex, pictures will favor low-knowledge learners but pictures per se will have a greater effect on deeper learning than on retention (2). Therefore, careful design of instructional graphics and an appreciation of the learner’s baseline knowledge become crucial. The cognitive theory of multimedia (11) highlights the dual coding model in which a learner selects and organizes words and pictures within the confines of a very limited working memory. Integration with unlimited long-term memory enables schema building, which reinforces learning. The very nature of a multimedia presentation is such that it can be “unlimited,” containing complex visuals, text, commentary, background music, etc. Therefore, transfer of an unlimited overload of information to unlimited-capacity long-term memory via a severely limited conduit (i.e., working memory) creates a problem.

Recognizing the importance of cognitive load theory in presentation design is fundamental to the success of multimedia as a learning tool. Cognitive load theory is presented as three components: extraneous cognitive load, intrinsic cognitive load, and germane cognitive load (14). Extraneous cognitive load describes the method of delivery (e.g., does the learner have control? Is all the material relevant?). Intrinsic cognitive load refers to the complexity of the topic to be learned (e.g., are there multiple interacting elements in the subject matter). Germane cognitive load is felt at the interface between working memory and long-term memory where men-
tal schemas need to be constructed. The three loads are additive and have an optimal level above which learning will not occur. Therefore, if a learning task, by necessity, has a high intrinsic load, then the designer should look for ways to reduce extraneous and germane loads. Within a multimedia context, at least nine ways of reducing load have been identified and described (9). A recent study (6) used a low cognitive load animation to reduce misconceptions (6), and in reviewing a themed journal issue on the cognitive loading of animations, different authors (1) concluded that cognitive load theory has a significant part to play. These authors also encouraged future research projects to consider comparing static presentation with animations to create a better appraisal of each. It can be assumed that a static presentation will carry a lower extraneous cognitive load and may therefore be more effective in some cases.

We investigated the use of multimedia presentations in the teaching of complex topics in cardiovascular science. Our original hypothesis was that using real data of 3-D vascular structure within a multimedia animation of neurovascular control would enhance student learning and be an improvement on more traditional ways of teaching the topic (i.e., via static diagrams). We used confocal laser scanning microscopic images to generate anatomically accurate 3-D models of the vascular wall. These models were then ported to sophisticated modeling software to create 3-D animations, which were composed to create a 4-min multimedia presentation (3). Moving images have a higher extraneous load than static images. However, our hypothesis was that moving (complex) images may facilitate a deeper learning than (simple) static images.

In the present study, we compared two instructional multimedia presentations. One version of the presentation used moving images, whereas the other version used only static (still) images. The audio commentary, background music, and on-screen text were identical in both presentations. Fifty-four level 3 life science undergraduate students participated in the study. In this report, we discuss the results of the test and offer suggestions for further study design and cognitive loading of instructional multimedia presentations.

METHODS

The present study was carried out with students from the University of Glasgow (a large research-intensive university in Scotland, established in 1451 and part of the Russell Group of Universities). The University of Glasgow comprises four colleges, with students from the School of Life Sciences (in the College of Medical, Veterinary and Life Sciences) taking part. Teaching in the School of Life Sciences is organized into four degree groups; this study recruited students from the Human Biology group (which includes degree programs in Physiology and Pharmacology).

Recruitment. Before any students were recruited, a full project proposal was approved by the College Ethics Committee of the College of Medical, Veterinary and Life Sciences. The test was delivered as part of the introduction to a teaching session on vascular structure and function. At the beginning of the session, all students were informed of the test details and were given an anonymized answer sheet. After the test students ticked a yes or no box to give permission to use their answers. The nature of the recruitment method precludes identification of the student by any of the study authors. One class comprised 26 third-year pharmacology undergraduates, and the other class comprised 28 third-year physiology undergraduates. Both teaching sessions were delivered on the same day, and each class was randomly split into two groups to watch either the animation or stills-based presentation.

Software. 3-D laser scanning confocal microscopy data were collected on a Bio-Rad Radiance 2100 using Lasersharp software. The 3-D data were segmented in AMIRA and imported into Autodesk MAYA. Multiple 3-D animation scenes were rendered in MAYA and composited in Adobe AfterEffects (3). The background music and audio commentary were recorded using CUBASE and incorporated into the AfterEffects project. On-screen text was added using AfterEffects. A single movie file was then rendered from AfterEffects.

Animation test. A 4-min full 3-D animation on vascular neuroeffector transmission was created using a previously published technique (3) and briefly described above. An additional 4-min movie was created using 17 still frames from the 3-D animation and containing the same audio commentary and soundtrack (see examples in Fig. 1A). Third-year physiology and pharmacology students were split into equal groups and shown either the 3-D animation or stills presentation. A previously unseen question (8 min, short essay style; Fig. 2) was then attempted by both groups. The question was part retention and part transfer test. The retention component of the answer required an anatomic description of vascular innervation. The transfer component required students to explain the effects of two drugs in this location. The answers were marked blind by one of the study authors (J. M. Bulloch), who had no knowledge of the groupings. A marking scheme was devised where both “essential information” (core marks), which we anticipated would be required to answer the question, as well as the “bonus material” related to correct use of additional appropriate terminology, which was mentioned in the video, was listed, and half-marks were awarded per item. Total marks and bonus marks were analyzed separately. All marks are presented as mean values with SDs and SEs calculated using Graph Pad Prism.

Fig. 1. Left: still images from a 4-min animation describing sympathetic neurotransmission in the vascular wall. These images were taken from the set of 17 images used in the final “stills” animation. The full animation can be viewed online at (www.cardiovascular.org/animations.html). The diagram (right) is typical of the type used in lectures to describe adrenergic neurotransmission from sympathetic nerve varicosities (SNV) and the receptors present on vascular smooth muscle cells (VSMC). NA, norepinephrine.
The figure below shows the contraction of a blood vessel following stimulation of the sympathetic nerves. The first response (a) is a sharp spike (transient contraction) caused by the release of noradrenaline from sympathetic nerves. The contraction is driven by alpha-adrenoceptors on the smooth muscle cells. Cocaine is a blocker of neuronal uptake. Rauwolscine is an alpha2-adrenoceptor antagonist.

Describe (briefly) the sympathetic innervation of a blood vessel and discuss why the contraction gets bigger after cocaine (b) and why, after addition of rauwolscine (c), the 'spike' gets bigger but the 'hump' disappears.

The marking criteria assigned core marks and an unlimited number of bonus half-marks for each answer. The only significant difference detected was within the pharmacology group, where the students who watched the stills presentation (0.1) were awarded significantly fewer bonus marks than those watching the full animation (0.6, $P = 0.04$; Table 1).

Student feedback. Forty-nine of fifty-four students (91%) offered feedback in response to the following open question: “What are your thoughts on the use of multimedia/animations for teaching and learning?.” Most of the comments (88%, 43/49 comments) were favorable, and four main overall themes were identified from the student responses:

1) learning preferences, music, and voiceover;
2) pace, repetition, and rewatching;
3) use for studying; and
4) visualizing, complexity, and understanding.

This feedback is discussed in more detail below.

Table 1. Test scores and bonus marks awarded for each group of students

<table>
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<th>Stills Only (All)</th>
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<th>Stills Only (Pharmacology)</th>
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Fig. 2. Immediately after viewing the 4-min presentation, students were asked to answer a question that tested their understanding of the presentation. By showing the responses of an isolated blood vessel to nerve stimulation, students would have to infer from their knowledge rather than relying on recall as the answer was not explicitly given in the presentation.

Staying Current

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neuroeffector transmission in blood vessels. The work is time consuming, but the resulting output is impressive. We are committed to the use of Autodesk MAYA and/or 3Ds Max as a platform for the construction of animations. Autodesk products are free for educational purposes and are compatible with our 3-D microscopy-based data sets. Therefore, we felt it was important to test this style of output as a learning tool. Visually, we expect the cognitive load to be fairly high due to the complex lighting, textures, camera angles, and movement. We decided to focus on only one aspect of the multimedia presentation: the importance of movement. Would a moving image enhance learning or simply add to the cognitive load (or overload)?

**Static versus animated images.** We investigated the use of animated versus static (still) images within a multimedia presentation for the delivery of complex material in teaching cardiovascular science. Our method of creating anatomically accurate 3-D scenes from confocal microscopy data has speeded the animation process (3) and reduced the chance of perpetuating misconceptions (4). However, the value of 3-D animation as a learning tool has not been extensively evaluated, and research in this area is limited. In a life science context, particularly physiology and pharmacology, there have been no studies of the type we have conducted.

To test learning and understanding, a three-part question was set relating to the elements of neurotransmission and the effects of drugs on the process (Fig. 2). We recognized that it was important to set a question that was not based solely on recall of information from the presentations but also would test whether newly acquired knowledge (of the anatomy and function of the neuroeffector junction) would assist in a problem-solving exercise based on drug action (a topic not explicitly covered in the video). Thus, the question was designed to test both understanding of the complex anatomy of the neuroeffector junction (based on new material and physiological vocabulary first presented in the video) and to assess the students’ ability to explain the outcome of drug manipulation in different scenarios (which would require some understanding of the structure and function of the neuroeffector junction). A strict marking guide was adhered to where students were awarded marks for including key or core points that were essential to the answer. Bonus marks were given to those answers that included correct use of terminology in a way that suggested a good degree of understanding. Interestingly, the only significant difference was observed in the bonus marks awarded to pharmacology students, where the stills group scored significantly lower that their classmates who watched the full animation. However, when combining total marks or bonus marks for both classes, we observed no statistically significant difference. All students were at exactly the same point in their level 3 courses and were tested on the same day. All had completed the same prerequisite courses in level 2 and could be assumed to have attended (or had access to) the same cardiovascular-based lecture material before the day of the test. No advanced warning was given about the content of the test presentation. Students watched the presentation only once and were then given 8 min to answer a question. Preliminary tests on an identical but smaller group (18 level 3 physiology and pharmacology students, with 9 students/group) the previous year confirmed that 8 min was sufficient to fully answer the question. Therefore, every effort was made to ensure that all 54 students would have as close as possible to the same prior knowledge on the day of the test.

We can conclude that in this style of presentation (i.e., a single viewing followed by testing) there is no gain in learning by having animated pictures. Alternatively, the cognitive loading of the presentation may have been too high, such that animation resulted in cognitive overload (discussed below).

Our original hypothesis was that students would prefer an animated presentation and that their learning would be enhanced by it. However, it has previously been reported that static images worked just as well as animation (13). These authors examined the illusion of understanding, which is the idea that students will invest less cognitive effort when viewing an animation that appears to be easier to understand. Their study confirmed that representational animations had a negative effect on learning. Our study used an animation that used elements of both representational and directive animations. The representational aspect showed the working of a nerve-muscle junction, whereas the directive element was controlled by varying camera paths and angles within the 3-D scene. However, it appears that by combining these animation types, we have failed to make an improvement over static images. As such, our results are in line with the illusion of understanding hypothesis (13) as the student feedback suggests more of a learning gain than was actually observed. Our results also support the view that animation per se will not necessarily enhance learning as this is dependent on a broad range of factors involving instructional design, cognitive loading, and learner knowledge (17).

**Multimedia design.** It has been reported that among life science (physiology) students, male students prefer multimodal learning, whereas female students prefer a single-mode kinesthetic style of learning (19). Animations of the type used in this study do not fit easily within one category of the visual, auditory, read/write, and kinesthetic (VARK) model of learning type and probably touches on all four. On the basis that male and female students express a variety of preferences for learning styles, it is important to account for a range of learning styles when designing new delivery methods.

Multimedia learning places high cognitive demands on the learner. This has been broken down into three cognitive processes: essential processing, incidental processing, and representational holding (9). For instructional animations, essential processing represents the selection and processing of words and pictures. The background music would represent incidental processing. Representational holding would be the process of retaining mental images from early parts of the animation to create (or maintain) the context. Future work must therefore take account of multimedia theory and examine methods of reducing cognitive loading by moving some “essential processing” from the visual channel to the auditory channel, segmenting the animations into bite-sized clips, using auditory signals (sound effects) to provide cues for processing visual material, etc. These general conclusions have also been drawn from previously published studies (15).

The complex nature of threshold concepts (12) in physiology and the detailed anatomic structure of our 3-D scenes may represent a significant intrinsic load. The extraneous cognitive load of both presentations was also significant in the sense that each had an audio commentary with detailed, complex, and to them “new” concepts and vocabulary, on-screen text (although limited), and background music. Giving control of some extraneous parameters to the learner (as requested by some students in the
present study) might be expected to reduce extraneous cognitive load and enhance learning. Interestingly, though, a 2009 review of animations in medical education cited an example where higher learner control actually decreased learning (17). A more recent study (18) found that compared with extraneous cognitive load, learner control had more effect on germane cognitive load. The interaction of the three categories of cognitive load theory therefore requires further study in relation to animation design.

On reflection, we feel that our animation could have been better designed and may partially account for the low scoring across both groups. In a study on the ways in which to reduce cognitive load in multimedia learning (9), it was suggested that lowering the incidental processing should be a consideration. In our study, removing the background music would be our obvious first step.

**Student feedback.** Analysis of the student feedback on multimedia in teaching and learning revealed four main themes that emerged: 1) learning preferences, music, and voiceover; 2) pace, repetition, and rewriting; 3) use for studying; and 4) visualizing, complexity, and understanding. These issues are clearly important to students and should therefore be considered when designing multimedia resources for teaching. There were no discernible differences in the type or number of comments made between any combination of groupings (physiology, pharmacology, stills, or animation), reflecting that learning is an individual experience and that different learning styles exist. Interestingly, while there was an overall preference for animations over stills as expressed in the comments, this was not reflected in student test scores, which were broadly similar between groups, at least as measured immediately after viewing. Future studies may also investigate any effect of varying this time interval.

**Future consideration.** With the trend toward online delivery of teaching materials as well as the availability of powerful hardware and software, we predict a continued growth in the use of animations for teaching purposes. We therefore suggest a pressing need for further investigations into the optimal design of educational multimedia animations for teaching physiology. A recent review that evaluated the effectiveness of >400 existing animations found that many animations did not follow the principles recommended for multimedia learning, and the authors suggested that empirical studies are required to establish which animations are effective for learning rather than relying on what intuitively may seem effective (20). The present investigation provides one such empirical study, and further work will include repeating our experiments with larger sample sizes and then creating and testing animations with a range of cognitive loads. A key question is whether it is possible to optimize learning by matching the appropriate cognitive load with spatial ability and, if so, could this “matching” be automatic or should it be learner controlled?

We believe a particular strength of our work is the use of real microscopic images, collected from years of confocal microscopy research in blood vessels and other tissues. Most animations currently are artists’ impressions; however, the potential to create teaching animations from actual research data is exciting, and such banks of images represent an untapped or underused resource. At present, our intention is to build fairly short 3- to 4-min animations, which would serve as lecture summaries and revision tools.

In conclusion, 3-D animations were well received by our students, who are keen to see further developments in this area. However, to avoid the illusion of understanding, great care needs to be taken in the design of instructional multimedia presentations. In particular, attention should be paid to reducing extraneous cognitive load and incidental processing.

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**DISCLOSURES**

No conflicts of interest, financial or otherwise, are declared by the author(s).

**AUTHOR CONTRIBUTIONS**

Author contributions: C.J.D., J.B., and M.M. conception and design of research; C.J.D. and J.B. performed experiments; C.J.D. prepared figures; C.J.D. drafted manuscript; J.B. and D.A. analyzed data; M.M. and D.A. interpreted results of experiments; M.M. and D.A. edited and revised manuscript.

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