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

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Abstract

Sophisticated 3D 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 have investigated the use of animated images versus still images by creating two versions of a 4 minute multimedia presentation on vascular neuroeffector transmission. One version comprised narration and animations whilst the other comprised narration and still images. 54 undergraduate students from level 3 pharmacology and physiology undergraduate degrees participated. Half 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 (SEM 0.4) (out of 11) whilst the 'stills' group scored 3.2 (SEM 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 (SEM 0.2) vs 0.1 (SEM 0.1) for animation vs stills respectively, $p=0.04$. However, when combined with the physiology group the significance disappeared. The feedback from students was extremely positive and identified four main themes of interest. In conclusion, whilst increasing student satisfaction, we do not find strong evidence in favour of animated images over still images in this particular format. We discuss the study design and offer suggestions for further investigation of this type.

Introduction.

The value of using computer-generated animations for teaching has been appreciated for over 20 years (8). Interestingly, in their 1994 publication, Lilienfield & Broering state 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. anatomical accuracy (the reality) should be preserved). This general view is supported by a study using interactive animations for teaching molecular chemistry (4). 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 3D models/animations would be a better teaching tool than static images or diagrams. A combination of hand held 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 3D visualisation for protein folding (using the 'Foldit' computer game). Therefore, many students are arriving at university with experience of using computer-based animation and 3D visualisation.

We have noted that many medical animations currently present on YouTube.com are very artistic but often bear little relation to reality. Whilst our animations are partly artistic, they are set within an anatomically accurate 3D 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 has shown that certain animation styles may not improve learning but simply create an '*illusion of understanding'* (13).

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 favour 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 organises words and pictures within the confines of a very limited working memory. Integration with the 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 and background music etc. Therefore, transfer of an unlimited-overload of information to an unlimited-capacity long term memory via a severely limited conduit (i.e. working memory) creates a problem.

Recognising the importance of cognitive load theory (CLT) in presentation design is fundamental to the success of multimedia as a learning tool. CLT is presented as 3 components; extraneous, intrinsic and germane (14). Extraneous cognitive load (ECL) describes the method of delivery (e.g. does the learner have control? Is all the material relevant?). Intrinsic cognitive load (ICL) refers to the complexity of the topic to be learned (e.g. are there multiple interacting elements in the subject matter). Germane cognitive load (GCL) is felt at the interface between working memory and long term memory where mental 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 the extraneous and germane loads. Within a multimedia context, at least 9 ways of reducing load have been identified and described (9). A recent study employed a low cognitive load animation, in order to reduce misconceptions (6), and in reviewing a themed journal issue on the cognitive loading of animations, different authors conclude that CLT has a significant part to play (1). These authors also encourage 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 have investigated the use of multimedia presentations in the teaching of complex topics in cardiovascular science. Our original hypothesis was that using real data of 3D 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 3D models of the vascular wall. These models were then ported to sophisticated modelling software to create 3D animations which were composited to create a 4 minute 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 this study we have compared two instructional multimedia presentations. One version of the presentation employed moving images whilst the other used only static (still) images. The audio commentary, background music and on-screen text were identical in both presentations. 54 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.

This study was carried out with students from the University of Glasgow (GU; a large research-intensive university in Scotland, established in 1451 and part of the Russell Group of Universities). GU comprises four Colleges, with students from the School of Life Sciences (in the College of Medical, Veterinary and Life Sciences (MVLS)) 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 programmes in physiology and pharmacology).

Recruitment: Prior to recruiting any students, a full project proposal was approved by the MVLS College Ethics Committee. 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. Following 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 3rd year pharmacology undergraduates and the other had 28 3rd 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: 3D laser Scanning Confocal Microscopy (LSCM) data was collected on a Biorad Radiance 2100 using Lasersharp software. The 3D data was segmented in AMIRA and imported into Autodesk MAYA. Multiple 3D animation scenes were rendered in MAYA and composited in Adobe AfterEffects (3). Background music and audio commentary was 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 four minute full 3D animation on vascular neuroeffector transmission was created using a previously published technique (3) and briefly described above. An additional 4 minute movie was created using 17 still frames from the 3D animation and containing the same audio commentary and soundtrack (see examples in Figure 1a). Third year physiology and pharmacology students were split into two equal groups and shown either the ‘3D animation’ or ‘stills’ presentation. A previously unseen question (8 minute, short essay style, Figure 2) was then attempted by both groups. The question was part *retention* and part *transfer test*. The *retention* component of the answer required an anatomical 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 (JB), who had no knowledge of the groupings. A marking scheme was devised where both ‘essential information’ (core marks) which we anticipated would be required in order 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 ½ marks were awarded per item. Total marks and bonus marks were analysed separately. All marks are presented as mean values with standard deviation (SD) and standard error of the mean (SEM), calculated using Graph Pad Prism.

Following the animation test, students were asked to reflect on the experience and to offer comments, by answering the open-ended question *“What are your thoughts on the use of multimedia/animations for teaching and learning?”* 49 of the 54 students answered this and their comments were analysed using a simplified version of content analysis (16). Responses were first transcribed into a single text document, which was read through a few times to get a general idea of points raised by the students. Phrases relating to points of a similar category were then highlighted with a particular colour throughout the document. This facilitated identification of the broad general categories commented on, including pace, enjoyment, Comments were then grouped together by “colours” (categories) to gain a more detailed breakdown of each theme.

Statistics. An Unpaired T-test was used to compare scores between groups. Graph Pad Prism was used for all statistical tests.

Results.

Animation tests. 54 Students (two groups of 27) viewed a 4 minute 3D animation or stills presentation (Figure 1). A short 8 minute essay question was then attempted (Figure 2). Answers were marked on scale of 0-11. Comparing the mean scores of all students viewing the animation (3.7) versus all students viewing the stills (3.2) presentation revealed no statistically significant difference (Table 1). Within the individual pharmacology and physiology classes there was also no statistically significant difference in overall scores (Table 1).

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 watching 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. 49 of the 54 students (91%) offered feedback in response to the open question, ‘What are your thoughts on the use of multimedia/animations for teaching and learning?’ 88% (43/49) of the comments were favourable, and four main overall themes were identified from the students’ responses: (i) Learning preferences, music, voiceover; (ii) Pace, repetition, re-watching; (iii) Use for studying and (iv) Visualising, complexity, understanding. This feedback is discussed in more detail below.

Discussion.

The results of previous studies of the effectiveness of multimedia as a learning tool are mixed and can depend largely of the study design (15). However, on balance, a Meta-Analysis found that a multimedia approach can improve learning gains (15). In the current study we have used one of the most sophisticated, industry standard, 3D animation packages available (Autodesk Maya) to create a multimedia presentation of 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 construction of animations. The Autodesk products are free for educational purposes and are compatible with our 3D-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 vs Animated images.

We have investigated the use of animated vs static (still) images, within a multimedia presentation, for the delivery of complex material in teaching cardiovascular science. Our method of creating anatomically accurate 3D scenes from confocal microscopy data has speeded the animation process (3) and reduced the chance of perpetuating misconceptions (4). However, the value of 3D 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 (Figure 2). We recognised 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 which 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 the pharmacology students where the stills-based 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 pre-requisite courses in level 2 and could be assumed to have attended (or had access to) the same cardiovascular-based lecture material prior to 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 minutes to answer a question. Preliminary tests on an identical, but smaller group (18 Level 3, physiology and pharmacology students; 9 in each group) the previous year confirmed that 8 minute 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 which employed elements of both *representational* and *directive* animations. The *representational* aspect showed the working of a nerve-muscle junction whilst the *directive* element was controlled by varying camera paths and angels within the 3D 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 is 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 whilst female students prefer a single-mode kinesthetic (K) style of learning (19). Animations of the type used in this study do not fit easily within one category of the VRAK model of learning type (Visual, Auditory, Read [textual], Kinesthetic) 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, 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 in order 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 anatomical structure of our 3D scenes may represent a significant intrinsic load. The extraneous cognitive load (ECL) 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 ECL and enhance learning. Interestingly though, a 2009 review of animations in medical education cites an example where higher learner control actually decreases learning (17). A more recent study found that compared to ECL, learner control had more effect on germane cognitive load (18). The interaction of the three categories of CLT 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 is 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 emerging: (i) Learning preferences, music, voiceover; (ii) Pace, repetition, re-watching; (iii) Use for studying and (iv) Visualising, complexity, 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, 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 their 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, and 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 evaluating the effectiveness of over 400 existing animations found that many animations did not follow the principles recommended for multimedia learning, and the authors suggest 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, then creating and testing animations with a range of cognitive loads. A key question is whether it is possible to optimise learning by matching 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 under-used resource. At present, our intention is to build fairly short 3-4minute animations which would serve as lecture summaries and revision tools.

In conclusion, 3D animations were well received by our students who are keen to see further developments in this area. However, in order 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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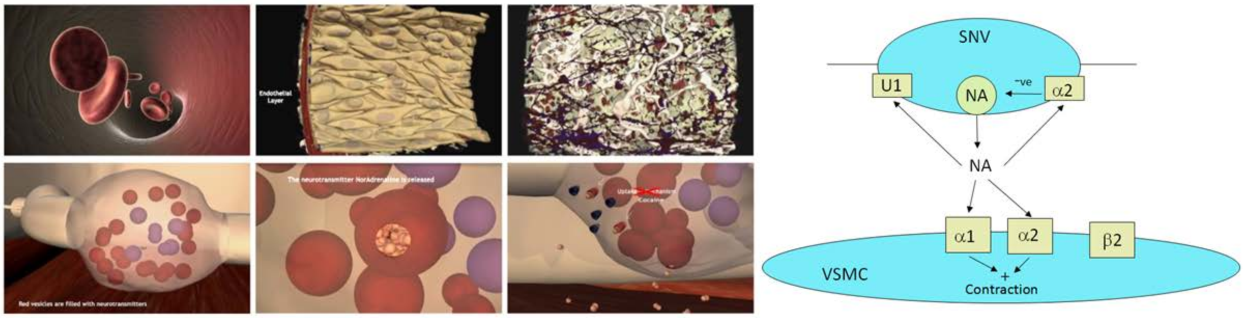
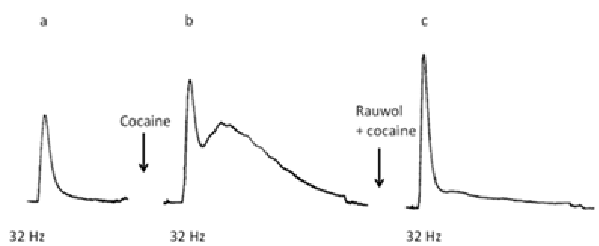


Figure 1. Still images from a 4 minute animation describing sympathetic neurotransmission in the vascular wall. These images are taken from the set of 17 used in the finals 'stills' animation. The full animation can be viewed online at [www.cardiovascular.org/animations.html]. The diagram (right) is 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).

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.

Figure 2. Immediately after viewing the 4 minute presentation, students were asked to answer a question which tested their understanding of the presentation. By showing the responses of an isolated blood vessel to nerve stimulation the students would have to infer from their knowledge rather than relying on recall as the answer was not explicitly given in the presentation.

Table 1. Test scores for Level 3 pharmacology (pharm) and physiology (phys) student groups viewing either a fully animated multimedia presentation (Animation) or a still-image-based (Stills Only) presentation. Test scores were marked 0-11 and unlimited 0.5 mark bonuses were awarded as described in the text. A significant difference (*, p=0.04) was detected in the bonus marks awarded to the pharmacology stills group vs the pharmacology animation group.

		Animation (All)	Stills Only (All)	Animation (Pharm)	Stills Only (Pharm)	Animation (Phys)	Stills only (Phys)
Test Scores	Mean	3.7	3.2	3.9	2.8	3.5	3.5
	SD	2.2	2.4	2.1	1.9	2.3	2.7
	SEM	0.4	0.5	0.5	0.5	0.6	0.7
Bonus Marks	Mean	0.6	0.4	0.6	0.1*	0.7	0.6
	SD	0.7	0.6	0.7	0.2	0.6	0.8
	SEM	0.1	0.1	0.2	0.1	0.2	0.2