Animation and learning: Value for money?

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Animations are increasingly used in technology-based learning resources because of their assumed superiority over static graphics. However, empirical research has failed to provide evidence for such superiority. Recent investigations suggest that benefits from educational animations are not achieved because of the way learners process the presented information. It appears that current intuitive approaches to the design and use of animations can be ineffective because they do not take account of the information processing challenges posed for learners. New approaches using principled design guidelines based on research into perceptual and cognitive processing are required to fulfil animation's educational potential.

Keywords: Animation, cognitive processing, instructional design

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Introduction

Many disciplines taught in universities deal with dynamic subject matter. Students of these disciplines are required to learn about sophisticated natural, social, or technological systems that change over time. However, the complexities of the change involved are often difficult to understand if presented verbally or numerically. Increasingly, graphic representation is favoured as a way of addressing such difficulties. The graphic emphasis in many of the electronic learning resources used in university teaching today contrasts markedly with the far greater reliance on verbal and numerical information in former times. A distinctive feature of the more recent resources is their use of animations. Computers now make it possible for even those with a rudimentary technical background to produce highly interactive forms of animation that give users extensive control over the way subject matter is presented. Nevertheless, animations will remain more time-consuming and expensive to produce than their static predecessors. In an era of contracting university budgets and expanding accountability requirements, do the educational benefits of using animations warrant their additional costs?

Roles of animation in learning

Current educational use of animation suggests two main underlying assumptions about their role in learning. Firstly, many animations are apparently used to fulfil an *affective* function, that is, to attract attention, engage the learner, and sustain motivation. Affectively-oriented animation often portrays activity that is humorous, spectacular, or bizarre but that may have little to do with facilitating comprehension of the subject matter itself. In tertiary education, animations are more likely to be used for a second and very different purpose; to fulfil a *cognitive* function. In this role, animations are intended to support students' cognitive processes that ultimately result in them understanding the subject matter. The main focus of this paper will be upon animation's potential to play this cognitive role.

Benefits of animation

The current explosion in use of animation reflects the conviction of many educational practitioners that it benefits learning. In some cases, this conviction is based upon a naïve view of the power of animation's affective characteristics. Other advocates for animation promote its potential benefits for information processing. They believe that it can help make difficult content easier to understand, particularly if the subject matter is dynamic; animations should be superior to static graphics in depicting dynamic content because animations can portray the dynamics *explicitly*. Static depictions must rely on added symbols to indicate temporal change indirectly (arrows, dotted lines, etc.). However, the adding these ancillary graphics produces a more cluttered visual display that learners may find daunting. Further, in order to understand static representations of dynamic situations, the learner must interpret these ancillary symbols correctly and then 'mentally animate' the depiction in an appropriate fashion (Hegarty, 1992). This is a cognitively demanding task because static graphics only imply dynamics without fully specifying them.

As a consequence, there is potential for learners to make errors when attempting to infer the actual dynamics from an impoverished static depiction. In contrast, animations do not require the learner to perform mental manipulations of the display material because the depicted situation's dynamics are available to be 'read off' directly. A learner's processing resources can thus be devoted to the central task of understanding the content rather than being diverted to generating and running an internal dynamic mental model from a static external representation. For learners who otherwise lack the capacity to carry out the necessary cognitive processes on the basis of a static depiction alone, animation can have an *enabling* effect. However, animation can also benefit learners who already possess the necessary capacity but who could process the information more readily if its dynamic aspects were presented explicitly. In this case, animation is described as having a *facilitative* effect (Schnotz & Rasch, in press).

Is animation superior?

Despite the plausibility of cognitively-based arguments for the benefits of animation, research to date has failed to provide unequivocal evidence that it is superior to static depiction (Tversky, Morrison, & Betrancourt, 2002). In some case animations may even prejudice learning (Lowe, 2001; Schnotz, Böckheler, & Grzondziel, 1999). Given the amount of time and money increasingly devoted to using animations in educational materials, this should be of great concern to developers. Evidence is beginning to accumulate that designing educationally effective animations may require a far more sophisticated approach than is found at present. Currently, educational animations are designed largely on the basis of intuition. This approach does not systematically address the complexities of how learners actually deal with dynamic explanations (see Schnotz & Lowe, 2003). Recent fine-grained studies indicate that the reasons why animations can be much less educationally effective than expected may lie in the way learners process the presented information (Lowe 2003, 2004). Two distinct types of problems have been suggested: *overwhelming* and *underwhelming* (Lowe & Schnotz, in press). The first of these is thought to arise if presentational characteristics of the animation are such that the learner is unable to process the available information effectively under the prevailing conditions. For example, if the animation presents a complex set of information very rapidly, the learner may be overwhelmed by the flux of information and so be unable to keep pace with its delivery. There is a mismatch between the way in which the animation delivers information on one hand, and the learner's capacity to process it effectively on the other.

Underwhelming can be thought of as the converse of overwhelming: the animation leads to the learner being *insufficiently* engaged so that the available information is under-processed. Because animations can provide a direct depiction of the changes involved in a dynamic system, learners need do no more than observe these dynamics as they are portrayed. There is no need to carry out the intensive mental manipulations required for a static depiction of the same situation. It may be that by making change processes directly visible, the explicit external depiction provided by animations can give learners a false impression that they understand what is going on. However, students with higher cognitive capabilities are likely to be able to fulfil the demands required for understanding the subject matter without external support for mental simulation. For these students, animation can save them from having to perform beneficial learning-relevant cognitive processes on their own (Schnotz & Rasch, in press). Using animations with students who can cope without them runs the risk of engendering superficial processing that may actually inhibit their learning.

Why animation can be demanding

The entertainment industry has built up enormous experience in how to produce 'successful' animations, that is, animations to attract an audience. This situation contrasts markedly with that in education where the goals are very different and where there is little tradition of using animation to foster learning. As a consequence, guidance is lacking about how to design animations that are specifically educational and that depend on effective perceptual and cognitive processing of information. The main concern of animators who work for the entertainment industry is obviously to entertain; they are unlikely to consider their role to be one of helping people build coherent understandings. However, the development of understanding is a primary goal of educators who use animation to explain their subject matter.

Current educational animations typically offer what can be termed a 'behaviourally realistic' depiction; they portray a situation's dynamics in a relatively straightforward analogue fashion. The learner is presented with a continuous flow of changing information that maps quite directly onto changes that occur in the referent situation. Thus a student who understands the animation will also understand the actual situational dynamics. However, the same distinctive characteristics that allow animation to make the dynamics of a situation explicit may also pose various information processing challenges to learners. These processing challenges are not present with a static graphic and include (i) the amount of information presented (animations present multiple frames instead of a single frame of information), (ii) the very limited availability of that information (each frame must be quickly replaced by the next to sustain the dynamic effect, (iii) the need to integrate spatially disparate changes (events are distributed across the display area), (iv) the requirement to remember information presented on previous frames (successive frames overwrite their predecessors so they are no longer available). If the subject matter is somewhat difficult and unfamiliar to the learner (a popular context for the use of animation), the processing load from a behaviourally realistic animation may exceed the learner's capacity to deal with the information being presented (Lowe, 2001). In order to sustain processing in this potentially overwhelming situation, it appears that learners adopt selective strategies that have the effect of reducing their load. However, this can result in relevant information being neglected because learners make inappropriate selections of what to attend to and what to ignore.

Addressing animation's demands

The behavioural realism of today's educational animations contrasts starkly with the highly *un*realistic treatment of the static graphics used in education. The latter are the result of the development and refinement of many powerful explanatory graphic techniques evolved over hundreds of years. *Visuospatial* techniques such as cross-sections, exaggeration, and visual highlighting are routinely used in static graphics to reveal and simplify. However, no corresponding set of *temporal* manipulations has yet been developed to enhance the educational effectiveness of animations and reduce information overload.

One approach suggested for tackling this overload is to give learners control over the animation (Hegarty, Narayanan, & Freitas, 2002). For example, a set of video-like controls allows learners to vary characteristics such as the speed, direction, and continuity of the presentation and so better match presentation to their own information processing capacities. However, studies of the strategies learners invoke when interrogating a user-controllable animation indicate that the actions they take to make the animation more tractable may actually result in the neglect of information that is highly relevant to the learning task (Lowe, 2003, 2004). Because the learners participating in these studies lacked expertise in the depicted domain (meteorological charts), they were apparently unable to select appropriate subsets of the information provided by the animation. This was attributed to their lack of background knowledge about the meteorological domain and a resulting dependence on perceptual characteristics rather than thematic relevance. Being unaware of the relative importance of different aspects of the presented information, they often looked in the wrong spatial or temporal locations within the animation and failed to detect key attributes of the display.

Towards more effective educational animation

While providing learners with extensive user control radically changes the opportunities learners have for interacting with the animation's information set, it cannot change what they bring to learning situation. Sufficient background knowledge about the depicted content appears crucial for being able to take proper advantage of such control. This suggests that animation needs to be well designed and supported if it is to fulfil its undoubted educational potential (see Lowe & Pramono, 2003). A systematic approach to animation development should be founded on research-based educational design principles; creative intuitions are insufficient. Approaches to the design of educational animations need to progress beyond the current adherence to behavioural realism. A repertoire of principled techniques is required that provide ways of manipulating content for the benefit of learners.

Research into how people learn from animations is beginning to indicate what types of visuospatial and temporal manipulations may help to improve their educational effectiveness (Lowe, in preparation). A key issue is how a learner's information processing load can be kept within the limits of available processing capacity while ensuring that what is provided remains highly relevant to the learning task. One approach that learners were found to employ when interrogating a user-controllable animation was extended pausing of the presentation on specific single frames (Lowe, in preparation). During these pauses, learners analysed the visuospatial structure of the material in the frame, something that can be difficult to do when a display is continually changing. Unfortunately, they rarely chose to pause on the frames that were of most relevance to their learning task. The findings from this investigation suggest that learners were comfortable with modifying the animation's playing characteristics so that it no longer presented its information in a behaviourally realistic manner. Unfortunately, in terms of the set learning task, the way in which they implemented these modifications was usually relatively ineffective. A possible implication from these findings is that user control of animations needs to be guided to some extent so that learners' interrogation strategies are more productive. Designers of educational animations would then have the responsibility to consider which portions of the total dynamic sequence may be more effective if presented as static frames rather than in animated form. Learners could be directed towards these portions and given guidance as to the aspects warranting particular attention. Modifications of this type that help provide learners with more powerful explanations could greatly improve the educational effectiveness of animations. This advance requires animation designers to progress beyond the current preoccupation with behaviourally realistic depictions to more interventionist approaches that really are able to provide educational value for money.

References

Hegarty, M. (1992). Mental animation: Inferring motion from static diagrams of mechanical systems . *Journal of Experimental Psychology: Learning, Memory and Cognition, 18,* 1084-1102.

Hegarty, M., Narayanan, N.H., & Freitas, P. (2002). Understanding machines from multimedia and hypermedia presentations. In J. Otero, J.A. Leon, & A. Graesser (Eds.), *The psychology of science text comprehension* (pp. 357-384). Hillsdale, NJ: Lawrence Erlbaum.

Lowe, R. K. (2001). Understanding information presented by complex animated diagrams. In J.F. Rouet, J. Levonen & A. Biardeau (Eds.), *Multimedia learning: Cognitive and instructional issues* (pp. 65-74). Amsterdam: Elsevier.

Lowe, R.K, & Pramono, H. (2003, August). *Design features and the effectiveness of instructional animation.* Paper presented at the 10th European Conference for Research on Learning and Instruction, Padua, Italy.

Lowe, R.K. (2003). Animation and learning: Selective processing of information in dynamic graphics. *Learning and Instruction*. *13*, 157-176.

Lowe, R.K. (2004). Interrogation of a dynamic visualisation during learning. *Learning and Instruction, Special Issue on Learning with Dynamic Visualisations*.

Lowe, R.K., & Schnotz, W. (in press). Les animations: aspects cognitifs et perceptuels. To appear in J-F Boucheix (Ed.), *Les animations graphiques et les technologies pour l'apprentissage* P.U.F: Presses Universitaires de France, Paris.

Lowe, R.K. (in preparation). Learning from animation: Where to look, when to look. To appear in R.K. Lowe & W. Schnotz (Eds.), *Learning with animation: Research and implications for design*. New York: Cambridge University Press.

Schnotz, W, & Rasch, T. (in press). Enabling, facilitating, and inhibiting of animation in multimedia learning: why reduction of cognitive load can have negative results on learning. To appear in Educational Technology Research and Development.

Schnotz, W., & Lowe, R.K. (2003). External and internal representations in multimedia learning. *Learning and Instruction*. *13*, 117-123.

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