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Relative effectiveness of animated and static diagrams: An effect of learner prior knowledge

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Abstract

This paper investigates the relationship between instructional effectiveness of animated vs. static diagrams and levels of learner expertise in the task domain of transforming graphs of simple linear and quadratic functions. It was demonstrated on many occasions that instructional formats that are effective for low-knowledge learners could be ineffective, or even deleterious, for high-knowledge learners, and vice versa (the expertise reversal effect). The levels of learner (university students) expertise in this study were measured using an online rapid diagnostic method, a rapid verification technique, that involves presenting learners with a series of possible solution steps reflecting various stages of the solution procedure and asking them to rapidly verify the suggested steps. The results indicated a significant interaction between levels of learner expertise and instructional formats. Novice learners benefited more from static diagrams than from animated diagrams, while more knowledgeable learners benefited more from animated rather than static diagrams. A theoretical explanation of the effect is suggested within the framework of cognitive load theory.

Keywords: Animations; Learner prior knowledge; Expertise reversal effect; Diagrams; Learner-tailored instruction

A number of recent studies have demonstrated significant interactions between levels of learner expertise and instructional methods. According to the expertise reversal effect, instructional techniques and procedures that are effective for novice learners may become ineffective, or even harmful, for more experienced learners, and vice versa. The effect was

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demonstrated with such diverse instructional techniques as embedding textual explanations into diagrams to reduce learner split attention; using narrated verbal explanations synchronized with animated diagrams; providing learners with detailed worked-out examples of problem-solving steps, etc. (see Kalyuga, 2005, 2006b; Kalyuga, Ayres, Chandler, & Sweller, 2003 for overviews). The major instructional implication of the effect is the need to tailor the selection of instructional methods and the design of learning environments to changing levels of learner expertise.

The effect was explained within the framework of cognitive load theory (see Van Merriënboer & Sweller, 2005, for a recent overview) by considering processing limitations of our cognitive architecture and the role of organized knowledge base in human learning and performance. Our working memory is severely limited in duration and capacity when dealing with unfamiliar information (Baddeley, 1997; Miller, 1956; Peterson & Peterson, 1959). However, in familiar domains, the available knowledge base in long-term memory allows us to encapsulate large amounts of information in larger chunks that are treated as single elements, thus reducing working memory limitations. Human learning and performance alter significantly with the development of expertise in a domain. In the absence of relevant prior knowledge, novices have to deal with many novel elements of information that may easily overwhelm working memory capacity. Therefore, without considerable external instructional support, they may experience significant cognitive overload. On the other hand, if such detailed instructional support is provided for more experienced learners, the process of reconciling the related components of their available knowledge structures in long-term memory and externally provided guidance would likely to require additional working memory resources and could also increase unnecessary cognitive load. Consequently, less capacity could be available for new knowledge acquisition and performance improvement.

Animations have long been regarded as an essential part of new computer-based instructional technologies. There are serious theoretical and cognitive arguments in favor of greater effectiveness of animated rather than static images, and corresponding principles for designing and using animation in instruction (e.g., Mayer & Anderson, 1992; Reed, 2005; Rieber, 1990; Weiss, Knowlton, & Morrison, 2002). However, existing research literature does not provide compelling and clear empirical evidence about educational advantages of animations over static graphics. Some existing reviews concluded that animations are no more (and sometimes less) effective than the equivalent static graphics (e.g., Hegarty, Kriz, & Cate, 2003; Tversky, Morrison, & Betrancourt, 2002). The transient nature of animations and limited duration and capacity of working memory could be the major reason for these failures of animated instructions to demonstrate clear advantages (Chandler, 2004; Lowe, 1999).

When learning from animations, many new elements of information may need to be processed in very limited time. New information can be hold in working memory for no more than few seconds (unless rehearsed). In order to construct an integrated mental representation of novel material in working memory, a learner needs to hold information from earlier frames of the animation while attending to the following frames. If the next frame is processed before the information from the preceding frames is incorporated into an organized knowledge structure, new information may interfere with the earlier information. Cognitive demands of processing new information while holding previous information in working memory could overwhelm working memory resulting in cognitive overload. In contrast, static graphics do not create such transitivity problems, because elements of still pictures can be revisited any required number of times.