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Does animation enhance learning? A meta-analysis

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ABSTRACT

This meta-analysis investigated whether animation is beneficial overall for learning compared to static graphics, while also identifying moderator factors affecting the global effect. A systematic search was conducted for experimental studies comparing the impact of animated vs. static graphics displays in the context of knowledge acquisition. A total of 50 papers were considered, and consecutively 61 primary studies (N = 7036), yielding 140 pair-wise comparisons of animated vs. static graphic visualizations in multimedia instructional material were analyzed using a random-effects model. An overall positive effect of animation over static graphics was found, with a Hedges's g effect size of 0.226 (95% confidence interval = 0.12–0.33). Additional moderator analyses indicated substantial effect sizes when the animation was system-paced (g = 0.309), when it was coupled with auditory commentary (g = 0.336) or when the instruction did not include any accompanying text (g = 0.883).

1. Introduction

In the last two decades, increased computer capacities and expansive use of computers in learning situations have resulted in the tremendous development of multimedia instructions in initial or continuing education. One particular instance of multimedia instruction is animation, in which objects appear to move continuously. Animation is a term frequently used in literature, with a degree of uncertainty around its delineation. This paper will use the definition first suggested by Bétrancourt and Tversky (2000) who saw it as "any application, which generates a series of frames, so that each frame appears as an alteration of the previous one, and where the sequence of frames is determined, either by the designer or the user" (p. 313). As it conveys change over time, animation should be particularly beneficial for memorizing and understanding dynamic systems such as biological processes, natural phenomena or mechanical devices.

Though a vast number of studies have been conducted in the last decade to investigate the effect of animation on learning, there is little empirical evidence to support the hypothesis of the instructional benefit of animation. Literature reviews on studies comparing animated and static visualizations report inconsistent or inconclusive findings regarding the effect of animation on learning (Bétrancourt & Tversky, 2000; Hegarty, Kriz, & Cate, 2003; Moreno & Mayer, 2007; Schneider, 2007; Tversky, Bauer-Morrison, & Bétrancourt, 2002). In many studies, the animation condition did not significantly lead to better learning outcomes than the static condition. The explanations provided to account for the lack of difference were often highly speculative and rarely based on objective data. In other studies, the two conditions differ from each other relative to factors

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other than the visualization per se, such as an unequal amount of information conveyed by both displays, or non-equivalent procedures used in the conditions (Bétrancourt & Tversky, 2000).

Höffler and Leutner (2007) reviewed a large body of research on the instructional effectiveness of animation compared to static graphic displays, by conducting a meta-analysis of 76 pair-wise comparisons out of 26 studies, covering the period 1973–2003. The meta-analysis procedure allows the synthesizing of a large number of pair-wise comparisons. Its advantage over a qualitative review is that it standardizes findings across studies for direct comparison (Lipsey & Wilson, 2001). Results led to an overall beneficial effect of animation over static graphics, with a medium overall effect size of $d = 0.37$, and the identification of several moderating factors.

After a first phase in the 1990's where research focused on the comparison between dynamic versus static graphics in terms of learning outcomes, it became necessary to understand the mechanisms that would *explain* a differential learning effect (Hegarty, 2004b). This last decade has seen a shift in multimedia research towards assessing the conditions under which and the reasons why dynamic representation displays may improve or facilitate learning. Research now investigates the cognitive processes involved in processing dynamic visualization and the steps that lead to the comprehension of the content at hand, and ultimately to learning. Usually in multimedia research, learning refers to the construction of a mental model of the spatial, temporal and functional components of the dynamic content (Lowe & Boucheix, 2008; Narayanan & Hegarty, 2002; Schnotz, 2005). While the conditions of its instructional effectiveness are still unclear, the factors that influence the processing of animation have been largely identified. Three categories may be distinguished; those a) *specific to the learners*, such as their prior knowledge level (ChanLin, 1998; Kalyuga, 2008) and visuospatial ability (Hegarty & Sims, 1994; Lowe & Boucheix, 2009; Yang, Andre, & Greenbowe, 2003), b) *specific to the instructional material*, such as the type of dynamic changes within the animation (Lowe, 2003), its perceptual salience (Lowe & Boucheix, 2009; Schnotz & Lowe, 2003), the presence of accompanying information (Ginns, 2005; Moreno & Mayer, 1999; Tabbers, 2001) or the control over the pace of the animation (Fischer, Lowe, & Schwan, 2007; Mayer & Chandler, 2001), and *c) specific to the learning context* – e.g., the type of knowledge and the instructional domain (Bétrancourt & Tversky, 2000; Schneider, 2007).

By including recent studies and new moderator variables, this present meta-analysis will complement the first meta-analysis conducted on this topic by Höffler and Leutner (2007).

1.1. Instructional functions and cognitive processing of animation

Animations in instruction may be used for several purposes. Firstly, they can be used as an attention-gaining device, attracting learners' attention to a specific area of the instructional material. Animated cues or arrows fall in this category. Secondly, animation may be used as a demonstration of concrete or abstract procedures to be memorized and performed by the learner, such as tying nautical knots (Schwan & Riempp, 2004) or completing puzzle rings (Ayres, Marcus, Chan, & Qian, 2009). A third purpose of animation is to help learners understand the functioning of dynamic systems that change over time, with an analogous and continuous representation of the succession of steps, such as in the flushing system (Hegarty et al., 2003; Narayanan & Hegarty, 2002), or in lightening formation (Mayer & Chandler, 2001). The animations taken into account in this meta-analysis fall into this latter category. There are two reasons behind this choice. One is that these expository animations have been more frequently studied in the multimedia literature than other types of animation. The other is in their ability to support conceptual understanding.

Expository animations can serve three instructional functions (Hegarty & Just, 1993; Narayanan & Hegarty, 1998). First of all, they can convey the configuration of a system or a structure. In this case, animations depict how the parts or elements of a system are integrated or decomposed and give learners the "raw material for building hierarchically organized mental representation" (McNamara, Hardy & Hirtle, 1989; cited by Schnotz & Lowe, 2008, p. 313). Secondly, animations can convey the system dynamics, by explicitly representing the behavior or movement of its components (Schnotz & Lowe, 2003). Thirdly, animation can convey the causal chain underlying the functioning of dynamic systems. The understanding of the causal chain is favored by showing the temporal order of the events occurring within the system (Narayanan & Hegarty, 2002).

There are advantages as well as disadvantages to animation in comparison to static visualization. As concerns the positives of animation, an obvious advantage is its ability to directly depict the spatial organization of the elements (Bétrancourt, Bauer-Morrison, & Tversky, 2001). As changing information has to be inferred by learners from a series of static graphics, animation provides the direct visualization of the microsteps that are the *minute changes* occurring in a dynamic system, thus avoiding misinterpretation and cognitive overload (Bétrancourt et al., 2001; Tversky et al., 2002). Conversely, a series of simultaneously presented static graphics allows for the different states or steps within a depicted process to be consulted and compared, while they are never presented at the same time in an animation (Bétrancourt et al., 2001).

Current views on learning from multimedia information assume that after being selected and organized, information from different sources is integrated within a mental representation linking the new information with previous knowledge (Mayer, 2005; Schnotz, 2005). These processes occur in working memory and are demanding in terms of cognitive resources. Providing animation can lower cognitive demands since dynamic changes are directly perceived and do not have to be inferred. However, it is important as Tversky et al. (2002) recommend, that animations only depict changes that match the learning objectives and do not provide extra information. This helps learners build the conceptual model for which the animation was designed.