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). As the heterogeneity was high, moderator analyses were explored.

Keywords: meta-analysis; animation; static graphics; instructional design; teaching/learning strategies.

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. As it conveys change over time, animation should be particularly beneficial for memorizing and understanding dynamic systems such as biology 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 still no solid empirical evidence to support the assumption 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). In many studies, the animation condition did not significantly lead to better learning outcomes than the static condition.

This last decade has seen a shift in multimedia research towards assessing why and when 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. While the conditions of its instructional effectiveness are still unclear, the factors that influence the processing of animation have been clearly identified in the literature. Three categories may be distinguished; those a) *specific to the learners*, such as their prior knowledge level and visuospatial ability, b) *specific to the instructional material*, such as the type of dynamic changes within the animation, its perceptual salience, the presence of accompanying information or the control over the pace of the animation, and *c) specific to the learning - instructional context* – e.g. the type of knowledge and the instructional domain.

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 synthesizing a large number of pair-wise comparisons. Its advantage over a qualitative review is that it standardizes findings across studies for direct comparison. The results led to an overall beneficial effect of animation over static graphics and the identification of several moderating factors. By including recent studies and new moderator variables, this present meta-analysis will complement and update Höffler and Leutner (2007) research conducted on this topic. They identified seven variables as potential moderators: function of the animation, type of knowledge, instructional domain, type of animation support, level of realism, presence of accompanying text and signaling cues. We kept or redefined their moderators and added two other variables extensively studied in the last decade: control over the pace, and modality of the verbal commentary (if any). Owing the fact that the impact of individual differences in terms of prior knowledge and visuospatial ability can be observed at several levels, from pure information processing to strategic behavior, they deserve meta-analysis og their own (e.g. Höffler (2010)), and were not integrated in the present analysis..

Method

Starting with the studies selected in Höffler and Leutner's study (2007), literature search was expanded and updated by a systematic search for studies published up to December 2013, comparing animated versus static graphic displays of dynamic phenomena. This was done through the PsycInfo (1806–2013), ERIC (1966–2013), Francis (1984–2013), MedLine (1950–2013) and Psyndex (1945–2013) databases. The following keywords were searched: *animation, multimedia, multimedia animation, interactive animation, static graphic, multimedia learning, dynamic picture, static picture, dynamic visualization, computer animation, interactivity.* Based on eligibility criteria, 73 articles were selected for this review. Fourteen articles were excluded because we did not obtain the missing information. This reduced the number of articles to 50 and the number of experiments to 61.

Main Results

One hundred and forty effects (140) derived from 61 between-group experiments were extracted from these articles. The overall Hedges's g effect size showed a significant value 0.226 (p = < .001, 95% confidence interval (CI_{95}) 0.12–0.33). This result suggests that studying with animation when learning dynamic phenomena is beneficial compared to static graphic display. The overall test for homogeneity indicated heterogeneity across samples ($Q = 643.18$, df=139, $p <.001$; $I^2 = 78.38$), indicating that one of more moderator characteristics might account for this heterogeneity.

Regarding moderators, there is evidence that the pacing control of the display produced a significant effect on the animation effect ($Q_B = 8.921$, $p = .003$). The effect size when learning is system-paced, that is to say when learners had no control over the pace of the display, was statistically different from a light, a regular or a full pacing control of the display ($g = 0.309$, $Z = 4.637$, $p < .001$). With respect to the abstract quality of the visual representation, results indicate that the animation effect differs by types of representations ($Q_B = 6.357$, $p = .042$). The effect size within the iconic representations subgroup is statistically different from the abstract representation subgroup ($g = 0.245$, $Z = 3.598$, $p < .001$). Thus, learning with animations that employ iconic representations, namely realistic, photo-realistic or schematic pictures was more effective for participants than learning with abstract animated representation, such as analytic pictures or formal notations.

Discussion

The analysis of 140 pair-wise comparisons from the 61 studies taken into account indicated a weighted mean effect size of $g = 0.226$ (95% CI 0.12-0.33), which can be considered of small magnitude according to Cohen's rule of thumb (1988). As expected, instruction with animated visualizations yields higher learning gains than instruction with static graphics. With more than 7000 subjects included in this meta-analysis, the generalization of this study is stable. This study thus confirms and supports the findings of previous meta-analysis conducted by Höffler and Leutner (2007), who found an overall small-to-medium positive effect of animation of $d = 0.37$. The smaller effect size in our meta-analysis can be explained by the inclusion of 41 additional experiments in the analysis as well as the higher percentage of pair-wise comparisons (10% compared to 2,6 %) favoring static graphics. A comprehensive interpretation of this overall effect size can only be done by considering the moderating conditions. Interestingly, the abstraction quality of the visual representations, coded using the characterization proposed by Ploetzner and Lowe (2012), was clearly identified as a moderating factor (not considering the unavailable data comparisons). Indeed, studying animated iconic representations, such as schematic, realistic or photo-realistic pictures led to greater learning gains than studying animated abstract representations (analytical pictures, formal notation, symbols, charts, diagrams, graphs, or maps). These findings highlight the impact of the semiotic characteristic of the representations (Imhof, Scheiter, & Gerjets, 2007). An important finding of this meta-analysis is that animations that were system-paced, or in other words animations which provided no control over the pace, were more effective for learning than any modalities of learner-paced animations. Whereas the research reported inconsistent findings, with some studies showing a benefit of control, these findings are in line with other studies that found no benefit (for example Adesope & Nesbit, 2012). As such, a system-paced presentation, together with the transient nature of animation, frequently seen as a drawback, did not impede learners to study the current information while integrating the previous learning content. However, it is highly probable that the effect of pacing control interacts with other factors, like type of instruction, prior knowledge and/or modality of the accompanying information. While the present meta-analysis showed the overall positive effect of using animation compared to static graphics, it also showed that several factors acted as significant moderators, which explains why most studies could not find a significant benefit of animation over static graphics. An effort should be made to better describe our visualizations in papers, whether static or animated, for example in establishing a specific categorization of their functional and semiotic roles in instructional material.

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