Computers & Education 85 (2015) 1–13

Contents lists available at ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

Animations showing Lego manipulative tasks: Three potential moderators of effectiveness

Juan C. Castro-Alonso [a, *], Paul Ayres [a], Fred Paas [a, b]

[a] School of Education, University of New South Wales, Australia
[b] Institute of Psychology, Erasmus University Rotterdam, The Netherlands

ARTICLE INFO

Article history:
Received 23 July 2014
Received in revised form
22 December 2014
Accepted 26 December 2014
Available online 14 February 2015

Keywords:
Animation–static comparison
Transient information
Embodied cognition
Lego manipulative task
Virtual and physical learning environment

ABSTRACT

Evidence suggests that transient visual information, such as animations, may be more challenging to learn than static visualizations. However, when a procedural-manipulative task is involved, our evolved embodied cognition seems to reverse this transitory challenge. Hence, for object manipulative tasks, instructional animations may be more suitable than statics. We investigated this argument further by comparing animations with statics using a Lego task shown to university students, by examining three potential moderators of effectiveness: (a) the environment of manipulation (virtual or physical), (b) the quality of visual information (focused or unfocused), and (c) the presence of hands (no hands or with hands). In Experiment 1 we found an advantage of animation over statics, and no differences among the environments. In Experiment 2, we again observed an animation advantage, a small advantage of focused static information compared to unfocused static information, and a positive effect of not showing the hands.

1. Introduction

Research into the effectiveness of instructional dynamic visualizations (e.g., animation and video) has been extensive. A common strategy has been to compare animated presentations with static equivalents, with the desired aim of showing that dynamic visualizations are the superior format. Even though some domains most conducive to learning from animations and videos have been identified (see Höffler & Leutner, 2007; van Gog, Paas, Marcus, Ayres, & Sweller, 2009), research has frequently produced mixed outcomes and identified a number of moderating variables (see Tversky, Morrison, & Betrancourt, 2002). Consequently, there is still much to be done in order to understand and identify the multitude of factors that impact on the effectiveness of instructional animations.

With the current study we aimed to extend the research comparing animated with static presentations by using a manipulative task (Lego bricks), which required the memorization of its final position (object memorization task). We also examined some of the moderating variables that could impact on the effectiveness of both the visualization and the execution of the manipulative task. In particular, we investigated two visualization moderators: (a) the presence of an embodied element (hands), and (b) the quality of visual information shown. We also studied one moderator for the execution of the task: whether it was performed in a virtual or in a physical environment.

1.1. Animated versus static instructional visualizations

There has been much expectation that animated visualizations should provide a more effective learning environment than static presentations (see Chandler, 2009). The meta-analysis by Höffler and Leutner (2007) identified some moderating variables (such as knowledge depicted or task content) that promoted instructional animations over statics (see Section 1.1.2). However, if these moderators are not controlled, animations may be less or equally effective than static images for learning. An example where groups studying static illustrations outperformed groups studying animations was reported by Mayer, Hegarty, Mayer, and Campbell (2005) in four experiments where

* Corresponding author. School of Education, John Goodsell Building, Level 1, University of New South Wales, Australia.
E-mail addresses: j.c.castroalonso@unsw.edu.au (J.C. Castro-Alonso), p.ayres@unsw.edu.au (P. Ayres), paas@fsw.eur.nl (F. Paas).

http://dx.doi.org/10.1016/j.compedu.2014.12.022
0360-1315/

university students had to learn about mechanical systems. Similarly, statics have been observed to be better or more efficient educational resources than animations in learning about topics of probability (Scheiter, Gerjets, & Catrambone, 2006), biology (Koroghlanian & Klein, 2004), and symbol memorization (Castro-Alonso, Ayres, & Paas, 2014b). Also, there are studies showing no significant differences between dynamic and static images, in tasks such as learning the mechanisms of brake systems (Mayer, DeLeeuw, & Ayres, 2007), or a flushing toilet (Narayanan & Hegarty, 2002). Because of the uncertainty surrounding the learning performance due to instructional animations, researchers have started to examine the reasons why they might not be effective. One reason gaining considerable support is the *transient information effect* (see Ayres & Paas, 2007a, 2007b).

1.1.1. The transient information effect

The transient information effect is a relatively new research area (see Sweller, Ayres, & Kalyuga, 2011), and occurs when a permanently displayed educational material produces higher learning outcomes than an equivalent transient format. Arguably the most ubiquitous form of transient information in education is speech, which disappears as soon as it is spoken (unless it is recorded in some fashion). Studies (e.g., Leahy & Sweller, 2011; Singh, Marcus, & Ayres, 2012) have shown that lengthy spoken explanatory texts (transient form) may lead to less learning than identical written texts (permanent form).

The transient information effect can also be observed with instructional animations, where many of these depictions can include fleeting images that do not stay visible on the screen for very long. When studying from a transient animation, learners may have to remember previous critical information that has disappeared, and integrate it with new information, in order to understand and learn about a new concept (see Ayres & Paas, 2007b). According to cognitive load theory (a theory that considers how instructional design impacts on working memory and learning; see Sweller et al., 2011) this type of mental processing is very demanding for working memory, and leads to learning deficiencies (e.g., Castro-Alonso et al., 2014b). In contrast, static visualizations, which are more permanent forms of information, can be reexamined as needed and impose less cognitive burdens. Under such conditions, instructional static pictures may produce better learning outcomes than comparable dynamic visualizations, as some empirical findings described above have shown.

Due to these problems with some animations, instructional strategies such as *segmenting* (to show shortened versions rather than a whole animation; e.g., Wong, Leahy, Marcus, & Sweller, 2012) and *learner control* (to include buttons to slow down or pause the animation; e.g., Höffler & Schwartz, 2011) have been used effectively to manage the transitory information of animations (see Ayres & Paas, 2007a, 2007b; Castro-Alonso, Ayres, & Paas, 2014a). However, research has also shown that some domains are particularly suited to learning from animations, regardless of transitory effects. One such collective domain is learning about human movement through procedural–manipulative tasks.

1.1.2. Procedural–manipulative tasks and the human movement effect

Höffler and Leutner (2007) identified several moderators for the effects of animated or static presentations on learning. One of these moderators was the type of knowledge depicted, whether *procedural-motor*, *declarative*, or *problem-solving* knowledge. The highest advantage of animated over static presentations ($d = 1.06$) was reported when procedural–motor knowledge was to be learnt. For example, greater outcomes from animations over static images have been reported in procedural–manipulative tasks as diverse as (a) disassembling a machine gun (Spangenberg, 1973), (b) bandaging a hand (Michas & Berry, 2000), (c) replicating *origami* models (Wong et al., 2009), (d) solving puzzle rings (Ayres, Marcus, Chan, & Qian, 2009), and (e) copying different knots (Ayres et al., 2009; Garland & Sánchez, 2013).

To explain this phenomenon of better learning with animations (in spite of their transient information) when the task involves procedural–manipulative knowledge, or human movement, researchers have proposed links with the work of Geary and evolutionary biology. Geary distinguishes between *biologically primary skills*—evolved and thus relatively effortless cognitive abilities—and *biologically secondary skills*—not evolved and thus effortful abilities that must be learnt through instruction (see Geary, 1995, 2002, 2007). As biologically primary skills are easier to learn, they consume less working memory capacity than secondary skills. In consequence, when learning from animations that show primary skills (e.g., a manipulative task), students can handle the transiency problem of these depictions in a much effective manner than when dealing with secondary skills. Paas and Sweller (2012) have termed this phenomenon as *the human movement effect*.

In conclusion, humans learn manipulative tasks easily because this is an evolved effortless primary skill. In other words, tasks that involve employing the hands to manipulate objects following a sequence or procedure are relatively easy to humans. This implies that there are evolved cognitive mechanisms that allow humans to manage the transiency of the manipulations. Arguably, the most important of these mechanisms is the *mirror neuron system* (see van Gog et al., 2009).

1.1.3. Mirror neurons and related systems aiding in manipulative tasks

Mirror neurons are visuomotor cells that are activated not only when individuals perform an object manipulation, but also when they watch other individuals doing the same action (see Rizzolatti & Craighero, 2004). These neurons compose the mirror neuron system, which, in connection to other perception–action mechanisms, provide an extensive brain representation to aid understanding of human movement (e.g., Cross, Hamilton, & Grafton, 2006) and manipulative tasks. Noteworthy, the existence of these systems is an indicator that humans have evolved an *embodied cognition*, namely a cognitive architecture that links perception and bodily action to allow humans to thrive in their environment (see Barsalou, 2010; Wilson, 2002).

Because the simultaneous activation of perceptual and motoric streams is an evolved phenomenon, this activation is expected to be more pronounced with natural and evolved manipulative tasks rather than non-natural object manipulations. For example, embodied cognitive systems are activated to a greater extent when watching human-as compared to robotic-arm motions (e.g., Kilner, Paulignan, & Blakemore, 2003; Press, Bird, Flach, & Heyes, 2005). Similarly, Shimada and Oki (2012) reported that an area of the mirror neuron system was triggered more when watching fluent and natural rather than jerky and paused arm movements. This result can explain the human movement effect and why animated visualizations that show natural motions are better than static images to model manipulative tasks. In conclusion, these findings suggest that the mirror neuron system and related embodied mechanisms are preferentially triggered in natural situations, aligned with their evolution. This could imply that, when designing an instructional visualization, natural situations should be preferred. In other words, the effectiveness of an instructional visualization to learn a manipulative task may be moderated by embodied mechanisms, as discussed next.