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Should hand actions be observed when learning hand motor skills from instructional animations?

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ABSTRACT

This study investigated whether the effectiveness of learning a hand-motor task through an instructional animation required observation of the hands or not. Cognitive load theory was used to predict that both animated conditions (with and without hands) would be equally effective, and that both animations would be superior to an equivalent static graphics presentation. 36 adults were randomly assigned to three groups (With-hands animation, No-hands animation, Statics graphics) and were required to learn how to tie two knots. Test results confirmed that both animations led to superior learning compared to the static presentation. However, the With-hands animation strategy had a further advantage in that it had higher instructional efficiency than the No-hands animation.

1. Introduction

Much research effort has been devoted to testing the effectiveness of instructional animations against static graphics, however results have been fairly inconsistent. Tversky, Morrison, and Betrancourt (2002) found little evidence that animation was superior to static graphics. Whereas, Mayer, Hegarty, Mayer, and Campbell (2005) found that static graphics were superior to animations when learning about mechanical systems. In contrast, a meta-analysis by Höffler and Leutner (2007) identified some conditions where animations had an advantage over static graphics. These conditions included argumentation techniques such as cueing and user-control, but the largest effect size was found when the animations featured procedural-motor knowledge. Since this meta-analysis, more evidence has emerged in support for a special case in learning about human motor skills, especially for tasks requiring hand manipulations. For example, when learning to complete origami (see Wong et al., 2009) and puzzle ring tasks (see Ayres, Marcus, Chan, & Qian, 2009), animations were found to have a clear advantage over equivalent static presentations. The present study continues the research into instructional animations. In particular, it investigates whether the effectiveness of animations is moderated by learner observations of the hand when learning about hand manipulation tasks.

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2. Literature review

Just as the research into the effectiveness of instructional animations has been inconclusive, there has also been a lack of coherence and consistency in the theoretical underpinnings of their use (see Ploetzner & Lowe, 2012). A number of different reasons have been proposed as to why animations have not been found to be consistently advantageous. However, one promising argument that is gaining traction is the role played by additional cognitive load caused by transient information. Ainsworth & VanLabeke, 2004 observed that transience is a particular characteristic of dynamic representations that has ramifications for working memory load. Ploetzner and Lowe (2004) have also suggested that animations might create a high cognitive load. Ayres and Paas (2007a, 2007b) developed the cognitive load explanation further arguing that information transience is a major roadblock to learning from animations. This paper adopts a theoretical argument based on cognitive load theory (see Sweller, Ayres, & Kalyuga, 2011), which is briefly outlined in the next section.

2.1. Cognitive load theory

Cognitive load theory (CLT) is heavily dependent upon the properties of the memory systems and how they influence learning, thinking and problem solving. Using this human cognitive architecture, CLT has successfully predicted a number of instructional effects. A central tenet of CLT is that working memory (WM) plays a critical role in learning. However, WM is very restricted by its very limited capacity (Cowan, 2001) and duration (Peterson & Peterson, 1959). Instructional design that fails to account for the limitations of WM can negatively impact learning. CLT postulates three major types of cognitive load: intrinsic, extraneous and germane load (for more extensive discussion, see Sweller, van Merriënboer, & Paas, 1998; Sweller et al., 2011). Intrinsic load is the load caused by the complexity of the learning materials. It is influenced by element interactivity, the number of elements of information that need to be processed simultaneously by the learner to be meaningful (see Marcus, Cooper, & Sweller, 1996; Sweller & Chandler, 1994). High element interactivity makes learning difficult and consumes large amounts of WM resources. In contrast, low element interactivity leads to easier learning and consumes less WM resources. Extraneous load is the load caused by suboptimal instructional design, and can directly interfere with learning. Poorly designed instructional materials generate extraneous cognitive load, as limited WM resources are directed away from learning (see Sweller et al., 1998). In other words precious WM resources are spent following ineffective instructions or completing redundant tasks, rather than focusing directly on learning. Germane load is the load directly invested in schema acquisition. Materials that have high intrinsic and/or extraneous cognitive load are difficult to learn, as few, if any, WM resources remain to directly engage in learning (germane load). Effective instructional designs increase germane load and decrease extraneous cognitive load.

2.2. Transitory information and extraneous cognitive load

Ayres and Paas (2007a, 2007b) argued that instructional animations maybe ineffective because they frequently generate high levels of extraneous load as a result of the transitivity inherent in animations. That is, animations often contain information that appears, and then quickly disappears from the computer screen, before the learner has time to fully process it. Animations, by their very nature are dynamic and consist of a series of frames. As frames roll from one to another, visual information disappears from sight. Regardless of how well information is integrated, if information from previous frames is needed to understand later frames, then the conditions for a transient information effect are present. The transitivity of animations means that learners must process new information whilst simultaneously remembering and integrating previously presented information, thus generating extraneous cognitive load. In contrast, static graphics do not require learners to hold information in WM, as the information in static graphics is readily available to be reviewed as required.

In a non-animated environment Leahy and Sweller (2011) collected evidence demonstrating the negative impact imposed by lengthy spoken text. All speech is transient and will disappear unless it is recorded in some fashion. If it is important information, then the learner must try to remember it. As the length of spoken increases, remembering and processing the information becomes more difficult. Leahy and Sweller investigated the impact of length of text on the modality effect, which occurs when students learn better from spoken text and pictures compared to written text and pictures (see Low & Sweller, 2005). Leahy and Sweller found that the modality effect disappeared when the text was too large due to transient information. Singh, Ayres, and Marcus (2012) found a similar transient effect showing that written text led to higher learning than spoken text.

From the perspective of animated designs, indirect support for a transitory effect has come from studies that have stopped the animation through either user control (see Hasler, Kersten, & Sweller, 2007: Schwan & Riempp, 2004), or by system control (Mayer & Chandler, 2001). In both cases animations that were stopped led to better learning outcomes than continuous presentations. Another effective method is to divide the animation into smaller segments (see Mayer & Chandler, 2001; Spanjers, Wouters, Van Gog, & van Merriënboer, 2011; Wong, Leahy, Marcus, & Sweller, 2012). Both interventions (stopping or segmenting) compensate for transient information, by reducing the amount of information that the learner must deal with at one time. That reduction can ameliorate the negative effects of transience when using animated instructional presentations.

2.3. Instructional animations and the learning about human movement

As argued above the existence of inbuilt transitory information within instructional animation is a plausible explanation for why many animations have failed to show clear advantages over equivalent statics. However, the argument does not account for results that have found animations to be superior to static graphics for procedural-motor tasks (e.g., Ayres et al., 2009; Höffler & Leutner, 2007; Imhof, Scheiter, Edelman, & Gerjets, 2012; Lee & Shin, 2012; Watson, Butterfield, Curran, & Craig, 2010; Wong et al., 2009).

To explain this apparent 'special case' relating to human movement, Van Gog, Paas, Marcus, Ayres, and Sweller (2009) argued that it is due to the human mirror neuron system (for more information, see Rizzolatti & Craighero, 2004). The neuroscience literature suggests that mirror neurons allow humans to engage in imitative learning (Blandin, Lhuisset, & Proteau, 1999). Based on Geary's concept of biologically primary knowledge (see Geary, 2007), Van Gog et al. (2009) proposed that humans have evolved to be able to learn certain types of knowledge (primary) effortlessly, one example being human movement. Humans may have evolved the neural mechanisms (i.e., mirror neurons) to learn movement from others, which may be a form of biologically primary knowledge. Conversely, learning non-human movement based information (e.g., calculus), which Geary refers to as secondary knowledge, may be more effortful because humans may not have evolved the neural mechanisms that enable us to learn such information (Van Gog et al., 2009). From the perspective of learning motor skills from an animation, transitory information may be less problematical because the content may not tax working memory resources to the same extent as non-human movement. Learning motor skills from an instructional animation may thus tap into our innate ability to learn by observing. In essence we may be using biologically primary knowledge (viewing human movements) to assist in the acquisition of biologically secondary knowledge (knot tying).

2.4. The present study

The main aim of this study was to extend the research on learning human motor skills through animations, with a specific focus made on the role of the human body displayed in the presentations. Research into the mirror neuron system varies on this aspect. Some evidence has suggested that the mirror neuron system may only respond to actions made by another human (Tai, Scherfler, Brooks, Sawamoto, & Castiello, 2004), but other studies (see Gazzola, Rizzolatti, Wicker, & Keysers, 2007; Press, Bird, Flach, & Heyes, 2005) have shown that the mirror neuron system responds to actions made by a robot as well as another human.

Despite some discrepancies in the neuroscience literature, the studies conducted into animations suggest that human presence in the presentation may not be necessary. In the Ayres et al. (2009) study, which found animations to be superior to static graphics in learning to solve puzzle rings, hands were clearly shown in the learning materials. In contrast, Wong et al. (2009) who demonstrated the superior performance of animations in completing origami shapes did not show hands. Similarly, Watson et al. (2010) also recently found animations to be superior to static graphics for learning an assembly task that did not show the hands