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Rotational perspective and learning procedural tasks from dynamic media

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ABSTRACT

There have been conflicting accounts regarding the effectiveness of animations for learning. Procedural motor learning represents one of the few areas in which animations have consistently shown to be facilitative. Some have suggested that this benefit is related to activation of the mirror neuron system (MNS), with higher activation leading to better performance. This study examines this explanation, and observed the effects of instructional media (animation vs. static), as a function of viewing perspective (face-to-face vs. over-the-shoulder) on understanding a procedural motor task (knot tying). Results indicate that performance was significantly improved with animations over static images, however this appeared to be most pronounced in situations which matched the learners' own perspective (i.e., over-the-shoulder). These findings have implications for the design of instructional media for procedural motor tasks and provide confirmation of the assertion that appropriate activation of the perceptual system can be leveraged to increase performance.

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1. Introduction

The notion that dynamic external visualizations can provide some efficacy over alternative presentations such as textual descriptions has been suggested many times (Larkin & Simon, 1987; Tufte, 2001). While there is some evidence suggesting that animations do not facilitate learning (Boucheix & Schneider, 2009; ChanLin, 2000; Hegarty, Kriz & Cate, 2003; Mayer, Hegarty, Mayer & Campbell, 2005; Tversky, Morrison & Bétrancourt, 2002), numerous other studies have found that animations can indeed enhance learning under certain constraints (see Höffler & Leutner (2007) for a review). For example, animations have been shown to be more effective than static visualizations for the acquisition of process knowledge in cell biology (Münzer, Seufert, & Brünken, 2009), and learning concepts in chemistry and earth science (Falvo & Suits, 2009; Sanchez & Wiley, 2010). However, an open question is what leads to this differential pattern of results regarding the effectiveness of animations for learning?

Some have suggested that perhaps animations are particularly well suited for certain content areas, and less so for others. In a meta-analysis conducted by Höffler and Leutner (2007), it was found that animations can be more effective than static images if they are a realistic approximation of the task, and especially so if the task involves procedural motor learning. For example, studies on the learning of basic first aid procedures (e.g., what to do when someone is choking, or how to bandage a hand) found that animations produced higher levels of recall than static images or text alone, and also produced faster rates of learning (Arguel & Jamet, 2009; Michas & Berry, 2000). Similarly, Ayres, Marcus, Chan, and Qian (2009) found that observing animations of knot tying and ring assembly puzzles produced the highest levels of both forward and reverse learning, and increased the ability to recognize next or previous steps versus similar static presentations.

So what is it about procedural motor learning tasks that make them so amenable to animated presentations? As animations demonstrate changes over time and/or sequence, it is possible that the inclusion of this underlying temporal component might produce a higher degree of match to procedural tasks versus other contexts, as these procedural tasks themselves often contain a temporal sequence of

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events. This is consistent with the intuitions of Rieber & Kini (1991), who suggested that animations can reduce the abstract nature of temporal changes, thus providing a more tangible way to understand material. In other words, the representation of time in these dynamic visualizations potentially increases the match between the to-be-learned material, and how said information is instructionally conveyed. Simply, the method of instruction more closely matches the constraints of the content domain it is meant to represent. It has been speculated that this *congruence* between content area and instruction underlies the most effective animations (Rieber, 1990; Tversky et al., 2002).

How then are we able to capitalize on heightened levels of congruence between instruction and content to improve learning and thus realize the full benefit of animations? In other words, what might be the underlying mechanism by which the effects of congruence are realized? While to date this has not been explicitly tested neurologically, it has been proposed that such animations potentially activate the mirror neuron system (MNS). It is believed that this activation facilitates learning in these tasks by providing a perceptual basis to interpret and understand these visualizations (Ayers et al., 2009; Chandler, 2009; Wong et al., 2009), akin to the perceptual benefit originally attributed to static illustrations alone (Larkin & Simon, 1987). From this perspective, activation of the MNS permits an almost effortless simulation or embodiment of the material which can then be used to encourage the activation of relevant knowledge and connections between material, and thus better understanding (van Gog, Paas, Marcus, Ayres & Sweller, 2009).

1.1. The mirror neuron system and procedural learning

Originally identified in primates, the MNS represents a neurophysiological circuit distributed across the pre-motor cortex that selectively activates when either conducting a specific action, or when observing another individual performing the same action (Pellegrino, Fadiga, Fogassi, Gallese & Rizzolatti, 1992). It was originally believed that this system offered a perceptual mechanism to understand goal-directed action and intent (Gallese & Goldman, 1998) and perhaps might even serve as a gateway to language and communication (Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Rizzolatti & Arbib, 1998). More recent research has refined this definition and identifies the MNS as critical for not only understanding others' movements, but also generating plans for one's own actions and execution (Fogasi et al., 2005; Meltzoff & Prince, 2002). For example, while simply observing an individual play guitar chords did activate the MNS, watching the same material with the intent to replicate or reproduce (i.e., to learn) the actions produced even higher levels of activation within the MNS (Buccino et al., 2004). As such, some have suggested that this underlying architecture is potentially responsible for our ability to learn through imitation, which is a unique to higher apes and humans (Rizzolatti & Craighero, 2004). Given this conceptualization, it is not surprising that this neural circuit might be especially relevant for procedural learning, as the fundamental goal of any procedural learning task is to successfully imitate or reproduce a given pattern of motor events.

If this mirror neuron explanation is correct, and thus mediates the effectiveness of a given animation, one would expect to see an interaction between animations and the degree to which they activate the MNS. For example, when animations most activate the MNS, we would expect to see the highest levels of learning as these visualizations leverage the perceptual system in such a way as to enable better understanding of the to-be-learned motor task. However, when animations fail to strongly activate the MNS, it is reasonable to expect a similar decline in overall performance as this perceptual processing benefit is not realized. One way to test this explanation would be to systematically vary the degree of activation of the MNS, while holding informational content constant. Shifting action away from first-person perspectives has been shown to moderate activation of the MNS, such that face-to-face presentations activate the MNS to a lesser degree than over-the-shoulder perspectives (Jackson, Meltzoff & Decety, 2006; Maeda, Kleiner-Fisman & Pascual-Leone, 2002). In other words, watching someone else demonstrate an action has been shown to produce lower levels of activation in the MNS than watching action from a perspective more akin to actual experience (e.g., through your own eyes). The question then is: does reducing activation of the MNS simultaneously produce lower levels of learning from animations when informational content is the same? If the suggestion that the MNS is largely responsible for the facilitation of animations in procedural learning, than one would expect lower facilitation in situations that less strongly activate the MNS.

Finally, previous research has indicated that individual differences in visuospatial and attentional ability might also moderate the instructional effectiveness of any kind of visualization, including animations. Visuospatial ability has been shown to interact with animations to affect learning of mechanical information (Mayer, 2001; Mayer & Sims, 1994), and spatial science topics (Höffler & Leutner, 2011; Sanchez & Wiley, 2010; Yang, Andre, Greenbowe & Tibell, 2003). Similarly, Cognitive Load Theory (van Merriënboer & Sweller, 2005), Mayer's (2005) Cognitive Theory of Multimedia Learning, and Schnotz's (2005) Integrative Model of Text and Picture Comprehension all speculate that appropriate visualizations offload processing demand from the working memory system, thereby freeing resources to better dedicate to the learning process. Given these proposed connections between learning from visualizations and individual differences in cognitive ability, it seems prudent to control for these abilities when evaluating a causal theory such as the MNS explanation.

1.2. Current study & hypotheses

To explore learning in procedural motor tasks and how they may interact with our perceptual system and presentation, a study was conducted which manipulated both of these characteristics. Participants were shown a procedural knot tying task from either an animated or static media, which was either consistent with their perspective when completing the task themselves (i.e., over-the-shoulder, OTS), or instead rotated 180° into a face-to-face (FTF) orientation. It is hypothesized that for procedural motor learning tasks, instruction via animations instead of static images will facilitate overall performance resulting in faster time, fewer errors and more steps correct. This would be consistent with a host of psychological research regarding the efficacy of such dynamic media (Höffler & Leutner, 2007). Further, this performance benefit may also interact with perspective of the demonstration. If the mirror neuron explanation is correct, those orientations that would activate the MNS most strongly will realize the largest benefits of animation. Conversely, those that lessen activation of the MNS should perform less well. In order to control for individual differences in general cognitive processing and visuospatial manipulation, both of which have been suggested to influence learning from animations (Hegarty & Waller, 2005; Mayer & Moreno, 1998), additional measures of these cognitive abilities were collected and entered into subsequent analyses.

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