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Do dynamic work instructions provide an advantage over static instructions in a small scale assembly task?

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Abstract

Recent studies exploring the effects of instructional animations on learning compared to static graphics have yielded mixed results. Few studies have explored their effectiveness in portraying procedural-motor information. Opportunities exist within an applied (manufacturing) context for instructional animations to be used to facilitate build performance on an assembly line. The present study compares build time performance across successive builds when using animation, static diagrams or text instructions to convey an assembly sequence for a handheld device. Although an immediate facilitating effect of animation was found, yielding a significantly faster build time for Build 1, this advantage had disappeared by Build 3.

Keywords: Instructional animation; Procedural-motor learning; Assembly task; Dynamic visualisation; Industrial learning

1. Introduction

Much debate still surrounds the assumed effectiveness of using animation as a graphic device in learning and instruction and, in particular, the advantages it may possess over static pictures or text (Hoffler & Leutner, 2007). Many studies have explored the use of instructional animations in facilitating the understanding of complex systems. However, procedural-motor tasks, in particular, assembly tasks, provide an interesting situation in which to study the effectiveness of instruction. It must be noted from the outset that although the term "learning" will be used, here, it does not refer to learning material for retention and later recall. Instead, learning in this instance refers to the successful perception of instructional information about a motor task in order to carry out that action quickly and accurately.

1.1. Processing procedural instructions

The popular cognitive view on how any information is processed is centred on the idea that we construct internal representations from information presented through external representations. The way in which we do this will differ depending on the form of the external representation. Descriptive and depictive are terms used to describe forms of representation. Descriptive information has no similarity to its referent and is symbol-based (e.g., text), whereas depictive representations present information that is similar to its referent, for example, pictures (Kosslyn, 1994; Schnotz, 2005). Depictive representations are more 'informationally complete' and the information can be read directly rather than having to make sense of a description. Schnotz and Bannert's (2003) theory of how we process text and pictures suggests that this dichotomy (descriptive vs. depictive) applies to mental representation as well. Paivio's (1986) dual coding

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theory suggests that we possess two separate channels to deal with these different representations. This is central to recent models of multimedia learning such as Schnotz's (2005) ''Integrative Model'' and Mayer's (2001) ''Cognitive Theory of Multimedia Learning'' (CTML). These models assume that both channels have a limited capacity for material and that successful learning only occurs when the learner actively engages in cognitive processing. Other theories sit well with this, including the ''Cognitive Load Theory'' (CLT; Sweller, 1994, 2003; Sweller, Chandler, Tierney, & Cooper, 1990) which is concerned with the limited capacity of the working memory.

With respect to descriptive representations, and particularly text comprehension, Van Dijk and Kintsch (1983) proposed a three-stage model of how we build mental representations when we read text. Firstly, we construct a text-surface structure representation, followed by a propositional representation, followed finally by a mental model of the text content. This also applies to understanding pictures − first a perceptual representation is created, followed by a mental model of the content. Ganier, Gombert, and Fayol (2000) extended this three-stage model to how a reader of instructions moves from perceiving instructions to performing an action, that is, (a) the reader either jointly or sequentially activates and/or maintains the goal of the task in working memory; (b) encodes the instructions, encodes the characteristics of the device and elaborates an integrated representation (mental model) of all these sources and an action plan; and (c) finally, executes the action. Guthrie, Bennett, and Weber (1991) had previously proposed a ''Transformational model'' − whereby transformation of information represented verbally in a procedural text must be transformed into a procedure represented behaviourally in a performance. The model proposes that in order for this transformation to be successful, users must form a conceptual model of the performance, encode procedures from the document, engage in self-testing and conduct self-corrections to repair mistakes. Ganier (2004) suggests that the cognitive load involved in the construction of a mental model (and action plan) is lower with presentation formats that include pictures, again due to the more direct similarity of the information to the referent. Building a mental model from text will require a deeper level of processing using more cognitive resources, because of the extra steps involved in processing the descriptive nature of the information, hence inducing a heavier cognitive load.

The above 'depth of processing' idea is also supported by Mayer, Hegarty, Mayer, and Campbell (2005) who suggest that static forms of information will also involve deeper processing as inferences will have to be made from frame to frame rather than a passive observation. Ganier (2004), on the other hand, suggested that accompanying text with pictures will enhance the elaboration of a mental model because of the similarity of structure of these external representations with the equipment to be learnt, thus supporting the user's internal representation. Following from this, the use of animation in this context could, according to the same line of reasoning, enhance the elaboration of the mental model even further as spatial and temporal elements will be introduced. This will again heighten the resemblance between the external and internal representations. However, benefits of animation have not been shown consistently in the literature.

1.2. Acquisition of procedural knowledge from animation

Hegarty (2005) suggested that at an intuitive level, using animation to portray dynamic events will be more effective than using static diagrams, because with static diagrams ''mental animation'' is required, that is, inferences must be made between frames as to the dynamic properties of the event. With animated diagrams, it becomes a case of successful perception of dynamic properties rather than successful inference of motion. Recent reviews, however, have not found consistent results supporting the effectiveness of animation. Betrancourt and Tversky (2000) completed a review of instructional animation studies finding a positive effect of animation on a measure of performance for only seven of the twelve studies reviewed. Where advantages were found to exist, it was thought to be due to non-equivalence of information across the formats (Tversky, Morrison, & Betrancourt, 2002).

Hoffler and Leutner (2007) conducted a meta-analysis of 26 primary studies by comparing static pictures vs. animations in an attempt to identify factors responsible for effective instructional animations. Specifically, 76 pair-wise comparisons were carried out. In contradiction to previous reviews (Betrancourt & Tversky, 2000), results revealed a medium-sized overall advantage of instructional animations over static pictures. Effect sizes were largest when animations were realistic, representational (rather than decorational) and when procedural-motor knowledge was to be acquired. The use of less effective decorational animations may be a contributory factor to the mixed results that studies in this area yield, along with other inconsistent features of the animations themselves, such as interactivity (Hasler, Kersten, & Sweller, 2007) and segmentation (Moreno, 2007).

Only a small number of studies (Michas & Berry, 2000; Palmiter & Elkerton, 1993; Spangenberg, 1973) in the last few decades have moved away from the type of instructional animation that is used to enhance understanding of concepts to explore the use of animated instructions *per se*, that is, tasks in which procedural-motor knowledge or the ability to replicate the procedure (e.g., assembly instructions) is the desired learning outcome. Much work in the 1980s by Patricia Baggett looked at instructional design for procedural texts, based on how we conceptualise assembly instructions (Baggett, 1987; Baggett & Ehrenfeucht, 1988, 1991). Much of this work led to successful design principles for assembly instructions regarding task hierarchy. With computer-based animations becoming more synonymous with manufacturing enterprises in the real world, there is once again a need to explore the effectiveness of instructional animation over more 'traditional' text and/or picture-based work instructions for assembly tasks. In many manufacturing industries, dynamic digital mock ups are often created for one or more