Learning and Instruction 47 (2017) 13–24

Contents lists available at ScienceDirect

Learning and Instruction

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

Not the silver bullet: Learner-generated drawings make it difficult to understand broader spatiotemporal structures in complex animations

Rolf Ploetzner*, Benjamin Fillisch

University of Education, Institute of Media in Education, Kunzenweg 21, D-79117 Freiburg, Germany

ARTICLE INFO

Article history:
Received 13 April 2016
Received in revised form
20 September 2016
Accepted 6 October 2016
Available online 23 October 2016

Keywords:
Learning from animation
Learning strategies
Learner-generated drawings
Reflection

ABSTRACT

Because drawing is a highly successful strategy in learning from text, it has recently been investigated whether drawing can also improve learning from animation. Several theoretical and practical arguments, however, make drawing a questionable strategy for learning from animation. In an experimental study, we investigated the effectiveness of drawing for learning from animation. One group of 26 students had to draw what they had observed in the animation. A second group of 26 students had to reflect on what they had observed in the animation. After learning, all students had to demonstrate their understanding by making use of a physical model. The students' demonstrations were assessed by means of an event unit analysis. More extensive spatiotemporal structures were significantly less recognized by students who drew than by students who reflected. The results suggest that drawing might not be an adequate strategy for learning from visuospatially and spatiotemporally complex animations.

1. Introduction

Animations are a common part of digital learning environments. They offer behaviorally realistic depictions of complex systems such as mechanical (e.g., Hegarty, Kriz, & Cate, 2003) and biological systems (e.g., De Koning, Tabbers, Rikers, & Paas, 2010a; Lowe, Schnotz, & Rasch, 2011). Because animations can depict both visuospatial changes (i.e., changes of the visual and spatial organization of entities) and spatiotemporal changes (i.e., changes of the spatial and temporal organization of entities) explicitly, the learners are freed from having to mentally animate the dynamics of the portrayed subject matter. Instead, the learners can directly observe the animated system's behavior. However, animations not only offer advantages to the learners, they also place specific processing demands on them. For instance, the learners need to identify and process the relevant entities and events in an animation while the display is continuously changing. In particular, if the animated systems are complex, are not accompanied by spoken or written explanations, and the learners possess only little prior knowledge about the animated subject matter, the learners can easily become both perceptually and cognitively overwhelmed (cf. Hegarty, 2004; Lowe, 2003, 2004, 2008; Wong, Leahy, Marcus, & Sweller, 2012). As a consequence, the learners might process the display in a highly selective manner, miss relevant information, and construct merely incomplete, incoherent, and inconsistent mental models of the animated subject matter (Lowe, 2003, 2004, 2008).

Two main approaches aim at supporting learners to process animations comprehensively and successfully. Both approaches rely on theories of human memory (e.g., Baddeley, 1999), multimedia learning (e.g., Ayres & Sweller, 2014; Mayer, 2009, 2014), and – more specifically – learning from animation (Lowe & Boucheix, 2008; Lowe & Schnotz, 2014). The first – and much more common – approach is to design animations in such a way that the learners are supported in identifying, selecting, organizing, and integrating the relevant information. Numerous empirical studies have demonstrated that the theory-based design of animations can improve learning (e.g., Boucheix, Lowe, Putri, & Groff, 2013; De Koning, Tabbers, Rikers, & Paas, 2007; Moreno, 2007; Ploetzner & Lowe, 2014; for an overview see Ploetzner, 2016).

The second – and less common – approach is to equip the learners with strategies that enable them to systematically and comprehensively perceive and process especially demanding animations. Although this approach has a long tradition with respect to learning from text (cf. Gambrell, Morrow, & Pressley, 2007; Mandl & Friedrich, 2006; Pressley & Harris, 2006; Pressley, Symons, McGoldrick, & Snyder, 1995), it is still only rarely applied to learning from animation (e.g., De Koning, Tabbers, Rikers, & Paas,

---

* Corresponding author.
E-mail addresses: rolf.ploetzner@ph-freiburg.de (R. Ploetzner), benjamin.fillisch@ph-freiburg.de (B. Fillisch).

http://dx.doi.org/10.1016/j.learninstruc.2016.10.002
0959-4752/

2010b; Kombartzky, Ploetzner, Schlag, & Metz, 2010; Ploetzner & Schlag, 2013; for an overview see Ploetzner, 2016).

An example of a successful strategy for learning from text is to encourage the learners to produce their own drawings of the subject matter described in the text (for overviews see Leutner & Schmeck, 2014; Van Meter & Firetto, 2013). It has recently been investigated whether this approach can also be successfully applied to learning from animation (e.g., Mason, Lowe, & Tornatora, 2013; Zhang & Linn, 2011). The results achieved in these studies are promising and demonstrate that drawing not only supports learning from text but can also facilitate learning from animation. However, the animations employed in these studies – an animation of Newton's cradle in case of Mason et al. (2013) and an animation of hydrogen combustion in case of Zhang and Linn (2011) – were structurally rather simple. Both animations consisted of just a few uniform entities that changed over time. In contrast, a lot of learning material includes dynamic visualizations that are made up of more entities which are less uniform and are spatially and temporally related to each other in many different ways.

In this paper, it is investigated whether the strategy of drawing – in comparison to the strategy of reflecting – facilitates learning not only from structurally simple, but also more complex animations that are not accompanied by spoken or written explanations. In the following section, two theoretical models as well as empirical findings relevant to the research reported in this paper are summarized: (1) the Animation Processing Model as suggested by Lowe and Boucheix (2008, 2011) and (2) the Cognitive Model of Drawing Construction as put forward by Van Meter and Firetto (2013). Thereafter, an experimental study is described in which two groups of learners studied an animation of a four-stroke engine. The learners in one group were asked to draw what they observed in the animation, whereas learners in the second group were encouraged to reflect on what they observed in the animation. A discussion of the results concludes the paper.

2. Theory and empirical findings

2.1. Comprehending animations: The Animation Processing Model

The Animation Processing Model (APM; Lowe & Boucheix, 2008, 2011; see also Lowe & Schnotz, 2014) describes how learning from animations without spoken or written explanations can progress as a cumulative activity in which bottom-up and top-down processes interact in order to construct an increasingly comprehensive mental model of the animated subject matter. The APM distinguishes five phases of animation processing.

During Phase 1, the learner parses the animation's continuous flow of information in order to isolate and internalize localized event units which may be presented at various spatial and temporal locations. Event units denote graphic entities and the behavior they exhibit. If the learner possesses only little prior knowledge about the animated subject matter, the isolation of event units will mostly be a bottom-up process. That is, it will mainly be based on the perceptual properties of the visual display such as the color and size of an area in the display or the relative rate at which an area in the display changes.

The event units isolated in Phase 1 make up the building blocks for Phase 2 processing. The localized event units are progressively and iteratively combined into broader but still regional structures. Central to this combinatorial activity is the formation of visuospatial and spatiotemporal relationships that are influenced by the perceptual properties of the animated display. For instance, in accord with the Gestalt principle of proximity (cf. Koehler, 1947/1992), event units that are close in space and/or time are likely related and combined into superordinate spatiotemporal structures termed dynamic micro-chunks.

Further hierarchical structuring activity continues through Phase 3 in which spatially and temporarily distributed dynamic micro-chunks are bridged to form more extensive relational structures such as causal chains. This requires the learners to make use of domain-relevant general knowledge such as knowledge about general principles in physics, chemistry, or biology. By taking advantage of such general knowledge, the learners are able to establish broader visuospatial and spatiotemporal structures that can encompass the animation's entire spatial and temporal scope, and thus finally provide a global characterization of the animation.

Domain-specific knowledge plays a key role in Phase 4 as well as in Phase 5. By means of domain-specific prior knowledge, the learners in Phase 4 assign functional roles to the previously identified relational structures. As a consequence, the relational structures are characterized as functional episodes which constitute the overall functionality of the particular system presented in the animation. During Phase 5, the learners further elaborate the established functionality to cover different operational conditions and requirements of the presented system. If successful, this results in a complete, coherent, and consistent mental model of the animated subject matter that can also be applied to novel but structurally equivalent systems.

The succession of phases in the APM is not meant to indicate that the learners process the phases in a strictly linear order. Rather, especially learners with only little prior knowledge will have to repeatedly apply the corresponding perceptual and cognitive processes before sufficient understanding is achieved. Furthermore, the APM not only provides a model of how animations can successfully be processed, it can also be used as a framework to analyze the perceptual and cognitive demands an animation places on the learners. Such an event unit analysis (cf. Lowe & Boucheix, in press; for a detailed example see Section 3.2.3.1) starts with identifying all the event units that are included in the animation (cf. Phase 1 processing in the APM). Subsequently, the starting time and the stopping time are determined for each event unit. Finally, the starting and stopping times of all event units are arranged according to the time line. Such an analysis yields a graphical representation of the relative durations and temporal distributions of event units. It reveals, for instance, whether certain events occur temporally distributed, immediately one after the other, or even completely simultaneously. In the research reported in this paper, we took advantage of an event unit analysis in order to assess how well the learners recognized the relevant event units and dynamic micro chunks in the employed animation (cf. Section 3.2.3.1).

The APM predicts that learners who do not possess sufficient domain-specific knowledge of the animated subject matter will hardly be able to engage in Phase 4 and Phase 5 processing. Therefore, these learners can neither be expected to achieve a functional understanding of the animated subject matter nor to construct a comprehensive and coherent mental model of the animated subject matter. Instead, their perceptual and cognitive processing of the animation will largely be confined to the first three phases of the APM. As a consequence, these learners will at most be able to establish broader visuospatial and spatiotemporal relationships that globally characterize how the animation changes over time. Empirical studies conducted by Lowe and Boucheix (2008, 2011) confirm the predictions derived from the APM. Furthermore, several empirical studies have demonstrated that learners quite often fail to even adequately process animations with respect to the first three phases of the APM. Especially if an animated system is visuospatially and/or spatiotemporally complex, the learners can easily become both perceptually and cognitively overwhelmed. As a consequence, the learners process the display selectively, miss relevant information, and only