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Simultaneously presented animations facilitate the learning of higher-order relationships

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ABSTRACT

In an experimental study, we investigated how the simultaneous and sequential presentation of animation episodes affects learners' perceptual interrogation of the animation as well as their acquisition of higher-order relationships. Of the 60 students who participated in the study, 30 studied the animation episodes presented simultaneously and 30 studied the same episodes presented sequentially. The eye movements of eight participants from each group were recorded while they studied the animation episodes. The simultaneous presentation resulted in significantly more visual transitions between the episodes than the sequential presentation. Further, in case of the simultaneous presentation significantly more bi-directional visual transitions occurred than in case of the sequential presentation. Learning of higher-order relationships was significantly more successful from simultaneously presented episodes than from sequentially presented episodes.

1. Introduction

The efficacy of animations as tools for fostering learning remains a contested area. Although they can be useful in some circumstances, such as for learning procedural motor skills (Höffler & Leutner, 2007), animations as typically used nowadays are not an educational panacea. Despite the apparent advantages put forward for animations (Kriz & Hegarty, 2007), they persistently fail to live up to educators' high expectations. It seems that the dynamic characteristics of animations are a two-edged sword; their advantages in depicting temporal change explicitly may be offset by the processing challenges they can pose for learners (Lowe, 2004, 2008).

Interventions that are intended to improve the educational effectiveness of animations have met with some success. However, certain deeper aspects of learning resist efforts at improvement. For example, although novel forms of attention direction such as dynamic progressive path cueing (Boucheix, Lowe, Putri, & Groff, 2013) are considerably more effective than conventional cues with respect to learning about particular localized movements, measurements of learning about higher-order relationships that result from generalizations across single instances remain obstinately low even with such interventions. Tversky, Heiser, Mackenzie, Lozano, and Morrison (2008) suggest that a possible way through this type of impasse is to consider some of the successful approaches that have been developed for learning from static graphics throughout the ages and adapt them for animations. On this basis, these authors identify the spatial and temporal properties of animations as likely candidates for potentially beneficial manipulation: "If static graphics play tricks with space and time, why shouldn't animated graphics do the same?" (Tversky et al., 2008, p. 281).

For instance, one long-established technique widely used with static graphics is the simultaneous presentation of multiple pictures – very often pairs – in which temporally distinct aspects of the subject matter are shown via spatially adjacent depictions (e.g. Boucheix, Lowe, Ainsworth, Bétrancourt, & de Vries, 2012; Kim & Astion, 2000; Weidenmann, 1994). Likewise, novel spatio-temporal arrangements of animations can deviate from behavioral realism by presenting multiple events simultaneously that in reality occur one after the other. Fig. 1 shows an example of what such an arrangement might look like. Two different but related sailing courses of a yacht are presented next to each other. Both sailing courses are individual instances of more general principles that apply to the sailing of a yacht such as the more the yacht sails against the wind, the more the sail needs to be hauled in. The design intention of such pairings is to provide learners with affordances for executing comparison and contrast processes across the individual instances. These processes should facilitate the learners in the

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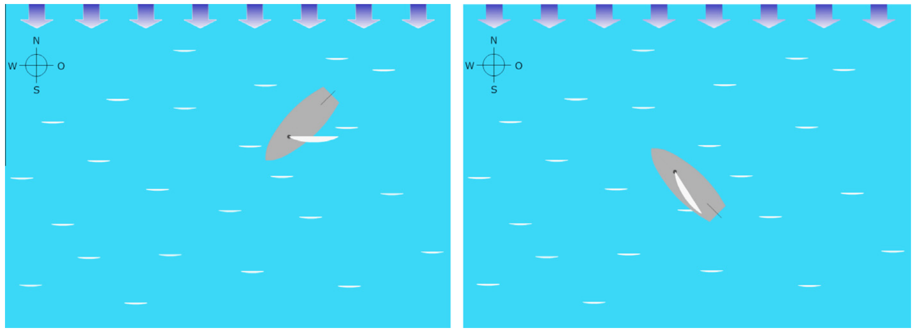

Fig. 1. A pair of pictures displaying two different sailing courses.

construction of generalizations that are central to a deeper understanding of the subject matter. Klauer and Leutner (2007), for example, denote compare and contrast processes as "... the silver bullet for solving inductive tasks" such as generalization (p. 298; translation by the authors; cf. also Holland, Holyoak, Nisbett, & Thagard, 1986).

However, an approach in which multiple depictions are displayed concurrently in order to facilitate relation-building may be considered problematic when applied to animations. In particular, split-attention effects (e.g. Ayres & Sweller, 2005) could conceivably undermine any benefits that might be anticipated from comparing and contrasting different animated episodes within a single display. Perhaps for this reason, educational animations almost exclusively present their subject matter in a behaviorally realistic manner (Schnotz & Lowe, 2008) as a temporal sequence of episodes. However, in a recent review of research on learning from expository animations Ploetzner and Lowe (2012) identified one notable exception that investigated learning from simultaneously presented animations. Morand and Bétrancourt (2010) compared the effect of two ways of presenting animated episodes on collaborative learning in student dyads. In one animation, episodes depicting the complete process of meiosis were displayed sequentially while in the second animation these episodes were presented simultaneously. Although the dyads learned no more from the simultaneously presented animation than from the sequential presentation, they did not learn less. Morand and Bétrancourt (2010) also found that the simultaneous presentation was processed significantly faster than the sequential presentation.

The study reported in the present paper further investigated the effects of simultaneous presentation on the educational effectiveness of animation. Its particular focus was upon the learning of high-level relationships from an animation about sailing a yacht successfully along different types of courses. Identifying these more global relationships allows learners to understand sailing courses beyond the specific courses that are explicitly presented in the animation. The investigation was set in the context of the Animation Processing Model (APM) proposed by Lowe and Boucheix (2008). After describing the model, the research questions and hypotheses are put forward. Next, the empirical study and its results are reported. The paper concludes with a discussion of how the affordances offered by alternative presentation possibilities could benefit learning from animations.

2. Theoretical background

Fig. 2 summarizes the five-phase Animation Processing Model (APM) that characterizes learning from animation as a cumulative activity in which bottom-up and top-down processes interact in order to construct a mental model of the referent subject matter (Lowe & Boucheix, 2008, 2011). The APM regards event units (i.e. entities plus their associated behaviors) as fundamental to mental model construction. During Phase 1 processing, the learner parses the animation's on-going flow of dynamic information to extract and internalize event units from various spatiotemporal locations.

The event units identified during parsing provide raw material for Phase 2 processing in which local fragments of information are progressively and iteratively combined into broader regional structures according to the constraints and proclivities of the human information processing system. Central to this combinatorial activity is the formation of visuospatial and spatiotemporal relationships that are strongly influenced by the perceptual properties of the animated display. For example, in line with the Gestalt principle of proximity, event units that are close in space and/or time are likely to be treated as related and condensed into a superordinate spatiotemporal assembly termed a *dynamic micro chunk*.

Further hierarchical structuring activity continues through Phase 3 in which isolated regional dynamic micro chunks are bridged to form more extensive domain-general relational structures, such as causal chains, that provide a global characterization of the animation. This requires the learner to establish large-scale relationships that can encompass the animation's entire spatial and temporal scope.

Domain-specific knowledge plays a key role in Phase 4 during which previously identified relational structures are characterized as functional episodes that together constitute the functionality of the particular system operation represented in the animation. During Phase 5, further elaboration of this functionality to cover a variety of operational requirements results in a flexible, high quality mental model of the referent system.

The Phases 2 and 3 of the APM are particularly relevant to the present investigation because of their key role in establishing both local and higher-order relationships in the learner's developing mental representation. The relationships involved can connect individual event units (i.e. local relationships) or event unit clusters across both space and time (i.e. higher-order relationships). The sequential sailing animation used in the present study consists of a sequence of four episodes that are conceptually linked by higher-order relationships. Any one of these episodes depicts a specific set of local relationships amongst aspects such as the orientation of the yacht's hull, the sail, and the wind direction. However, there are also higher-order relationships bridging the individual episodes at a more global level. These relationships concern general aspects such as how the sail's orientation affects the speed the yacht will travel. In order to develop a rich and hierarchically structured mental model, the learner needs to internally represent not only local relationships from within particular constituent episodes of such an animation, but also higher-order between-episode relationships that encompass information from across the animation as a whole. In this situation, constructing a satisfactory mental model that includes high-