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# The role of process information in narrations while learning with animations and static pictures

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A B S T R A C T

The role of process information in annotating narrations used for learning with animations compared to static pictures is examined. In two experiments, seventh and eighth graders from German high schools were randomly assigned to learning environments which differed in the combination of visualization (no visualization vs. static pictures vs. animation) and type of narration (no narration vs. non-process narration vs. process narration). Results revealed that visualizations were necessary for this kind of instructional material to gain a deeper understanding. Moreover, the results consistently show a significant superiority of animations over static pictures. Concerning narrations, results display a significant superiority of process descriptions only in Experiment 1. Contrary to prior assumptions, the interaction of specific information in narrations with the type of visualizations was not significant.



## 1. Theoretical background

Technological development enables education systems to create and combine enormous amounts of different learning materials. However, there is still a large gap between advanced technology and our understanding of how humans can best learn with this technology (Chandler, 2004). The demands of multimedia learning settings are described in Mayer's Cognitive Theory of Multimedia Learning (CTML; Mayer, 2001, 2006, 2009). Based on the assumptions that the learners' working memory is limited in capacity (Baddeley, 1986; Sweller, 1999) and that it is structured in an auditory and a visual channel (Paivio, 1986), the learner has to select and organize new verbal and visual information to build single models, and integrate existing knowledge to build the final mental model.

A further theory describing cognitive processes during learning is the Cognitive Load Theory (CLT; Sweller, 1988, 2010). According to CLT, cognitive load is caused by the complexity of the learning content (intrinsic load) as well as by the design of the learning material (extrinsic load). To prevent a cognitive overload (and inefficient learning), learning environments should be designed using considerations of cognitive load and human cognitive architecture in general (Sweller, Ayres, & Kalyuga, 2011).

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In multimedia contexts, learning with dynamic visualizations like animations has become a topic of major interest in the last decade (cf. Höffler, Schmeck, & Opfermann, 2013; Lowe & Schnotz, 2014). In comparison to static pictures, the term 'animation' can refer to any display element that *changes* its attributes over time (Schnotz & Lowe, 2008). It can be defined as a series of rapidly changing computer screen displays suggesting movement to the viewer (Rieber & Kini, 1991). When comparing the effectiveness of animations and static pictures, the question whether one or the other is better suited for learning in general may not be productive and often leads to inconclusive results (cf. Berney & Bétrancourt, 2016; Höffler & Leutner, 2007; Tversky, Morrison-Bauer, & Bétrancourt, 2002). A more helpful focus is to investigate the conditions for which animations might be more appropriate than static pictures – and vice versa (Bétrancourt, 2005; Rieber, 1990).

Thus, further theories or models might be needed to describe how (dynamic) mental models are built up when learning with static or dynamic media; in this case, Narayanan and Hegarty (1998), for instance, developed a model of how dynamic systems are learned. The "runnable" mental model is a result from the process of decomposing a dynamic system into simpler components, retrieving relevant background knowledge about these components and mentally encoding the relations between components to construct a static mental model. This static model then needs to be mentally animated (Narayanan & Hegarty, 2002). It becomes obvious that the process of building a dynamic mental model might be significantly influenced by the characteristics of each medium and especially by the combination of different media. Imagine a process is to be learned: Whereas in case of animations, the process is already dynamically presented and "only" needs to be selected, the learner has to animate static information autonomously when using static pictures. Adding narrations which explain the process might then support the learning process differently due to the fact that the visualizations show the process differently.

When animations and static pictures are accompanied by textual information, which is usually the case in multimedia learning (cf. Mayer, 2009), the role of the textual information in supporting the different types of visualizations is still unclear, despite considerable research. This issue will be addressed in the following sections.

### 1.1. Learning with animations and static pictures

Empirical studies on learning with animations and static pictures have yielded somewhat inconclusive results: On the one hand, meta-analyses revealed a medium advantage of animations over static pictures (Berney & Bétrancourt, 2016; Höffler & Leutner, 2007). On the other hand, there are several studies showing no advantage or even a disadvantage for learning with animations (e.g., Castro-Alonso, Ayres, & Paas, 2014; Hegarty, Kriz, & Cate, 2003; Mayer, Hegarty, Mayer, & Campbell, 2005; Tversky et al., 2002). Such mixed results indicate that it is necessary to take a deeper look and determine exactly when learning with animations is most promising.

Since spatial changes of elements are depicted in animations – in comparison to static pictures – directly, they are supposed to be particularly well suited for situations in which processes are to be learned (e.g., chemical processes). In such instances, animations might be expected to not unduly increase cognitive load (see CLT; Sweller et al., 2011) because of their relevance, and therefore support learners in constructing a dynamic mental model of the content (Hegarty et al., 2003; Schnotz & Lowe, 2008). However, a noted drawback of animations is their transient nature (see Ayres & Paas, 2007; Wong, Leahy, Marcus, & Sweller, 2012). Because dynamic representations flow forward frame-by-frame, important information can be lost from view before the learner has time to adequately select and process this information. This can raise cognitive load as the learner must temporarily store previously viewed information, while processing and linking it with new information. If cognitive load exceeds the limit of working memory, a cognitive overload might diminish learning success. One way of counteracting the demands imposed by the transient nature of animations is to implement interactive elements, so that learners have the chance to stop or replay the animation in instances of high cognitive load (e.g., Boucheix, 2008; Höffler & Schwartz, 2011; Lowe, 2008; Schwan & Riempp, 2004). Another way of counteracting is to use annotating narrations as a second source of information which might highlight relevant visual aspects (Roscoe, Jacovina, Harry, Russell, & McNamara, 2015).

### 1.2. The role of annotating narrations

Although the understanding of how humans process only a single medium like animations is still in its infancy, there is a big necessity to explore the relation between both visualization and narration (Plötzner & Lowe, 2004; Schmidt-Weigand & Scheiter, 2011). A narration is a spoken version of text, which can describe, supplement, and highlight what can be seen in the visualization (Tversky et al., 2002). In comparison to written text, the learner processes this information in the auditory channel, which might be crucial in terms of learning success when the learner is simultaneously watching visualizations (cf. modality effect; Low & Sweller, 2014). In multimedia learning, however, it is not sufficient to consider each type of medium in isolation because media interact with one another in a form of 'representational chemistry' (Ainsworth, 2006).

In the context of multimedia learning environments, which are by definition comprised of text and visualizations (Mayer, 2009), the so-called multimedia principle (Mayer, 2009) states that visualizations added to text should *enhance* learning; this has been investigated extensively (e.g., Mayer & Anderson, 1991, 1992; Mayer, 1989; Moreno & Mayer, 2002) and can thus be considered as well-established. If text by itself was sufficient for understanding and led to the same learning outcome, additional visualizations would not be necessary at all. This is the case when visualizations serve merely for decorative purposes (see Höffler & Leutner, 2007; Mayer, 2009). Along the same lines, it has been shown that visualizations without text can be sufficient for learners if the text contains redundant material that is also represented in the visualizations (see