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How repeated studying and testing affects multimedia learning: Evidence for adaptation to task demands☆

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A B S T R A C T

Two biases can occur in multimedia learning: overconfidence and over-reliance on text processing. The present research sought to identify these biases and to investigate whether they can be reduced, and hence learning fostered, when studying and testing are repeated. In 2 experiments (Exp.1: $N = 79$, Exp.2: $N = 52$), students learned either with text only or with text and pictures (multimedia) about how the toilet flush works, gave judgments-of-learning (JOLs), were tested on the learning contents; afterwards this study-test cycle was repeated. Results from both experiments revealed stronger overconfidence due to multimedia in both study-test cycles (JOLs higher than learning outcomes). Eye movement data showed a relative increase in attention on the picture versus text from cycle 1 to cycle 2; this relative increase in attention was related to better learning outcomes. Repeated studying and testing thus helped to reduce over-reliance on text processing in multimedia learning, fostering performance.

1. Introduction

It is a well-established finding that when students learn with text and corresponding pictures, they achieve higher levels of recall and understanding than when they learn with text alone (i.e., multimedia effect; Butcher, 2014). This multimedia effect was mostly obtained by having students learn the instructional materials once, followed by the knowledge tests. Even though this setup is methodologically sound, it might be too constrained to capture the wealth of processes that can occur when learning with multimedia. For instance, when students prepare for an exam, they may repeatedly study the contents of the multimedia lesson and take practice tests between periods of study. How does such a behavior affect the multimedia effect? And which role do cognitive and metacognitive processes play in this? These questions were investigated in the present research; among others, by using eye tracking as a process measure. To this end, the present research extended the usual setup to study multimedia effects by *repeating* the study-test cycle and by investigating the effects on a process-level. Referring to theoretical frameworks on multimedia learning and metacognitive monitoring and regulation, it was tested whether repeated studying and testing would reduce biases in multimedia learning, thereby fostering study success.

1.1. Multimedia effect

Influential theories of multimedia learning (e.g., Mayer, 2014) mostly rely on cognitive processes to explain multimedia effects. According to the cognitive theory of multimedia learning (CTML, Mayer, 2014) learning with multimedia (i.e., text and pictures) entails selecting and organizing information from both text and pictures into two separate mental models in working memory. These two mental models are subsequently integrated with the help of prior knowledge. Referring to dual coding theory (Paivio, 1986), CTML assumes that when learning with text and pictures information will be stored in both a verbal and a nonverbal (pictorial) code. When trying to retrieve the processed information at a later point in time, this is possible by retrieving either the verbal or the pictorial or the integrated code. After learning with text (or picture) only, information can be retrieved only by one code in memory, which makes successful retrieval less likely. Therefore, better recall is assumed to result from learning with text and pictures compared to learning with text only, which has been confirmed by a vast number of empirical studies (see Butcher, 2014 for a review).

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According to the integrative model of text and picture comprehension (ITPC; Schnotz, 2014), presenting a picture in addition to text facilitates mental model construction. Against the backdrop of the construction-integration model (Van Dijk & Kintsch, 1983), ITPC assumes that deeper comprehension is achieved only when readers construct a representation of the meaning of a message (i.e., text base) that can then be integrated into a mental model of the described situation with the help of prior knowledge. According to ITPC, presenting a picture in addition to text can facilitate construction of a richer mental model, because the picture as external representation shares a more direct relationship with the respective mental model than text does. Ideally, spatial relations from the picture can be directly mapped onto conceptual relations in the mental model (analogous structure mapping), so that subsequent mental model construction from text can be based on spatial relations initially extracted from the picture. The picture thus acts as a mental scaffold facilitating subsequent processing and comprehension of text (Eitel, Scheiter, Schüler, Nyström, & Holmqvist, 2013). Therefore, presenting pictures in addition to text can foster comprehension, especially if pictures are processed early, and thus, prior to or simultaneously with the text (Eitel, Scheiter, & Schüler, 2013; Eitel & Scheiter, 2015).

Aside from exerting their scaffolding function, pictures can lead to a stronger multimedia effect the more intensely they are processed as well as the more they are processed in an interleaved manner with the text, because the likelihood of constructing a richer mental model is increased. More extensive and integrative processing can be identified by using eye tracking as a research methodology. In particular, eye tracking provides high-frequent data about where the eyes are located at a given point in time and it is generally assumed that when having an engaging task (e.g., learning with multimedia), students think about what they fixate with their eyes (eye-mind hypothesis; Just & Carpenter, 1980). Hence, studies that have successfully linked better learning outcomes to more eye fixations on the picture (Schwonke, Berthold, & Renkl, 2009; Scheiter & Eitel, 2015) and to more transitions between text and picture (Hannus & Hyönä, 1999; Jamet, 2014; Johnson & Mayer, 2012; Mason, Pluchino, & Tornatora, 2015; Mason, Tornatora, & Pluchino, 2013) can be taken as indirect evidence that a more extensive and integrative picture processing yields a richer mental model, resulting in a stronger multimedia effect. In line with these findings, some studies failed to find multimedia effects when pictures were hardly processed (e.g., Folker, Ritter, & Sichelschmidt, 2005). Reasons for an insufficient processing of pictures are discussed in the following.

1.2. Biases in multimedia learning

In classical multimedia learning situations students are required to study the multimedia materials in preparation for an upcoming knowledge test, but they often do not know the exact demands of this test. Thus, they often do not know how to process the materials to be optimally prepared. This is especially true for the processing of pictures, given that learning with pictures is much less common than learning with text, for which students have usually acquired general cognitive strategies (slow reading, re-reading relevant and complex contents; Lorch, Lorch, & Klusewitz, 1993). Accordingly, studies in multimedia learning have found that learning with text and pictures is strongly guided by the text (Hegarty & Just, 1993), and that – in the absence of explicit cues or prompts (Stalbovs, Scheiter, & Gerjets, 2015) – pictures are sometimes processed insufficiently. For instance, studies using eye tracking as a process measure showed that, compared to text, very few eye fixations fell on the picture. According to the eye-mind hypothesis (Just & Carpenter, 1980), this suggests that little attention and cognitive processing were devoted to them (Folker et al., 2005; Hannus & Hyönä, 1999). Moreover, results from a study by Lenzner, Schnotz, and Müller (2013) revealed that students' eye fixations fell on the pictures only briefly at the beginning and at the end of the instruction, suggesting that aside from capturing initial attention pictures were hardly processed. This can be detrimental to successful learning, because (too) little attention on the picture can be negatively related to study outcomes (Eitel, Scheiter, & Schüler, 2013; Scheiter & Eitel, 2015; Stalbovs, Scheiter, & Gerjets, 2015).

Students may also process text and pictures insufficiently, because they are subject to biases in their monitoring of learning and understanding. Such biases can be identified by comparing students' estimated performance (judgment-of-learning; JOL) with their actual performance in a subsequent test (Nelson, Dunlosky, Graf, & Narens, 1994). The rationale of this method is that JOLs reflect self-monitoring of one's own learning progress, which serves as the basis for decisions as to whether learning is continued, intensified, or terminated (cf. metamemory framework; Nelson & Narens, 1990). Self-monitoring is considered accurate when JOLs resemble actual learning outcomes (good calibration; Alexander, 2013). Only if self-monitoring is accurate, adequate decisions for re-study behavior are made and self-regulated learning is successful (Thiede, Anderson, & Therriault, 2003).

When having a complex task such as learning with expository text, students often monitor their learning progress by relying on heuristics such as anchoring and adjustment (Zhao & Linderholm, 2008), domain familiarity (Shanks & Serra, 2014) or ease of processing (Rawson & Dunlosky, 2002). Such heuristics do not always provide students with valid cues on which they can base their learning judgment. Rather, they might bias students' judgments so that they judge their learning to be better than it actually is, thus demonstrating poor calibration accuracy known as *overconfidence* (Koriat, Lichtenstein, & Fischhoff, 1980).

Interestingly, the fact that contents of a text-based instruction are additionally illustrated in a picture can lead to higher confidence levels, even if the pictures are merely decorative and hence do not foster the actual learning performance (multimedia heuristic; Serra & Dunlosky, 2010). Thus, multimedia per se can trigger overconfidence (Ackerman & Leiser, 2014; Jaeger & Wiley, 2014). One reason for overconfidence due to multimedia is that learners perceive comprehension processes as being easier when these processes are based on passive perception of illustrations rather than on active elaboration of a text (illusion of understanding; Bétrancourt, 2005; Kühl, Scheiter, Gerjets, & Gemballa, 2011; Paik & Schraw, 2013; Salomon, 1984). Such overconfidence can be detrimental to learning (Dunlosky & Rawson, 2012), because students may prematurely believe that they have reached an appropriate understanding of the multimedia contents. In consequence, they may invest too little effort (Paik & Schraw, 2013) and allocate study time ineffectively by premature study termination.

To conclude, there are two biases in multimedia learning. First, because students lack knowledge about how to prepare for an upcoming knowledge test, they can be prone to over-rely on the processing of text. Second, due to the multimedia heuristic students can become overconfident, being related with reduced study time and effort in multimedia learning. One potential means to diminish such biases is to give students the opportunity to repeat studying after assessing their understanding in a knowledge test.

1.3. Reducing biases: repeated studying and testing

In more basic memory research, the study of learning often involves several cycles of learning and testing (i.e., multitrial learning), sometimes as many as it takes to recall the information reliably (Karpicke & Roediger, 2008; Thiede & Dunlosky, 1999).