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The relationship between metacognitive experiences and learning: Is there a difference between digital and non-digital study media?

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ABSTRACT

Technological development has influenced the ways in which learning and reading takes place, and a variety of technological tools now supplement and partly replace paper books. Previous studies have suggested that digital study media impair metacognitive monitoring and regulation (Ackerman & Goldsmith, 2011; Ackerman & Lauterman, 2012; Lauterman & Ackerman 2014). The aim of the current study was to explore the relationship between metacognitive experiences and learning for digital versus non-digital texts in a test situation where metacognitive experiences were assessed more broadly compared to previous studies, and where a larger number of potentially confounding factors were controlled for. Experiment 1 ($N = 100$) addressed the extent to which metacognitive monitoring accuracy for 4 factual texts was influenced by whether texts were presented on a paper sheet, a PC, an iPad, or a Kindle. Metacognitive experiences were measured by Predictions of Performance (PoP), Judgements of Learning (JoL), and Confidence Ratings (CR), and learning outcome was measured by recognition performance. Experiment 2 ($N = 50$) applied the same basic procedure, comparing a paper condition with a PC condition with the opportunity to take notes and highlight text. In both experiments, study media had no consistent effect on metacognitive calibration or resolution. The results give little support to previous claims that digital learning impairs metacognitive regulation.

1. Introduction

In today's society there is an increased use of digital equipment, with PC's and tablet devices now being used more frequently also in educational settings. This has opened up for new ways of learning, both at an individual level but also at a group level. For instance, there is currently a large interest in the development of collaborative e-learning environments and multidisciplinary learning groups (e.g., Dascalua, Bodea, Lytras, Ordoñez de Pablos, & Burlacua, 2014), and technology is also seen as an important element of knowledge management (e.g., Zhao & Ordóñez de Pablos, 2011). This development calls for more knowledge about if and to what extent cognition is influenced by digital versus non-digital presentation format (Carr, 2010). In an educational context, digitalization has resulted in an increased emphasis on students' *digital competence*. In parallel, there is an additional focus in today's schools on students' ability to engage in *self-regulation*, defined as the extent to which the learner is "metacognitively, motivationally and behaviourally active participants in their own learning process" (Zimmerman, 1986, p. 308). The combined focus on digital competence and self-regulation necessitates more knowledge about the relationship between learning and self-regulation in digital compared to traditional paper-based learning.

According to the above definition, self-regulation refers to students' ability to regulate learning through metacognitive processes. From this perspective, self-regulation requires the ability to engage in *metacognition*, i.e., cognition about one's own cognition (Metcalfe, 2000). A distinction is often made between *metacognitive monitoring*, where metacognitive thoughts or feelings reflect aspects of ongoing cognitive processing, and *metacognitive control*, where the output of such monitoring is used to regulate cognitive processes and behaviour (Koriat, 2000, 2007). An example would be the decision to read a text once more if one felt that comprehension was low. Within such a framework, metacognitive monitoring is a prerequisite for metacognitive control and self-regulation.

Self-regulation and metacognition have become central concepts in a wide variety of studies on online learning, e-learning and digital media use. For instance, a recent study by Pellas (2014) that

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explored student engagement and learning in a virtual reality learning environment, found that metacognitive self-regulation was one predictor of emotional and cognitive engagement. Similarly, in an experimental study looking at "preflective prompts" (i.e., a request for reflection before the learning task) in e-learning, Lehmann, Hähnlein, and Ifenthaler (2014) found that metacognitive awareness was a significant predictor of effective self-regulation.

In this paper we focus on the relationship between learning and metacognitive monitoring in digital and non-digital learning contexts where the learning material is written texts. Previous research has shown that people's subjective preferences for reading texts are often in favour of paper-based rather than digital formats (Buzzetto-More, Sweat-Guy, & Elobaid, 2007; Jamali, Nicholas, & Rowlands, 2009; Spencer, 2006; Woody, Daniel, & Baker, 2010). A number of studies have also explored effects of study media on learning outcome (e.g., Mangen, Waldermo, & Brønnick, 2013) and on subjective experiences (e.g., Mangen, 2006), of which metacognitive experiences would be one example. However, to our knowledge only three studies to date have specifically compared how learning and metacognition is related in digital versus non-digital learning contexts (Ackerman & Goldsmith, 2011; Ackerman & Lauterman, 2012; Lauterman & Ackerman, 2014). Here the relationship between learning and metacognitive monitoring was measured as the degree of correspondence between memory performance and *prediction of performance* (PoP), reported either after the study participants had completed an entire text or at regular time intervals during text reading. Absolute monitoring accuracy, referred to as *calibration bias*, was calculated as the absolute difference between memory and total PoP. One of the studies (Ackerman & Goldsmith, 2011) also included a measure of relative monitoring accuracy, referred to as *metacognitive resolution*, which is the correlation between PoP's and recognition scores for a series of texts. The general finding in these studies was that participants in on-screen conditions showed more overconfidence than participants in on-paper conditions, interpreted as calibration bias being influenced by study media. This was found for both free and fixed study time. The only study that included a measure of metacognitive resolution, i.e., relative monitoring accuracy, found that this was not influenced by study media (Ackerman & Goldsmith, 2011). As to the question of whether study media influences learning outcome, results from the studies were mixed.

If metacognitive monitoring and regulation are influenced by presentation format, this has potentially wide-ranging implications both for teaching and research. For instance, it could mean that educators should adjust their expectations of student performance depending on whether a test is conducted on screen or on paper, and also address how students' metacognitive skills in digital learning contexts can be improved. Furthermore, it may encourage researchers to include study media as a potentially relevant variable in research on study processes and metacomprehension. However, in our opinion there is reason to be cautious about drawing such inferences on the basis of the aforementioned studies alone. One reason is the relatively small total number of studies and participants, and the need to replicate the basic effect. Another reason is some potential shortcomings of the basic paradigm used. In the following, we outline each of these, and present two experiments that were specifically designed to address these concerns.

1.1. Measuring metacognitive experiences

One potential shortcoming of the above studies is that they only include one measure of metacognitive experiences, namely PoP. Because reading involves a wide range of cognitive activities, it is likely that a variety of different forms of metacognitive experiences may arise in conjunction with these activities both before, during, and after reading. In order to better capture possible differences in metacognitive experiences across study media and thereby increase the validity of the findings, one should therefore broaden the range of metacognitive measures applied.

A related point is that only one of the studies measured metacognitive resolution. Whereas calibration bias refers to the person's ability to estimate their actual performance level, metacognitive resolution refers to the ability to discriminate between differences in memorability of individual knowledge units (Dunlosky & Metcalfe, 2009). The only measure of metacognitive resolution included in the study by Ackerman and Goldsmith (2011) was also based on PoP. Because PoP was measured either once for each text (Experiment 1) or every 5 min during reading (Experiment 2), each individual correlation was based on very few data points. This statistical limitation was also pointed out by the authors, who referred to recent criticisms of the use of gamma correlations in metacognition research (Benjamin & Diaz, 2008; Masson & Rotello, 2009). Moreover, without specifically controlling for which part of the text each PoP refers to, the degree of correspondence between PoP and performance does not necessarily reflect the relationship between metacognition and learning at the level of individual knowledge units. One possibility is to increase the number of times at which PoP is measured within a single text. A problem with this solution is that frequently measuring PoP may interfere with text reading itself and thus reduce the ecological validity of the reading situation.

One should therefore look for procedures where metacognitive experiences can be measured more specifically in conjunction with different information units contained in the text, but where such measurement does not interfere with the reading process. One obvious candidate is the Judgment of Learning (JoL), which can be defined as "judgments made by participants at the end of a learning trial regarding the likelihood of remembering the acquired information on a subsequent memory test" (Koriat, 1997, p. 490). In other words, it refers to an item-specific prospective metamemory judgement (Metcalfe, 2000). What distinguishes it from other metamemory judgements (like for example Feelings of Knowing, Koriat, 1993) is that it is normally measured in the context of newly acquired knowledge rather than, for example, general semantic knowledge.

Although JoL, like PoP, is a measure of the predicted accuracy of future performance, it could be argued that JoL cannot straightforwardly be applied as a measure of metacognitive experiences in text reading. This is because, unlike PoP, it is rarely rated during the learning situation itself but most often at the end of the learning session, in conjunction with the presentation of a series of memory items. However, the focus in the present study is not so much on the phenomenology of metacognitive experiences during the learning process, as on metacognitive experiences related to the text material and their relationship to learning outcome. From this perspective, it could even be an advantage to measure metacognitive experiences after rather than during text reading. This is because learning outcome mainly reflects long-term memory, whereas a metacognitive rating given during reading mainly reflects short-term memory. This point was raised by Thiede, Griffin, Wiley, and Anderson (2010), as an argument against measuring metacognitive accuracy as the relationship between a metacognitive rating given during reading and performance on a subsequent memory task.

An alternative would be Confidence Ratings (CRs) conducted after participants have answered each of a series of recall/recognition questions (see, e.g., Norman & Price, 2015; for an introduction to CR measurement). In the context of memory, confidence refers to "the state of believing that a particular piece of