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Prompting and visualising monitoring outcomes: Guiding self-regulatory processes with confidence judgments

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ABSTRACT

Sensible self-regulated study decisions are largely based on monitoring learning and using this information to control learning processes, but research has found that such processes may not be initiated automatically. To support learners, we adopted prompting and visualisation methods by asking learners to assign confidence ratings to learning tasks and visualising them during re-study, and tested the effects on metacognitive and cognitive measures in an experimental study ($N = 95$). Results show that prompting monitoring increased study efforts while visualising monitoring outcomes during learning focussed these efforts on uncertain answers. Due to low monitoring accuracy, metacognitively sensible regulation did not lead to cognitive learning gains. While the results support the idea of using visualisation techniques to implicitly guide self-regulated learning, more needs to be done to increase monitoring accuracy. Further, our study suggests that researchers should be aware of the effect that assessing confidence judgments has on subsequent learning behaviour.

1. Introduction

1.1. Metacognitive regulation of learning processes

Theories on metacognitive self-regulation of learning assume a cyclic model, in which learners monitor their learning process and use this information to control learning decisions (Efklides, 2008; Nelson & Narens, 1990). According to Nelson and Narens' framework (1990), learners monitor their learning processes and outcomes (i.e., their object level) and use this information to build a dynamic, meta-level model. This model is used as information to control the learning process itself and thus in turn alters the object level. For example, learners may monitor their attempt to retrieve specific information from memory and, due to experiencing difficulties, judge the information as not learned sufficiently. Based on this information, they may decide to re-study the information altering their actual knowledge. There has been extensive research on how and how well learners monitor their learning (e.g., Maki, 1998), how they use this information to control the learning process (regulation of study, e.g., Nelson & Leonesio, 1988; Thiede, Anderson, & Therriault, 2003), and how this affects learning outcomes (e.g., Nelson, Dunlosky, Graf, & Narens, 1994; Thiede, 1999). Researchers widely assume that learners use their monitoring judgments to control studying (cf. Winne & Hadwin, 1998), and research has repeatedly produced strong evidence that learners can do so successfully (e.g., Kornell & Metcalfe, 2006; Metcalfe, 2009; Thiede, 1999). However, metacognitive self-regulation can still be very demanding and overstrain inexperienced learners (Kalyuga, 2009). Thus, in this paper, we introduce a study that investigates ways to support learning processes and outcomes by implicitly guiding self-regulation efforts based on metacognitive monitoring.

When studying, self-regulated learners have to make important decisions about their learning processes, such as what to study when, whether to continue or terminate studying or how long to study material (Nelson & Narens, 1990). According to Metcalfe and Kornell (2005), allocating study time consists of two stages: choice and perseverance. At the choice stage, learners decide which items they need to study and the order in which to study them. Items already mastered are mostly discarded while items not yet mastered are likely candidates for study. Although different views such as the region of proximal learning framework (e.g., Metcalfe & Kornell, 2005) and discrepancy reduction views (e.g., Thiede & Dunlosky, 1999) suggest different approaches, they agree that not-yet mastered items are prioritised. At the perseverance stage, learners decide on how much time to spend on the chosen items

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and thus when to terminate study. All of these decisions may be based on process monitoring (Nelson et al., 1994), but can also be part of overall task goals or agendas (Dunlosky & Ariel, 2011; Dunlosky & Thiede, 2004; Thiede & Dunlosky, 1999). Even if effective agendas vary greatly depending on personal and situational factors, they all involve self-evaluation strategies to adapt study behaviour to subjective needs (Ariel, Dunlosky, & Bailey, 2009). The learner must detect such need and keep it mentally present to make study decisions accordingly. However, this might not be possible in challenging learning scenarios. Thus, there are two obstacles to regulating learning processes: the detection of a need to study and its mental presence in order to make adequate control decisions.

To detect the need to study, learners have to monitor their learning. However, such monitoring processes and the judgments that result from it (monitoring judgments) can only provide a sound basis for controlling the learning process (and thus lead to effective regulation) if they are sufficiently accurate (Dunlosky & Rawson, 2012). There are two possible cases of misjudgement: (1) overconfidence (e.g., a firm belief in the correctness of objectively incorrect information), which could lead to understudying (Dunlosky, Rawson, & Middleton, 2005) or misinformed decisions (Leclercq, 1983); and (2) underconfidence, which might yield positive results due to overlearning given unlimited resources, but might have detrimental effects if it requires that scarce resources be allocated to already mastered learning material (Dunlosky & Rawson, 2012). Regardless of the accuracy of monitoring judgments, low confidence discloses gaps in knowledge that need to be addressed to gain usable knowledge (e.g., Hunt, 2003). Therefore, learners should be likely to address uncertainties if they are aware of them.

Research has shown that actively trying to retrieve an answer from memory positively affects the accuracy of metacognitive judgments (Dunlosky et al., 2005). For example, response confidence judgments (RCJs), which require learners to evaluate their responses to learning tasks, have been shown to be more accurate in predicting actual performance than judgments made prior to retrieval attempts (e.g., Costermans, Lories, & Ansay, 1992; Maki, 1998). As discussed above, accurately monitoring performance is highly important for self-regulated learning processes and outcomes, as it influences the usefulness and the effectiveness of study decisions (Dunlosky & Rawson, 2012), such as deciding when to re-study an item or topic (Thiede, 1999). Consequently, RCJs seem to be a suitable basis for such decisions, as learners can (re-)study if they are not confident about their responses to learning tasks.

As stated, RCJs are subjective post-answer evaluations of the validity of one's own answers (i.e., subjective validity) (Leclercq, 1983) and may thus be used as a guide for further learning. While the formation of such metacognitive evaluations may be an unconscious process (Efklides, 2008), their strategic usage requires an active maintenance of the information in memory in order to compare specific evaluations (Dunlosky & Ariel, 2011) and thus conscious awareness (Efklides, 2008). This active processing consumes cognitive capacities, especially if learners must prioritise and choose between simultaneously presented materials. Item selection within simultaneously presented material activates planning activities, presumably due to automatic engagement of inter-item comparison processes necessary to make well-founded study decisions (Dunlosky & Thiede, 2004). Consequently, metacognitive processes are related to high mental effort. While assigning cognitive resources towards sensible regulation (e.g., sensible item selection) may benefit learning by focussing attention on relevant material, it may still overstrain inexperienced learners (Kalyuga, 2009). The additional effort required by metacognitive processes may be one reason why effective regulation sometimes fails: Learners do not always actively monitor their learning (production deficiency, cf. Veenman, Kerseboom, & Imthorn, 2000; Winne, 1996) or do so only implicitly, which might result in less aware metacognitive information and thus no solid basis for control decisions. Conversely, learners might thoroughly monitor their learning but fail to use this valuable information to control learning processes, resulting in a fall-back to habitual behaviour strategies (Ariel & Dunlosky, 2012; Ariel, Al-Harthy, Was, & Dunlosky, 2011), because the metacognitive information is not readily available and hard to mentally obtain during learning. Thus, effective regulation support should address not only the lack of monitoring, but may also foster the usage of its outcome by enhancing its salience and reducing the effort of utilising this information.

1.2. Fostering metacognitive self-regulation

Metacognitive self-regulation may fail if learners are not able or not willing to monitor their learning appropriately. There are various methods to overcome availability deficiencies of monitoring, such as strategy training (e.g., Nietfeld, Cao, & Osborne, 2006), which have been successfully used to improve deficient monitoring skills. Production deficiencies, in contrast, happen when available behaviour is not executed, for example due to distraction (cf. Veenman et al., 2000). Here, direct instruction may be used more cautiously to allow for individual regulation (cf. *assistance dilemma*, Koedinger & Aleven, 2007) and instructional methods can be limited to an activation of favourable processes, e.g., by prompting. Prompting has repeatedly been found to be an effective means to support self-regulated learning (Bannert & Reimann, 2012; Wirth, 2009). Metacognitive prompts merely stimulate recall or execution of skills and thus do not teach new information (Bannert, 2009), but they do put emphasis on specific processes or concepts. A mandatory judgment on monitoring outcomes, for example, asks the learner to monitor their cognitive processes explicitly and to externalise the outcome by rating it on a given scale. Following these prompts thus triggers monitoring and additionally makes the outcome more salient. Recent research has shown that monitoring judgments, i.e. judgments of learning, are highly reactive, affecting for example study time allocation (Mitchum, Kelley, & Fox, 2016) or memory (Soderstrom, Clark, Halamish, & Bjork, 2015). While judgments of learning are assumed to foster an active memory search, which may act as rehearsal in case of successful recall, RCJs do not serve this function since they refer to already retrieved answers. Thus, it remains unclear whether assessing RCJs influences self-regulated study processes.

Whilst monitoring processes have been prompted successfully in the past, promoting their usage to guide study decisions seems more difficult. As we discussed earlier, adequate control strategies even though available (e.g., choosing appropriate items to study) might fail if the task exceeds the mental capacities of the learners. Computational systems offer the possibility to permanently take study decisions off the learners' hands (e.g., Kornell & Metcalfe, 2006; Nelson et al., 1994), but this digresses far from the idea of self-regulated and autonomous learners. Thus, support strategies are needed that relieve the cognitive system while tacitly guiding the learners' self-regulation attempts. One strategy, borrowed from group awareness research, is the salient visualisation of knowledge-related information to support learners in structuring their common learning processes (Janssen & Bodemer, 2013); this includes visualisations of metacognitive judgments (Dehler, Bodemer, Buder, & Hesse, 2011). By providing salient, easily comparable visualisations of (lacks of) knowledge, such tools may guide learning while still enabling a self-directed approach (Bodemer, 2011). Previous work conducted in group awareness research