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Editorial

Improving self-monitoring and self-regulation: From cognitive psychology to the classroom

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A B S T R A C T

Although there is abundant experimental metamemory research on the relation between students' monitoring, regulation of learning, and learning outcomes, relatively little of this work has influenced educational research and practice. Metamemory research, traditionally based on experimental paradigms from cognitive psychology, can potentially contribute to designing and improving educational interventions that foster self-monitoring and self-regulation in children, adolescents, and young adult learners. We describe the metamemory paradigm, and provide a short overview of the insights it has generated with regard to improving metacognitive skills in these groups of learners. Moreover, we summarize the contributions to this special issue on translating insights from cognitive psychology research on metamemory to educational research and practice, and describe possible themes and directions for future research that could further bridge the gap between fundamental and more applied research on metacognition, so as to design effective educational interventions.

1. Introduction

Imagine a fifth grade student, studying a 1000 word long expository text on Antarctica in class. While doing so, various cognitive processes are simultaneously in action in the students' mind, such as deciphering the words, making sense of them within the context of a sentence, and connecting the meaning of sentences to information in long-term memory. To enable this, the student occasionally pauses while reading, looks back in the text to reread pieces of it, estimates whether she has understood the information, and decides when to continue with a novel text segment. These *meta*cognitive processes are vital for adequate comprehension of the text, and are exercised with varying success by different students. Not only in text comprehension, but also in learning of procedural tasks (e.g., mathematics) and verbal learning tasks (e.g., foreign vocabulary learning) do such metacognitive processes play a role.

A Web of Knowledge search showed that interest in metacognition as a research subject has grown disproportionately over the last decade. The number of articles containing the topic "metacog*" increased with 98% (from 453 articles in the last decade of the 20th century to 898 in the first decade of the 21st century, excluding clinical psychology articles), whereas for instance the total number of articles in the subject area Education and Educational Research in general has grown by 'only' 47% during that time (from 149,605 to 219,711 articles). A lot of experimental laboratory research on the nature and development of metacognitive processes in relation to learning, in particular on the accuracy of self-monitoring and how that impacts self-regulation of study, has been conducted in cognitive psychology. Relatively little is known about how to foster self-monitoring and self-regulation through instructional interventions in classrooms.

The goal of this special issue on self-monitoring and self-regulation is to provide a set of state-of-the-art innovative empirical studies, in which insights from the above mentioned studies from cognitive psychology inspired the development of instructional interventions to improve self-monitoring and self-regulation in educational contexts. These are studied with a variety of tasks, domains, and learners. Four studies and two commentaries are reported. The four empirical studies encompassed various text-based learning tasks in different domains, such as studying key terms from introductory psychology textbooks (Dunlosky & Rawson, 2012), answering general information questions (Metcalfe & Finn, 2012), studying hypertexts on biology (Pieschl, Stahl, Murray, & Bromme, 2012), and studying expository science texts (Redford, Thiede, Wiley, & Griffin, 2012). Moreover, students' developmental level ranged from elementary school third grade children to college undergraduates. The two commentaries by Efklides (2012) and Koriat (2012) provide a critical discussion of the findings and indicate thematic and methodological directions for future research. This introduction will provide a short historic overview of research on metacognitive processes in school-age children and young adults, detailing some of the general conclusions that can be drawn based on these studies. We will then try to place the contributions of the special issue within this theoretical framework, and provide a number of directions for future research. To foreshadow, the abilities of young students to judge their memory and comprehension of learning material seem to be better than originally thought. When metacognitive instruction takes into account a number of design principles, accuracy of metacognitive processes in children can equal that of adults.

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2. The metamemory framework

The origin of the scientific study of metacognition can be traced back to two influential authors in this domain. Hart (1965) was the first to experimentally study metacognitive experiences, and gave the Feeling-of-Knowing state (FOK) its name. That is, when asked a semantic knowledge question (such as "Who was the president of the USA during World War II?"), people can quite adequately and quickly indicate whether or not they will be able to retrieve the correct answer from memory, even though they are not yet attempting to retrieve it. This is called a feeling of knowing. It is still a popular research topic, judged by the number of articles that are published on it each year (e.g., Chua, Schacter, & Sperling, 2009; Hertzog & Touron, 2011; Thomas, Bulevich, & Dubois, 2011). Much inspired by Jean Piaget's work, Flavell (1976, 1979) introduced the term 'metacognition', defining it as any cognitive activity or knowledge that takes as its cognitive object an aspect of cognitive activity. Flavell particularly theorized about the individual's ability to monitor and manage the content of his memory. He was the one to introduce the term 'metamemory'. In his view, metacognition can be regarded as conscious and purposeful, intended to reach a specific outcome. But it wasn't until Nelson and Narens' seminal publication (1990; see also 1994) that a general metacognitive model described how metacognitive processes act upon and interrelate with cognitive processes (see Fig. 1). This model sketches two layers, the object level and the metalevel. The object level is made up of cognitions, typically related to objects in the outside world. The metalevel consists of cognitions about cognitions from the object level.

Within this model, information is considered to flow from the object level to the metalevel, thereby providing input for metacognitive thoughts and feelings about specific cognitions (Nelson, 1996). Having these metacognitive thoughts and feelings about cognitions is referred to as 'monitoring'. Moreover, based on the outcome of metalevel processing, the metalevel informs the object level on how to respond to the environment or adapt behavior. This is called 'control' (or 'regulation'). The latter process, for example, causes a student to reread a text, or quit studying it, when the metalevel diagnoses comprehension problems. For the metalevel to influence the object level, it needs to have a dynamic model of the current state of the object level, it has to have a goal state, and it needs to know what strategies are possible to change the object level to attain the goal state. As a result, the metalevel can evaluate cognitions (e.g., realize that comprehension of a text is below that envisioned), and act to improve it (e.g., rereading a portion of the text that is considered crucial). Van Overschelde (2008) describes how monitoring strictly refers to gathering and interpreting information from the object level. It can be seen as analogous to sensory perception, referred to as 'metaperception'. Any action or intention to act that derives from monitoring is termed control or regulation (which we will use from now on as it is the more common term in educational research). We will use the term 'metamemory' when referring to the memory approach to studying metacognition that inspired much of the studies in this special issue.

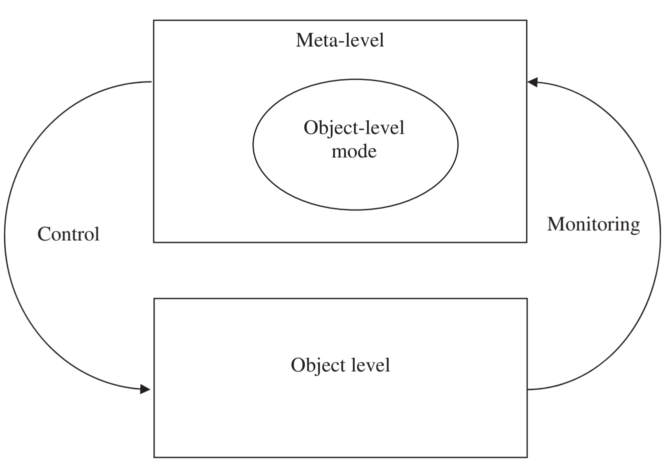

Fig. 1. Nelson and Narens' metacognitive model (Nelson & Narens, 1990, 1994). The metalevel contains a representation of the object level.

As educational researchers, we are primarily interested in influencing learning outcomes. So how do students' monitoring and regulation processes relate to their learning outcomes? According to the discrepancy reduction theory, monitoring, regulation, and learning are intertwined and together enable the learner to reach a desired learning goal (e.g., Butler & Winne, 1995; Dunlosky & Hertzog, 1998; Thiede & Dunlosky, 1999). That is, the learner has a desired level of understanding of the to-be-studied material in mind, and during or after study monitors to what extent this state has been reached. If a discrepancy exists between desired and current level of understanding, the learner will regulate learning behavior by continuing to study the material. During restudy, the learner will again monitor the level of understanding and determine whether further restudy is necessary. This process continues until the discrepancy between desired and current level of understanding has disappeared. Generally, this should cause learners to spend more time on the most difficult parts of a task, as the experienced discrepancy is largest there (Dunlosky & Hertzog, 1998). A competing hypothesis, the region of proximal learning account (Kornell & Metcalfe, 2006; Metcalfe, 2002; Metcalfe & Kornell, 2005), posits that students have adaptive strategies when regulating learning, and will for example allocate their attentional resources to studying the easiest parts or items first when study time is constrained, and move on to more difficult items if there is time left. More recently, Ariel, Dunlosky, & Bailey (2009), Dunlosky & Ariel, 2011) introduced the concept of agenda-based regulation (ABR). According to ABR, learners set a specific agenda or goal prior to study, and will select material for restudy based on their agenda. Depending on their agenda, item difficulty need not be the foremost criterion for restudy selection. Ariel, Dunlosky, & Bailey (2009) for example showed that reward structure of the task may drive restudy to a greater extent. In sum, ABR does not defy a discrepancy reduction or region of proximal learning strategy, but draws the boundaries for when either of these is likely to drive regulation of learning.

2.1. Metamemory: the paradigm

Having laid out some of the dominant theories on the relation between monitoring, regulation, and learning in the domain of metamemory, it is important to detail the prevailing research paradigm in this field. A number of common characteristics of metamemory experiments can be identified, although there are of course more variations than commonalities (see Benjamin & Diaz, 2008; for a thorough analysis of the paradigm). First, participants are typically asked to study learning material, often consisting of a list of items, such as paired associates (e.g., Benjamin & Bird, 2006; Koriat, Sheffer, & Ma'ayan, 2002; Nelson & Dunlosky, 1991), but it could also be a number of texts (Thiede, Anderson, & Therriault, 2003; Thomas & McDaniel, 2007), or pictures (Masur, McIntyre, & Flavell, 1973). An experimental manipulation is usually introduced related to studying the items. For instance, the nature of the items is manipulated within subjects (e.g., high- versus low-frequency words, Benjamin, 2003; items are presented massed or spaced, Son, 2004), or subjects are given different instructions when studying the items (e.g., generating versus reading, Begg, Vinski, Frankovich, & Holgate, 1991). Alternatively, participant characteristics are manipulated (e.g., testing children of diverse ages; Schneider, Visé, Lockl, & Nelson, 2000; or younger versus older adults; Hertzog, Kidder, Powell-Moman, & Dunlosky, 2002).

Next, participants are required to provide some sort of judgment about their memory or understanding of the material they just studied. This judgment is typically made offline; that is, *after* studying an item or a set of items. Several types of judgments have been listed. Apart from the already mentioned Feeling-of-Knowing judgment, a large number of studies included Judgments of Learning (JOL), which refer to the judged likelihood that the target material will be remembered on a later test, or Ease-of-Learning judgments, which are made prior to study of the material and require learners to indicate how easy the material will be to learn (Nelson & Narens, 1994). Learners indicate these judgments on a scale from "highly unlikely to recall/learn" to "highly likely to recall/learn". Various numerical characterizations of this scale are used (e.g., from 1 to 5, 1 to 7, or in a percentage from 0 to 100%), depending on planned analyses and nature of the participant group. With young children, for example, a representation of a thermometer has been used, on which children have to indicate their estimated chance of recalling a target item as how 'hot' or 'cold' they experience this chance (Koriat & Shitzer-Reichert, 2002). An experimental manipulation can also be introduced with regard to the judgment process, so as to alter the judgments in a specific manner (e.g., by varying the delay between studying the items and providing JOLs, Nelson & Dunlosky, 1991).

Finally, some sort of test is included, where learners are required to demonstrate memory or understanding of the studied material. When paired associates are used, the test usually consists of retrieving the target of the word pair when presented the cue. When texts are used, the test could for example be inference or detail questions, in a multiple-choice or open answer format.

The metamemory paradigm is characterized by a quantitative approach to measuring metacognitive activities of learners. The foremost metacognitive variable is (self-)monitoring accuracy, or the relation between learners' judgments and test performance. When texts are used, this is usually referred to as 'metacomprehension accuracy' (Maki & Berry, 1984). The higher these correlate, the more accurate the learner was able to predict his test performance. The predominant method to calculate monitoring accuracy is the Goodman-Kruskal gamma correlation (Goodman & Kruskal, 1959; see Nelson (1984) for a discussion on why gamma is the measure of choice). The gamma correlation is a measure of relative accuracy that ranges between -1 and $+1$ and determines to what extent items that are judged as relatively more difficult are remembered less on the test, and vice versa. A gamma close to $+1$ indicates high monitoring accuracy, as learners correctly distinguished which items would be remembered on the test and which would not. A gamma close to zero shows poor monitoring, and a gamma close to -1 means that learners had poor memory for items they judged to know well and good memory for items judged low. Gammas are typically determined intra-individually, and then compared statistically across experimental conditions to assess whether the experimental manipulation had the predicted effect on monitoring accuracy. An increasingly used alternative is to calculate absolute accuracy, or the discrepancy between absolute level of JOLs and test performance (Nelson, 1996). When JOLs are higher than test performance, overconfidence is observed. When test performance exceeds JOLs, underconfidence is seen. Note that these measures of metamemory are independent of memory performance. A learner might score poorly on a test, but have high monitoring accuracy when he correctly identifies the poverty of his performance. Traditionally, monitoring accuracy gammas are found to be fairly low, around $+.30$ (Begg, Duft, Lalonde, Melnick, & Sanvito, 1989; Leonesio & Nelson, 1990). Judgments of Learning are often based on heuristic cues that are not necessarily valid (Koriat, 1997). One such cue is ease of processing (Hertzog, Dunlosky, Robinson, & Kidder, 2003); if items are easier to process, students typically believe they will remember them better, even though this is not necessarily the case. Likewise, the fluency with which items are retrieved from memory is often used as a basis for JOLs, even though this does not guarantee accurate monitoring (Benjamin & Bjork, 1996). Improving monitoring accuracy therefore largely lies in improving the cues that students use when providing JOLs. One manipulation that proved to have a robust effect on monitoring accuracy is inserting a delay between studying items and providing JOLs (Nelson & Dunlosky, 1991). Presumably, the delay leads to improved monitoring accuracy because JOLs are no longer based on information in working memory, but on retrieval from long-term memory. The latter more closely resembles memory at the test situation, leading to a closer correspondence between JOLs and test performance.

In a subset of the metamemory studies, (self-)regulation was also measured. This is typically done by asking learners to select which part of the study material they wish to restudy, before or after taking the test. By calculating a gamma correlation between judgments and selections, an indication of the quality of self-regulation is achieved. Items that are selected for restudy are numerically marked as one, items that are not are marked as zero. Adequate self-regulation is seen when items that received high JOLs were not selected for restudy and items that received low JOLs were selected, in which case the gamma will be close to -1. When learners wrongfully select items they judge to know well, gamma will be close to $+1$. An alternative measure of self-regulation is to compute a gamma correlation between JOLs and the amount of time allocated to restudying the items, where high JOLs should accompany short restudy times and low JOLs correlate with long restudy times (Nelson & Narens, 1990).

In general, accurate monitoring is considered a prerequisite for adequate regulation of learning (but see Koriat, Ma'ayan, & Nussinson, 2006; for the reverse: regulation affecting monitoring). Probably for this reason, the vast majority of metamemory research has been directed at unraveling the basis for metacognitive monitoring judgments, and improving the often poor judgments. In comparison, the number of studies that have experimentally addressed the relation between monitoring and regulation, is relatively small, and even fewer studies have covered the effects on learning outcomes. One example of a study that did look at this relation is a study by Thiede et al. (2003) in which students studied expository texts and rated comprehension of the texts. A subset of the students was required to generate keywords prior to rating their comprehension of the texts. Students who generated keywords monitored text comprehension more accurately, and regulated study behavior better by selecting the texts for restudy that were least understood. These students also outperformed those who did not generate keywords at the ultimate test. The effect of keyword generation was only observed when this was done at a delay after text study, presumably because generating keywords at a delay more closely resembles the test situation and hence provides a better cue for judgment. Of course, this type of research is highly important for education. Only when we are able to shed light on how monitoring, regulation of study, and learning interact, are we able to design interventions to improve instruction. The study by Dunlosky and Rawson (2012) is another example of one that focuses on the link between monitoring and eventual learning outcomes. By controlling for regulation, they are able to show that monitoring indeed affects learning performance: when learners are overconfident, their test performance suffers. We will review their study in more detail below. In the next section, some of the insights that have originated from research in this domain that are particularly relevant to various levels of education will be described.

2.2. Metamemory research in children and adolescents: monitoring

We will mainly focus on studies involving JOLs and Ease-of-Learning judgments, as these are most relevant to the research reported in this special issue and probably to learning in the classroom in general (for a summary of findings on Feeling-of-Knowing studies in children, see Schneider & Lockl, 2008). The study by Schneider et al. (2000) can by now be considered as a classic with regard to investigating the metamemory paradigm with young children. These authors set out to evaluate whether the delayed judgment of learning (JOL) effect extended to children (for additional theoretical discussion of the mechanisms producing the effect see Dunlosky & Nelson, 1997; Spellman & Bjork, 1992). Their results were much in line with those found in adults: even six-year old children more accurately monitored memory performance when JOLs were made after a delay than when they were made immediately. Building on these results, Koriat and Shitzer-Reichert (2002) showed that young children (second and fourth graders) used item difficulty as a cue when providing JOLs. Even second graders were able to distinguish between easy and difficult items, providing higher JOLs to the former. The accuracy of their JOLs improved with practice over learning trials, just as it does in adults (but see Lipko, Dunlosky, and Merriman (2009) for an example of a study with four and five year-old children, where practice did not improve monitoring accuracy). There is also evidence by now that children have low, but better than chance levels of accuracy for immediate JOLs (Son, 2005, 2010).

Koriat and Shitzer-Reichert's (2002) study also showed that younger children exhibit more overconfidence in memory performance than older children. This overconfidence is clearly visible in Ease-of-Learning judgments, when children are asked to estimate the number of items they will be able to memorize (Visé & Schneider, 2000). These overestimations are most prominent in preschoolers and kindergarteners, and diminish in elementary school children (Worden & Sladewski-Awig, 1982). As the studies on JOLs show, young children's post-learning memory monitoring equals that of adults, so a memory monitoring deficiency can hardly explain the overconfidence. An alternative explanation posited is the tendency to apply wishful thinking: Young children estimate the number of items they would *like* to remember, but fail to notice that this differs from what they are *able* to remember. Visé and Schneider (2000) indeed found that four- and six-year old children could not differentiate between performance they *wished* to attain and performance they *expected* to attain. Children believed that if they exerted effort, they would be able to remember as much as they wanted to, which led to unrealistically high memory predictions. These data provide at least partial support for a motivational explanation of overconfidence in preschoolers.

In sum, these studies show that as of elementary school, children are able to monitor their own memory to a considerable extent, even comparable to the level of adults. Although overconfidence is widespread, especially in preschoolers and in judgments made prior to the learning task, these overestimations diminish in school-age children. But what happens when children are not asked to memorize lists of words or pictures, but have to process more real-life like learning materials, where understanding of the gist of the material is more important than literal recall? Recently, a number of studies have looked at this. For instance, Roebers, von der Linden, and Howie (2007) asked eight and ten-year old children to watch a video of a short event and then to rate how well they would remember the content of the video later on. The subsequent test included questions that contained information that was not present in the video, and that were thus unanswerable. Results revealed that even the youngest children were able to differentiate between correct and incorrect answers, and between answerable and unanswerable questions. Regardless of age, these children correctly used retrievability as a cue for JOLs, with gammas between JOLs and memory performance ranging from .53 to .70.

A recent study by De Bruin, Thiede, Camp, and Redford (2011) explored to what extent school-age children were able to provide accurate metacomprehension judgments of texts. It was known from research with adults that asking learners to merely rate their comprehension led to inaccurate judgments. Instead, a cue activation instruction that required learners to activate cues that indicate comprehension prior to providing judgments positively influenced metacomprehension accuracy. Cue activation techniques that have proven to be successful in adults are providing a summary (Thiede & Anderson, 2003), or generating keywords (Thiede et al., 2003). These techniques were only effective when done at a delay after text study, however (for more evidence on the link between metacomprehension and cue use, see Thiede, Griffin, Wiley, & Anderson, 2010). In the study by De Bruin et al. fourth, sixth, and seventh graders were asked to generate keywords after a delay and prior to rating comprehension of a number of expository texts. For sixth and seventh graders, generating keywords improved metacomprehension accuracy. Fourth graders were unable to profit from the keyword generation task; their metacomprehension accuracy did not differ significantly from zero. However, gamma correlations for the sixth and seventh graders lagged behind what is typically found in metamemory research: .27 for seventh graders and .42 for sixth graders. Clearly, monitoring comprehension of text is a more difficult task for children than monitoring memory of word pairs, despite use of a cue activation technique as generating keywords. De Bruin et al. (2011) conclude that activation of the situation model (Kintsch, 1998) of the text prior to judging comprehension might explain the positive effect of keyword generation on metacomprehension accuracy. The absence of the effect of generating keywords in fourth graders suggests that activation of the situation model as a metacognitive cue is more complex for younger learners. More research is needed that directly addresses the link between activation of the situation model and metacomprehension accuracy.

In general, it seems we can conclude that when it comes to simple verbal learning tasks (e.g., paired associates, foreign translation pairs), even young elementary school students are well able to monitor their memory performance. When complexity of the task is higher and working memory load increases, such as in text comprehension tasks, cue activation techniques are necessary, but still insufficient to achieve high metacomprehension accuracy in younger students. Not until the age of around 12 are students able to accurately monitor text comprehension. It should be noted, however, that metacomprehension research in children is still in its infancy, and possibly more elaborate instruction on cue activation techniques might prove successful in the future.

2.3. Metamemory research in children and adolescents: regulation

As outlined above, learning outcomes can only be positively influenced in the metamemory paradigm when monitoring is accurate and is used to regulate further study behavior. Effective regulation would involve a negative gamma correlation between either JOLs and restudy time, or JOLs and item selection (see Nelson, Dunlosky, Graf, & Narens, 1994; Thiede, 1999).

A number of studies have looked at children's capability to regulate study behavior and their results are more inconclusive as those on monitoring behavior summarized above. Masur et al. (1973) asked 7-year-olds, 9-year-olds, and college students to study a list of pictures and select half of the list for restudy. The 9-year-olds and college students showed effective self-regulation by correctly selecting those items for restudy they did not recall on the first trial, whereas the 7-year-olds chose items randomly. However, the fact that students *had* to select half of the items for restudy is not representative of normal learning situations and might have affected the results. A study in which restudy behavior was manipulated more realistically is one by Dufresne and Kobasigawa (1989) in which spontaneous study time allocation was researched in 6- to 12-year olds. Similar results were found: The 6- and 8-year old children could not differentiate study time between easier and more difficult items, but the 10- and 12-year olds studied effectively and spent more time on the harder items. Even though the younger children were aware of the variance in difficulty of the items, they could not translate this into differential study times.

However, later studies questioned young learners' inability to regulate study behavior. When the difference in item difficulty was highly salient (i.e., comparing highly familiar and unfamiliar objects, Kobasigawa & Metcalf-Haggart, 1993), even first grade students regulated study behavior effectively by dedicating more time to study of the unfamiliar items.

A further study providing evidence for adequate self-regulation in young children was done by Lockl and Schneider (2003), who had 7- and 9-year-old children study easy and difficult paired associates, provide JOLs, and restudy the word pairs once more in a self-paced way. Both age groups monitored the difference between the word pairs, and dedicated more time to restudy of the difficult ones. Results, however, showed that the ability to adequately allocate study time improved with age; gamma correlations between JOLs and study times were stronger for the older children (gamma $= -.40$) than for the younger children ($-.22$).

Roebers, Schmidt, and Roderer (2009) also provide evidence that young children show emerging regulation skills. Third and fifth graders rated the correctness of their answers on a test about a previously learned science topic and regulated their test taking behavior by being able to withdraw answers they were unsure about. Both age groups monitored their performance accurately on the test as indicated by high gammas (.63–.75) between predictions and performance. Moreover, adequate regulation skills were shown by their more often withdrawing incorrect than correct answers, and providing lower JOLs for the withdrawn answers. However, third graders more often withdrew correct answers than the fifth graders, possibly indicating a stricter response criterion. Krebs and Roebers (2010) added to this that retrieval processes play an important role in monitoring and regulation behavior. In their study, children more often withdrew incorrect answers from unanswerable items than from answerable items. Again, this effect was more pronounced for the fifth than for the third graders, which suggests that the use of retrievability as a cue in monitoring and regulation is dependent on age. Finally, in the text comprehension study by De Bruin et al. (2011) it was found that even the fourth graders were able to translate JOLs into accurate restudy decisions. It seems that the question to select those texts for restudy that they believed to have understood less was correctly interpreted even at such a young age. Nevertheless, because their JOLs were inaccurate, their text selections were suboptimal too.

Finally, Vidal-Abarca, Maña, and Gil (2010) examined 7th and 8th graders' self-regulatory skills while reading texts and answering questions about the texts. That is, skilled and poor text comprehenders processed two texts, during which several behavioral indicators of self-regulated learning activities (such as looking back in the text or answering a question on the test after searching for information in the text) were gathered. Their results showed clear differences between the poor and skilled comprehenders. Skilled comprehenders more often noticed inconsistencies in the test questions, were able to find more relevant information in the text, and regulated restudy behavior better by giving the right answer to the question at hand more often when they decided not to search for more information in the text. Overall, deciding not to search was accompanied by high JOLs, which indicated that students judged the likelihood that they would answer the question correctly as high when they did not refer back to the text to search for the answer. Vidal-Abarca et al.'s data show emerging self-regulatory skills during online text comprehension and question answering in adolescent students.

In sum, the literature shows that the ability to regulate study behavior does not develop as early as memory monitoring skills. Moreover, young students' ability to translate monitoring into effective regulation of study seems highly dependent on task characteristics and specific instructions provided. When the task material is highly familiar, and when regulation instructions are age appropriate (see De Bruin et al., 2011; Kobasigawa & Metcalf-Haggart, 1993), research provides evidence that elementary school students are fairly well able to regulate their study behavior based on monitoring judgments.

3. New avenues in metacognition research: contributions to the special issue

3.1. Investigating absolute accuracy and effects of feedback

From this synthesis of part of the metamemory research in children, a number of gaps and possible directions for future research emerge, that could contribute to increasing the impact this research inspired by cognitive psychology could have on educational science. For example, there seems to be a trend in metamemory research toward more interest in absolute accuracy instead of the relative accuracy that the gamma correlation expresses (see also Boekaerts & Rozendaal, 2010). Absolute accuracy is measured for instance by asking learners to estimate the absolute quality of an answer they produced on a test, or to guess the number of items they will answer correctly on a test. Such a shift in focus is interesting from an educational perspective, as one could argue that absolute learning judgments are probably more important for effective self-regulation than relative ones. That is, it is already very helpful when learners can make a distinction between items they are more likely and less likely to remember, or between texts they will be more likely or less likely to answer questions on. However, only knowing that you know one item better than another does not necessarily inform you on whether you know that item well enough or should continue to study it. Hence, insights from research on absolute accuracy potentially have clearer educational implications, and may be easier to translate to educational environments. The study by Dunlosky and Rawson (2012) assesses how absolute accuracy affects learning. Undergraduate college students studied key term definitions and were required to self score the correctness of their definitions. Half of the students compared their definitions to a standard consisting of several idea units prior to self scoring. Their results indicate that those who are most overconfident (in this case, mainly those who did not compare their definitions to a standard) learned less. Their second experiment underlines that this was not an effect of the standard or of longer study times, but mainly emerged because of more thorough processing in students that were less overconfident. This study is one of the few that provides concrete evidence for the direct detrimental effect of overconfidence on study behavior and learning performance.

The study by Metcalfe and Finn (2012) also focuses on absolute accuracy, but adds an important neglected factor in metamemory research, namely the effect of feedback on monitoring and learning. Metcalfe and Finn show that, when school-age children are highly confident of an answer on a test that turns out to be incorrect, they are more likely to correct it on a further test. This phenomenon that was previously identified in adults is termed the hypercorrection effect (Butterfield & Metcalfe, 2001). Possible explanations include the effect of surprise that the feedback of incorrectness generates, and more attentional resources being deployed to mend the unexpected incorrect answer. Metcalfe and Finn show that children indeed had partial knowledge of the correct answer, but compared to adults, this is considered less of an explanation for the hypercorrection effect, because children often showed to be unable to indicate the correct answer. That is, when children were pushed to provide the correct answer after realizing their primary answer was incorrect, they were unable to do so. Moreover, when having to select the alternative correct answer from a list, children failed too. The hypercorrection effect demonstrates that the effect of feedback on monitoring and learning is not as straightforward as one might expect; Even when children were highly confident of an answer that turned out to be incorrect, they were able to correct that answer fairly easily when given feedback. Given the omnipresent feedback learners receive in education, there is a need for more research that can provide a clearer theoretical framework on how feedback affects metacognitive processes and learning.

3.2. Extending to other kinds of monitoring and learning tasks

Moreover, it is clear that tasks that have been used thus far are mainly paired associates or short expository texts. While such learning tasks do play an important role in education, they constitute only a part of a wide variety of learning tasks. So in order to truly inform educational practice, there is a great need for studies with other learning tasks as well. In addition, hypermedia learning environments are increasingly used in education, and the nature of hypermedia might affect monitoring and regulation in a different way from printed text (Ackerman & Goldsmith, 2011). The study by Pieschl et al. (2012) used a hypertext learning environment on genetic fingerprinting. Undergraduate college students were required to complete three different tasks (two simple remember tasks and one more complex evaluate task). Given the nature of the learning task, this type of research methodologically departs to a considerable extent from metamemory studies, without losing focus of the importance of studying the relation between monitoring and regulation on learning. Monitoring and regulation were assessed by use of a task-specific questionnaire of over 30 items, and by analyzing the log files of students' study behavior through the hypertext environment. Even in this more complex set-up, students showed accurate monitoring and regulation of study behavior, correctly adapting learning strategies to the differential complexity of the three tasks. However, this was mainly so when looking at students' actual adaptation to task demands as indicated by the log files, and less so for self-report measures of monitoring accuracy. This suggests some sort of dissociation between explicit reflection and behavioral indicators of monitoring and regulation of learning. Koriat (2012) describes the latter form of monitoring as data driven, in that there is little deliberate planning or regulation, but rather, study behavior is adapted online by responding to task demands. In such a relatively authentic learning environment, even average learners provide evidence for the intricate relationship between monitoring, regulation, and learning performance.

Another type of learning task that plays an important role in education, but has received relatively little attention in metamemory research, are procedural and problem solving tasks, which play an important role in subject matter domains such as mathematics, engineering, economics, physics, and chemistry. Relatively few studies have attempted to transfer insights from metamemory research to problem solving tasks (Boekaerts & Rozendaal, 2010; De Bruin, Rikers, & Schmidt, 2005, 2007; Efklides, 2001). Given that problem-solving relies on very different cognitive processes, the question is whether the same results would be found as in verbal learning tasks such as paired associates or text studies. On the one hand, judging comprehension of problem solving tasks might resemble judging text comprehension, where the quality of the situation model of the text has to be judged, rather than the ability to literally retrieve it. Analogically, in problem solving, the quality of the cognitive schema of the problem solution has to be judged. On the other hand, problem solving always involves generation, as problems are often isomorphic (belonging to the same category, having the same solution procedure, but different numerical values, so that calculation remains necessary), the act of which could provide learners with immediate cues to base their judgment on. In that case, one might expect immediate JOLs to be more accurate than delayed JOLs with problem solving tasks as these cues will be less available after a delay (some initial evidence seems to suggest this is the case; Baars, van Gog, De Bruin, & Paas, submitted for publication).

With regard to innovation in tasks intended to improve children's monitoring skills, the study by Redford, Thiede, Griffin, and Wiley (2012) introduced a novel cue activation technique. The cue activation technique that was applied here, which can be easily implemented in educational practice, is concept mapping. In the first experiment in this paper, seventh graders either constructed concept maps or reread the text prior to rating comprehension. The concept map group had marginally higher metacomprehension accuracy than the rereading group. However, metacomprehension accuracy for the concept map group did not differ significantly from zero, indicating that the overall effect of this cue activation instruction was limited. Post hoc analyses revealed that the quality of the constructed concept maps was quite poor, despite prior instruction by an informed teacher. Therefore, the second experiment included a more elaborate training session (8 instead of 3 sessions) for all students that emphasized how to represent information from the text in the concept map and how concept maps could help answer inference questions. In the experimental manipulation, a third of the students constructed concept maps, a third viewed already constructed concept maps, and the final third did neither, but only read and rated comprehension of the texts. The concept map construction group had the highest metacomprehension accuracy, the reading only group had the lowest. Moreover, for the concept map construction and concept map viewing groups, metacomprehension gammas differed significantly from zero. All in all, these experiments provide evidence that an elaborate concept map instruction, combined with actual concept map construction improve metacomprehension in junior high school students.

4. Conclusions and outlook

In sum, the contributions to the special issue provide several novel insights with regard to the development and improvement of metacognitive skills. All four studies can be viewed as inspired by the traditional metamemory paradigm, but with a strong focus on educational applicability. These insights might help building a conceptual framework of the metacognitive learner in the classroom, and translate this to design interventions that foster development of metacognitive skills in learners from elementary school to higher education.

Given the increasing importance of taking into account regulation of learning in applied metamemory studies, a further question to look at is whether students are able to select novel information to study. At some point, students need to move on to studying novel information, and adequate regulation skills are indispensable in this regard. This requires a consideration of characteristics of the new information, to ensure a good fit with the student's current level of knowledge or performance. As such, it is even more complex than a decision on what information to restudy. A recent study suggests that instructing students on how to evaluate (cf. self-score judgment) their own performance on a task (in this case, a problem solving task), and how to use this information in relation to task characteristics to select a novel task, led to more effective self-regulated learning (Kostons, Van Gog, & Paas, in press). It would be interesting to combine this kind of approach with the metamemory research paradigm, to extend this paradigm and include 'transfer' of metacognitive skills to future learning tasks as an additional step in the cycle of monitoring – regulation – learning.

Finally, a factor in metamemory research that has received comparatively little attention, and is emphasized by Efklides, concerns the role of metacognitive feelings (Efklides, 2001; Efklides, 2008; Efklides, 2012). Efklides distinguishes between metacognitive feelings and metacognitive judgments, the latter being estimates that are directly related to observable outcome measures, such as judgment of task complexity, or judgments of response correctness. On the other hand, metacognitive feelings have a more subjective basis, such as confidence or satisfaction ratings. We tend to forget that learners have explicit but also implicit feelings and motives toward learning materials and their ability to influence the learning process that should not be ignored when studying the monitoring-regulation-learning cycle. In the agenda-based regulation model posited recently (Ariel et al., 2009), room is provided for such non-cognitive factors that co-determine metacognitive processes. Moreover, in Metcalfe and Finn's study (2012) the surprise explanation for the hypercorrection effect also alludes to the role of metacognitive feelings in study behavior. To gain a full-fletched understanding of metacognitive processes in the classroom, more attention should be given to prior and current affective experiences and how these influence learning.

As the commentaries by Koriat and Efklides acknowledge, we are still far from deriving a comprehensive set of instructional guidelines to transfer metamemory insights to educational settings. However, the present studies cover a diversity of possible educational interventions, such as comparing answers to an idea-unit standard, providing corrective feedback, constructing concept maps, and using hypertexts, which were examined in a well controlled setting that nevertheless complied with a number of basic assumptions of educationally relevant research. The studies in this special issue show that, even though steps need to be taken to further approach the ecological validity of the classroom, research has clearly moved forward over the last decade from cognitive psychology based metamemory research to studies that are mainly motivated by educational questions with methodology matched to these questions. We hope that this special issue can provide a modest contribution to further inspiring this trend.

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