Psychological Topics 23 (2014), 1, 1-30

Review article – UDC – 159.95
159.953

How Does Metacognition Contribute to the Regulation of Learning? An Integrative Approach

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Abstract

The paper addresses issues related to the accuracy of metacognitive monitoring and the effectiveness of control. Based on the enriched model of metacognition (Efklides, 2008), the facets and levels of functioning of metacognition are presented as well as the processes underlying each facet at the various levels of metacognition. Review of current research on monitoring (i.e., metacognitive experiences and metacognitive knowledge) suggests that monitoring can be inaccurate but factors such as prior knowledge, feedback, and attending to task context and response features can increase accuracy. Control, on the other hand, can be triggered by cognition, affect and metacognition. Research evidence on the relations between monitoring and control suggests that monitoring accuracy can support more effective control decisions but not always. Moreover, control can be ineffective due to lack of resources. What is of interest is that control decisions are often influenced by motivational considerations rather than objective task difficulty and through effects of affect on metacognitive monitoring. This implies that metacognition should be viewed within a broader theoretical framework of self-regulation such as the Metacognitive and Affective model of Self-regulated Learning (Efklides, 2011). The implications of the model are discussed as well as the challenges for future research on metacognition.

Keywords*:* metacognition, monitoring, control, affect, motivation

Introduction

One of the biggest promises – and challenges – of metacognition research is the increase of the effectiveness of control people have over their cognition or behavior, and particularly students over their learning. In the last 30 years, since Flavell (1979) introduced the term metacognition, monitoring and control are considered the two functions of metacognition that are inextricably connected

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This paper is based on the keynote speech at the 5th Biennial Meeting of the EARLI Special Interest Group 16 Metacognition, 5-8 September 2012, Milan, Italy

between them and with cognition. However, if control is to be effective then (a) monitoring should accurately represent cognition; (b) control should inform cognition as to what needs to be done, particularly when automatic processing fails, and (c) control decisions should be appropriate for the person's goals, task demands and situational characteristics. In this article I shall claim that monitoring is not always accurate; furthermore, control exerts its effects on cognition through cognitive and metacognitive strategies and is not always effective; and third, control can be triggered by cognitive, metacognitive, affective, motivational, or volitional factors, and, therefore, its effectiveness should be viewed in a self-regulation framework.

In what follows I shall first present the "enriched model of metacognition" (Efklides, 2008) which posits that metacognitive monitoring can take various forms (facets) that function at various levels of awareness, ranging from a non-conscious level to personal level (subjective experience) awareness and social level awareness. The various facets of metacognition in the various levels of functioning make use of different underlying processes and capture different aspects of cognition. This has implications for the accuracy of monitoring. That is, metacognitive monitoring can be accurate under certain conditions but not others. Following this, I shall discuss the relations between monitoring and control and claim that metacognitive monitoring and control can regulate cognitive processing in a top down or bottom up manner. Moreover, the effectiveness of metacognition (monitoring and control) in the context of SRL presupposes the operation of both general person characteristics (ability, cognitive, metacognitive, affective, motivational and volitional characteristics) that operate across tasks and situations, and response to task-specific demands and processing features (Efklides, 2011).

The Enriched Model of Metacognition

The classical model of metacognition as depicted in Nelson's (1996) seminal paper (see also Nelson & Narens, 1994) posits two levels: the *object level* that corresponds to cognition and the *meta* level that corresponds to metacognition. The meta level is informed by the object level through the monitoring function and informs the object level through control. However, this model depicts metacognition as if it were one unitary process and does not distinguish facets of it, as Flavell (1979) does. Flavell (1979) distinguishes *metacognitive experiences* from *metacognitive knowledge*, although they are both manifestations of the monitoring function. Metacognitive experiences take the form of metacognitive feelings (e.g., feeling of confidence) and judgments (e.g., judgment of learning) related to features of cognitive processing vis-à-vis the task as the person works on the task (Efklides, 2006). Metacognitive knowledge, on the other hand, is declarative knowledge about persons, tasks, strategies, and goals. It is knowledge we retrieve from memory, beliefs and theories we have about cognition and its functioning, about knowledge and criteria of validity of knowledge, about our and others' thinking (Efklides, 2006). Finally, there are metacognitive strategies (also called *metacognitive skills*, Veenman & Elshout, 1999), such as planning, which represent the control function of metacognition. It should be noted, however, that metacognitive control cannot be reduced to metacognitive skills, because control can operate by calling in cognitive strategies as well (Nelson & Narens, 1994).

The enriched model of metacognition (Efklides, 2008) is based on Nelson and Narens' (1994) model but makes explicit the *facets* of metacognition, namely metacognitive experiences (ME), metacognitive knowledge (MK) and metacognitive skills (MS). Furthermore, it distinguishes three *levels* of functioning of metacognition. That is, there is monitoring and control processes at the *object level* (i.e., cognition) that are not conscious (see Paulus, Proust, & Sodian, 2013, for implicit metacognition in young children). These are distinguished from the respective processes at the *personal awareness level*, in which the person is consciously aware of the contents of their consciousness (monitoring and control of cognition) regarding online task processing and previous encounters with similar tasks. Moreover, according to the enriched model, metacognitive processes are not limited to the individual. There is growing evidence for socially shared and socially mediated metacognition (Iiskala, Vauras, Lehtinen, & Salonen, 2011; Volet, Summers, & Thurman, 2009). There are social effects on the individual regulation of cognition. This level of metacognition, the social, is depicted as a meta-meta level, and this is consistent with Nelson's conceptualization of metacognition in which more than one meta levels may exist.

To illustrate the processes involved at each level of metacognition, one can take the following example regarding text comprehension. During reading, monitoring at the object level informs on the fluency of the meaning-making process (comprehension); as long as the comprehension process runs automatically, one goes on with text reading. If, however, comprehension fails temporarily, then monitoring informs control, and reading is slowing down (more attention being given to the phrases that do not make sense). The effortful processing is manifested in the recursive eye movements during reading without the person being aware of the back and forth eye movements. However, the person is not aware of the control being exerted as long as cognitive processing is restored without a major break down. If, on the other hand, despite automatic regulation, cognitive processing is not restored (e.g., comprehension processes fail), then the person becomes consciously aware of the lack of progress in cognitive processing. Thus, the outcome of non-conscious monitoring and control can reach the level of conscious awareness (personal awareness level) in the form of metacognitive feelings or judgments. In the above example, the metacognitive feeling experienced is that of metacomprehension: "I do not understand!" At the personal level awareness there is also presence of metacognitive knowledge (e.g., about reading comprehension and the factors influencing it): "Some word is probably missing from the phrase that does not make sense". There is also awareness of physiological indicators of effort expenditure (e.g., increased attention to specific phrases or unknown words) as well as experiences of agency (Metcalfe & Greene, 2007; Skinner, 1996), in the sense that it is "I" who is (or is not) in control of the comprehension process and the agent of strategies to overcome the breaking down of the comprehension process. Moreover, there is awareness of emotions or affective states related to the task and its processing or the outcome of processing (Touroutoglou & Efklides, 2010). For example, surprise or frustration that one does not understand what they are reading. Finally, monitoring of subjective experiences (metacognitive, physiological, volitional, or affective) at the personal level awareness is coupled with observation of performance as it unfolds and its outcomes. In the above example, the person realizes that they cannot answer questions on the text. This awareness of metacognitive experiences in conjunction with performance allows the integration of all this information into a single representation of the task, the context, behavior and its outcomes as well as the person (as agent) dealing with it in a specific place and time.

Monitoring at the personal awareness level, in its turn, provides the input for conscious and deliberate regulation of cognition, that is, use of cognitive and metacognitive strategies as well as volitional strategies for the control of emotions, motivation, and the environment. Conscious or deliberate control at the personal level awareness involves use of cognitive strategies and metacognitive skills. For example, use of orientation strategies ("What is exactly that I do not understand?"); planning (e.g. "I need first to locate the point where the problem in comprehension started, then reread the text and check whether I missed some word or look at the dictionary for the meaning of unknown words"); monitoring of the application of the selected/planned strategy, and evaluation of the outcome of the strategy applied, that is, if comprehension has been restored or the problem persists. If the problem is not resolved, then new control decisions need to be made, e.g., abandon effort or start a new round of self-regulation of comprehension.

Another strategy is to ask for help from a fellow student or the teacher. In such a case, the student has to explain to the other what is the problem (e.g., "I do not understand this sentence" or "This sentence seems to contradict the previous one"), and the other person has to represent the student's difficulty vis-à-vis the text and one's own experience of metacomprehension. This is an example of the functioning of the social-level awareness, where monitoring is based on reflection and observation of the subjective experiences, thoughts or actions of the others (vis-à-vis our own). Control at this level takes the form of instructions to the student on what strategy to use, explanations, or joint effort aiming at meaning making, e.g., reading and thinking aloud so that the student can follow the comprehension process of the partner as it takes place, etc. Collaborative learning presupposes this level of functioning of metacognition. The development of science, formal models of cognition, teaching of thinking skills as well as regulation of cognition in a rational manner are also based on this level of awareness.

Different Processes in Monitoring and Control at the Various Levels of Metacognition

Two implications of the enriched model of metacognition are the following: First, there are different processes underlying monitoring and control at the different levels of functioning of metacognition. Second, metacognitive monitoring and control are influenced not only by cognitive but also by affective factors. In so far as the nature of monitoring and control processes is concerned, one can assume the following (see Table 1): Monitoring at the object level detects fluency (or lack of fluency) in cognitive processing, interruption of processing, conflict of response, and error (Koriat, 1997; Touroutoglou & Efklides, 2010), expectations about factors that affect memory or cognition (e.g., that the font size of words to be learnt affects recall, McDonough & Gallo, 2012), or anchoring on peer performance (Zhao & Linderholm, 2011). Control, on the other hand, at the object level involves cognitive control (e.g., gaining or losing control depending on contingent conditions, Skinner, 1996; forming of abstract rules or task sets, Collins & Frank, 2013), increase of time, effort, and attention on the task; initiation and termination of processing (Nelson & Narens, 1994) and operating of executive functions, namely inhibition of response, updating, shifting of attention, and switching of response (Roebers, Cimeli, Röthlisberger, & Neuenschwander, 2012; Shimamura, 2000).

Monitoring at the personal level awareness is based on awareness of metacognitive experiences (e.g., metacognitive feelings and judgments), awareness of one's thoughts, task and context characteristics (e.g., online task-specific knowledge), and awareness of affective, motivational as well as volitional experiences. Processes that give rise to personal-level-awareness metacognition vary from non-conscious heuristic, inferential processes based on familiarity and cue utilization (Koriat, 1997) to social cognition processes (e.g., De Carvalho Filho & Yuzawa, 2001; Yzerbyt, Dardenne, & Leyens, 1998; Zhao & Linderholm, 2011), conscious analytic processes of the contents of one's consciousness, and observation of one's performance and its outcomes. Specifically, metacognitive experiences (ME), and particularly metacognitive feelings and judgments, are inferences based on heuristic processes that make use of cues from the task, context, or cognitive processing (Koriat, 1997; Korial & Levy-Sadot, 2000). Metacognitive knowledge (MK) being declarative knowledge or beliefs about the object level or the world and the person's prior encounters with specific tasks/situations is presumably based on abstraction, reflection and observation of one's cognitive endeavors and the accompanying experiences whereas another part may originate from formal instruction and social cognition. That part of MK can be explicit.

Control at the personal level awareness involves the formation and application of explicit general task rules that shields task processing from distraction or interference (Dreisbach, 2012). At this level control also takes the form of selection, use and change of cognitive strategies, such as repetition, spacing, allocation of study time, etc (e.g., Karpicke, 2009; Toppino & Cohen, 2010). At the personal awareness level metacognitive skills are employed as strategies that operate on and regulate cognition (Veenman & Elshout, 1999). Finally, at the social level awareness monitoring is based on observation of and reflection on others' behavior, performance and its outcomes, on interaction and communication with others (Iiskala et al., 2011), and knowledge of formal theories of cognition, based on rational, analytic processes (McCabe, 2011). Control, on the other hand, involves use of learned strategies acquired through instruction and social interaction processes, as well as application of metacognitive skills in social interaction or collaborative contexts (Volet et al., 2009).

Table 1. *Possible Monitoring and Control Processes at Various Levels of Metacognition Functioning*

Monitoring	**Control**
Monitoring of features of cognitive processing: fluency/lack of fluency; interruption; conflict; error	Increase of time, effort and attention on task or processing; Initiation and termination of processing; Inhibition of response, updating, shifting of attention, switching of response
Awareness of one's metacognitive experiences (feelings, judgments, thoughts, …); Observation of performance and its outcomes	Forming and applying general task rules; Selection of strategy, strategy use, change of strategy
Reflection on metacognitive experiences (one's own and others') and performance and its outcomes vis-à-vis the task and its context	Applying metacognitive skills
Social cognition and interaction with others; formal theories of cognition	Use of learned strategies in various knowledge domains

Implications of the Enriched Model

Between and Within Person Variability

Since the meta and meta-meta levels are representations of their respective object level (i.e., the object and the personal awareness level, respectively) and these representations are based on inferential or analytical processes applied to selective features of the situation, task, or process, it is understandable that metacognitive experiences and metacognitive knowledge can differ among different individuals (e.g., a task is represented differently by the teacher and the student), and this implies that there are *individual differences*. For example, some individuals tend to be more confident than others regardless of the task (Dunlosky & Rawson, 2012). Moreover, there can be differences in the same individual from one occasion to the other (*within subject variation*), depending on the cues, beliefs, or information being implicated in the representation process. For example, judgments of learning can change as the person learns more about a topic and better understands task demands (Pelegrina, Bajo, & Justicia, 2000).

Monitoring Inaccuracy

Furthermore, monitoring can be inaccurate, if the cues used are not valid for the "object" that is being represented. For example, if the person is heeding mnemonic cues such as fluency and not cues related to the accuracy of the recalled information, then the relation of metacognition with performance can be low or non-existent. Specifically, a fluently retrieved answer to a question can be associated with high confidence that it is correct even though it is not (Koriat, 1997; Schwartz & Efklides, 2012). Such a discrepancy between metacognitive experiences or knowledge and performance accuracy has implications both for the reliability and validity of metacognitive experiences and metacognitive knowledge (e.g., relations with performance).

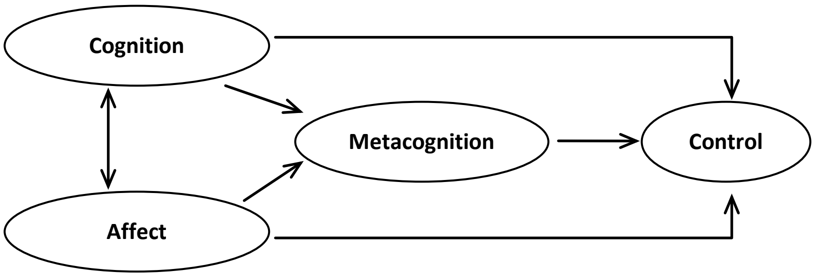
Effectiveness of Control Decisions

Inaccurate monitoring of cognition has implications for the effectiveness of control decisions. For example, a highly confident response prevents further engagement with the same task although checking of response accuracy is needed before concluding memory search or problem solving. Or, confidence that one will recall in a future test a particular piece of information (judgment of learning, JOL, Nelson & Dunlosky, 1991) in comparison to another one influences allocation of study time to the individual items. If JOLs are inaccurate, then allocation of study time is also flawed.

Affect, Metacognitive Experiences and Control

Metacognitive feelings are influenced not only by cognitive but also by affective factors, such as mood (Efklides, 2006, 2011; Efklides & Petkaki, 2005). Moreover, cognitive conditions such as cognitive interruption give rise to both metacognitive and affective reactions, namely feeling of difficulty and surprise (Touroutoglou & Efklides, 2010; for the role of surprise in relation to metacognition see also Metcalfe & Finn, 2012). This implies that control responses such as increased effort or time on a task can be triggered by metacognitive monitoring factors but also by cognitive or affective factors, directly or indirectly (see Figure 1). To put it differently, cognitive conditions such as familiarity, fluency of processing, interruption, conflict, or error are monitored at a cognitive level (Touroutoglou & Efklides, 2010; Van Veen & Carter, 2002) and automatically trigger control processes, such as increased effort or time on the task. At the same time, the outcome of monitoring reaches conscious awareness in the form of feelings (metacognitive or affective, e.g., feeling of familiarity, feeling of knowing, confidence, satisfaction, pleasure, surprise, curiosity) and control decisions can be made based on these feelings if cognitive control fails.

Figure 1. *The Multiple Sources of Effects on Control*



Metacognitive Control

Since cognitive events or the person's affective state can automatically trigger regulatory processes (i.e., at the "object" level) this can take place even before metacognitive feelings are consciously analysed and used for deliberate control decisions. Metacognitive control presupposes metacognitive awareness of the task, metacognitive experiences, and/or metacognitive knowledge. Specifically, since metacognitive feelings are non-analytic and inferential in nature, attributions and metacognitive knowledge of the factors that might have produced these feelings are activated when the person tries to make sense of their experiences and the task. Hence, conscious control at the personal awareness level that is initiated by metacognitive experiences may involve the person's more general knowledge, affect, perception of the task context, metacognitive knowledge or even social metacognition.

Having outlined the enriched model of metacognition and its implications for understanding the multiple facets and functioning of metacognition, I am turning now to research evidence that supports the claim that monitoring being inferential in nature, can be accurate or inaccurate depending on the cues and attributions made about the source of the metacognitive experiences.

Monitoring Accuracy

Monitoring accuracy is important for a number of reasons (see Hattie, 2013): a) it informs on the compatibility of new with prior knowledge. For example, inaccurate feeling of familiarity may lead to rejection of new knowledge as irrelevant or treating something old as new; b) it determines the level of effort needed –more or less effort depending on task demands and experienced difficulty; c) it can trigger already available or effective strategies or avoid use of new strategies; d) it can help a person realize their actual level of knowledge and decide where they should be targeting. That is, people often set their own standards for a task (e.g., rote learning instead of deeper processing and comprehension); e) it can interfere with help seeking (e.g., ask help when not needed or on less important points rather than on critical issues). In what follows, I shall present evidence showing that monitoring can be inaccurate but there are conditions that can support higher accuracy.

Metacognitive Experiences

There are two ways in which to measure monitoring accuracy of metacognitive experiences: Calibration or absolute accuracy and resolution or relative accuracy. *Calibration* refers to the extent to which monitoring (e.g., in the form of confidence or JOLs) reflects the overall accuracy of response. *Resolution* refers to the ability to differentiate correct from incorrect responses or between items of different levels of difficulty (Schwartz & Efklides, 2012). The two measures of monitoring accuracy are related but not identical: One can be well calibrated, that is, show small discrepancy between performance and monitoring overall (e.g., students can quite accurately predict their final grades in a course), but not very successful in resolution (e.g., predict their performance at specific tasks, Hattie, 2013). Evidence from both measures of monitoring accuracy suggests that in many cases monitoring is inaccurate. What is this evidence and what does it suggest for the mechanism that underlies ME? (In this article I shall limit the review to metamemory research.)

Overconfidence

The discrepancy between confidence judgments and task performance is well documented in metacognition literature. *Overconfidence* is a classical example. People are much more confident in the correctness of their response than their actual performance is. The curse of being ignorant and not being aware of it is the epitome of this phenomenon (Kruger & Dunning, 1999, 2002). *Prior knowledge* is a critical factor for the accuracy of confidence judgments and calibration. As Hacker, Bol, Horgan, and Rakow (2000) showed, students in the top 20% of attainment in a university course were well calibrated in the prediction (before exams) and post-diction (after exams) of their performance, and even a little underconfident. The rest 80% of students were overconfident and those in the lowest quintile of performance were the most overconfident. Dinsmore and Parkinson (2013) also showed that low ability students are less accurate in calibration (i.e., overconfident), have less skills at learning, and are less likely to know they are inaccurate and how close they are to desired learning (see also Hattie, 2013).

Miller and Geraci (2011) found that even with *feedback* on the accuracy of their current performance students' predictions of their future learning were overconfident. This was also found by Dunlosky and Rawson (2012). What is interesting in the latter study is that when students were asked to self-score their responses and were given idea units for checking the correctness of their answers, even then they self-scored higher than the feedback they had from the idea units. Idea units is a way of summarizing the main points of a text and thus checking one's comprehension. Students could check in an one-to-one manner their response against the idea units, and then self-score. Overconfidence means that they scored themselves higher than what the comparison of their response with idea units suggested. Despite the biased self-scoring, feedback helped students reduce their overconfidence and become better calibrated. Thus, high prior knowledge and realistic feedback are two factors that contribute to monitoring accuracy.

But corrective feedback may not suffice for monitoring accuracy if the task is new or the person cannot understand the basis of correct response (Efklides, 2012; Pieschl, Stahl, Murray, & Bromme, 2012; Redford, Thiede, Wiley, & Griffin, 2012). Feedback is essential for confidence and learning provided it informs on what is being learnt and what success looks like (Hattie, 2013). Prior knowledge is also necessary but not sufficient for the accuracy of monitoring, because there are individual differences factors that influence confidence irrespectively of prior knowledge or feedback (Efklides, 2012; see also Dunlosky & Rawson, 2012). That is, overconfidence as a person characteristic can be moderated but not eradicated. Moreover, as Hattie (2013) suggested, having no prior knowledge may be more conducive to accurate monitoring than partial or inaccurate prior knowledge because the person is aware of their ignorance and more open to feedback.

The dissociation between accuracy and confidence was confirmed in another study in which participants had the option to generate a single answer consisting of one alternative or a plural answer consisting of the single answer and two other alternatives (Luna, Higham, & Martin-Luengo, 2011). Each answer was rated for confidence or the likelihood of being correct, while one of the answers was selected for reporting. Participants selected single answers when their accuracy and confidence were high. They opted for plural answers when accuracy and confidence were low. What is worth noting is that response accuracy was higher for selected plural than single answers but the opposite pattern was found in the case of confidence or correctness likelihood ratings. These findings suggest that participants had significant overconfidence as regards single answers but under-confidence as regards plural answers.

The opposite of overconfidence is *under-confidence*. It has been found that practice can lead to under-confidence, which is also a manifestation of poor monitoring accuracy. Meeter and Nelson (2013) showed that judgments of learning after one study trial were overconfident but after two study trials under-confident in terms of absolute calibration. However, relative calibration was not influenced by study trials. Hadwin and Webster (2013) also showed that people become less overconfident with time as regards the calibration of their goal setting. This means that with practice people may focus on different cues for their monitoring. It is plausible that practice increases awareness of the various cues (intrinsic, external, mnemonic[1], Koriat, 1997) that are indicative of response accuracy and of the factors that may have an effect on one's performance. This increases awareness of the potential of error even if actual performance is correct. This could explain why high achieving students are often under-confident.

Hattie (2013) suggested that students may have two sources of information for their calibration. They may know when they know (i.e., calibration of success) but not when they do not know (i.e., calibration of failure). This means that students do not necessarily recognize which items they get incorrect (see van Loon, de Bruin, van Gog, & van Merriënboer, 2013), and hence overconfident. This can be due to the use of invalid cues for judging their response, namely ease of processing, familiarity, amount of information retrieved rather than the quality of information. However, with practice students get information on what they do not know, and this decreases their confidence in the accuracy of their response.

Hypercorrection. There is another phenomenon that is worth mentioning with regard to confidence accuracy and its relation to performance: It is the *hypercorrection* of responses that were endorsed with high confidence (Metcalfe & Finn, 2012). That is, students correct most readily responses that had been given high confidence ratings initially. This is counterintuitive because high confidence means that the person believes that the answer is correct and hence should not be changed. The condition for hypercorrection is corrective feedback (Metcalfe & Finn, 2012). When students in multiple- choice questions were given corrective feedback not only did they change their highly confident response but said they "knew it all along". How could students judge their incorrect response as correct if they knew the correct answer all along? The "knew it all along" experience suggests that participants did not have access to the correct response but rather their initial confidence was based on some inference that it was correct. Then, when the correct response was presented the cues changed and the students felt they knew it from the past.

[1] The cues on which metacognitive experiences rely can be (a) extrinsic, such as the context in which the task takes place, for example the number of study trials; (b) intrinsic to the task, such as task features, and (c) mnemonic cues, that are related to the fluency with which the task is encoded or the answer retrieved.

JOLs and Memory Performance

In a recent paper with Bennett Schwartz (Schwartz & Efklides, 2012) we reviewed evidence showing cases in which judgments of learning (JOLs) and other metacognitive experiences matched or not actual memory performance. The theoretical framework used was Koriat's (1997) and the claim is that metacogntive experiences are more accurate when the person focus on extrinsic rather than on intrinsic or mnemonic cues. Moreover, people can use their metacognitive knowledge for their judgments rather than only cues (see also Koriat, Bjork, Sheffer, & Bar, 2004). Let's take some examples:

1. *The timing of JOLs – Immediate or delayed JOLs.* One of the very first findings in JOL research was the remarkable improvement in the accuracy of JOLs when they were made more than 10' after studying (Nelson & Leonesio, 1988). When JOLs are made after the learned material has been retained in long-term memory and judgments are based on cues diagnostic of actual memory of the items, they are more accurate.

   The importance of focusing on cues related to retrieval rather than encoding fluency was also shown by Koriat and Ma'ayan (2005). McCabe and Soderstrom (2011) replicated this effect; they asked participants to make judgments of remembering and judgments of knowing. The former are based on contextual information whereas judgments of knowing are not based on details of retrieval but on confidence. Judgments of remembering (recollection based) were more accurate than judgments of knowing. Therefore focusing on encoding fluency only or retrieval cues can make a great difference for JOLs irrespectively of actual memory.

2. *The effect of stimulus perceptual characteristics*. Larger font size and loudness increase JOLs, that is, people predict better learning, although memory performance is not affected (Rhodes & Castel, 2008, 2009). In a related study words were presented in inverted form (Sungkhasetee, Friedman, & Castel, 2011). This treatment increased effort for encoding ("desirable difficulties", Bjork, 1994) and consequently led to better retrieval later on. However, JOLs did not predict this memory effect: The expectation was for lower retrieval. Obviously in both of these cases people are basing their judgments on encoding fluency rather than on the monitoring of actual memory.

3. *Relatedness and overlearning.* When learning paired associates (e.g., tree – nurse) people predict better learning (JOLs) when the pairs to be learnt seem related (e.g., money – doctor) compared to unrelated pairs, although relatedness does not affect memory (Rhodes & Tauber, 2011). Moreover, delaying JOLs improves the accuracy of JOLs of unrelated pairs but not those

of the seemingly related pairs. This means that relatedness is a very strong cue, possibly emanating from beliefs about factors that influence text comprehension. Only when feedback on memory accuracy was provided did JOLs on seemingly related pairs improve, which is possibly part of people's MK about the task.

In another study it was found that even if the unrelated pairs were studied more times than the related ones, so that overlearning is achieved, JOLs were sensitive to relatedness but not to overlearning (Carroll, Nelson, & Kirwan, 1997), which is external cue. That is, people focus on relatedness even if it is not indicative of retrieval and not on overlearning, which a highly potent condition for learning and memory (Schwartz & Efklides, 2012).

4. *Memory for past test performance*. In cases where there is repeated study of items and repeated JOLs, people are basing their JOLs on whether an item was successfully recalled in the past rather than on the number of trials in which the item was presented. That is, people underestimate repetition as a factor affecting memory and rely more on their experience of remembering an item in the past (Finn & Metcalfe, 2007, 2008; see also Ariel & Dunlosky, 2011). The monitoring of memory performance seems to be a general strategy people use even in cases of no repetition. When asked to make predictions of how long they are going to remember information (judgments of retention), they do monitor recall performance and make more accurate judgments than when making JOLs. This suggests that the wording of the required judgment may be important for the information people monitor in order to form their judgments (Tauber & Rhodes, 2012).

5. *Stability bias*. JOLs reveal that people underestimate future forgetting and overestimate remembering (Kornell, 2011). For example, in a study by Koriat et al. (2004) participants learnt paired associates and made JOLs for a recall test to be taken 10 min or one week later. JOLS did not differ between the two groups. This suggests that participants based their judgments on encoding fluency rather than on the anticipated retention interval. Participants did not take into consideration forgetting. However, when the judgment was about forgetting, the difference in the retention interval (10' and one week) did differentiate judgments, although actual forgetting was still higher than anticipated. Thus, it seems that people are aware of forgetting in longer retention intervals but this metacognitive knowledge does not influence JOLs when they are experience-based. However, when retention interval was made salient through instructions for several retention intervals, JOLs were more representative of the actual recall rates. In this case JOLs were theory-based, that is, in accordance with MK about forgetting.

Also, people are aware of forgetting in cases of *directed forgetting* (Bjork, 1970), that is, when instructed *not* to remember something. In a recent study, participants studied words each of which was followed by a cue (R: Remember or F: forget). Then they made JOLs and then free recalled the list of items. Both recall and JOLs were sensitive to the R-F cue. People accurately predicted forgetting in their JOLs (Friedman & Castel, 2011), which means that people have some kind of MK (theory, belief) that people can forget things if instructed to do so.

6. *Primacy and recency effect*. The primacy and recency effect in the free recall of single word lists is well known in memory research. People in free recall conditions recall best the last items (recency effect), then the first in the list items (primacy effect) and least of all the items in the middle of the list. However, JOLs for items to be free recalled later on do not reflect this effect contrary to memory performance (Castel, 2008). When participants were given information on the primacy and recency effect and were not shown the items for making their JOLs but only the position of the item in the list, then their JOLs became more accurate. This finding is similar to the theory-based JOLs found by Koriat et al. (2004) and stresses the importance of metacognitive knowledge in the formation of judgments about future recall. However, MK can be overridden if encoding fluency becomes the major cue – this is the case when the list items are presented rather than their position in the list.
7. *List length.* Tauber and Rhodes (2010) found that JOLs did not accurately reflect the list length effect, that is, the lower probability of recall of the items of longer lists compared to items of short lists. However, when participants were instructed on the phenomenon and had practice, then JOLs became more accurate. This underscores again the importance of MK.

To sum up, the reviewed studies suggest that JOLs or confidence judgments can be flawed if they rely on an encoding fluency heuristic and not on retrieval cues. However, metacognitive judgments can be improved and monitoring can be quite accurate when the person has prior knowledge that allows the evaluation of retrieval correctness, when the person is given corrective feedback, and when the person has metacognitive knowledge on the functioning of memory and the factors that influence it.

Metacognitive Knowledge

Research on metacognitive experiences by large ignores MK, although in order to explain some of the findings one needs to assume there exists MK even if not directly measured. Because of the importance of MK of strategies for the control of cognition and particularly the need to teach strategies (cognitive or metacognitive) for improving the quality of control decisions, most of the research on MK regards the use of strategies and how this knowledge develops in young children. Also, strategies in specific domains of expertise such as reading, writing, text comprehension or mathematics have been investigated (e.g., Cromley & Azevedo, 2011; Pressley & Gaskins, 2006). Students' awareness of learning strategies has also received extensive attention in educational research. However, MK about persons and tasks is less well studied. In this article I shall refer to less well studied aspects of MK and particularly knowledge of one's self and tasks in which one has experienced fluency (or lack of it) in processing.

Metacognitive Knowledge of Self and Task

MK of tasks. Ackerman and Goldsmith (2011) found that students prefer studying from printed hard copy rather than computer screen. One group of students studied a text of three pages in printed form and another on computer screen. Then they answered a multiple- choice test on the text. When the study time was fixed, the two groups did not differ in their test performance. When study time was self-regulated the group studying the text on screen had lower performance than the hardcopy group. The authors concluded that the difference in performance was not cognitive but metacognitive, that is, less accurate prediction of performance and more erratic study time regulation on screen than on paper. This evidence suggests that students have beliefs about the means in which they are fluent and less fluent, and this MK may be flawed. Nevertheless, this MK guides their control decisions with implications for performance.

Metacognitive knowledge of self. Efklides and Vlachopoulos (2012) directly tested the assumption that students have MK about the tasks in which they are fluent, that is, are easy for them, and MK about the difficulty/easiness of tasks. Students' responses on the Metacognitive Knowledge of Self, Task, and Strategies in Mathematics questionnaire confirmed this prediction. There were two factors on MK of the self (easiness /fluency vs. difficulty/lack of fluency in mathematical notions), two factors on MK of tasks (easy vs. difficult mathematical tasks) and three factors on MK of strategies: One factor representing cognitive and metacognitive strategies, one representing strategies for enhancing competence in mathematics, and one on task avoidance. What is important is that MK of self (easiness/fluency), rather than MK of task, along with mathematical ability predicted younger students' performance on mathematical problems. Moreover, MK of self (easiness/fluency) was negatively related to prospective judgments of feeling of difficulty. This finding shows the possible effects of MK on ME. Two of the three factors of strategy use (cognitive/metacognitive strategies and competence-enhancing strategies) also predicted the prospective judgments of feeling of difficulty but not the retrospective judgments. The MK of the self (fluency) was negatively related to feeling of difficulty and so did the competence-enhancing strategy use. Unexpectedly, use of cognitive/metacognitive strategies was positively related to feeling of difficulty. This suggests that these strategies are applied in response to experienced difficulty during mathematical problem solving, and this MK is used as a basis for ME on later occasions. However, in university students MK of the self seems to have been incorporated into their self-concept of mathematics and performance was predicted by self-concept. Despite this, MK of the self (difficulty/lack of fluency) positively predicted prospective judgments of feeling of difficulty. To sum up, MK of the self and strategies is particularly important for the formation of prospective ME during problem solving and can even predict task performance.

It needs to be also stressed that competence-enhancing and avoidance strategies are not cognitive strategies but rather related to motivation and affect. This implies that students have an integrated representation of themselves as self-regulated learners in a domain. This MK can contribute to self-regulation either directly or indirectly through affect.

Metacognitive Knowledge of Strategies

MK of strategies can tap broader categories of strategies as in the Efklides and Vlachopoulos (2012) study, or more specific strategies such as learning strategies. McCabe (2011) found that university students could not accurately predict the learning outcomes of educational scenarios describing strategies such as dual coding, static vs. multimedia presentations, low interest extraneous details, self-testing, and spacing. Students showed weak endorsement of the strategy of generating one's own study materials. This means that students did not have well developed theories about factors affecting learning or the use of strategies that can enhance memory of learning materials. However, students who had followed courses on memory and learning at a postgraduate level and had extensively worked on relevant applied memory research increased the accuracy of their predictions of educational outcomes of learning scenarios. This is a clear case of socially-mediated metacognitive knowledge of strategies. People can have MK based on their experience and monitoring of their performance but this knowledge can be changed through instruction.

In school students are being taught strategies in specific knowledge domains. Thus, students have MK of strategies they use, e.g., in reading, or even knowledge of strategies they do not endorse themselves. When measures tap more specific strategies students use, e.g., in reading, then this MK can predict comprehension.

However, MK of strategies or strategy use itself does not suffice to explain performance outcomes. MK of strategy use explains a small percentage of performance variance. Cognitive ability factors, such as vocabulary, background knowledge and word reading (Cromley & Azevedo, 2011) explain a significant percentage of performance variance. This finding is in the same direction as Efklides and Vlachopoulos (2012), and suggests that metacognitive awareness of strategies does not suffice for the explanation of cognitive processing outcomes. What is important is what strategy the person actually uses during task processing. More importantly, Efklides and Vlachopoulos (2012) showed that students are using various strategies for the regulation of their learning in various knowledge domains which reflect motivation and affective concerns and not only cognitive or metacognitive regulation.

Relations Between Monitoring and Control

To exercise control or use a strategy there needs to be, besides the task itself, some cue or input that signals the necessity for a control decision. Familiar tasks trigger a habitual or automatic processing mode without the person being aware of it. However, automatic processing can fail or lead to undesired performance outcomes. Awareness of error is one of the cues that make the person aware of the need for strategy change and/or deliberate strategy use. In novel tasks, on the other hand, the person has no learned strategy to be automatically triggered. In such cases conscious and deliberate control is needed right from the beginning. Awareness of novelty (lack of familiarity), task complexity or task difficulty requires goal setting and conscious and deliberate control. And of course, strategy use can be part of task instructions. However, metacognitive experiences, such as feeling of familiarity, feeling of difficulty, feeling of knowing, confidence or JOLs, also trigger control decisions. The trigger can also be MK of the self or strategies that inform the person of prior encounters with the task or subjective task demands. In the case of task demands or instructions goal setting and strategy use is a top down process and metacognitively controlled. In all other cases strategy use is metacognitively or affectively guided and can be part of bottom up regulation of cognition (Efklides, 2011).

One implication of the above framework of strategy use is that control decisions can be non-optimal because ME can be flawed. Moreover, students have difficulty in self-assessment and this limits their ability for task selection (Kostons, van Gog, & Paas, 2012) and effective self-regulated learning. However, observing a human model engage in self-assessment and/or task selection or practicing these skills can help students improve their control decisions, based on social level awareness. As Haider, Frensch, and Joram (2005) claim, strategy change is not an automatic consequence of task practice. When people learn a new strategy, they are aware of it and can describe the task regularities that allowed for the generation and application of the new strategy. Moreover, they can transfer this knowledge to new tasks. But if their experience suggests that the new strategy cannot be used to the entire range of problems they are working on, then they do not opt to use the new strategy. That is, one needs to determine the exact conditions for the application of a strategy and this is a long learning process that feeds on the person's MK of strategies regarding the conditions of strategy use. Furthermore, students need to be motivated for strategy use. Vrugt and Oort (2008) found that students in SRL follow two paths: one from motivation to metacognition to study strategies and one from motivation to strategy use directly.

To sum up, strategy use is triggered by task characteristics, prior knowledge (skills) of strategies, metacognitive knowledge of strategies, metacognitive experiences that inform on processing demands, and, finally, motivation and affect that inform on the value of strategy use and provide the energy needed for the exercise of control and strategy use. In what follows, I shall review evidence on the effects of the various factors involved in strategy use.

Task Difficulty and Task Instructions: Habitual vs. Controlled Processing

Although item or task difficulty is a critical factor for strategy use, Dunlosky and Ariel (2011) found that students often do not take into consideration task demands. In their study students preferred to study items in a left to right or top down order regardless of item difficulty. That is, habitual processes or automatic cognitive processing guided students' control decisions. However, in one of their experiments, Dunlosky and Ariel (2011) presented items in a sequential order from difficult to easy and vice versa. Participants were allowed to choose half of the items for restudy. This condition raised participants' awareness of item difficulty, and the instruction to select items for restudy enhanced a top-down self-regulation mode. In this case students tended to select items that had been presented before in the list rather than follow habitual processing. This suggests that students can follow both a bottom-up (habitual) and a top-down (controlled) mode of self-regulation in learning.

Item Difficulty and Affect

Detecting item or task difficulty is critical for effective control decisions. One way to do this is to rely on one's own experience of feeling of difficulty. Efklides and her collaborators (2006, 2011; Efklides & Petkaki, 2005; Touroutoglou & Efklides, 2010) have studied feeling of difficulty, that is, the subjective experience that arises as response to item difficulty, the monitoring of interruption of cognitive processing, conflict, or increased probability for error. It is this unpleasant feeling that alerts the person on lack of processing fluency, the presence of a problem or the possibility of committing an error. Feeling of difficulty is the interface between the person and the task, because it is determined by objective task difficulty (in terms of complexity or working memory demands), the person's ability, mood, and

MK of the self or self-concept in a task domain. Of course, feeling of difficulty can be flawed as all other ME, that is, a difficult task can be perceived as easy (Efklides, 2002). Nevertheless, it can inform on the need for effort expenditure (Efklides & Petkaki, 2005), strategy use or strategy change (Efklides, Samara, & Petropoulou, 1999). Moreover, it can trigger affective regulatory strategies such as avoidance or competence-enhancing ones (Efklides & Vlachopoulos, 2012).

Finn (2010) also investigated the effect of affective factors such as discomfort due to effortful learning experience on prospective study choices. People remember their hedonic past and often disregard the duration of the experience. They are influenced by the peak of and the final levels of discomfort and base their decision for future study on this information. Thus, students who had an extremely effortful study episode extended by a more moderate interval preferred such a schedule to a shorter, unextended interval, although test performance was higher following the shorter interval. Efklides, Kourkoulou, Mitsiou, and Ziliaskopoulou (2006) also showed that students have MK about effort and its affective or cognitive outcomes. Thus, for some students effort is a positive and effective means for achieving their goals and there are no negative sides to it. For others, effort is a negative experience that is associated with bodily symptoms, exhaustion, discomfort, and inefficiency. For these students the preferred control decision is the early abandoning of effort or avoiding effort altogether.

Autin and Croizet (2012) tested the assumption that difficult tasks subtly generate concerns about incompetence. They carried out an intervention study in young students in which they reframed the metacognitive interpretation of difficulty as indicative of learning rather than self-incompetence. The alleviation of concerns improved children's working memory and reading comprehension.

Therefore, metacognition can contribute to control decisions but strategy use is influenced by affective and task factors and not only by MK and ME.

JOLs and Study Time Allocation

One of the metacognitive experiences that has received extensive attention in relation to control is judgments of learning. JOLs are sensitive to objective difficulty of the material, and students allocate study time according to their JOLs. However, students learn better the easy items than the difficult ones. That is, they do not manage to compensate for item difficulty (Pelegrina et al., 2000). Moreover, if they give too much study time to the difficult items then they run the risk of "labor-in-vein", because they still do not recall them compared to the easy ones (Nelson & Leonesio, 1988). However, the labor-in-vein effect is present only when students are in control of study time. If study time is restricted, then students change strategy and study easy items more (Son & Metcalfe, 2000). This suggests that students regulate their study time more flexibly and take into consideration both item difficulty and time available for study.

Based on such evidence Metcalfe (2002, 2009; Kornell & Metcalfe, 2006) proposed the theory of the Region of Proximal Learning (RPL). According to the theory students in the context of limited study time should focus on the easiest items not yet mastered and then move on to more difficult ones if there is still time. They should, however, avoid very difficult items because the probability of learning these items is very low. In this way they avoid the labor-in-vein effect and maximize learning. Kornell and Metcalfe (2006) found that students spontaneously apply the strategy of the RPL, which facilitates decision on what items to study or not.

On the other hand, there is evidence suggesting that higher JOL accuracy (e.g., delayed JOLs that make better prediction of recall) does not necessarily lead to better control decisions. Specifically, Kimball, Smith, and Muntean (2012) found that the benefit of delayed JOLs was due to the selection of more items to restudy rather than to better discrimination between which items to restudy. This suggests a dissociation between monitoring and control, and that control may be informed by one's prior use of strategies rather than monitoring of the learnability of items.

Judgments of Improvement and Strategy Selection

To follow the RPL strategy presupposes that students monitor their improvement in learning as they study. That is, they need to know when to quit studying an item that they already mastered or quit trying altogether because the rate of learning drops with little or no progress in the course of learning. Townsend and Heit (2011) found that *judgments of improvement* were poorly correlated with memory performance but correlated with change in JOLs. This implies that students monitored the changes in learning based on their ME and not actual performance. Still JOLs were not the only predictors of judgments of improvement: sense of fluency, interest, frustration and other non-cognitive factors seem to contribute to the formation of judgments of improvement (Metcalfe & Kornell, 2005). Indeed, as Carver and Scheier (1998) propose, there is monitoring not only of the outcome of processing and discrepancy reduction between one's goal and performance but also monitoring of the rate with which one reaches their goal. This monitoring gives rise to affect, positive or negative, as well as a hazy expectation that the goal can or cannot be reached depending on whether the discrepancy reduction is faster or slower than anticipated. This implies that strategy selection is associated with monitoring as the model of metacognition posits, but also with affective factors as stated above.

Stability Bias and Retrieval Practice

One of the most powerful findings in memory research is that repeated testing (or self-testing) of a certain material brings better recall than restudying of the same material. However, students do not use repeated recall or self-testing as a strategy for improving learning. Karpicke (2009) compared three groups of students who had to learn a number of items for later recall. The first group practiced repeated testing, the second restudying and the third group could remove items that had been successfully recalled after recall. In the condition in which the strategy was controlled by instructions (e.g., teacher controlled) the first group had best learning and retention. However, when students could select the strategy for learning, the preferred strategy was to remove items. This led to poor retention. The benefits of retrieval practice were further shown by Karpicke and Smith (2012), who compared retrieval practice with restudying that was accompanied by elaborative study conditions. Elaborative studying benefitted initial encoding but did not affect long-term retention contrary to retrieval practice that improved long-term memory. This suggests that students believed erroneously that once something is learnt (short-term retention) it is maintained in memory (see stability bias) and does not need to be repeated again through retrieval practice.

Rawson, O'Neil, and Dunlosky (2011) found that self-test and evaluation of one's learning before selecting passages for restudy improved recall compared to restudy of selected passages only. However, students self-tested not because they appreciated the importance of the strategy of retrieval practice but because they wanted to evaluate their progress so that they could know how much more they need to study. Therefore use of the retrieval practice strategy may indicate the influence of motivational factors rather than metacognitive knowledge of strategies.

The effect of self-testing became even stronger when the evaluation of responses was made with the use of idea units, that is, the main ideas that should be included in the response. This suggests that self-testing as a control strategy for the learning of complex material may not suffice: accurate feedback is required, because only then monitoring can be accurate and translate into effective SRL (see also Dunlosky & Rawson, 2012; Lipko et al., 2009).

Massed vs. Spaced Study

The beneficial effects of spaced study, that is, study distributed over time, are also well known in memory research. However, students usually prefer massed study rather than spaced. Toppino and Cohen (2010) investigated students' use of spaced study. They found that learners' preference for spaced practice increased with greater item difficulty. This finding is consistent with a discrepancy-reduction-like account of metacognitive control or an agenda-based regulation of learning. This explanation was further tested in another experiment of the Toppino and Cohen study, in which item difficulty and point value for the final test were included. Learners preferred spaced practice for items with high than low value, and this decision was unaffected by item difficulty. This finding supports the agenda-based account of selection of learning strategies and underscores the importance of motivational factors in strategy use.

A similar finding with regard to allocation of study time was found by Soderstrom and McCabe (2011). Participants allocated study time based on item value and relatedness, which influences JOLs as we have already seen. Therefore there was monitoring of item difficulty and prediction of learnability but study time allocation was not a function of metacognitive monitoring only. Motivation, in the sense of value attached to task performance, is crucial for the initiation of agenda-based regulation.

Control and Resources

It is very important to bear in mind that control can be ineffective for other reasons besides inaccurate monitoring. For example, use of strategies is effortful and the person may fail to control their behavior because of limited resources. For example, initial efforts at executive control (e.g., controlling the focus of attention) temporarily undermine subsequent efforts at executive control (Schmeihel, 2007). This phenomenon is explained with the limited resource model of executive control.

The limited resource model also explains why self-control has considerably higher costs than self-regulation (Kuhl & Fuhrmann, 1998). Self-control is a temporary means to accomplish the initiation or maintenance of goal-directed behavior that is not yet an integral part of one's self. Self-regulation, on the other hand, serves the concurrent satisfaction of a majority of short- and long-term personal needs that represent an integrated self (self-maintenance) when pursuing a goal.

To sum up, the evidence presented in relation to control argues in favor of a model of self-regulated learning in which there is both top-down and bottom-up regulation. ME offer the input for bottom-up regulation whereas motivational factors favor a top-down process. However, control is facilitated or constrained by the availability of resources and affective factors. These ideas are at the core of the Metacognitive and Affective model of Self-Regulated Learning (MASRL; Efklides, 2011) that extends previous SRL models by integrating metacognition with affect and motivation.

Conclusions

At the beginning of this article I posited three questions: (a) Does monitoring accurately represent cognition? (b) Is control informed only by metacognitive monitoring and (c) How effective is control in the regulation of cognitive processing and/or behavior?

As regards the first question the evidence suggests that monitoring in the form of ME and MK does not always accurately represent cognition and the factors that influence the outcome of cognitive processing. Moreover, people do not pay sufficient attention to task and context characteristics that have a direct effect on processing outcomes and performance.

The answer to the second question is that control is not informed only by metacognitive monitoring. Rather, control is triggered by task, cognitive, affective, and motivational considerations as well as metacognition.

The answer to the third question is that control is not effective in cases in which the monitoring input for the control decision is inaccurate. However, monitoring may be accurate but the person do not have at their disposal the appropriate strategies, or habitual ways of responding prevail over metacognitively informed ones. Furthermore, monitoring can be accurate but strategy use fails because it requires resources for effortful processing and there is depletion of resources.

Implications for Future Research

What are the implications for research on metacognition?

1. Research on monitoring, particularly JOLs, is extended and has led to significant theories in the field. However, each ME has its own characteristics and it is possible that different cues are involved in the formation of each of them. For example, self-assessment is different from JOLs, and feeling of difficulty monitors *lack of* fluency rather than fluency which is at the core of feeling of knowing or JOLs. Moreover, there are suggestions in calibration research to use two different calibration indicators one depicting monitoring of correct responses and one depicting monitoring of incorrect responses or error (Schraw, Kuch, & Gutierrez, 2013).

2. Research on control processes in metacognition has been largely focusing on the use of cognitive or metacognitive strategies in specific domains. However, a broader conception of control is needed (e.g., cognitive, executive, metacognitive, volitional) that can highlight the interrelations between the various manifestations of control and their relations with monitoring. The constraints on control due to limited resources has to be further pursued as well. For example, use of metacognitive strategies or skills can be highly demanding when first taught and this may have adverse effects on problem solving or learning of new content knowledge.

3. Research on ME has been largely independent from research on MK. The relations between the two facets of monitoring need to be more systematically explored. For example, the reasons for making a confidence judgment may differ between people (Dinsmore & Parkinson, 2013), and this may have implications for the accuracy of monitoring and the interactions of monitoring with control processes. And, of course, the distinction between explicit vs.

implicit MK needs to be further developed and investigated as to its implications for monitoring and control.

4. The interrelations between cognition and affect have been explored in social psychology since the 1980s. However, the relations of affect with metacognition are only in their beginning. Research in this direction can highlight the integrated nature of human consciousness and lighten the nature of monitoring and control processes.
5. There is growing research on social metacognition but still this work is limited. The effects of social factors on both individual and collaborating peers' ME, MK and control is of great importance. This will highlight possible nonconscious social effects on metacognition and its relations with cognition and performance.

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Received: September 10, 2013