Metamemory: An Update of Critical Findings

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Metamemory refers to our knowledge and awareness of our own memory content and processes. For example, when a person asserts that he or she is good at remembering maps and directions, but poor at remembering faces, that person is making a statement concerning metamemory knowledge, at a global level. Similarly, when he/she says that he/she is better than most people at remembering facts, he/she is operating at a global level. If this is, in fact, true, we say he/she exhibits global accuracy. When he/she claims that it is highly likely that he/she will remember a particular fact or event, but may forget another event, he/she is making a metamemory judgment at the level of particular items—evaluating his/her relative strength in memory. If he/she is correct, we call this latter kind of metamemory "relative accuracy" or, sometimes, "resolution," and in principle, it is distinct from global accuracy.

A person may not know that he/she has an extraordinarily good memory—better than that of other people, and hence might show little or no metacognitive awareness at a global level. He/she might also not know how well he/she did on a test, showing overall over- or underconfidence—a different kind of global metacognitive judgment. At the same time, he/she could know perfectly well which items will be remembered and which are likely to be forgotten, and hence have excellent metamemory at a relative accuracy level. These global and relative level flavors of metacognition are often conflated, but in principle they are distinct. For instance, it is frequently claimed that people have poor emotional metacognition. This is true at the global level: people usually do not know whether they are more emotionally sensitive and perceptive than other people (Ickes, 1993; Koole, 2009). Indeed, it has even been found that people who are particularly narcissistic (and hence insensitive to others) think they are exceptionally emotionally sensitive (Ames and Kammrath, 2004). But even though people appear to have inaccurate emotional metacognition at a global level, it is not the case that people have poor emotional metacognition at the relative accuracy level: most people know whether they have understood or not understood particular emotional expressions—indeed, people with autism notwithstanding, most people are very good at these relative judgments of emotional expression (Kelly and Metcalfe, 2011; Zimmerman and Kelley, 2010).

Both global and relative accuracy level metacognition have consequences for control. In metacognition research, the term control means our ability to regulate our learning or retrieval. But the consequences of global and relative accuracy level metacognition are different. For example, having high confidence that you have remembered everything and are doing very well, at a global level, might lead you to stop studying and go to a football game. (If you were wrong about how well you have remembered, this resultant lack of study might hurt your test performance.) Being inaccurate about *which* items you know and do not know may also impact performance, but in a different way. Presumably, if your control processes were intact you would choose to study the items you thought you did not yet know, and would not waste your time on items you already know. But if a person were wrong about which ones they knew and did not know they would almost inevitably end up choosing to study the wrong items—perhaps those that they already knew. Of course, having accurate relative accuracy does not guarantee that it will be used appropriately—metacognitive monitoring and control are different and dissociable processes. For instance, middle-childhood children have been shown to have highly accurate relative accuracy—they know whether they know particular items or not. Nevertheless, they frequently choose to study items that they already know (saying things like they want to study items they already know because they are more fun or they like them better, see Metcalfe and Finn, 2013).

In contrast to these information-based evaluations of our memory and knowledge (see, Efklides, 2011; Winne and Azevedo, 2014), metamemory awareness refers to our *feelings* or *experiences* of our own memory (Schwartz and Metcalfe, 2011). For example, in a tip-of-the-tongue state (TOTs), a person has a strong feeling that an unretrieved item will be recalled even though that retrieval is actually not taking place. What makes a TOTs unique is the strong feeling that marks its presence—it cannot be shaken, and elsewhere one can find colorful quotes that have been used to describe it (Metcalfe and Schwartz, 2016). TOT experiences occur often, but other metamemory experiences may take place only rarely. Déjà vu experiences occur quite rarely and represent strong feelings that an experience now occurred earlier as well (Schwartz and Cleary, 2016). Consider a person who visits Bimini in the Bahamas for

 http://dx.doi.org/10.1016/B978-0-12-809324-5.21056-0

the first time and is struck by a feeling of déjà vu. The feeling persists even if the person is certain that he/she has never been there. Déjà vu experiences can be resolved, as when the person realizes he/she saw the main street in Bimini in a movie. It is likely that feeling states also are part of other metamemory judgments, but TOTs and déjà vu states are likely relatively "pure" metacognitive feeling states.

Research on metamemory experience derives from two historical trends within cognitive psychology. First, Endel Tulving and Stephen Madigan proposed that we need to understand the phenomenological experiences that accompany memory to understand human memory (Tulving and Madigan, 1970). In particular, they emphasized that one of the unique aspects of human memory is its self-knowledge. This view has led to the focus on the mechanism of metamemory—that is, what are the underlying cognitive causes of such judgments. But Tulving and Madigan also emphasized the control aspect of these experiences—that our feelings may drive our behavior—that these judgments evolved and have consequences. This has played out in our attention to the relation between judgments and self-regulated control of behavior (Bjork et al., 2013). Second, metamemory research also arose from theories within cognitive development stating that improvements in memory as children grow older are likely the result of children acquiring more awareness and knowledge about how memory works (Flavell, 1979). This focus has led to the work on metacognitive knowledge and how this metaknowledge structures both our learning and our retrieval. In particular, Flavell's influence laid the path for the attention to global aspects of metamemory and how they play out in everyday learning (Efklides, 2011). Our focus here will be on the Tulving/Madigan approach.

Empirically, it was the work of Thomas Nelson and his colleagues that brought metamemory research into mainstream cognitive psychology during the 1980s and 1990s (Nelson and Narens, 1990; also see Bjork, 2016). An important contribution made by this group was the construction of a set of general-information questions that allowed researchers to test whether people knew what they knew and would know, along with a method of testing and evaluating the correlation between metamemory and later performance (Nelson and Narens, 1980a,b). It is notable that one recent trend is the extension of the reach of metacognition beyond the limited domain of general-information questions—to domains such as perception (Fleming et al., 2012), problem solving (Ackerman and Thompson, 2015), emotion recognition (Zimmerman and Kelley, 2010), judgments of agency (Metcalfe et al., 2013; Vuorre and Metcalfe, 2016), text comprehension (Dunlosky and Lipko, 2007; Dunlosky et al., 2011), schizophrenia (Bacon et al., 2015), Alzheimer Disease (Cosentino et al., 2007), as well as research on animal metacognition (Beran et al., 2016; Hampton, 2001; Kornell, 2014).

Nelson and Narens (1990) also introduced an important conceptual framework for studying metamemory, in which both monitoring and control were featured. For Nelson, monitoring operated at a metalevel, which examined and evaluated basic-level cognitive processes. The results obtained at the metalevel could then be used to inform further study or further retrieval attempts, and hence to exert control over memory processes, including memory search, allocating study time, or even study or retrieval cessation. In this view, monitoring may involve the awareness of ongoing memory activity. It can be measured by asking participants to make judgments about their learning or their retrieval. It follows that the outcome of these judgments can affect how people decide to learn and remember—that is, how they control their own memory.

From a functional standpoint, Nelson and Narens (1990) argued that metamemory needs to be accurate to allow good control. It has largely been taken as an article of faith by the community studying metamemory that this contention is true, although there have been some exceptions. Indeed, there is substantial research showing that people are inaccurate in their judgments much of the time (e.g., Bjork et al., 2013; Koriat et al., 2004; Kornell and Finn, 2016), but that sometimes those inaccuracies paradoxically result in efficacious control. For example, Finn (2008) and Metcalfe and Finn (2008) has shown that underconfidence results in people choosing to continue their study. This inaccurate metacognition may, hence, result in adaptive behavior: on a later test they may perform better than someone who was perfectly calibrated and hence decided not to study. There are many cases in which metamemory has been shown to be inaccurate. But although metamemory is almost never perfectly accurate at predicting memory performance, it is nearly always better than chance (see Dunlosky and Metcalfe, 2009; Souchay, 2016).

Although Nelson and Narens (1990) set an agenda for research to attend to the functional significance of metamemory, around the same time, researchers began investigating the underlying mechanisms of metamemory. Not that researchers had ignored this previously, but two important papers firmly established the importance of heuristic inferential processes as the chief underlying mechanisms in metamemory judgments (Koriat, 1993; Metcalfe, 1993). Koriat (1993) advanced that people use retrieved information to infer the likelihood that an unrecalled item would be recognized. Metcalfe (1993) argued that the familiarity of cues was used to infer the likelihood that an unrecalled item would be recognized. In both cases, the vector through which metamemory worked was heuristic in nature, rather than through direct access to the target memory, as had been assumed by a great many researchers dating back to metamemory's infancy, in the seminal work of Hart (1965) and Brown and McNeill (1966).

Since that time, metamemory research concerning the mechanisms underlying metamemory judgments has flourished. Metamemory has been studied across the learning process, from just prior to the initiation of learning (ease-of-learning judgments), to at the time of learning [judgments of learning (JOL) and judgments of forgetting], to during retrieval in (feeling-of-knowing judgments and TOTs), and to following learning in the form of retrospective judgments (see Dunlosky and Metcalfe, 2009). Metamemory has been linked to many interesting phenomena including remember-know judgments and the déjà vu phenomenon (Schwartz and Cleary, 2016). Indeed, as Bjork (2016) points out, metamemory research has increased dramatically each of the last few decades. This chapter focuses on two common metamemory judgments, JOLs and TOTs, as being the areas that are most informative in making generalizations about the nature of human metamemory. We start with JOLs.

Judgments of Learning States

JOLs are predictions of future remembering made at the time of learning (Nelson and Leonesio, 1988). Typically, in the lab, a participant is given a cue-target paired associate (e.g., "cat-fork") or a language translation pair (e.g., "cheetah—guépard"), and after studying will make a judgment as to whether he or she has learned and will remember that item at some later point in time. JOLs are typically given on 0 to 100 scales, though Likert scales are also used. Research has shown that JOLs can be accurate at predicting future performance, especially if they are made at a delay rather than immediately. Immediate judgments tend toward being less accurate because the subject still has the to-be-remembered information in working memory and therefore cannot sample long-term memory accurately (see Cowan, this volume). But even when made at a delay, when the memory sampling inherent in how people usually make the judgments is similar to that which will be needed at time of test, there are ways in which JOLs may still show systematic distortions and biases (Rhodes, 2016). Typically, though, when researchers examine the cues used to make JOLs or the biases in these processes, immediate JOLs are investigated. With this method, the researchers can focus on the distortions and biases, rather than on the influence of retrieval, as in delayed cue-only JOLs (see Rhodes, 2016). JOLs illustrate a number of important aspects of metacognition in general. These include issues of accuracy, issues of underlying mechanisms, and issues of application. We turn to each of these now.

In a highly influential theory concerning the mechanisms underlying JOLs, Koriat (1997) argued that JOLs are heuristic judgments based on three classes of cues: intrinsic, extrinsic, and mnemonic. Within Koriat's framework, intrinsic cues are properties of the to-be-learned material, such as size, font, vividness of a picture, concreteness of words, the difficulty of those items, and imageability. Extrinsic cues are based on properties of the learning environment, such as instructions to use imagery, rote encoding, or relational processing. Extrinsic cues include the amount of time allotted to study items and the spacing of items across study. Finally, mnemonic cues are based on the person's subjective experience. They include the fluency with which items are perceived during study as well as the fluency with which items are retrieved at test. Koriat originally thought that intrinsic and extrinsic cues would have the largest influence on JOLs. Recent work, however, has shown the importance of the mnemonic cues, especially fluency (Koriat et al., 2014; Li et al., 2016; Rhodes and Castel, 2008).

One of Koriat's (1997) original contentions was that people attend more to intrinsic cues than to extrinsic cues during study. Indeed, many illusions that affect JOLs arise from an unjustified attention to intrinsic characteristics and a lack of attention to extrinsic characteristics (Kornell et al., 2011). Kornell et al. presented single words for study in either small fonts or large fonts. To-be-remembered words were presented either once or multiple times. Consistent with Koriat's view, the intrinsic property of words' font size affected JOLs, leading to higher JOLs for large-font words than small-font words, even though this did not affect later memory performance. However, JOLs were barely affected by whether a word had been presented once or multiple times, an extrinsic characteristic, even though this later strongly influenced memory. Indeed, an interesting corollary of Koriat's view is the following: people pay more attention to the intrinsic characteristics than they should, and should pay more attention to extrinsic characteristics than they do. There are important consequences for everyday learning to both of these biases.

Numerous other studies support Koriat's (1997) view that intrinsic cues influence JOLs more than do extrinsic cues. For example, Carroll et al. (1997) compared the relative contribution of overlearning (extrinsic) and cue-target relatedness (intrinsic) on memory and JOLs. Carroll et al.'s participants overlearned unrelated pairs, but only studied related pairs to criterion, thus putting the two variables into conflict with each other for subsequent JOLs. Under these circumstances, the overlearning of the unrelated pairs produced better recall than did the criterion learning of the related pairs (53% correct vs. 42% correct). However, people's JOLs predicted the opposite. They thought that the related pairs would be remembered better, despite the extra study they had given to the unrelated pairs. These results are in keeping with Koriat's prediction: the intrinsic cues—favoring relatedness—influenced JOLs more than the extrinsic cues. The study is impressive because the memory results showed the obverse of the JOLs.

Rhodes and Castel (2008) also demonstrated that JOLs are subject to an illusory effect based on an overreliance on intrinsic cues. Their participants made JOLs on word pairs, some of which were in smaller fonts whereas others were in larger fonts. The larger fonts created an illusion of better learning, as manifested by higher immediate JOLs, consistent with the view that intrinsic cues—that may or may not be important for memory—are important to JOLs (see Kornell et al., 2011). Similarly, Rhodes and Castel (2009) showed that JOLs are influenced by how loudly the stimuli were presented. Word pairs that were read more loudly to participants were given higher immediate JOLs than those that were presented more softly. Neither of these manipulations, at least in these studies, influenced memory. The interpretation of these data is consistent with Koriat's (1997) framework, which indicated that participants were relying on the size or loudness of the words to determine their JOLs, thus demonstrating the importance of intrinsic cues. However, it is also possible that the larger fonts and the louder voices increased ease of processing. If this were the locus of the effect then, within Koriat's framework they would be considered mnemonic cues. (Or, of course, the loudness of the sound or the size of font might be a social marker of the importance of the materials, as indicated by the experimenter. If this were the case, then the metacognitive effects might be due to nothing more than implicit demand characteristics.) Either way, the higher JOLs were illusory in that they were not mirrored by better performance, at least in the earlier-cited experiments.

In addition to supporting the intrinsic/extrinsic distinction, the data presented thus far also support the view that JOLs are driven by heuristics. Like many other heuristic-based judgments, JOLs are subject to systematic biases. One near-universal bias in metacognition research is overconfidence (Son and Kornell, 2009). However, overconfidence is a complex issue. Initially, JOLs tend to be overconfident, but with more study, they grow less so, switching to underconfidence after the first study trial (Koriat et al., 2006). One question that can be asked is why people's JOLs are overconfident initially and then why do they become underconfident later. We look at overconfidence first.

Overconfidence is partially based on a fundamental aspect of memory, namely, forgetting. It turns out that people underestimate the likelihood of forgetting (Kornell, 2011): they seem to think that if they know it now, they will know it forever. To illustrate this empirically, Koriat et al. (2004) required one group of people to predict how they would perform on a test in 5 min and another group predicted how they would perform on a test in 1 week's time. The groups made nearly identical predictions, despite the fact that with 1 week, a lot more forgetting is going to occur. Thus, those who were predicting their performance in a week showed a very high degree of overconfidence. Kornell and Bjork (2009) called this failure to take into account the fact that forgetting would occur over time stability bias.

To test other implications of stability bias, Kornell and Bjork (2009) instructed participants to study some paired associates one time and other paired associates four times, in preparation for an upcoming cued-recall test. They found that recall increased with the number of learning trials, but JOLs did not show the same pattern: JOLs given on once-presented paired associates were not lower than those given for pair that had been studied on multiple learning trials. This finding suggests that participants' JOLs did not take into account the strengthening of each memory trace that came from the further study. In fact, one possible interpretation of these data is that people continue to rely on intrinsic cues (the difficulty of the stimuli) even when their JOLs would be more accurate if they had, instead, focused on extrinsic cues (the repetition of the same items). Thus, research on stability bias generally supports the Koriat (1997) view.

Overconfidence is also seen, fairly consistently, on the first trial in experiments in which subjects engage in learning of particular materials over multiple trials (Koriat et al., 2004; Kornell, 2011). The reason for this first-trial overconfidence is very likely the same failure to take into account forgetting over time that is described earlier. But then something strange happens. On the second and subsequent trials, people go from being overconfident, overall, to being consistently underconfident. This phenomenon is known as the "underconfidence with practice" effect (Koriat et al., 2006).

Interestingly, the shift to underconfidence with practice, whereby in the second and subsequent trials, people predict that they will underperform, appears to be attributable to people misusing, rather than completely ignoring, a cue about the strength of their memory. Finn and Metcalfe (2007, 2008) showed that the underconfidence that is exhibited on the second and third trial of a multiple-trial learning task is attributable mainly to those items that the person got wrong on the previous test. But people learn something during the study trial that comes after the test, and they do better on these previously incorrectly remembered items on trial $n+1$ than they did on trial n. Nevertheless, they act as if they will perform on these items just as they did on the last test. Indeed, it is important for the effect that they do remember how they did on the items on the last test. Ignoring the fact that they have just learned something about these items, they persist in thinking that they will forget them again. Finn called this reliance on a faulty cue that gives rise to the underconfidence with practice effect the "memory for past test heuristic." Interestingly enough, people who have a lack of awareness that they have a memory deficit (anosognosia) who clinically present as not knowing that there is anything wrong with their memories—do not (or perhaps cannot) use this memory for past test heuristic (Cosentino et al., 2007). It is as if they cannot remember that they got certain items wrong on the last test. For these patients, the second and third trials are like the first trial: they fail to use the memory for past test heuristic and so they continue to show overconfidence over multiple trials (Cosentino et al., 2007).

The Role of Judgments of Learning States in Self-Determined Study

Several questions arise in the applied domain with respect to JOLs. First, can JOLs help guide people toward effective study? Second, given that JOLs are themselves made at the time of learning and are often thought to involve processes that impact learning, do JOLs contribute to learning or is their role strictly metacognitive? One way of thinking about these questions is in terms of whether or not effective ways to control learning can be based on the information we obtain from monitoring our learning. One proposed adaptive strategy is that indicted by Metcalfe's Region of Proximal Learning model, which states that efficient learning occurs when people study the easiest items that have not yet been mastered (Kornell and Metcalfe, 2006; Metcalfe, 2002; Metcalfe and Kornell, 2005; see Atkinson, 1972). In this model, JOLs can be used to sort out items that have been already learned—and do not require further study—and items that are just too difficult to master. These too-difficult-to-master items will not get studied. Instead, items given intermediate JOLs—not yet learned, although not too difficult—are the items on which a student should focus. To illustrate this point, Son and Kornell (2009) asked participants to make JOLs on GRE word–synonym pairs (e.g., ignominious—shameful). Participants then had the opportunity to choose which items to study, and for how long. In support of the Region of Proximal Learning model, participants focused on the easier items first, studying them in advance of the more difficult items. However, participants shifted their focus from the easy items to the difficult items and studied the latter more often as study continued, just as the model predicts. Although we do not have the space here to update the research on this model, the study does illustrate how JOLs can lead to adaptive studying (see Rhodes, 2016; Kornell and Finn, 2016 for such updates).

Ariel et al. (2009) offer a different model of how people translate their metacognitive experiences into the practice of controlling learning. As well as taking into account people's relative judgments, this model additionally and smoothly incorporates people's global metacognition as well as the task constraints. The model is called Agenda-Based Regulation because it requires the individual to first set an agenda for studying. The basis of this view is that, depending on the circumstances and goals of the individual, as well as their own self-knowledge at a global level, a person may choose different studying strategies based on their JOLs. Thus, a student who is just trying to pass the course and not worry about a top grade may focus on items given high JOLs to ensure he/she knows enough to "get by." In contrast, a student determined to master the material and get the best grade may focus on the items to which he/she gave low JOLs, in an effort to master everything. Thus, knowing the agenda a person has will likely determine how that person translates his/her JOLs into study-directed action. Ariel et al. showed that when participants were given values associated (e.g., "this item is worth more on the test") with particular to-be-learned items, they tended to study the high-value items more than the low-value items, regardless of the level of difficulty. Furthermore, Ariel (2013) found that participants studied high-value items more even when value was not explicitly given, but had to be determined by which items had been tested earlier. The Agenda-Based Regulation view is not inconsistent with the Region of Proximal Learning model, per se, but adds an additional much-needed layer of top-down control. The Region of Proximal Learning model provides "mid-level management"—which items are best to study right now for optimal performance; the Agenda-Based Regulation model, provides, in addition, "upper-level management"—what is the goal and how do we achieve it?

Do JOLs, Themselves, Influence Learning: A Metacognitive Heisenberg Effect?

This question concerns whether or not the act of making a JOL might, itself, alter memory. Whereas we typically think of JOLs as monitoring outcomes that, themselves, have no impact on the underlying memories unless they are explicitly and consciously used to control study allocation or efforts at retrieval, there are also researchers who are concerned about reactivity, or the extent to which the mere act of making the judgment might influence learning (Mitchum et al., 2016). For example, Mitchum et al. found that participants were more likely to focus on studying easy items than on difficult items when they were making JOLs than when they were not making JOLs. Moreover, the very act of making JOLs influenced recall performance, at least for some items. For the related pairs, there were no differences between later recall for those items given JOLs and those not given JOLs. For the unrelated pairs, however, making a JOL lowered later recall relative to the condition in which people did not make JOLs. In the view of Mitchum et al., the focus on metamemory altered the approach to controlling study, leading to changes in both studying behavior and ultimately, performance. Thus, the act of making a JOL influenced people's mental processes—the judgment process of ascertaining high JOLs or low JOLs was not encapsulated but rather had an impact on memory.

Reactivity is also a practical concern. If the mere making of JOLs alters the learning process, we need to understand how and why, so that we can advise learners on the best use of JOLs while studying. In many domains of performance, including music, athletics, and public speaking, such introspective awareness of one's own performance is often thought to interfere with fluent performance rather enhance it (see Peynircioglu et al., 2014 for a discussion of music and metamemory). People choke when they are too self-aware about what they are doing (Beilock, 2010). If so, should we discourage a focus on metamemory in these domains? In aiming sports (e.g., archery), more activity in the prefrontal lobe, which may involve continued planning, is associated with poor performance relative to less activity in the frontal lobe (Kim et al., 2008). Thus, it may be that the act of monitoring in a JOL may to some extent also interfere with encoding.

Although it is likely that metacognitive monitoring could sometimes harm learning or performance, most researchers have focused on the possibility that making a JOL—because of the memorial retrieval processes that are purportedly involved in making these judgments—contributes in a positive way to learning (Tauber et al., 2015). Consider delayed cue-only JOLs, in which participants make their JOLs in the presence of only the cue and at a time delay after the original learning experience. The dominant theory of the process of making a delayed cue-only JOL is that the individual uses the cue provided to try to retrieve the desired target. If that retrieval is successful, a high JOL is assigned; if it is unsuccessful, a low judgment is assigned. Thus, the process—when it is fully enacted—is just like retrieval.

If a delayed cue-only JOL is like retrieval, then making such JOLs should affect learning. It is well known that retrieval practice results in memory benefits (see Karpicke, this volume). Insofar as people actually practice retrieval when they make JOLs, the metacognitive assessment should also produce retrieval practice benefits. Accordingly, Jönsson et al. (2012) compared the making of JOLs to retrieval practice using language–translation pairs—they taught Swahili translations to their Swedish-speaking participants. Participants originally studied the word pairs, and then received four practice trials. The practice trials involved either attempting retrieval of the target (Swedish word) or making a JOL about it. In support of the postulated mechanism thought to underlie the JOL process, final recall was not significantly different between the JOL condition and the testing condition, and both of these conditions were superior to a condition that involved less self-testing. Thus, this finding suggests that making JOLs is in itself an act or learning and strengthens the connections among to-be-learned items. Of course, if the individual made the judgment on some basis other than retrieval practice (such as on the size or loudness of the stimulus, neither of which is, in its own right thought to enhance memory), the benefit might not occur. But, in the case of delayed cue-only JOLs, the JOL does double duty—it helps monitor the learning process, but also it helps learning directly.

To summarize the research on JOLs, there is consensus in the research community that JOLs are based on heuristics (Rhodes, 2016). For that reason, though, they can be subject to biases that result from the misapplication of those heuristics (Bjork et al., 2013). Even so, they are sometimes accurate and nearly always better than chance, and hence, usually provide useful information in allowing people to allocate study time and effort across time and items. Furthermore, because of the memorial processes in making the judgments they may, sometimes, also, directly contribute to learning.

Tip-of-the-Tongue States

TOTs are defined as the subjective experience that an unrecalled item will—with enough time and effort—be recallable (Brown, 2012; Schwartz and Metcalfe, 2011). Most people report that they occur in everyday life, sometimes as frequently as once a day. They may occur for ordinary words as well as proper names, such as the names of celebrities (Brown, 2012). In everyday life, TOTs are often accompanied by the retrieval of partial and related information, which often seems to confirm that the item is known, but may just not be retrievable at the moment.

The first empirical study on TOTs was conducted by Roger Brown and David McNeill and was published in 1966 (Brown and McNeill, 1966). They introduced a method called "prospecting," which has been used in TOT research ever since. They showed definitions of rare words, such as "a flat-bottomed Chinese wooden boat" (sampan). If participants did not recall the word, they indicated whether they were experiencing a TOT. Later, Brown and McNeill presented the target word to participants and asked if the presented word was the word for which they were experiencing a TOT. Since Brown and McNeill's seminal study, the prospecting method has been extensively used to study TOTs. TOTs have been elicited for rare-word definitions, general-information questions, photographs of the faces of famous people, newly learned fictional animals, unusual idioms, and translation equivalents (see Brown, 2012; Schwartz and Cleary, 2016). In most of these studies, there is a final recognition or recall test to determine if the TOTs are accurate at predicting later performance, which they invariably are (Brown, 2012).

TOTs have been studied with two major goals in mind. First, from the perspective of psycholinguistics, TOTs are of interest because during a TOT, retrieval is apparently blocked, inhibited, or in some way slowed down. Thus, TOTs are used as a means of examining the retrieval or lexical access process (D'Angelo and Humphreys, 2015). In the metacognitive perspective, TOTs are a result of a process that monitors the retrieval attempt and determines that the missing target word can be recovered. In this view, the TOT informs us of the likelihood that we will eventually be able to retrieve a target word that we cannot retrieve now. Because, during a TOT, we have a particular nagging experience that we find difficult to ignore, we are goaded, by this feeling state, into engaging in metacognitive control processes that nearly always ensure the desired retrieval. Thus, for metacognition researchers, it is the experience of the TOT, and its consequences, rather than the linguistic failure itself, that motivates the research (Schwartz and Metcalfe, 2011).

From the psycholinguistic perspective, Nordmann et al. (2013) were interested in TOTs for well-known idioms in English, such as "money doesn't grow on trees" (meaning, "don't be spendthrift") or "all hands on deck" (meaning, "everyone needs to be working"). Participants were given idiom definitions and then asked to recall the idiomatic expression that fit that definition. If they could not recall the target idiom, participants indicated if they were in a TOT for the idiom. Nordmann et al. also looked at partial retrieval of idiom components when participants could not recall the entire expression. They found that relative to "don't know" responses, TOT responses were correlated with the recall of individual words from the idiom (e.g., "money" in "money doesn't grow on trees") and words related to the literal meaning of the idiom (e.g., "ship" in "all hands on deck"). Thus, they concluded that during TOTs, the representation of literal meaning of idioms is accessed, and that this occurs prior to the stage in which the figurative meaning is retrieved. The emphasis is here on not what causes the TOT to occur but on what levels of the representational structure of the missing target are accessed.

In contrast to such a psycholinguistic approach, Schwartz (2008) approached TOTs from the perspective of metacognition. His reasoning was as follows: if metacognition is a high-level executive process that requires consciousness and attention, then dividing attention by implementing a divided attention task should lower the rate of metacognitive hits, in this case, the number of TOTs. In the study, participants answered general-information questions either while maintaining a concurrent digit-span load or not. The results showed concurrent digit-span load did not interfere with the retrieval of the answers to the general-information questions relative to the no-load control. However, TOTs were reduced. This dissociation between basic-level memory retrieval and metalevel TOTs is evidence that conscious attention-demanding inferential processes impact the metalevel selectively—in this case the TOTs. These results, of course, are consistent with a metacognitive view of TOTs.

As is the case with JOLs, TOTs are thought to be dependent on heuristics (Schwartz and Metcalfe, 2011). In this view, when retrieval comes up short, a metacognitive monitor determines whether sufficient information is present to indicate that retrieval might be successful eventually, if the person keeps trying to amass more information. If so, a TOT will result. The contributing information can be partial phonemic, orthographic, or semantic information about the target, related information, or even the familiarity of the cue. Metcalfe et al. (1993) showed that repetition of the cue led to more TOTs regardless of the memory status of the item. Koriat and Lieblich (1977) showed that longer cue questions were associated with more TOTs as well. For example, Koriat showed that definitions with repetitive elements, such as "a circle, or any indication of radiant light, around the heads of divinities, saints, sovereigns in pictures, medal, etc." (nimbus), tended to produce more TOTs than did more concise definitions, such as "the science of coins" (numismatics). With respect to retrieved information, Warriner and Humphreys (2008) showed that remembering that one had been in a TOT earlier was associated with being in a TOT later. Moreover, when one is in a TOT, one makes attributions about the status of the to-be-remembered item. For example, Cleary and Claxton (2015) showed that when people made TOTs for unretrieved words, they judged those unretrieved words to be bolder and clearer than unretrieved words for which no TOT was given. Thus, there is substantial evidence that TOTs are related to these inferences or heuristics, which may be unconscious (see Thomas et al., 2012 for similar arguments for feeling-of-knowing judgments).

Neuroscience of Metacognition

One of the important and growing areas in the field of metamemory is understanding the neural underpinnings of metamemory. In addition to the growth of research in metacognitive neuroscience (see Metcalfe and Schwartz, 2016 for a review), there has also been attention to metamemory in patient populations (Pannu and Kaszniak, 2005). We will focus on neuroimaging here and focus on the relation between metacognition and the prefrontal lobe.

We start with an important experiment that dissociated the neural processes associated with the metamemory level from those at the cognitive level. Fleming et al. (2012) asked participants to do a perceptual judgment task in which on two-thirds of the trials they were asked to make a retrospective confidence judgment about whether they had been correct or not on the just completed perceptual decision. On one-third of the trials they did the perceptual task, as before, but then just moved the cursor to mimic the motor movements they would have had to make in the metacognitive task. The contrast between making and not making a metacognitive judgment revealed increased activity in BA10 (specifically right lateral PFC), the anterior cingulate gyrus (which is also in the prefrontal lobe), and right posterior parietal cortex. Additionally, Fleming et al. found that the magnitude of the anterior frontal activation was correlated with individual differences in the goodness (e.g., accuracy of predicting performance) of participants' metacognitive judgments. In essence, Fleming et al. (2012) separated the effect of underlying cognitive performance from metacognitive differences (also see McCurdy et al., 2013).

Several other imaging studies have dissociated memory from metamemory (see Chua et al., 2014). For example, in an fMRI study, Do Lam et al. (2012) found a dissociation between the processes underlying monitoring and predictions, which were located in the mPFC, and those associated with object-level memorial processes, which were located in the medial temporal lobes. Kao et al. (2005) also examined JOLs in the scanner, but the task was to make a JOL concerning the potential recognition of a picture that would be provided later. They found activity across areas of the prefrontal lobe (as well as in the posterior parietal lobe). Maril et al. (2003) found that the retrieval of previously studied items was associated with activity in the hippocampi and medial temporal lobes but that differences in the magnitude of feeling-of-knowing judgments were associated with a variety of activity in different areas of the prefrontal lobe.

Metcalfe et al. (2012) investigated confidence judgments in semantic memory question answering. Previous researchers (e.g., Butterfield and Metcalfe, 2001) observed what is called a "hypercorrection effect," that is, that there is greater recall of correct answers to questions that were initially answered incorrectly with high rather than low confidence. This finding contrasts with the predictions of many theories of memory that indicate that answers produced with high confidence should be exceedingly difficult to overwrite or update. In Metcalfe et al., participants were presented with general-information questions, such as "What is the capital of Jamaica?" (Kingston). Participants answered the questions outside of the scanner, giving their confidence about each answer, but received a reminder of the questions, their answers, their confidence in their (wrong) answer, and corrective feedback giving the right answer, later while being scanned by fMRI. Then, later, a retest was given outside of the scanner.

During the feedback phase, items were selected from the pool of questions such that some high confidence but incorrect items were always included (e.g., Montego Bay, high confidence, but incorrect). Brain activation was contrasted between the corrective feedback event to questions that had been answered erroneously but with low confidence (which would evoke relatively little conflict) and to wrong answer given with high confidence (which would evoke considerable conflict). In addition, Metcalfe et al. (2012) investigated brain activation during the feedback provided to low-confidence correct answers (which show a mismatch between expectation and feedback) as well as during feedback to high-confidence corrects (in which no conflict would, presumably, be experienced). The study revealed that anterior cingulate activation (in both the left and right hemispheres) was correlated with the mismatched conditions—during feedback to high-confidence errors and to low-confidence corrects. The anterior cingulate was much less active when recall was correct and confidence was high, or when recall was incorrect and confidence was low. Thus, the anterior cingulate data do not reflect either high confidence or correctness, but rather the mismatch between the two. In addition, this mismatch was also correlated with activation in the medial frontal gyrus. The right dorsolateral prefrontal cortex was associated with error suppression, consistent with its role in metacognition. The fMRI data from this study showed patterns of activity consistent with the idea that the anterior cingulate is important in monitoring and eliciting conscious awareness of surprising events.

Moreover, we see anterior cingulate activity when there is an opportunity to experience conflict between the judgments and the prospect of recall. In the Do Lam et al. (2012) study of JOLs, they looked at face–name associations and then tested later when showing only the faces, thus allowing for the possibility of perceived conflict between a high JOL coupled with an inability to recall. Participants viewed photographs of faces, randomly paired with gender-appropriate names. Immediately after study, the face was presented alone and the participants made a JOL about later recall of the target name. Recall was then assessed 4 s after the JOL. All phases were done while the participant was in the scanner. Do Lam et al. found that memory performance was correlated with bilateral activity in the hippocampi. JOLs, though, were correlated with activity in the anterior cingulate.

Turning now to TOTs, given that the TOT state illustrates an internal conflict that propels behavior, we would expect activity in the anterior cingulate. Indeed, in the handful of studies looking at TOTs during neuroimaging, this is exactly what is found. For example, Maril et al. (2005) gave participants cues such as "Carmen, composer," and the participants were expected to generate the target (e.g., "Bizet"). Participants indicated that they recalled the target, did not know the target, or were in a TOT for the target. Accuracy of recalled answers was verified later outside the scanner. Maril et al. compared the brain activity across these three responses. They found that the areas of the brain uniquely activated during TOTs were mostly in the right prefrontal lobe including, prominently, the anterior cingulate, the right dorsolateral prefrontal cortex, and the right inferior prefrontal cortex, similar to the areas seen by Metcalfe et al. (2012).

As evidenced by these studies, there is a pattern of neural activity seen across these various neuroimaging studies (Metcalfe and Schwartz, 2016). In particular, the prefrontal lobe appears to be the hub of metamemory. The studies also point to a more specific division of labor in the prefrontal lobe. In particular, the anterior cingulate cortex seems to be associated with conflict detection in metamemory, whether that is the TOT experience in which one is sure one can recall something that one is actually failing to do so, or the hypercorrection effect, in which someone discovers that a high-confidence answer is, in fact, incorrect. Furthermore, BA10 (specifically right lateral PFC) is also highly associated with metamemory, particularly as regards its link to the self. Given that metamemory is self-referential—it refers to what the individual knows about him or herself, this link to a brain region seemingly involved in self-identity may be important (Kelley et al., 2002; Ochsner et al., 2004).

Conclusions

Metamemory research is a vibrant and growing area of study. The research we have outlined has focused on its accuracy or lack of accuracy, the cognitive mechanisms responsible for it, and the neural underpinnings. In addition, there has been considerable and important research on applied aspects of metamemory, that is, how metamemory helps us (or hurts us) with ongoing learning and how metamemory directs that learning. In this paper, we have chosen to focus on the research on JOLs and TOTs to illustrate many of the concepts in metamemory as a whole. We have also focused on the neuroscience research that now shows specific areas within the prefrontal lobes as being critical for metamemory.

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http://www.earli.org/special_interest_groups/metacognition – European Association for Research on Learning and Instruction.
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