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REVIEW ARTICLE

When Confidence Is Not a Signal of Knowing: How Students' Experiences and Beliefs About Processing Fluency Can Lead to Miscalibrated Confidence

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Abstract When students monitor the effectiveness of their learning and accuracy of their memories, the presence or absence of specific content knowledge is not the only information that guides their evaluations. Equally important are the metacognitive experiences, subjective feelings, and epistemological beliefs that inform and accompany learning and remembering and guide achievement-related behavior. Students use a variety of cues (e.g., Koriat *Journal of Experimental Psychology*: *General*, *126*, 349–370, 1997), including experiences of and beliefs about processing fluency to determine confidence in their knowledge. This article addresses why some illusions of knowing that arise while learning and remembering are so pervasive. We draw on converging research from social and cognitive psychology to discuss the allure of processing fluency and influence of metacognitive beliefs on assessments of confidence. We include a discussion of research on the interaction of naïve theories of intelligence with perceptions of processing fluency. Finally, we provide a number of suggestions to mitigate mistakes of confidence.

Keywords Calibration · Confidence · Overconfidence · Metacognition · Fluency · Beliefs

In universities and colleges across the USA, academic advising centers and student affairs centers offer recommendations about a range of strategies and skills that students can implement to foster adaptive study habits and practices to improve learning. Aside from offering students useful counsel about time scheduling and organizational methods, a number of university study centers also offer students a variety of techniques to improve retention of what they are studying, with many tips based on findings from cognitive psychology. The

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Student Counseling Center at Texas A&M discusses a variety of mnemonic techniques such as the method of loci that can be used to aid retention of class information ("Self Help Memory" 2015). The Academic Skills Center at Dartmouth ("Improving Concentration, Memory" 2015) and the Center for Teaching and Learning at Stanford (Stanford University 2008) urge students to be active learners by asking questions as they read. The University of North Carolina at Chapel Hill Health Services office suggests spacing study out before an exam rather than cramming ("Avoiding Study Traps" n.d.), and the Division of Student Affairs at Virginia Tech tells students to test themselves for better long-term learning ("Study Skills Information" 2015). Though not widespread, there is occasional mention of some of the metacognitive cues that students should tune into as they learn. For example, the Weingarten Learning Resources Center at the University of Pennsylvania recommends that students pay attention to metacomprehension cues that signal that they have not understood particular words or sentences. The center goes on to suggest that if comprehension problems occur, then students should try rephrasing the passages in their own words (e.g., "Creating Better Processes" 2015).

These resources can certainly be useful for helping students learn more effectively, and it is encouraging to see some recommendations based on research in memory and learning. However, there are some notable gaps. Consistently missing from the guides is information about the metacognitive biases and illusions that can mislead students as they study. Implicit in this omission is the assumption that students are making accurate assessments of what they do and do not know as they learn and that a student's confidence is a reliable indicator of their knowledge. Even when appropriate study strategies are identified, if students are overconfident about what they know, learning outcomes will be suboptimal.

Of course, students themselves are susceptible to the same metacognitive mistakes. Students' experiences of processing fluency—the ease of mental processing—can lead them to misinterpret how much has been learned. A priori beliefs about what processing fluency indicates about learning can also lead to miscalibrated confidence in learning. The goal of this article is to address the myth that many students believe (and evidently the student learning centers that advise them) that feelings of confidence based on processing fluency are a reliable index of knowing. In reality, metacognitive evaluations based on processing fluency can be mismatched with actual learning—resulting for example, in a student's overconfidence that they have learned something well, when in reality they have not—or in underconfidence that they have not learned as much as they actually have. We focus our discussion on how the experience of and a priori beliefs about processing fluency are evaluated and interact to influence educationally relevant judgments and decisions.

A study by Carpenter et al. (2013) highlights a metacognitive mismatch in a classic academic context: the college lecture. In their study, the researchers presented students with a video of an instructor explaining a scientific concept with either a fluent presentation, in which the instructor spoke fluidly, did not use notes, and stood upright, or with a disfluent presentation, in which the instructor spoke haltingly and looked away from students. Though lecture fluency did not affect how much information students learned, it had a major influence on students' confidence in their learning during the lecture. The students given the fluent lecture predicted that they would remember much more information after viewing the fluent as compared to students who were given the disfluent lecture. Indeed, students were vastly overconfident about how much they had learned during the fluent lecture presentation. Carpenter et al. warned that if students base their own understanding on how well a lecture is given (regardless of content), they will not have an accurate estimation of whether they themselves could explain it, which, ultimately, is what is needed for them to demonstrate competence.

When students evaluate their knowledge, the presence or absence of specific content knowledge is not the only information that guides their judgments. Equally important are the metacognitive experiences, subjective feelings, and a priori beliefs that accompany learning and remembering and that are tremendously important for guiding achievement-related behavior. The disagreement between confidence in knowing and actual knowing is often due to an overweighting of factors that are not always diagnostic of memory—such as ease of processing—and a failure to account for a number of features of learning that do influence memory—such as number of study repetitions (Kornell and Bjork 2009; Koriat 1997). There are now a number of reviews (e.g., Hartwig and Dunlosky 2012; Kornell and Bjork 2007; Yan et al. 2014) that have documented a range of learning scenarios that show confidence to be an unreliable gauge of how much has been learned. In the current article, we focus on metacognitive miscalibration, with particular attention to overconfidence brought about by processing fluency biases in educational contexts. We consider two types of overconfidence as distinguished by Moore and Healy (2007): Overconfidence as an overestimation of learning—believing that you have learned something better than you actually have, and overconfidence as an overplacement of one's own abilities relative to others—believing that you perform better than the average person on the same task. Though both types of overconfidence are addressed, the bulk of the discussion will center on overconfidence as an overestimation of learning.

The review draws on converging research from social and cognitive psychology to discuss the allure of processing fluency and influence of metacognitive beliefs on educationally relevant judgments and decisions. The review will cover four major topics. Our first topic, *Educational Impact of Metacognitive Monitoring Accuracy*, will provide a high level overview of the importance of metacognitive accuracy in educational contexts. We will discuss overconfidence in learning and highlight the pernicious effects of overconfidence on study regulation. This section is intended to provide a foundation for understanding how processing fluency biases can impact self-regulated learning. Our second topic, *Experiences of Processing Fluency Influence Evaluations of Knowing*, will discuss situations in which students make maladaptive assessments of what their experiences of encoding and retrieval fluency signal about learning. We discuss research detailing how illusions of knowing based on processing fluency arise while learning and remembering. The third topic, *Beliefs about Processing Fluency Influence Evaluations of Knowing*, describes how a priori beliefs about processing fluency impact metacognitions and learning strategies. This section includes research showing that beliefs about intelligence can influence interpretations of processing fluency, a research area that has not been covered in great depth in the metacognitive literature on processing fluency. Finally, our fourth topic, *Overcoming Fluency Biases*, offers six techniques that students and instructors can implement to mitigate bias related to processing fluency. The section includes research-based strategies for providing feedback and for altering beliefs about intelligence.

Educational Impact of Metacognitive Monitoring Accuracy

Metacognitive monitoring has been shown to be critical in students' regulation of their strategies for learning and remembering (e.g., Bransford, Brown, and Cocking 2000; Metcalfe and Finn 2008; Nelson and Narens 1990; Rawson and Dunlosky 2013). Metacognitive evaluations incorporate information about past, present, and future knowing. To evaluate our knowledge, we reflect on the current status of our knowledge, the outcome of previous experiences, such as whether we got something right or wrong on a prior test, expectations about what we will remember and forget in the future. Our epistemological and personal beliefs can influence interpretation of these evaluations. The outcomes of these appraisals drive important academic decisions making it critical to understand when and why our metacognitive judgments become biased.

Overconfidence is a perennial student problem, which affects students from the earliest years of school (Finn and Metcalfe 2014; Schneider 1998; Stipek et al. 1984). As students study, they monitor their learning and use that information to control their study (Dunlosky and Ariel 2011; Metcalfe and Finn 2008; Son and Metcalfe 2000). Thus, good metacognitive accuracy is critical to effective self-regulated learning (Begg et al. 1992; Dunlosky and Rawson 2012; Metcalfe and Finn 2008; Thiede 1999; Thiede and Dunlosky 1999). A recent study by Dunlosky and Rawson (2012) underlines the negative impact of overconfidence on self-regulated learning. The researchers asked students to learn definitions for key terms and rate their confidence in the accuracy of their definitions during practice cued recall trials. Results demonstrated that when students were overconfident about the correctness and completeness of their responses, they stopped studying sooner during the practice session

Though self-evaluations do become more accurate with age (Schneider 1998), up to a point (e.g., Rogers et al. 2012), our confidence about our performance continues to overshoot reality. Although older students' judgments are less exaggerated than younger students', they continue to overestimate their own abilities (Falchikov and Boud 1989) in most domains (see Kruger 1999) and throughout adulthood. For example, over 95 % of high school students say that they are average or better when asked about their schoolwork (Chevalier et al. 2009), an example of overplacement of one's own abilities relative to others. Ninety percent of freshman college students show the same overplacement of their abilities (Thorpe et al. 2007). College students' self-evaluation of their class performance and actual class performance show correlations between .20 and .39 (Falchikov and Boud 1989; Hansford and Hattie 1982), indicating overconfidence. The correlation between freshman students' class evaluations and their instructors' evaluations of them is only .35 (Chemers et al. 2001), and older college students' evaluations are not more in line with those of their instructors (Arnold et al. 1985; Falchikov and Boud 1989). Given the disparity between student and instructor ratings, it should come as no surprise that 68 % of the time college students give themselves higher grades than their instructors do (Falchikov and Boud 1989).

Drilling down to a learning episode, our metacognitions influence our determination of whether something is learnable, whether to continue or quit studying, whether and when to revisit a particular item or topic, and our expectations about our performance on a future test. In general, experiences that make learning or remembering feel more effortful but that benefit long-term retention—what Bjork (1975) calls desirable difficulties—tend to reduce students' confidence in their learning. In contrast, experiences that give rise to feelings of processing fluency tend to inflate students' confidence. Students often become overconfident about how much they have learned as a result of non-optimal study strategies they have applied during the course of their learning. Strategy selection, which is systematically impacted by miscalibrated confidence, includes choices about how much time to study an item or topic (Thiede and Dunlosky 1999; Wahlheim et al. 2012; Metcalfe and Kornell 2003), how to distribute study time (Son 2005), and when to terminate study (Karpicke 2009; Kornell 2009).

Experiences of Processing Fluency Influence Evaluations of Knowing

Encoding Fluency Encoding fluency refers to the experienced ease of learning. It can have a misleading influence on our confidence. There are learning situations in which use of encoding fluency is diagnostic. For example, Koriat and collaborators (Koriat et al. 2006; Koriat 2008) provide evidence for adaptive use of feelings of fluency via the easily learned, easily remembered (ELER) heuristic. In a demonstration of the adaptive use of the heuristic, Koriat (2008) asked students to study and rate their confidence by making judgments of learning (JOLs) for cue-target pairs over several study-test trials. When a cue-target pair was answered correctly during the test phase, it was dropped from future study-test trials. On the final recall test, performance was inversely related to trials to acquisition. That is, items that were learned more readily during the study-test phase were more likely to be answered correctly on the final test. JOLs accurately reflected the advantage of the more easily learned cue-target pairs and were higher for the items that were more easily learned. These findings are in agreement with other studies showing that processing fluency is used as a metacognitive cue.

However, fluency is not always diagnostic of whether the presented material has been well learned. Inflexible use of fluency to inform one's confidence in learning can be problematic because study methods that give rise to fluency are often related to shallower, less elaborate encoding. When something feels more difficult to learn, as when using methods that introduce desirable difficulties, the less well students tend to think that they have learned it (Besken and Mulligan 2013; Koriat 2008; Miele et al. 2011) and the less likely they are to use those methods on their own (Karpicke 2009; Kornell and Bjork 2007).

Consider the spacing effect, which dates back to Ebbinghaus (1885/1964) and refers to the finding that spacing out or distributing study over time enhances learning to a much greater extent than when study events are massed together, which can lead to rapid forgetting (e.g., Cepeda et al. 2006; Dempster 1988). Though spacing has clear benefits for learning for both adults and children (Son 2010; Toppino 1991, 1993) without imposing greater time costs, most students fail to recognize the benefits (Kornell et al. 2010) and fail to optimally incorporate a spacing strategy into their study decisions (Kornell and Bjork 2007). Why? One reason that students seem to overvalue massed practice is that it makes encoding feel fluent, which gives the perception that information has been learned. The result is student's greater confidence in their learning following massed as compared to spaced practice (Kornell and Bjork 2008; Simon and Bjork 2001).

Interactive imagery is a strategy that can boost learning. To illustrate, students asked to learn the word pair "table-monkey" would combine the two words and draw up a mental image of the two interacting—perhaps an image of a monkey dancing on a table. Hertzog, Dunlosky, Robinson, and Kidder, (2003) asked students to do just that by forming interactive images during cue-target learning. The response latency to generate the image was recorded. The latency to generate an image was largely unrelated to recall performance. However, students' confidence in their later recall of the information was higher when images came to mind quickly and was lower when images took more time to form. That is, a negative correlation was apparent between confidence and the response latency to generate an image. Subjective experiences during encoding misled students' judgments.

Self-testing is another undervalued learning strategy. Indeed, it is now well established that testing oneself leads to long-term gains to learning as compared to restudying the same material (e.g., Bjork 1975; Roediger and Karpicke 2006). Kornell and Son (2009) had participants study sets of word pairs. Before a final test, half of the sets of pairs were restudied as the complete pair (restudy condition). For the rest of the pairs, the cue word was presented and participants had to come up with the target (test condition). Participants then made aggregate judgments about how many items they expected to recall on the final test. Results showed that in contrast with actual performance, judgments were higher for restudied as compared to tested items. It is likely that information was processed more fluently in the restudy condition compared to the self-test condition, which contributed to students' inaccurate judgments.

Retrieval Fluency Retrieval fluency refers to the speed or the ease with which information comes to mind during retrieval. As with encoding fluency, retrieval fluency can be diagnostic of correct target retrieval (Blake 1973; Koriat 1993; Schacter and Worling 1985). However, it has been shown to be a prominent metacognitive cue, even when it is a misleading indicator of knowing (Benjamin et al. 1998; Kelley and Lindsay 1993; Lindsay and Kelley 1996; Koriat and Ma'ayan 2005; Nelson and Narens 1990, and see also Jacoby and Dallas 1981 for a related discussion of familiarity). For example, a number of studies have demonstrated that as the time it takes to retrieve a target increases, JOLs decrease (Benjamin et al. 1998; Koriat and Ma'ayan 2005). In a similar demonstration, Krueger (1999) tested participants on a difficult or easy version of integrative ability—an invented skill. Students were presented with sets of three words and had to come up with a fourth, related word. Sometimes, the sets were easy to solve, and sometimes, they were difficult to solve. When they were easy to solve, participants said that their "integrative orientation ability" was above average. When they received the difficult version of the test and the fourth word was difficult to generate, they were less confident in their abilities.

It is often more difficult to bring many instances to mind than to bring fewer to mind (e.g., Schwarz et al. 1991; Winkielman et al. 1998 and see Tversky and Kahneman 1973 for a related discussion of the availability heuristic). Though we should have more confidence in the depth of our knowledge when more information is brought to mind, the relative difficulty of retrieving many items can reduce confidence is one's memory abilities. For example, Winkielman et al. asked some participants to recall 12 events from their childhood (which was difficult to do) and some participants to recall 4 events (which was easier to do). Even though participants asked to remember 12 events remembered more events in total than the participants asked to recall 4 events, they were more likely to say that there were large parts of their childhoods that they could not remember. Notably, when participants were shown a list of the recalled childhood events of other participants who had to generate either 12 or 4 events, they rated people in the 12-event condition as having better memories than the people in the 4-event condition (Wänke et al. 1996) demonstrating the bias results from subjective experience of trying to generate or recall.

Fluent retrieval may arise because a prior experience, one not indicative of correct target access, influenced the response outside of awareness (Jacoby and Hollingshead 1990; Kato 1985). Kelley and Lindsay (1993) asked participants to read a list of names of people, places, and things. Then, participants took a general information test. Some of the words on the initial list were answers to the questions, and some were incorrect but related to the answers (e.g., Dallas for the question: What is the capital of Texas?; see also Blaxton 1995; Erickson and Mattson 1981). Results showed a negative correlation between confidence and response time. This pattern was also in evidence when people responded with incorrect answers demonstrating that when incorrect information is retrieved fluently, students think that it is correct information.

The illusion, which results in overconfidence in the stimuli that are easier to retrieve, occurs because of errors in the attribution process (e.g., Jacoby and Dallas 1981). Kelly and Jacoby (1996) provide a clear example of misattribution leading to misplaced confidence. In their study, participants solved anagrams (e.g., fscar=scarf). Some of the participants read the word solution to the anagram in a prior phase of the experiment before they were asked to solve it, which, of course, decreased the time it took to solve the anagram (previously solved anagram condition). More troublesome, however, was the finding that people who solved the anagrams faster because their performance had been facilitated by seeing the solution earlier judged the anagrams as easier (see Fig. 1). Participants misattributed the speed of their responses to the ease of the item not to the fact that they had been given an advantage with prior exposure to the solution.

During the retrieval process, familiarity with the information being used to cue retrieval can also influence confidence in recall of the target (Koriat and Levy-Sadot 2001; Metcalfe and Finn 2008; Metcalfe et al. 1993; Reder and Ritter 1992; Reder and Schunn 1996). Metcalfe et al. (1993) manipulated the number of times that the cues and targets in a cue-target pair were presented before a final cued recall test. Though the number of times a cue was presented had no benefit on target recall, participants' confidence reflected the number of times the cue had been presented. Using a related paradigm, Metcalfe and Finn (2008) showed that when confidence judgments were speeded and thus judgments were based primarily on familiarity of the cue rather than on retrieved target information, manipulations like repetitions that increase the familiarity of the cue had a similar biasing effect on target confidence. In sum, a student's confidence in recall success can be influenced by familiarity with irrelevant information about the cue.

Consider how retrieval fluency misattribution could potentially lead both instructors and students to make inappropriate academic choices. For example, a fluency illusion could impact how instructors design their tests and evaluate their students. Instructors have a great deal of prior knowledge, which could influence how easily they judge the items that they select or create for their students' upcoming test. What may be difficult to the student seems less so in the eyes of an instructor who does not have problems coming up with the response (i.e., the curse of knowledge). A student studying for an upcoming exam may make an assessment of

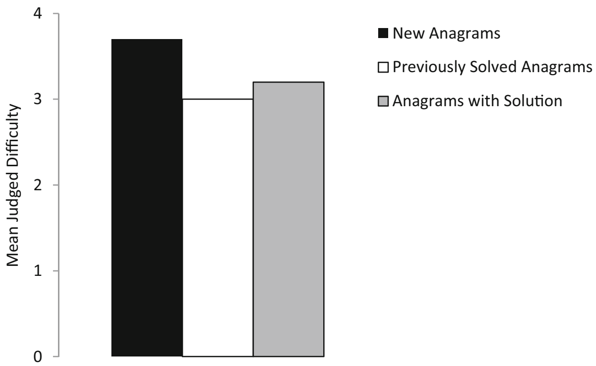

Fig. 1 Ratings of anagram difficulty for anagrams that were new at time of judgment, anagrams that the participant had solved previously, or anagrams in which the solution was presented with the anagram. Higher ratings indicate greater rated difficulty. Data adapted from Kelley and Jacoby (1996)

how well they have learned a particular concept based on familiarity of the chapter heading or study questions and make maladaptive study choices that reflect their mistaken confidence.

Beliefs About Processing Fluency Influence Evaluations of Knowing

As noted above, experiences of fluency can have a profound influence on one's confidence. A priori beliefs about fluency (as compared to experienced fluency) (Flavell 1979; Kardash and Howell 2000; Koriat 1997; Schommer 1990). For example, if a student believes that she can learn all that she can to from reading the textbook chapter once, then she may not prepare adequately for the exam and may end up with a poor grade. In some cases, fluency may play a larger role than beliefs; in other situations, beliefs may play a larger role, and in other circumstances, fluency and beliefs may both contribute or interact to influence assessments of confidence (for a review, see Dunlosky et al. 2015). Evaluations of students' beliefs suggest that students may have a surprising number that can guide their judgments. Our primary focus here is on students' beliefs and naïve theories about what fluent processing indicates about learning.

Kreutzer, Leonard, and Flavell (1975) were among the first to investigate metacognitive beliefs, and they adopted a developmental approach to the issue. Kreutzer et al. conducted detailed interviews with children (kindergarten through fifth grade) about their beliefs on memory. Each interview included general questions about memory (e.g., personal memory ability, forgetting) as well as the effects of specific variables on memory (e.g., relearning, relatedness, retention interval, the amount of material to-be-remembered, etc.). Results revealed that in general, older children had more accurate beliefs about how memory worked than did younger children. However, in some circumstances, even young children had accurate metacognitive beliefs (e.g., relearning).

A number of recent investigations have focused on the degree to which metacognitive beliefs about fluency are related to assessments of confidence. For instance, Mueller, Dunlosky, Tauber, and Rhodes (2014) investigated whether people have beliefs about how a perceptual cue might influence memory. In particular, participants were asked to learn words presented in a large or small font and to make JOL for each. In one group, participants made their judgments prior to actually studying the words, which prevented them from gaining any experiences with processing fluency. Pre-study JOLs revealed higher judgments for large fonts than for smaller fonts, even though font size did not actually impact recall. People also reported beliefs about how font size influenced memory when directly probed. Finally, when processing fluency was measured, it was not shown to differ between the small and large font items. People used their beliefs about how processing fluency influences memory when making confidence judgments. In this case, people had inaccurate beliefs about font size, so their judgments were not diagnostic of later memory performance. Related research suggests that people's beliefs about fluency contribute to the effects of relatedness on judgments (e.g., learning related word pairs such as cat-dog; Mueller et al. 2013, but see Undorf and Erdfelder 2014) and to the effect of alternating format on judgments (Dunlosky et al. 2015).

Students' beliefs about how processing fluency influences memory also impacts study strategy selection, such as massed versus spaced practice or restudy versus self-testing. For example, 66 % of college students report that they "cram" the night before a test based on the belief that they will learn more doing so (Dunlosky and Hartwig 2012). And while it is encouraging that a moderate percentage of students (68 %) report using flashcards while studying (Wissman et al. 2012), students, and even their instructors, assume that a test provides a diagnostic evaluation of what has and has not been learned but is not a learning event in its own right (Karpicke 2009; Kornell and Bjork 2007; Kornell and Son 2009). As can be seen in Fig. 2, the main reason students quiz themselves while studying is to see how well they have learned the material. When contrasting restudy with testing oneself, students believe that they can learn much more from restudying than they can from testing.

Beliefs about fluency are related to confidence evaluations and to learning itself. Schommer (1990) asked students to answer a questionnaire about their epistemological beliefs about learning. The questionnaire included items that asked students whether they thought better learning happened more quickly. For example, items related to this factor asked students to rate their belief in statements such as, “successful students learn things quickly,” or “almost all the information you can learn from a textbook you will get during the first reading.” After rating their epistemological beliefs, the participants were asked to read a science passage as if they had a test coming up. The last paragraph was omitted from the passage. Students were asked to rate their confidence in how well they understood the passage, to write a concluding paragraph, and to take a final comprehension test based on what they read. Stronger endorsement of the belief that quick learning is a sign of good learning predicted a number of maladaptive performance outcomes. The students who subscribed to the quick learning belief were more likely to have overconfident comprehension ratings, have an oversimplified concluding paragraph, and to perform more poorly on the final test than students who did not hold this belief.

Beliefs Can Influence Interpretation of Processing Fluency. As previously noted, metacognitive beliefs and fluency can both influence judgments, and the two may interact in some interesting ways as well (Hertwig et al. 2008; Koriat et al. 2014; Miele et al. 2011; Unkelbach 2006; and see Dunlosky and Tauber 2013 for a detailed discussion). For instance, naïve theories of intelligence influence interpretations of processing fluency (Miele et al. 2013; Miele and Molden 2010). Miele and collaborators showed in several studies that both younger and older students who think intelligence is a fixed attribute (i.e., entity theorists, see Dweck and Leggett 1988) interpret experiences of processing difficulty as an indication that they are reaching the limits of their ability and as a result become less confident when fluency decreases. In contrast, participants who view intelligence as a malleable attribute developed through study and effort (i.e., incremental or growth theorists) do not typically interpret processing difficulty as reflecting their innate abilities. When fluency declined for incremental theorists, they did not report less confidence in their performance. Instead, these participants viewed effort as leading to increased mastery such that decreases in fluency led to higher reported confidence.

Response	*% of respondents*
I learn more that way than I would through presentation	20%
To figure out how well I have learned the information I’m studying	66%
I find quizzing more enjoyable than presentation	4%
None of the above	10%

Fig. 2 The figure depicts participants’ responses to the question, “which best describes the reason you quiz yourself when you study?” from experiments 1 and 2 in Kornell and Son (2009)

On a related note, a student's beliefs about their self-efficacy in mathematics, which is related to experiences of and beliefs about what processing fluency indicates about one's learning plays a major mediational role in larger scale achievement decisions such as the process of choosing mathematics-related classes (Betz and Hackett 1983; Eccles and Jacobs 1986; Hackett 1985; Lee 2009). Participation in mathematics courses influences college aspirations to pursue careers in the STEM disciplines (Eccles-Parsons 1983; Eccles and Jacobs 1986; Helmke 1989; Singh et al. 2002; Wigfield and Eccles 1992). Indeed, perceived mathematics self-efficacy has been shown to be a stronger predictor of whether a math college major will be chosen than gender, years of high school math, standardized math scores, scores on college math exams, or math anxiety (Hackett 1985; Siegel et al. 1985). How a student perceives their abilities influences their considerations about the costs and benefits of attending higher education (Chevalier et al. 2009). If a student underestimates their ability, they may decide not to enroll, whereas overconfident students may not accurately consider and prepare for the competition and challenge that comes with attending many institutes of higher education (Chavlier et al. 2009)

Overcoming Fluency Biases

Metacognitive monitoring and control are assumed to involve dual processing that can engage analytic, deliberate processing mechanisms and/or use of heuristics which involve fast, non-analytic, automatic processes (Epstein 1994; Kelley and Jacoby 1996; Koriat and Levy-Sadot 2001; Jacoby and Brooks 1984; Kahneman 2003; Sloman 1996; Stanovich and West 2000). Fast, effortless, heuristic-based judgments, such as those based on experiences of processing fluency are the prepotent response to confidence queries. Heuristics can be unavailable to reflection (Stanovich and West 2000) and, thus, difficult to override (Lindsay and Kelley 1996; Rhodes and Castel 2008). One obvious intervention to reduce overconfidence based on processing fluency biases is to ask students to engage in more deliberate judgment making. Ask them to slow down, think more carefully, and consider all the potential factors that could impact their learning aside from their feelings of fluency before rating their confidence. Slowing down and increasing the effort to make the judgment can mitigate bias but only if people are using the right strategies once they slow down (Shafir and LeBoeuf 2002). Below, we address several promising strategies to mitigate miscalibrated confidence.

Thinking About Alternative Outcomes One approach that has met with some success is to ask people to think about ways that things might have turned out differently (Fischhoff 1982). Consideration of contradictory alternatives and outcomes has been shown to successfully reduce overconfidence by encouraging more deliberative processing when making confidence judgments. Koriat, Lichtenstein, and Fischhoff, (1980) asked people to consider reasons why their answer might be wrong before rating confidence in their answer. Results showed that consideration of reasons that contradicted their original answer diminished overconfidence and thus improved calibration.

Thinking about your previous experiences with similar academic tasks in relation to a current academic task can also reduce overconfidence. Buehler, Griffin, and MacDonald (1997) asked students to make predictions about how long they thought it would take to complete a school assignment. Typically, people are overconfident about how much time they need to complete a project and underestimate how much time they will actually need—a phenomenon known as the planning fallacy (Kahneman and Tversky 1979). Buehler et al. found that asking students to think about their past experiences completing school assignments and explicitly make a connection between the past assignment and the current assignment, immediately before generating their current predictions about when they would finish the current assignment led to more realistic estimates of completion time. A similar tactic may be useful when students' evaluations about their learning have been biased by their current feelings of processing fluency. Asking students to think of previous experiences in which processing fluency was not a diagnostic indicator could potentially help mitigate bias in the current setting.

Sometimes, consideration of alternative outcomes can backfire. Larrick (2004) reviewed research demonstrating that when people consider the alternative outcomes or contradictory reasons for their responses, they sometimes end up working harder to convince themselves that their original judgment was correct, which can exacerbate the problem of overconfidence. In addition, if a student is asked to consider too many reasons why their answer might be wrong, they might have difficulty coming up with many. The effort involved in thinking of many reasons may lead one to think that since it was so hard to come up with alternative reasons (i.e., alternatives were not easily accessible); then, they must have been right in the first place. Sanna and Schwarz (2004) asked students to make confidence judgments about their exam grade. When they rated their confidence, they also listed either 0, 3, or 12 thoughts about succeeding or failing on the exam. (Generating 3 was experienced as easy where as 12 was considered difficult). When students had to come up with 12 reasons for failing—which was difficult—it had a positive impact on confidence. In contrast, generating 12 reasons that you would succeed led to negative impact on confidence.

Highlighting the Correct Cues Research on recognition memory has demonstrated that if fluency can be attributed to an irrelevant source, which sometimes occurs spontaneously (Oppenheimer 2006), it will not influence the judgment (Bornstein and D'Agostino 1992; Bornstein and D'Agostino 1994; Schwarz and Clore 2003; Jacoby and Dallas 1981). When other cues are more salient, they will be privileged over fluency and familiarity. For example, recollection of detail, distinctiveness, and vividness are more diagnostic of memory than familiarity (Gardiner 1988; Israel and Schacter 1997; Jacoby 1991; Johnson, Hashtroudi, and Lindsay 1993; Lindsay 1993; Suengas and Johnson 1988) as is demonstrated by higher confidence for remember as compared to know judgments (Yonelinas 1997). A strong familiarity bias can be countered by asking people to recollect their previous experiences before answering (Jennings and Jacoby 1997). In sum, when more diagnostic cues are available, people can override fluency (Johnson et al. 1993; Oppenheimer 2006; Oppenheimer and Frank 2008).

To summarize, might be possible to reduce overconfidence by asking students to consider reasons why the exam might not go well, to remember an instance when they did not perform as expected, or to take into account alternative sources of their feelings of fluency and familiarity. But, these reasons must come to mind, and come to mind easily.

Reframing the Evaluation Task How task instructions are framed can diminish errors in confidence calibration due to evaluations of processing fluency. We previously highlighted a study by Winkielman et al. (1998) in which participants who were asked to recall 12 events from their childhood (difficult) were more likely to say that there were large parts of their childhoods that they could not remember than were participants asked to remember only 4 events (easier). Framing the task as a difficult one resulted in fewer participants in the 12-event condition judging that there were large parts of their childhood that they could not remember. In another demonstration of how task framing can influence confidence, Novemsky, Dhar, Schwarz, and Simonson 2007) told participants that to-be-presented information would be difficult to read because it was written in unclear font. Participants that were given these instructions were able to reduce illusions due to processing disfluency and correct their underconfident predictions. (Note that Rhodes and Castel (2008) did not find that participants were able to correct their miscalibrated predictions even after being informed about the source of the bias.)

Getting Feedback Receiving feedback about your performance has been shown to be an effective method of mitigating overconfidence (Russo and Schoemaker 1992). Feedback allows students to learn how challenging a particular task is and to adjust their confidence to reflect that challenge (Fischhoff 1982; Mihalca et al. 2015; Pulford and Colman 1997). When students attempt to retrieve information either through a delayed judgment of learning or a test, the retrieval attempt provides feedback about the accessibility of target information. Koriat, Sheffer, and Ma'ayan (2002) showed that although people are overconfident when they first study, their judgments show improved relative accuracy and shift toward underconfidence on and after the second study-test trial (but see Hanczakowski et al. 2013). Performance on a prior test is a primary source of information that people use to inform their future judgments (Finn and Metcalfe 2007, 2008; Tauber and Rhodes 2012). When test outcomes are available, people shift their cue use from processing fluency to retrieval outcomes, which is a more diagnostic cue. Where before fluency was the prepotent cue, the outcome of test performance becomes more salient.

Corresponding research on developing more accurate professional metaknowledge has shown that professionals that get systematic feedback develop more accurate metacognitive evaluations of what they do and do not know (Russo and Schoemaker 1992). An analysis by Russo and Shoemaker found that weather forecasters tend to make well-calibrated judgments about the likelihood of weather events. According to the researchers, the reason weather forecasters are well calibrated is because they get precise, timely feedback about the accuracy of their predictions and they get it every single time they make a prediction.

Though feedback can boost metacognitive accuracy, the benefits of feedback on calibration may primarily be in evidence when the same or very similar information is being evaluated (Hacker et al. 2000). For example, getting performance feedback in one class may not have a large impact on overconfidence about one's expected performance in another class. In addition, the utility of feedback about how one performed on a test does seem to have developmental limitations (Finn and Metcalfe 2014; Lipko et al. 2009; Shin et al. 2007) and to be better utilized by higher performing students (Hacker et al. 2000).

Altering Beliefs About Fluency Altering a student's beliefs about the significance of fluency during learning also requires engagement of more deliberative, reflective processing. But, students may not even be explicitly aware of the beliefs they hold or be aware that their beliefs may be maladaptive. Schoenfeld (1985) demonstrated that before college, most math problems are solved in less than 2 min. In college however, more advanced math classes require more complicated computations, which can take longer and feel less fluent. Students may enter college math courses unaware that they have beliefs about fluency based on their previous academic experiences and which are not a good fit with their current academic contexts—such as the belief that they should be able to solve most problems within 2 min. Nist and Holschuh (2005) argued that these mistaken beliefs might lead students to lose confidence in their abilities when the amount of effort to complete a task increases. It is likely that students enter college with fluency beliefs based on their pre-college experiences for a number of academic tasks, such as how much time it should take to read a chapter thoroughly or to write a paper. Though whether beliefs are domain specific (Palmer and Marra 2004; Schommer-Aikins et al. 2003) or domain general (Buehl et al. 2002) remains under debate. According to Nist and collaborators (Nist and Holschuh 2005; Simpson and Nist 2000), it is critical to instruct students about whether their beliefs are diagnostic of learning to facilitate incorporation of more adaptive epistemological perspectives. For instance, if students are made aware that they are giving up to soon because of a mistaken belief about fluency, they may change their approach and persist longer on the task.

Researchers have also suggested that beliefs can be influenced through the type of curriculum, assignment, and instruction that students receive (Hofer 1999; Nist and Holschuh 2005). Though the connection to beliefs about processing fluency was not explicitly made in the study, Hofer (1999) showed that students taught calculus using a constructivist curriculum, which required collaborative construction of mathematical knowledge, developed more adaptive epistemological beliefs (i.e., were less likely to hold simplistic beliefs emphasizing the importance of getting the right answer quickly) than students who were taught using a curriculum based on lecture and instructor-led demonstration of problem sets, which likely felt more fluent because it demanded less effort on the part of the student.

Another method researchers have suggested to help students become aware of their beliefs is to read scenarios that describe how another student studies and learns in the same course and then contrast it to their own approach (Nist and Holschuh 2005). Hofer (2001) suggests that belief change may occur similarly to conceptual change, which begins when students become aware that their current beliefs are unsatisfactory and continues when the student is able to make connections between the new belief and their currently held beliefs (e.g., Pintrich et al. 1993). Chinn and Brewer (1992) warn however that even if a student is able to reflect on alternative beliefs, it does not always mean that they truly understand the new belief or that it will be incorporated into their own set of epistemological views.

Altering Beliefs About Intelligence A student's beliefs about their intelligence—that intelligence is fixed or can be improved over time—have an important influence on their academic outcomes. An incremental or growth view of intelligence, as compared to a fixed view, is related to better academic outcomes, in particular for challenging tasks. Improved outcomes such as higher final grades for students who hold a growth view of intelligence have been linked to greater use of effortful learning strategies (Blackwell et al. 2007; Grant and Dweck 2003). In these groups, reductions in processing fluency that occur when effortfully engaging in a task signal that they are working hard, not floundering. Interventions designed to encourage students to hold an incremental view of intelligence, for example, by teaching them that the brain can be developed like a muscle, are related to improved test scores and increased belief that effort signals progress (Blackwell et al. 2007; Dweck 1999; Good et al. 2003). Recent evidence suggests that such mind-set interventions are beneficial across diverse student samples (Paunesku et al. 2015). In sum, encouraging to students to view reductions in processing fluency as a positive sign that they are working hard rather a sign that they are faltering should improve their metacognitive accuracy and as a result their self-regulatory learning behaviors.

Final Points

Our subjective experiences are critically important to any discussion of learning and memory processes (Brewer 1992). When students monitor the effectiveness of their learning and accuracy of their memories, they use a variety of cues to make their evaluations including experiences and beliefs about processing fluency (e.g., Koriat 1997). However, miscalibrated judgments result when people use incorrect or incomplete information or inappropriately apply beliefs or heuristics to make their judgments (e.g., Kelley and Rhodes 2002; Lichtenstein et al. 1982; Winkielman et al. 2003).

We highlighted overconfidence because it has particularly pernicious consequences in academic scenarios. For students who are required to self regulate much of their own learning however, there are clear costs to metacognitive miscalibration. This is especially true for the tens of thousands of students enrolled in massively open online courses (MOOCS) who work outside of an academic community and may have many more competing demands on their time (Breslow et al. 2013). Unfortunately, students across the educational spectrum typically are not given comprehensive training on how to mitigate metacognitive bias (Kornell and Bjork 2007; Larsen et al. 2008; Eva and Regehr 2005), which results in less than optimal outcomes. Training interventions that target the myth that confidence is always a reliable indicator of knowing will foster more adaptive achievement decisions, both large and small.

Metacognitive training should not only be given to students but to instructors as well. Teachers' beliefs and experiences influence their behavior in the classroom (e.g., Pajares 1992). For example, as teachers prepare lessons for students, they may be subject to their own experiences of processing fluency and fail to identify how difficult a problem may be for a student in the class. Teachers' beliefs about the influence of processing fluency in learning scenarios are also important in how students develop and update their own beliefs. Their beliefs about learning influence their decisions about which curriculum to adopt and what best practices to promote to students. Recently, Morehead et al. (2015) evaluated students' and instructors' beliefs about study strategies. Results indicated that instructors endorsed both optimal and non-optimal study strategies. The majority of instructors endorsed spacing and self-testing (61 and 68 %, respectively). But, over 90 % of teachers believed that students have different learning styles (i.e., one student may be a visual learner while the other may be a verbal learner), an idea that has not received empirical support (e.g., Kirschner and van Merriënboer 2013; Pashler et al. 2008). Moreover, 77 % say that they adjust their teaching to accommodate those differences.

In sum, students' metacognitive knowledge and monitoring of learning can lead to illusions of knowing such as overconfidence in their understanding of course material or overconfidence of their performance for an upcoming test. Overconfidence can be produced by experiences of fluency during learning or retrieval and by beliefs about fluency. Fortunately, there are promising methods to reduce or even eliminate fluency biases including thinking about alternatives, focusing on correct cues, reframing the task, and getting feedback. Thus, we remain optimistic about students' metacognition and hope to see more academic institutions provide them with guidance of optimal learning strategies as well as metacognitive cues.

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