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Processing Fluency in Education: How Metacognitive Feelings Shape Learning, Belief Formation, and Affect

Rolf Reber

Department of Psychology, University of Oslo

Rainer Greifeneder

Department of Psychology, University of Basel

Correspondence address: Rolf Reber, University of Oslo, Department of Psychology, Postboks 1094 Blindern, N-0317 Oslo, Norway. E-mail: rolf.reber@psykologi.uio.no

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Abstract

Processing fluency – the experienced ease with which a mental operation is performed – has attracted little attention in educational psychology, despite its relevance. The present article reviews and integrates empirical evidence on processing fluency that is relevant to school education. Fluency is important, for instance, in learning, self-assessment of knowledge, testing, grading, teacher-student communication, social interaction in the multicultural classroom, and emergence of interest. After a brief overview of basic fluency research we review effects of processing fluency in three broad areas, namely metacognition in learning, belief formation, and affect. Within each area, we provide evidence-based implications for education. Along the way, we offer fluency-based insights into phenomena that were long known but not yet sufficiently explained (e.g., the effect of handwriting on grading). Bringing fluency (back) to education may contribute to research and school practice alike.

In the last decades, school education systems in many countries have been inspired by central tenets of cognitive psychology. The symbolic mental processes examined by cognitive psychologists are often implicit to the way teaching and learning at school is conceptualized. An important branch of cognitive research deals with metacognition, that is, cognition about cognition, such as knowledge about cognitive processes, or strategies to monitor or control cognitive performance (Flavell, 1979). Metacognition further encompasses subjective experiences or feelings that arise when a mental operation is performed. Such metacognitive feelings include, for instance, feelings of knowing, feelings of familiarity, feelings of rightness, or feelings of coherence, that all depend on processing fluency (or just fluency; e.g., Alter & Oppenheimer, 2009; Greifeneder & Unkelbach, 2013; Reber, 2016). Although research on metacognitive feelings in cognitive and social psychology has accumulated a wealth of insights relevant to learning, belief formation, and affect in school contexts, this research has attracted little interest in education (for a recent exception, see Finn & Tauber, 2015). Among the few scholars within educational psychology who examined the role of feelings in metacognition have been Efklides and colleagues (e.g., Efklides, Samara, & Petropoulou, 1999; see Efklides, 2006; 2011).

This contribution aims to bring research on metacognitive feelings to the educational domain by reviewing research on processing fluency that was predominantly conducted in other fields and to discuss its implications for education. Processing fluency refers to the dimension of subjective ease or difficulty with which cognitive processes can be executed (e.g., Unkelbach & Greifeneder, 2013a). For example, when learners want to assess what they know, they may retrieve some fragments of relevant information and estimate their knowledge based on the experienced *ease* with which the information can be retrieved (see Koriat, 1993). This overview of research provides structure to the extant literature by organizing findings in various domains that are relevant for educational research and practice.

Beyond reviewing research, we identify potential educational implications from fluency theory that can inspire future applied and translational research. Knowledge about fluency and its potential implications is instrumental for at least two reasons (see Reber, 2016). First, understanding more broadly the factors that influence cognitive and affective variables might enable educators to teach more effectively. Specifically, it may be possible to use knowledge about fluency to help and facilitate the teaching process, thereby improving educational outcomes. Second, knowledge about fluency may be the *object of teaching*, and thus enrich all school subjects, including art, music, moral, and religious education. In particular, knowledge about fluency and its role in information processing empowers citizens in their daily life. For instance, it may help citizens to recognize attempts at persuasion or to decide more advantageously when selecting learning strategies. It is therefore worthwhile to think about the inclusion of teaching the effects of processing fluency in school curricula (see Noddings, 2003, for a similar view). We address both types of implications, with emphasis placed on the notion of facilitating the teaching process. We are aware of the challenge that arises from deriving general practical implications based on a research literature that often focuses on fine-grained details and was primarily conducted in the laboratory. We tackle this challenge by focusing on the big picture when suggesting implications, knowing that some studies may suggest different implications for specific situations, and that most implications still need to be validated via translational research in classroom settings.

In what follows, we first provide a brief review of basic fluency research and introduce sources and effects of fluency. We then demonstrate the diversity of fluency effects in three different areas relevant to education, namely metacognition in learning, belief formation, and affect. While the interrelation between fluency and learning has been intensively studied, the empirical evidence on belief formation and affect is less extensive. Yet, fragmentary as it is, this research points to interesting phenomena and new questions that are relevant for educational psychology.

Basic Research on Processing Fluency

Fluency refers to the dimension of ease or difficulty of cognitive processing and is thus by definition a feeling or subjective experience. Fluency researchers ask participants to provide subjective ratings of ease or difficulty with respect to the cognitive process in question. For example, in studies on retrieval fluency, participants are asked how easy or difficult it was to retrieve some specific piece of information from their memory (e.g., Schwarz et al., 1991). An alternative to this subjective assessment is to measure objective response speed, guided by the assumption that measurable response speed provides a reliable reflection of the felt ease or difficulty of actual execution. Reber, Wurtz, and Zimmermann (2004b), however, presented evidence that objective speeds at different stages of cognitive processing (e.g., detection and identification in perception) are independent from each other but jointly contribute to the global subjective experience of fluency. These authors therefore conclude that objective speed might be an invalid measure when not all stages of a cognitive process are covered, and that assessing subjective experiences of fluency is the only way to capture the global ease stemming from all processing stages.

Although fluency is a by-product of mental processing, its role is not confined to an epiphenomenon; rather, it provides valuable information that individuals are known to rely on when they, for example, learn or form beliefs. Several reasons have been mustered to explain fluency's key role: first, fluency is constantly available (e.g., Whittlesea & Leboe, 2003); second, fluency grants a window to cognitive processes that are otherwise inaccessible because – as we are going to discuss in more detail – fluency is a simple proxy for complex information, such as what a student knows, how much effort a learner expended, or whether a statement sounds familiar and true; and third, because fluency is a single piece of experiential information, it can be relied on effortlessly (e.g., Greifeneder & Bless, 2007). Fluency experiences are common and most individuals can easily report them when asked to do so.

Nevertheless, what fluency is and how it affects learning and belief formation is likely to be unknown by educational researchers and practitioners alike. This is surprising given the wealth of empirical evidence and the pertinence of this evidence for educational practice. To illustrate, we next introduce different kinds of fluency and their potential sources in educational contexts.

Different Kinds of Fluency and Their Sources

Research has identified several different kinds or qualities of fluency (for a classification, see Alter & Oppenheimer, 2009). Five of these are briefly reviewed here. First, *perceptual fluency* relates to the finding that some attributes of perceptual objects may be processed with higher speed than other attributes because the human perceptual system is built in a way that processing of certain attributes is facilitated. Examples of such attributes include high figure-ground contrast and symmetry. In educational contexts, perceptual fluency may be a function of the font-style in a textbook, the clarity of a teacher's voice, or repeated exposure to the same formula.

Second, *encoding fluency* refers to the ease with which information can be encoded in memory. Studies from Hertzog, Dunlosky, Robinson, and Kidder (2003) as well as Castel, McCabe, and Roediger (2007), for instance, suggest that encoding fluency serves as a metacognitive cue to assess how well new information has been learned. Advance organizers or chapter headings that prime or prepare a reader to receive information likely affect encoding fluency in educational contexts.

Third, fluency may result from coherence with existing conceptual knowledge, here referred to as *conceptual fluency*. For instance Topolinski and Strack (2009) have shown that participants more quickly identify word triads that are weakly associated with each other compared to word triads that lack semantic association. In educational contexts, the difficulty of a problem, the coherence of an explanation, or the match of an illustration to a text may all contribute to conceptual fluency.

Fourth, fluency may pertain to the ease or difficulty with which contents of memory can be retrieved, or *retrieval fluency* (e.g., Greifeneder, Müller, Stahlberg, Van den Bos, & Bless, 2011; Schwarz et al., 1991; for reviews, see Schwarz, 1998; Wänke, 2013). The amount of repeated practice in a topic and the level of mutual overlap between topics likely affect retrieval fluency in educational contexts. Finally, fluency may result from joint action among individuals, here referred to as *interpersonal fluency* (Ackerman & Bargh, 2010). Interpersonal fluency may arise, for instance, from the joint execution of action in sports or music classes.

Effects of Fluency

Having reviewed the sources of fluency, we turn to some of its effects. Fluency was first examined in the context of recognition memory (Jacoby & Dallas, 1981; Mandler, 1980), with recognition being a proxy for familiarity of an item in the absence of its direct recall (Whittlesea, 1993). Findings in this area of research suggest that fluency of mental processing plays a key role in recognition memory as well as in feeling of knowing (which will be discussed in the section on metacognition in learning). In addition, because fluency influences recognition, and recognition influences truth judgments (e.g., Hasher, Goldstein, & Toppino, 1977; see Dechêne, Stahl, Hansen, & Wänke, 2010), reseaerchers hypothesized and observed that fluency mediates the effect of repetition on judged truth (Begg, Anas, & Farinacci, 1992). Perceived truth increases even when fluency is manipulated by variables other than repeated exposure, such as figure-ground contrast of text to its background(Reber & Schwarz, 1999). This observation is relevant for findings reviewed in the section on belief formation.

Finally, repeated exposure does not only increase perceived truth but also positive affect (Zajonc, 1968; see Bornstein, 1989). For example, fluency manipulated by variables in single exposure paradigms, such as figure-ground contrast, influences affective judgments, with higher fluency leading to more positive judgments (Reber, Winkielman, & Schwarz, 1998;

Winkielman & Cacioppo, 2001). These observations are relevant for the topics discussed in the section on affect.

Psychological Processes Underlying Fluency Effects

The kinds of fluency reviewed above and their potential sources illustrate the strong impact of processing fluency in a multitude of realms. How can this impact be explained at the level of psychological processes? At least three possibilities deserve short mention here: First, several lines of research suggest that affective effects of processing fluency are *direct*, that is, high fluency is hedonically marked and therefore affectively inherently positive (Winkielman, Schwarz, Fazendeiro, & Reber, 2003; but see Unkelbach, 2006).

Second, individuals may draw meta-cognitive *inferences* from processing fluency, for instance, that an item processed fluently was probably encountered before (familiarity) or is likely to be true (truth judgments). In a classic study, Schwarz and colleagues (1991) asked participants to recall six or twelve instances of assertive behavior from their own life. After this autobiographical recall task, participants were asked to judge their own assertiveness. The authors found that participants judged themselves to be more assertive after having recalled six instances, which is easy, compared to twelve instances of assertive behavior, which is difficult. Findings such as these support the notion that fluency can also exert its effect indirectly, as a source of information from which to draw inferences. Further evidence for the inferential nature of fluency comes from studying misattribution of fluency, such as to a source that is irrelevant to the outcome variable being assessed in the study (for an extended discussion, see Greifeneder, Bless, & Pham, 2011). Note that an inferential explanation requires individuals to hold naïve theories about the meaning of experienced ease or difficulty (Schwarz, 2004; see Miele, Finn, & Molden, 2011; Winkielman & Schwarz, 2001, for examples; and Unkelbach & Greifeneder, 2013b, for a conceptual model).

The third possibility is based on a *functional perspective* on fluency experiences. If people can process information from the environment easily, their interaction with the

environment presumably goes smoothly. As a result, they may just proceed as they did previously or as usual, and rely on heuristic processing. Difficulty to process information, by contrast, indicates potential problems with this interaction, asking for more careful thinking and consideration. In line with this reasoning, Alter, Oppenheimer, Eyre, and Epley (2007) manipulated fluency by using more or less readable fonts. Participants were better at solving problems that elicited an intuitive but wrong answer when the font was disfluent. These particular results seem to replicate only for selected samples (Thompson et al., 2013) or not at all (see Meyer et al., 2015), but conceptual replications support the original findings (Keysar, Hayakawa, & An, 2012; Song & Schwarz, 2008a). Similar to this fluency-reasoning link, there is rich evidence that some disfluency during learning improves performance at test, as we shall discuss in more detail later.

Having introduced basic fluency research, the following three sections each review evidence for fluency effects that are relevant for education, focusing on three thriving topics in educational psychology: metacognition in learning (e.g., Efklides, 2006; 2011; Winne & Nesbit, 2010); belief formation, which is an important aspect in the emerging field of epistemic cognition (e.g., Chinn, Buckland, & Samarapungavan, 2011); and affect, which relates to research on emotions in the classroom (e.g., Meyer & Turner, 2002; Pekrun, Goetz, Titz, & Perry, 2002). Each section and subsection will include basic research on fluency and then its implications for education (see Table 1 for an overview of the phenomena we discuss).

Metacognition in Learning

The term metacognition denotes “knowledge and cognition about cognitive phenomena” (Flavell, 1979, p. 906) and includes monitoring and control of cognitive processes (Son & Schwartz, 2002). Based on theorizing by Flavell (1979) and Brown (1978), Efklides (2006) distinguished three facets of metacognition: first, *metacognitive knowledge* about oneself, tasks, and strategies; second, *metacognitive experiences* which include feelings

of familiarity, difficulty, knowledge, confidence, and satisfaction, but also judgements of learning or feeling of knowing; third and finally, *metacognitive skills*, such as time allocation and planning. We focus here on the second category, metacognitive experiences, to the extent that they are related to fluency. However, as explained later, judgments based on metacognitive knowledge and experience may influence metacognitive skills, which contribute to the control of learning.

To illustrate the many realms in which fluency plays a role in metacognitive experiences, let us assume that a high school student named Katy prepares for a history exam. Katy first assesses what she already knows, thereby experiencing *feelings of knowing*. Subsequently, Katy estimates how much work she has to invest to muster the remaining content, which causes fluency-based *judgments of effort*. While learning, Katy wants to predict her learning outcomes, resulting in *judgments of learning*. In some cases, Katy may encounter obstacles that improve learning but decrease judgments of learning, a phenomenon we discuss in the section on desirable difficulties. After the exam, Katy appraises her *performance*, and this appraisal may at least partly depend on fluency.

The sequence of these fluency-based feelings and judgments maps onto Efklides' (2011) "metacognitive and affective model of self-regulated learning" (MASRL). This model distinguishes among task-related (prospective), activity-related (present), and outcome-related (retrospective) metacognitive experiences. In the following sections we describe the role of fluency in feelings of knowing (FOK), judged effort, judgments of learning (JOL), desirable difficulties, and performance appraisals, highlighting the implications for education for each aspect of fluency-based experience.

Feeling of Knowing (FOK)

Katy wants to excel in the history exam. She faces the question how she can be reasonably confident in mastering the subject matter. One way is to try to recall relevant information and check whether she can retrieve all she needs to know; while commendable

because retrieval itself enhances learning (Roediger & Karpicke, 2006), this strategy is not always feasible because it is time-consuming. An alternative strategy is to rely on a metacognitive experience called the *feeling of knowing* (FOK, Hart 1965; Koriat, 1993), which depends on the fluency with which pieces of knowledge can be retrieved from memory. Even if the recalled knowledge is fragmentary, individuals can rely on how this recall felt, when drawing inferences about the extent of their knowledge. For instance, if Katy is able to come up with some relevant knowledge, but this retrieval process felt difficult, she may infer that her knowledge is scarce. Conversely, if recall is easy or fluent, she may conclude that the state of her knowledge is substantial. Interestingly, even if no knowledge is retrieved at all, FOKs may arise (e.g., Hart, 1965).

Research suggests that the FOK is rather accurate when individuals have to predict which of the items they previously failed to recall will nevertheless be correctly recognized (Hart 1965) or recalled (Hart 1967) in a later test. At the same time, several research findings question whether FOKs allow for valid predictions (see Finn & Tauber, 2015). For instance, the recall of both correct and incorrect fragments of knowledge increases the feeling that one knows the materials (Koriat, 1995), especially when the question is familiar (Koriat & Levy-Sadot, 2001). Relatedly, the predictive value of FOKs may vary with time after learning, with correlations between judgments of knowing and subsequent recognition being higher for shorter delays (Shimamura & Squire, 1986). Hence, for long delays between FOK and retrieval, the FOK may not constitute a valuable source for learners. From findings such as these, Finn and Tauber (2015) conclude that FOKs are better not relied on by students. In their review, Finn and Tauber focus on processes of attribution and interpretation in the inferential process and highlight what can go wrong.

Given the many findings that document a positive correlation between FOKs and subsequent retrieval (see Koriat, 1993, for a review and discussion), we take a more optimistic perspective and argue that FOKs constitute a helpful source of information about

knowledge more often than not. This perspective does not ignore the evidence reviewed by Finn and Tauber (2015), but questions whether it is *representative* for all the possible situations in which students may use FOKs. Arguably, the evidence reported in the literature reflects a sample of laboratory situations that are finely tuned to elicit the respective mistakes in attribution and interpretation. This fine-tuning is desirable from a theoretical perspective, because researchers often learn about underlying processes by focusing on mistakes in cognitive processing. But when gauging general validity, the selectiveness of this sample needs to be taken account, and likely affords a more optimistic perspective; in Koriat's (1993, p. 630) words, the FOK is "generally predictive of subsequent memory performance." Obviously, to allow for a representative perspective as suggested here, further empirical support is needed.

Implications for education and educational research. Feelings of knowing depend on the fluency with which pieces of information can be recalled from memory. With some notable exceptions, FOKs are quite accurate predictors of memory performance. These findings have important implications for students who are rarely taught how to assess their knowledge in order to optimize their workload. Telling students that the FOK predicts their knowledge with above chance accuracy may therefore prove beneficial. Using this feeling may be helpful, for instance, in multiple-choice tests where students have to select the right answer. At the same time, learners have to be warned of pitfalls. Despite its use for an efficient assessment of one's own knowledge about a subject, FOKs might deceive the learner if their source does not come from genuine knowing. To illustrate, imagine that Katy learns foreign language vocabulary with flash cards. Fluency theory predicts that if Katy peeked at the other side of the card, knowledge retrieval would become unduly fluent and therefore FOKs over-optimistic. The same applies if the FOK arises from the retrieval of false information. Finally, Rozenblit and Keil (2002) showed that individuals overestimate the extent and depth of their knowledge about the functioning of equipment in their everyday life,

such as how a television produces pictures or how a cylinder lock opens with a key. Presumably, the fluency with which people can imagine *what* a device does leads them to think that they also know *how* the device does it.

Fluency and Judged Effort

After Katy has gauged how much she already knows, she may want to predict how much effort she has to invest to learn the remaining content. One source of information that feeds into her estimates of effort may come from knowledge about the task, either from hearsay or from own prior experience.

In addition to, or alternatively, Katy may rely on the subjective experience that accompanies the preparation or the solution of a task (see Efklides et al., 1999). In particular, Katy may judge effort and allocate learning time based on how fluent a specific task feels. Supporting this argument, Nelson and Leonesio (1988) showed that the allocation of self-paced study time is related to encoding fluency during learning. Specifically, participants allocated more effort to difficult items, possibly because they relied on processing fluency when judging effort (see also Dreisbach & Fischer, 2011). In conceptually related research, Song and Schwarz (2008b) directly addressed the processing fluency account. They presented their participants with a recipe for cooking a meal. This recipe was written either in a well-readable font (fluent condition) or in a less readable font (disfluent condition). Participants estimated that it would take longer to cook the meal and that they had to invest more effort when they read the recipe in a disfluent font. This study supports the notion that when people plan an activity based on a presentation or description, they assess how easy a task feels in order to estimate the effort they have to exert.

Not only students anticipate the effort necessary to learn a topic. Teachers, too, estimate the effort that their students have to invest, for instance, in order to adjust the difficulty and amount of homework. Suggestive evidence comes from a study in which participants solved an anagram task and then estimated how difficult it would be for *other* students to solve the

same task (Kelley & Jacoby, 1996). Importantly, the authors manipulated the ease with which anagrams could be solved by showing or not showing the solutions in an earlier trial. Participants estimated the tasks to be less difficult for others when they themselves could solve the anagrams more easily because they had seen the solution before.

Implications for education and educational research. For materials that can be processed fluently, learners estimate that they need to expend less effort to achieve mastery. At least three important implications for educational practice may be derived from this evidence. First, one's own judgments of ease or difficulty of the task are likely to influence the resources invested in the learning process. Findings suggest that students will initially invest less time when (1) the task looks easy and/or (2) the task can be processed with ease because it was encountered earlier.

Second, one consequence of low fluency is that individuals invest effort. However, if this investment appears too big, it is also conceivable that the link from low fluency to high anticipated effort results in task disengagement (for a similar prediction, see Metcalfe and Kornell's, 2005, Region of Proximal Learning model). At the descriptive level, such disengagement fits research suggesting that students evade science (Johnstone, 1991) because it is perceived as a difficult subject, where high effort is needed to achieve an acceptable learning outcome. Over time, this may result in a vicious circle, where students avoid difficult topics that in turn get more and more difficult because of the ensuing lack of practice. For later career choices, this vicious cycle may have created a situation that is difficult to overcome. Although career choices are based on other factors as well (see Henriksen, Dillon, & Ryder, 2015), the link of fluency to anticipated effort may constitute a contributing factor that is not to be underestimated. Given the implications at the individual and societal level, educating teachers and students about this link appears vital.

Finally, fluency-based judgments of effort may influence how teachers prepare their materials and perceive the learners (see also Finn & Tauber, 2015). Findings suggest that

communicators overestimate the ease with which others understand their utterances (see Keysar & Barr, 2002). As teachers easily understand what they are conveying, they might underestimate the effort their pupils have to exert, in line with the study by Kelley and Jacoby (1996) discussed above. Such erroneous evaluations might be prevented by conveying knowledge about fluency effects on judgments of effort in teacher education.

Judgments of Learning (JOLs)

After having made judgments of effort, Katy embarks on learning. One question she may ask herself for every piece of new information is how likely she is to recall the material later, generally referred to as judgments of learning (*JOLs*; Nelson & Dunlosky, 1991). In particular, Katy may ask herself: What are the chances that I will recall this item later? (assessed, e.g., on a scale from 0 to 100%; Koriat & Ma'ayan, 2005). According to a fluency account, Katy will predict better learning when processing feels fluent.

Understanding JOLs, and the processes underlying their occurrence, is important because JOLs causally affect subsequent choice of study materials (Metcalfe & Finn, 2008; see also Metcalfe, 2009). Importantly, JOLs strongly depend on metacognitive experiences of ease or difficulty that engender from encoding (particularly when JOLs are assessed directly after knowledge acquisition) and recall (particularly when JOLs are assessed some time after acquisition). In support of fluency's critical role, Rhodes and Castel (2008) have shown that manipulating fluency extraneous to the learning material, namely by using small or large font sizes, strongly affects JOLs (but see Mueller, Dunlosky, Tauber, & Rhodes, 2014). Note that we selectively review the wealth of pertinent evidence, and that we place emphasis on retrieval predictions, despite the fact that JOLs may also pertain, for instance, to judgments of comprehension (e.g., Rawson & Dunlosky, 2002).

Study time and JOLs. Ample research suggests that, under certain conditions, learners allocate more study time to items that are judged difficult than to items that are judged easy (for a review, see Son & Metcalfe, 2000). Presumably, individuals monitor the extent of their

learning and rely on this monitoring to regulate study time (e.g., Nelson & Leonesio, 1988). Study time here is allocated based on how much effort an item "calls for" (Koriat, Ma'ayan, & Nussinson, 2006, p. 41), and self-regulation is *data-driven*. In such data-driven self-regulation, the relationship between study time and JOLs is *negative*: JOLs decrease with study time because invested effort is taken to be an indicator that the item is difficult to recall (see Koriat et al., 2006; Koriat & Nussinson, 2009). Moreover, in data-driven self-regulation, study time is negatively related to fluency and can thus be used to measure fluency, with shorter study time indicating higher fluency (see Koriat & Ma'ayan, 2005).

However, study time is not only influenced by how much an item calls for. For instance, research has shown that under severe time pressure, individuals tend to prioritize items judged as being easy (Son & Metcalfe, 2000). Moreover, bonuses awarded to the recall of some items over other items strongly impacts study time (e.g., Koriat et al., 2006). Together these findings demonstrate that individuals allocate study time strategically, for instance, based on the relative importance of the study material. In this case, self-regulation is *goal-driven*. Interestingly, in such goal-driven self-regulation, the relationship between study time and JOLs is *positive*: the more effort Katy devoted to study a specific item, the higher the predicted likelihood of recalling this item later. In contrast to data-driven self-regulation, study time in goal-driven self-regulation depends on strategic considerations and is therefore likely not a reliable, or even misleading, indicator of fluency.

Koriat and colleagues (2006) have demonstrated that goal-driven and data-driven self-regulation may occur within the same situation, suggesting that individuals draw quite flexibly on study time as a source of information when forming JOLs. This flexibility is not innate but appears to be subject to learning, as fifth/sixth graders were sensitive to both data-driven and goal-driven self-regulation, but not at the same time (Koriat, Ackerman, Adiv, Lockl, & Schneider, 2014). Moreover, Koriat, Ackerman, Lockl, and Schneider (2009)

observed that the relationship between study time and JOLs becomes stronger from first to sixth grade, suggesting that individuals need to develop adequate naïve theories.

The flexibility in the relationship between study time and JOLs can be accounted for by assuming that processes of attribution and interpretation regulate the inferences drawn based on study time (for direct evidence about attribution, see Koriat & Nussinson, 2009; Koriat, Nussinson, & Ackerman, 2014). This conclusion receives further support from studies on naïve beliefs about intelligence, which suggest that individuals differ in whether they see intelligence as a fixed entity or something that develops incrementally (e.g., Miele et al., 2011). For entity theorists, the relationship between study time and JOLs should be *negative:* the more effort Katy invested, the more she concludes that she reached the limits of her capacity, and hence the lower the perceived likelihood to recall the material later. For incremental theorists, in contrast, there may be a weak or perhaps even positive relationship between study time and JOLs when controlling for perceived item difficulty: the more effort Katy invested, and the more she thinks that effortful encoding leads to greater mastery, the higher she may perceive the chances to later recall the material (see also Miele & Molden, 2010; Miele, Son, & Metcalfe, 2013, for a developmental perspective).

Summing up, the relationship between study time and JOLs is not uniform but highly flexible, and so is the relationship between study time and fluency. This flexibility need not only reflect bias but also the flexibility that is inherent to the relationship between study time and future recall. While fluency usually is positively related to JOLs its relationship to study time is flexible, depending on the study situation.

JOLs and future recall. Fluency is important for understanding relations between JOLs and future recall. To illustrate, JOLs assessed directly after acquisition predict future recall relatively well (e.g., with correlations of .50 in Koriat et al., 2006, Experiment 1; see also Dunlosky & Nelson, 1994; Koriat, 2008). Interestingly, correlations are higher when the assessment of JOLs is delayed (e.g., with correlations of .90 in Nelson & Dunlosky, 1991).

According to one explanation, experienced fluency is a function of both study time and short term memory processes for immediate JOLs. For delayed JOLs, in contrast, experienced fluency is primarily a function of long term memory processes and reflects the ease or difficulty of recalling an item (see also Kelemen & Weaver, 1997). To the extent that future recall is also a function of long term memory, it is not surprising that delayed JOLs are better predictors of retrieval. From this evidence, a more general conclusion can be drawn: JOLs should be the more accurate predictors of future recall the more fluency (as the experiential basis for JOLs) is based on the processes relevant for retrieval. In contrast, JOLs are poor predictors when fluency is at odds with the probability of recall (for supporting evidence, e.g., Besken, 2016; Besken & Mulligan, 2013).

Consistent with this general conclusion, further research has shown that the accuracy of JOLs as predictors for future recall depends on the material and processes they are based on. Assume that Katy wants to learn pairs of English (e.g., table) and Spanish words (e.g., mesa). The English words here represent learning cues, and the Spanish words targets. JOLs based on the learning cue alone, compared to JOLs based on the simultaneous presence of cue plus target, yield more accurate predictions of future recall (Dunlosky & Nelson, 1992). Presumably this is because JOLs based on cue plus target reflect less well the processes that are present at test, that is, when only the cue is provided. Based on findings such as these, Metcalfe (2009) suggests that the combination of cue-only presentation and delay produces JOLs of extremely high accuracy.

A similar explanation may be advanced for a study by Benjamin, Bjork, & Schwartz (1998) in which participants answered general knowledge questions and provided JOLs. The authors measured the time it took participants to find an answer and observed that JOLs correlated negatively with the answer retrieval latencies: the faster the initial retrieval, the higher the JOL. On the next day, participants were asked to recall the answers they had given previously. Importantly, participants recalled those answers best on day 2 that got the worst

JOLs on day 1, reflecting a negative correlation of JOL and recall. The authors reasoned that JOLs formed on the first day were poor predictors of future recall because they reflect conceptual fluency associated with answering the general knowledge questions, but not processes associated with fluency related to retrieving information.

Finally, findings by Simon and Bjork (2001) suggest that JOL accuracy depends on the nature of learning. In their studies, students had to learn a perceptual skill. Learning feels easier if the schedule is blocked rather than random, that is, if participants have to learn the same stimuli in a row rather than interleaved among other stimuli. Reflecting this fluency, JOLs in the blocked condition are higher than in the random condition. However, because learning is superior in the random schedule, the JOLs were *negatively* related to actual skill acquisition. Again, JOLs did not accurately predict future recall because they were based on the fluency of processes other than those present at retrieval. Interestingly, it is likely for this reason that delaying JOLs helps to increase predictive accuracy (Dunlosky & Nelson, 1994).

Implications for education and educational research. As fluency informs JOLs, the source of fluency experiences has important bearings on JOL accuracy. In some situations, JOLs are quite accurate predictors of future recall and may serve well for test preparation. Accuracy may be enhanced if the experiences of fluency on which JOLs are based reflect the processes at information retrieval, and accuracy is hampered if JOLs reflect processes that are irrelevant for (Rhodes & Castel, 2008) or at odds with retrieval (e.g., Besken, 2016; Besken & Mulligan, 2013). In a nutshell, JOLs are most accurate when the task which is eliciting JOLs is similar to the processes at test. What are the implications for Katy learning vocabulary? If Katy knows that target words in the Spanish exam will be assessed by presenting cues (e.g., “table”), JOLs are likely assessed best some time after learning by presenting the cues only (“How likely is it that you will know the Spanish word for table?”).

Desirable Difficulties

JOLs have important bearing on so-called desirable difficulties. Ample evidence suggests that some difficulties during encoding increase later recall. For instance, McNamara, Kintsch, Songer, and Kintsch (1996) observed that memory of high-knowledge readers benefitted from a minimally coherent text. Diemand-Yauman, Oppenheimer, and Vaughan (2011) made learning materials difficult to process by means of a font manipulation. These authors found that text in a less readable font resulted in better learning than text written in a well readable font (see Weltman & Eakin, 2014, for a successful replication; c.f. Rummer, Schweppe, & Schwede, 2016). Finally, D'Mello, Lehman, Pekrun, and Graesser (2014) observed that confusion created by contradictory statements may enhance learning.

From findings such as these, and from the research reported at the end of the last section, Bjork and Bjork (2011) concluded that some difficulties in learning are desirable. These findings fit well with a fluency perspective on learning, as becomes evident when considering why low fluency may be related to better learning. At least two processes need to be mentioned here. First, the very mechanisms that decrease fluency may improve retrieval from memory. This is likely to be the case in distributed or interleaved practice (Simon & Bjork, 2001) where encoding feels more difficult but learning is more efficient than with a blocked schedule. Second, irrespective of its source (e.g., coherence of a text; font of moderate readability), low fluency may be interpreted as a signal that the learner needs to invest effort (see data-driven self-regulation above). Here, low fluency and improved memory are linked only by fluency's signaling function that motivates investment of effort.

Bjork and Bjork's (2011) conclusion about desirable difficulties and the supporting evidence may come as a surprise, because increasing the level of difficulty increases cognitive load and may therefore be perceived as detrimental to the actual learning task, as argued by cognitive load theory (e.g., Sweller & Chandler 1994). How can the two perspectives be reconciled? The contradiction between cognitive load theory and the desirable difficulty account is more apparent than real and can be resolved by invoking the distinction between

extraneous cognitive load and germane cognitive load (Sweller, Van Merriënboer, & Paas, 1998). While extraneous cognitive load produces additional cognitive load and inhibits learning, germane cognitive load is intrinsic to the task and improves learning. If we translate this distinction into the fluency terminology, disfluency hampers learning when it comes from extraneous sources that distract learners from encoding and integrating information. These are undesirable difficulties. Germane cognitive load, on the other hand, produces disfluency that stems from a need to process information more deeply, as it is the case with distributed practice. These are desirable difficulties.

Despite problems of empirically distinguishing extraneous from germane cognitive load (see De Jong, 2010), future research might examine the connection between cognitive load theory and fluency accounts. This connection may be facilitated by convergence in measurements: While cognitive load researchers often ask about how much effort it took to execute a specific mental process (e.g., see Paas, 1992; Paas & Van Merriënboer, 1994; for reviews, see Brünken, Seufert, & Paas, 2010; Schnotz & Kürschner, 2007), fluency researchers focus on how learners experience the execution of the process (e.g., Greifeneder, Bless, & Pham, 2011). Because effort feeds into fluency, both measures are probably related, but need not be the same.

The reviewed evidence suggests that some level of difficulty may be desirable from a learning perspective as long as cognitive load is germane, even though students may perceive the learning process as disfluent and unpleasant. In an early study, Baddeley and Longman (1978) found that postal workers needed less training hours to acquire a typewriting skill when they trained with a distributed schedule (1 hour per day) rather than a blocked schedule (4 hours a day).The authors observed that workers in the distributed schedule learned best but liked the training least while workers in the blocked schedule learned worst but liked the experience best. Presumably, a distributed schedule results in more learning difficulties than a

blocked schedule (see Simon & Bjork, 2001), leading to better learning outcomes but less liking.

Implications for education and educational research. Given that some difficulties and therefore lack of fluency in learning appear desirable, one may ask whether there are means to encourage people to persist longer in the face of obstacles and difficulties.

Two potential interventions are genuinely related to subjective experiences of ease and difficulty and can therefore be derived from fluency research. First, a teacher may instruct students about desirable difficulties in order to highlight benefits associated with learning difficulties. In particular, difficulties and therefore disfluent processing usually are signals to stop an activity. Yet students may be taught to reinterpret disfluency as a signal to persist. Whether providing such knowledge proves successful has yet to be determined, because evidence about the usefulness of changing fluency-based judgments is mixed (see Kelley & Rhodes, 2002). On the one hand, there are examples of lack of correction even if people are made aware of potential bias (e.g., Lindsay & Kelley, 1996; Rhodes & Castel, 2008), and instructing people about desirable difficulties did not change JOLs (Yan, Bjork, & Bjork, 2016). On the other hand, listeners correct their biases concerning the credibility of speakers with a foreign accent when made attentive to the difficulty to understand accents (Lev-Ari & Keysar, 2010), and grading becomes less biased when it becomes obvious that fluency might influence the judged quality of essays (Greifeneder et al., 2010). These two strands of literature may be reconciled in various ways. For instance, the success of correction may depend on whether individuals are merely asked to ignore some specific feature (e.g., font size, in Rhodes & Castel, 2008), or whether they are told that this feature or resulting fluency may bias judgment (e.g., Greifeneder et al., 2010). Moreover, the observation that instructing people about desirable difficulties after learning did not affect JOLs does not mean that similar instruction before learning would not change persistence. Finally, it is notoriously

difficult to know the right amount of correction, which leads to over- or undercorrection of biases (Schwarz, Sanna, Skurnik, & Yoon, 2007).

Second, based on principles of operant conditioning, (e.g., Skinner, 1938), an association could be established between lack of fluency and persistence, and in turn between persistence and subsequent success. Success in itself may be seen as a reward for persistence. This operant conditioning procedure may supplement existing knowledge about the association between persistence and success (see Nicholls, 1975). Refined knowledge about the relation between persistence and success, in turn, may increase performance expectations, and ultimately task persistence (Battle, 1965). Research suggests that effects on persistence are particularly pronounced if students attribute success to effort (Mueller & Dweck, 1998). Specifically, students develop the insight that lack of fluency may be a good sign, and therefore persist longer instead of giving up early. Finally, success after persistence yields positive affect, again especially when attributed to effort (see Weiner, 1986). Mastery by itself may subsequently facilitate processing and therefore increase fluency, which may independently increase positive affect.

Together these two fluency-based interventions – instruction about desirable difficulties and associating disfluency to persistence and success – may help to overcome the perhaps strongest "enemy" of desirable difficulties: that students do not recognize the benefits associated with desirable difficulties and therefore fail to appreciate the promise of learning strategies such as spacing (e.g., Kornell & Bjork, 2008; for a differentiation between learning strategies, see Kornell, Castel, Eich, & Bjork, 2010).

Implications for increasing persistence can be further derived from research outside the realm of fluency. A study by Coughlan, Williams, McRobert and Ford (2014) has shown that experts are more likely to persist in the face of difficulties than novices. How could interventions make novices behave like experts when it comes to persistence? One possibility was suggested by Oyserman, Bybee, and Terry (2006; Oyserman, 2015), who developed an

evidence-based intervention tested in educational contexts in which students attribute difficulties not to their incompetence (“not for me”), but to the importance of the materials. Other ways to increase persistence include (a) praise for effort instead of praise for ability (Mueller & Dweck, 1998), (b) double goal framing (intrinsic and extrinsic) instead of purely extrinsic goal contents (Vansteenkiste, Simons, Lens, Soenens, Matos, & Lacante, 2004b) or intrinsic instead of extrinsic goal setting (Vansteenkiste, Simons, Lens, Sheldon, & Deci, 2004a), and (c) autonomy support (Vansteenkiste et al., 2004a).

Of course, it is not always beneficial to increase mere persistence. For example, Nelson and Leonesio (1988) have shown that an increase in learning time for an item does not always translate into concomitant increases in learning outcomes, presumably because an increase in time is not sufficient – the time needs to be invested in learning with efficient strategies. The bottom-line is that teachers may want to increase persistence because it helps to harvest the benefits of difficulties in learning. To be successful, however, mere persistence is not enough: it needs to be invested in learning with efficient strategies. In terms of a fluency account, effective persistence means that disfluent processing can be taken as a useful sign that difficulties have to be overcome by the use of efficient strategies.

Beyond persistence, the research discussed in this section has implications for student evaluations of teaching that seem to be uncorrelated with student learning (Uttl, Carmela, & Gonzalez, 2016). A teaching context in which learning is facilitated and hence yields highly fluent processing experiences is likely to produce more positive student evaluations, but may hamper learning. Conversely, a teaching context that builds on desirable difficulties will likely increase learning, but may be evaluated more negatively. In the long term, when the information learned with difficulty can be retrieved with greater ease, evaluations might become more positively for teaching that included difficulties during learning. Although fluency is not the only source that contributes to such biases in evaluations, fluency

mechanisms might explain why subjective teaching evaluations need not reflect learning success (see also Carpenter, Mickes, Rahman, & Fernandez, 2016).

Performance Judgments

After having taken the history exam, Katy may ask herself how she has performed. In formal domains, like mathematics, or in exams asking for pieces of knowledge, like events in history, good students may know that they gave the correct answers. Other students, however, may not be sure about the correctness of their answers and have to rely on other sources of information in order to assess their performance. One such source is retrieval fluency. Students may ask themselves how easily they could retrieve the answer. If answers to the exam questions were easy to retrieve, students are likely to infer that they did quite well; if students had a hard time retrieving their answers, they may infer that they did not so well.

The most direct evidence for retrospective judgments of performance comes from a study by Reber, Meier, Ruch-Monachon, and Tiberini (2006). In one experiment, participants were pre-selected in accordance to whether they regularly exercised or not. They were individually tested and had to run in place; one group was stopped after 15 seconds and the other group after two minutes. Then, participants were asked to judge on a rating scale how well they performed in the running task, compared to the average student. Participants who regularly exercised did not show a significant difference between running 15 seconds and running two minutes. The group of students who did not regularly exercise, however, judged themselves to have performed better when they had to run 15 seconds than when they had to run two minutes. Presumably, these participants were not able to assess their performance analytically and had to rely on fluency as a heuristic cue. Further experiments in the same study excluded alternative cues, such as fatigue, and bolstered the notion that people base their performance judgments on the experienced ease of action execution (here running). Admittedly, it remains to be tested whether direct judgments of one's own performance which do not include comparisons to the average student reveal the same findings. However, given

that participants apparently do not take others' performance into account when making comparative judgments, as observed by Kruger (1999), we have strong reasons to predict that direct performance judgments are also informed by fluency.

Those who evaluate others also need to assess performance, and may similarly rely on fluency when doing so. However, fluency is now experienced by the evaluator instead of the learner, and thus emerges against the evaluator's processing background. One source of fluency in an educational context is the ease or difficulty with which handwritten material can be processed by the reader. For example, James (1929) reported that essays in legible versus harder to read (but still legible) handwriting were evaluated more positively (see also Briggs, 1970; Hughes, Keeling, & Tuck, 1983; Markham, 1976). Different mechanisms might contribute to the effect; perhaps the most important source, however, is fluency (Greifeneder et al., 2010; Greifeneder, Zelt, Seele, Bottenberg, & Alt, 2012). The logic is as follows: legible compared to less legible handwriting can be read with greater ease. As ease often signals a positive state of affairs (e.g., Unkelbach, 2006), or is even directly associated with positive affect (e.g., Winkielman et al., 2003), high fluency from legibility signals positivity. As this positivity signal emerges while the essay is evaluated, it is misattributed to the quality of the essay or the ability of its author.

In the legibility bias, fluency is perceptual in nature, in that it results from more or less legible handwriting. Another source of fluency is the ease or difficulty of understanding, denoted as conceptual fluency. To the extent that the main psychological ingredient to the legibility bias is fluency and not legibility per se, effects parallel to those reviewed above should be obtained when conceptual understanding is either easy or difficult. In support of this prediction, it has been observed that a higher level of complexity in essay writing style is associated with a lower intelligence attributed to the essay's author (Oppenheimer, 2006).

Implications for education and educational research. The evidence reviewed above strongly suggests that performance assessments are influenced by fluency. Notably, this holds

true for those who perform, as well as those who assess performance of others. For both groups, the validity of the judgment depends on the relationship between fluency and the outcome variable. If there is a substantive relationship, fluency likely constitutes a helpful source of information. If there is no substantive relationship, however, as is the case, for instance, when fluent processing emanating from the legibility of handwriting does not indicate content quality, relying on fluency may produce biased judgments. Notably, as research has demonstrated, being biased by undue influences of fluency is not destiny: individuals can discount fluency either spontaneously (as is presumably the case, for instance, for the trained athletes in Reber et al., 2006) or after being given a warning of its undue influence (e.g., Greifeneder et al., 2010). It may therefore prove helpful to educate students and teachers about the relationship between fluency and various outcome variables to enable them to develop an accomplished use of fluency experiences.

Belief Formation

We now turn to fluency's role in belief formation and begin with two independent sets of evidence. First, a strong body of research shows that fluency informs judgments of truth (for an overview, see Reber & Unkelbach, 2010). Second, evidence suggests that learners do not separate the processes of understanding a statement and endorsing its truth. They endorse the truth of a statement at the same time they understand a statement, that is, understanding means truth. To reject a statement that they have understood, individuals need to invest extra cognitive effort (Gilbert, Krull, & Malone, 1990). In conjunction, these sets of findings have important implications for education. Here we discuss learning wrong facts from lures in multiple choice exams, the detrimental effect of pictures on critical thinking, and the effect of accent on credibility.

Endorsing Wrong Answers in Multiple Choice Testing

Multiple choice testing is a common testing method in undergraduate education. It is considered an efficient and just method of testing, but there is a problem inherent to the nature of multiple choice testing: Test items consist of a question and several response options, often four or five. Of these response options, at least one is correct; some test formats allow only one correct answer, whereas others allow more than one. Importantly, several response options – most often the majority – are incorrect.

If multiple choice testing were only an assessment method, everything would be fine. However, students do not only retrieve information during a multiple choice test but they also learn new information, as the so-called testing effect demonstrates (see Karpicke & Roediger, 2008; McDaniel, Roediger, & McDermott, 2007; Roediger & Karpicke, 2006). The testing effect holds that testing after reading benefits student learning more than reading the materials once again. Roediger and colleagues therefore recommend frequent testing in order to improve student learning. In answering multiple choice items, students are exposed to new and wrong statements, which both become more fluent. As fluent processing signals truth, having seen the lure in a former test may increase the probability that the lure is recognized as true in the second test, because the prior presentation increases fluency (Roediger & Marsh, 2005). The fact that lures in test items are more likely to be endorsed as correct than new items that never have been seen before has been called the negative suggestion effect and has been observed in multiple choice testing (see also Brown, Schilling, & Hockensmith, 1999; Remmers & Remmers, 1926), for trivia statements (Brown & Nix, 1996), and for statements about medical facts (Skurnik, Yoon, Park, & Schwarz, 2005).

An ethical problem arises from these findings: If a teacher provides incorrect response options and a student learns wrong facts from them, incorrect knowledge has been acquired through the teacher's action. Although conveying incorrect facts has never been in the teacher's intention, the problem is inherent to the format of multiple choice testing. However, the problem is alleviated by three observations: First, the positive effect of testing on learning

is greater than the negative effect of endorsing incorrect response options, as shown by Roediger and Marsh (2005). Second, Garcia-Marques, Silva, Reber, & Unkelbach (2015) reported that after a delay of one week (and presumably more), learners are more likely to believe the opposite of what they have heard or read before than statements they have never encountered. Their observations allow for the intriguing speculation that if learners later hear a statement that corresponds to the correct alternative of a multiple choice question, they may believe it even more after having read the lures. This conjecture awaits further research. Third, students produce wrong statements in exams with open-format responses, too. The well-known generation effect (Slamecka & Graf, 1978) predicts that wrong statements may be even more harmful when they are actively generated than when they are passively received, as it is the case in a multiple choice exam. Indirect evidence for this claim stems from research that showed that students endorse a solution as correct if it comes to mind easily (Ackerman & Zalmanov, 2012; Thompson, Prowse Turner, & Pennycook, 2011; Topolinski & Reber, 2010). At later retrieval, an initially self-generated solution presumably comes easily to mind and might therefore be erroneously endorsed.

Implications for education and educational research. Fluency increases the perceived truth of a statement. A first implication of this observation pertains to teaching *about* fluency: Informing teachers about specific findings such as the negative suggestion effect is likely to be helpful; perhaps even more promising, however, is to instruct teachers about the underlying process – fluency – so that they can flexibly apply this knowledge across situations.

A second implication from this line of research is that teachers should – as a general rule – convey only true statements and avoid highlighting a fact or a rule by telling what is wrong. In a similar vein, educators should avoid warnings by telling what is wrong to do (see Skurnik et al., 2005). In the light of the results on the link between fluency and perceived truth reviewed above, affirmative messages about what is right to do seem to be more

appropriate. However, these are recommendations derived from basic laboratory research. Although laboratory research usually fits well with observations from field research where both kinds of studies exist (Anderson, Lindsay, & Bushman, 1999), research in school settings should further examine the claim that telling students what is false could lead to undesired outcomes in that students believe the wrong statements.

Non-Probative Illustrations

Illustrations such as pictures may constitute learning content by themselves or complement other learning material. But illustrations may also undermine critical thinking, that is, the "correct assessing of statements" (Ennis 1962, p. 83). The reason is that illustrations may increase fluency, and fluency in turn may result in less analytical processing. For instance, Hamill, Wilson, and Nisbett (1980) presented one group of participants a vivid story about a welfare recipient who was unable to escape misery. This experimental group showed a more negative attitude towards welfare recipients than a control group that did not read the vivid story. A third group read the vivid story and received statistical information revealing that the main character of the story was an atypical case because most welfare recipients do not need support for a long time. Remarkably, attitudes of this third group did not significantly differ from the experimental group, suggesting that vivid but unreliable stories and images outweigh prosaic but reliable data.

A more recent example of the seductive quality of illustrations has been observed with brain images in neuroscience publications (see Trout, 2008). While experts were able to distinguish good from poor scientific explanations regardless of whether text was accompanied by images, laypeople were not. The latter judged poor explanations accompanied by a brain image as being equivalent to good explanations (Weisberg, Keil, Goodstein, Rawson, & Gray, 2008). One reason for the allure of brain images lies in the ease with which such images can be processed (Keehner, Mayberry, & Fischer, 2011; but see

McCabe & Castel, 2008, for a different explanation). The effect of brain images on credibility has been generalized to non-probative images in general as well as to unrelated but attention-grabbing general knowledge facts (Newman, Garry, Bernstein, Kantner, & Lindsay, 2012). Findings such as these give rise to further concern because individuals' credulity may prevent them from seeking expert advice when materials can be encoded fluently (Scharrer, Bromme, Britt, & Stadtler, 2012).

Fluent processing due to illustrations or non-probative text may thus decrease the likelihood to properly think and reason. Other research complements this perspective by showing that disfluency may elicit analytical thinking styles and therefore improve critical thinking (Alter et al., 2007; Keysar et al, 2012; Song & Schwarz, 2008a). In particular, it has been shown that decreasing fluency improved syllogistic reasoning and decreased reliance on shortcuts, heuristics, or defaults (Alter et al., 2007). As these findings have not always replicated (cf. Meyer et al., 2015), future research has to establish the reliability and strength of disfluency effects on critical thinking before strong practical implications can be drawn.

Implications for education and educational research. According to proponents of critical thinking, a major fallacy is to yield to appeals to emotion (e.g., Moore & Parker, 2012). The studies reviewed in this section suggest a similar fallacy for so-called *seductive details* – glossy pictures or fascinating stories that are irrelevant for the learning content. Research in educational psychology has found that 85% of the pictures in sixth-grade mathematics textbooks were decorative rather than connected to the content of a problem (Mayer, 1993). Such seductive details are interesting but impair learning (Garner, Gillingham & White, 1989, Harp & Mayer, 1997; 1998), especially for weak students (Magner, Schwonke, Aleven, Popescu & Renkl, 2014). The deleterious effect of seductive details can stem from various sources. Part of this effect may be inherently fluency-based: students may draw erroneous conclusions from the picture-induced fluency to the mastery of the learning material because pictures can often be encoded easily, and students may misjudge the extent

of understanding, encoding, and learning (see section *Judgment of Learning*). Another part stems from directing attention away from relevant content (Sanchez & Wiley, 2006). A final part comes from lack of critical thinking because the learner does not or cannot discern that the picture is irrelevant to the text. In conclusion, both fluency-based and other mechanisms may combine to generate the harmful effects of seductive details.

These observations lead to two recommendations, one for students and one for textbook publishers. Students may benefit from learning about the harmful effects of non-probative but interesting materials on the credibility of arguments. Textbook publishers may fruitfully refrain from the use of seductive details that make instruction more interesting but impair both critical thinking and learning outcomes. Notably, we are aware that increasing interest is a valuable goal per se, as discussed later. But against the background of the theory and evidence reviewed above, it appears critical to understand that seductive details may impair learning when they do not facilitate the understanding of learning content. In contrast, the conceptual integration of pictorial and verbal material has proven advantageous (see Mayer, 2001).

Fluency in Social Interaction

A recent line of research is relevant for multicultural classrooms, because processing fluency has been shown to be involved in intergroup liking and in prejudice (e.g., Claypool, Housley, Hugenberg, Bernstein, & Mackie, 2012; Halberstadt & Winkielman 2014; Pearson, West, Dovidio, Powers, Buck, & Henning, 2008; Rubin, Paolini, & Crisp, 2010; see Lick & Johnson, 2015, for a review). This research shows that high fluency is associated with more positive social evaluations, and low fluency with more negative social evaluations. To illustrate, consider findings suggesting that a foreign accent decreases a speaker's credibility (Dragojevic & Giles, 2016; Lev-Ari & Keysar, 2010). Such a decrease of credibility has been attributed to the impact of stereotypes and prejudice (Dixon, Mahoney, & Cocks, 2002). Reminiscent to the study by Greifeneder et al. (2010) discussed earlier, Lev-Ari and Keysar (2010) disentangled the contribution of fluency from other variables that mediate the effect of

foreign accent on credibility. Participants in this study heard statements provided by the experimenter that allegedly were read by other participants (speakers) who were either native speakers, speakers with a mild accent, or speakers with a heavy accent. As the speakers just recorded statements the experimenter provided, there was no reason to doubt the credibility due to prejudice. Nevertheless, participants rated statements read by speakers with an accent as less credible than statements read by a native speaker. Presumably, accent results in lower processing fluency that in turn decreases credibility.

Recent research extended this effect to attitudes toward an instructor in an online learning environment where instructors with accented speech were judged more negatively despite the fact that learning outcomes for students did not differ between instructors with and without accent (Sanchez & Khan, 2016).

Implications for education and educational research. Research on fluency in the interpersonal realm is just at the beginning but the findings are worth noting. In school contexts, communication difficulties could influence both the evaluation of students by teachers and how much a student likes a teacher. However, further research has to examine how undue influence of fluency on evaluations of others could be minimized.

Affect

We have reviewed evidence that learners sometimes provide inaccurate predictions of their learning outcomes because they misinterpret fluent encoding as deep encoding. As high fluency yields positive affect and disfluency negative affect (e.g., Reber et al., 1998; Winkielman & Cacioppo, 2001; see Reber Schwarz, & Winkielman, 2004a, for the rich evidence on the fluency-affect link), the ease with which learners acquire knowledge not only influences their metacognitive judgments, but their liking of the learning process (see Baddeley & Longman, 1978). In this section, we discuss two effects of fluency on affective experiences that are relevant for education: Interpersonal rapport and the emergence of interest.

Interpersonal Rapport

Fluency not only influences credibility but also affect (e.g., Winkielman et al., 2003). It is therefore plausible that interpersonal fluency – the fluency of the interaction of two or more people – increases positive affect. Ackerman and Bargh (2010) summarized different examples of how interpersonal fluency might emerge. As people readily imitate others' behavior and coordinate or synchronize their actions with those of others, social interaction proceeds more smoothly and is therefore experienced more fluently. In line with these observations, Marsh and colleagues (see Marsh, Richardson, & Schmidt, 2009) examined a direct link between processing fluency and liking. Two participants were instructed to coordinate their actions – swinging a pendulum – in coordination tasks of different difficulty levels. Participants in the easy coordination task reported more liking for each other than participants in the difficult coordination task, which has been interpreted as a positive effect of fluency on affect. This finding provides an explanation for the observation that coordinating and imitating actions increases interpersonal liking (Chartrand & Bargh, 1999; Bernieri, 1988; LaFrance & Broadbent, 1976). Activities – especially in physical education – that increase coordination and synchronicity and therefore interpersonal fluency may result in an increase in trust (Wiltermuth & Heath, 2009) and interpersonal liking (Marsh et al., 2009; see also McNeill, 1995, for a historical account of social rapport by marching and dancing).

Implications for education. How could synchronous action be implemented in education? After World War II, the popularity of synchronous movement declined because the Nazis employed synchronous activity, such as marches and parades, to increase the rapport with their political movement; the same holds true for the other big totalitarian system of the 20th century, Stalinism (McNeill, 1995).

However, there may be good uses of synchronous movement. Indeed, people who want to participate in a group, for example in aerobics training, folk dance, or as cheerleaders, may seek out situations where they can move in synchrony. This activity increases interpersonal

fluency and in turn interpersonal liking (see Ackerman & Bargh, 2010). Schools may use synchrony in many ways. Moving in synchrony in physical education may give students a sense of unity and attachment. Surprisingly, research on the popularity of drill sergeants (Faris, 1976) suggests that strict teachers requiring marching in close order or other activities that result in behavioral coordination and discipline within a group may become quite popular in the long run. Obviously, interpersonal fluency comes with promises and perils; hence educating teachers about it is critical.

The emergence of interest

The positive effect of ease, or fluency, of processing on affect has implications for the interest of students in their subjects. Interest denotes long-term voluntary engagement in an activity (Dewey 1913). Schiefele (1991) distinguished between a feeling component and a value component. According to this account, being interested in a subject means voluntary long-term engagement in a topic for the sake of enjoyment and of achieving value, such as meaning or future educational success.

Reber, Hetland, Chen, Norman, & Kobbeltvedt (2009) speculated that fluency may play a crucial role in developing interest. In this regard, at least two predictions can be made from fluency research, one each for the two components of interest. First, the ease with which a learner can think about a topic and solve problems directly influences the affective component of interest. The experience of ease while pursuing an activity provides a positive feeling state. There is indeed evidence that ease of tasks results in positive affect. Finn (2010; see also Finn & Miele, 2016) examined whether the peak-end rule for hedonic evaluations (Fredrickson & Kahneman, 1993) and prospective choices (Kahneman, Fredrickson, Schreiber, & Redelmeier, 1993) applies for difficult tasks. When a set of 30 difficult tasks was extended by 10 moderately difficult tasks, participants felt less discomfort and chose to repeat the extended over the short list despite lower performance on the extended list. Hoogerheide and Paas (2012) demonstrated an analogous peak-end effect for easy lists that ended with

moderate difficulty. As maintained situational interest consists of both an affect component and a value component (Linnenbrink-Garcia et al., 2010; Schiefele, 1991), high fluency via positive affect helps maintain a positive feeling state and supports continuous engagement in an activity, at least when the activity is not boring.

Second, we have seen that people draw inferences from the ease with which they can retrieve information (Schwarz, 1998, for a review). This becomes relevant for the value component of interest when students have to ask themselves why a topic is relevant. Hulleman and Harackiewicz (2009) found that writing about why a topic is relevant increases the interest of students in a 9th grade science course who had low performance expectations. Combining the findings on the inferential effects of retrieval fluency with the research on relevance intervention, we predict that students with low performance expectations benefit from relevance interventions if they easily come up with factors that make a topic relevant. Indeed, Gaspard, Dicke, Flunger, Brisson, Häfner, Nagengast, & Trautwein (2015) found indirect evidence for this claim. They tested two relevance interventions to increase value-beliefs for mathematics, one based on reflection on statements and the other on writing an essay. The reflection-based relevance intervention showed superior motivational outcomes, presumably – as Gaspard et al. argue – because it is easier to reflect on statements than to write an essay.

Research about interventions to increase situational interest is just at the beginning. It awaits further clarification whether the ease with which the relevance of a topic could be generated influences experienced interest and behavioral engagement.

Implications for education and educational research. The findings reviewed here suggest that rendering materials easy to read and understand, that is, increasing fluency, may increase interest. Obviously, this implication is at odds with the notion of desirable difficulties discussed earlier. Perhaps the solution is not black-or-white, easy-or-difficult, but a mixture chosen with finesse. Teachers who understand the mechanisms of fluency may be able to

spark interest by making initial encounters fluent, and subsequently elicit appropriate learning regulation by making materials sufficiently difficult. Evidence on the peak-end rule suggests that an easy end of the lesson increases interest in the materials. Future research may fruitfully look at both aspects simultaneously, interest and learning regulation.

A Shortlist of Recommendations for Teaching and Research

This contribution aims to bring fluency research to the educational domain by reviewing research on processing fluency and offering implications for educational practice and translational research. We considered the role of fluency as a mechanism in three different areas relevant to education, namely metacognition in learning, belief formation, and affect. We wish to conclude this review with a selection of what could be taught on fluency in teacher education, what students may fruitfully learn about fluency in order to become mature citizens, and where future research has to address gaps. This selection is based on a weighing of both the scientific evidence and the potential leverage in educational settings; it is not meant as an exhaustive summary.

It is helpful for educators to know about the metacognitive functions of fluency and how these might influence judgments of both educators and students. Educators may benefit from such knowledge because they can instruct students about feeling of knowing or desirable difficulties; they are fluent in the topics they teach and may therefore overestimate the degree to which others understand them; their assessment of student performance might be biased because they cannot fluently understand the information the student conveys, be it because the student has a bad handwriting or a heavy foreign accent; the testing effect more than compensates for the damaging effects of the high fluency of lures in multiple choice tests; and that synchronous activity increases social rapport and trust.

Students might be informed about the possibilities to assess their knowledge, to estimate their effort, to predict future learning outcomes, and to judge their past performance, including the mechanisms underlying such judgments and the paradoxes of desirable

difficulties. When it comes to belief formation, it might be useful to inform students about the effects of fluency, especially repeated exposure, on perceptions of truth and liking. Moreover, knowing the effects of interpersonal fluency might help prevent students from being taken in by groups they actually do not want to belong to.

This article revealed the many gaps in translational research that examines fluency with a specific focus on educational practice. The ensuing recommendations for such research are manifold. When it comes to well-developed and extensive research fields like FOK or JOL, future research might not only examine open questions in basic research but also translate the findings from laboratory studies to applications in school settings. It will be important to examine how helpful metacognitive feelings are in different learning and test contexts. For example, is the usefulness of such feelings limited to traditional classroom teaching and multiple choice tests or do they predict performance in problem-based learning and essay-based testing?

The effects of fluency on belief formation and affect are well established in the laboratory but only partly in connection to applications in education. The educational implications are straightforward when it comes to the role of fluency in endorsing false response options in multiple choice tests, the role of handwriting on perceived essay quality, and on the role of accent on credibility. Less clear are the educational implications of the role of fluency in judged credibility of materials and social interaction.

The same applies for affect. Although there is ample evidence on how fluency influences affect, its translation is not straightforward. Interpersonal rapport and the development of interest are highly relevant for education, but only the latter – where evidence for the involvement of fluency has been weakest – is currently an object of research in educational psychology. When it comes to interest or interpersonal rapport, controlled laboratory studies have to establish the role of fluency and translational research may fruitfully explore its skilled use in educational practice.

We think that two topics not covered in this review may prove particularly fruitful in future research: the transmission of cultural beliefs and the emergence of tastes. For both, there is preliminary evidence for fluency effects that may be relevant for education (see Reber, 2016, for an extended discussion). However, although schools are central for transmitting cultural beliefs (see Bourdieu & Passeron, 1990) that lead to cultural fluency (Oyserman, 2011), the topic has not yet reached mainstream educational psychology. The same applies to the emergence of tastes, which has received scant attention in educational psychology, even though schools not only transmit knowledge but modes of appreciation in reading literature or analyzing art and music (see Reber, 2016).

To conclude, processing fluency is a general mechanism that explains various phenomena across the whole field of education. Appreciating the power of fluency helps teachers to design teaching from a fresh angle, students to understand the mechanisms behind learning and belief formation, and researchers to develop new hypotheses and even to identify new fields of research in educational psychology.

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Table 1

Fluency in different domains of education.

Domain	Primary Sources of Fluency
Metacognition in Learning	
Feeling of Knowing	Retrieval
Judgments of Effort	Encoding; Retrieval
Judgments of Learning	Encoding; Retrieval
Desirable Difficulties	Encoding
Performance Judgments	Perceptual (also motor feedback); Retrieval
Belief Formation	
Multiple Choice Testing	Perceptual; Conceptual; Retrieval
Non-Probative Illustrations	Perceptual; Conceptual
Social Interaction	Perceptual
Affect	
Interpersonal Rapport	Interpersonal
The Emergence of Interest	Encoding; Conceptual

Note. We list the primary sources of fluency as reviewed in the text; other sources are conceivable.