Metacognition in psychology

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Abstract

How has the concept of metacognition been used within basic and applied psychological research? We begin our answer by presenting a broad definition of metacognition, an historical overview of its development and its presence in research databases. To assess which function and facets are most frequently addressed within each of the sub-disciplines, we present results from separate literature searches. We then review how metacognition has been defined and empirically explored within selected sub-disciplines in terms of typical research questions, conceptual definitions, how the concept has been measured, and examples of interesting findings and implications. We identify similarities, inconsistencies, and disagreements across fields and point out areas for future research. Our overall conclusion is that it is useful to consider metacognition as a broad umbrella concept across different domains and across basic and applied research. Nonetheless, we recommend that researchers be more specific and explicit about their approach and assumptions whenever using metacognition in their research.

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Metacognition in psychology

A general introduction to metacognition

We just cannot help it. As we think, speak, argue, solve problems, or simply search for the right words in a conversation - we constantly monitor our own thinking. We evaluate it, we judge it, we sometimes even try to influence it. Only rarely do we rest in the present moment without engaging in metacognition - in «thoughts about one's own thoughts and cognitions» (Flavell, 1979). Sometimes we think about our own thinking because we intentionally choose to do so. However, most of the time metacognition happens largely automatically and involuntarily, so that we remain largely unaware of its presence.

The obvious benefit of being able to reflect upon one's own thinking is that it allows us to take control over our cognitive activity. Most researchers therefore agree that metacognition has at least two functions. One function is to *monitor* the current state of whatever cognitive activity we are engaged in (Dunlosky & Metcalfe, 2009). For instance, how well do we understand the text we are currently reading? Or, in the case where we are trying to remember something, to what extent do we think we will be able to succeed? The other function is to *control* our own cognition – to try harder or less hard to remember something, or to shift to a different strategy when we are stuck in attempting to solve a puzzle. Monitoring and control are closely intertwined: Whether or not we engage in metacognitive control, and the ways in which we try to regulate our cognition, will often depend on the outcome of metacognitive monitoring. Similarly, monitoring would be of little use if it could not elicit control attempts when necessary.

If metacognition is both about the way we monitor and control our own thinking, it covers a wide range of phenomena, including both introspective and self-regulatory processes. This is why some researchers have tried to identify distinguishable subcomponents of metacognition. A classic distinction (Efklides, 2008, 2011; Flavell, 1979) is between three

facets of metacognition: knowledge, strategies, and experiences. *Metacognitive knowledge* (Flavell, 1979) is the person's knowledge and understanding of their own and other people's cognitive abilities and strategies. For instance, most of us have found out from experience that repeating a phone number to ourselves multiple times increases the likelihood of future recall. *Metacognitive strategies* refer to the way in which we deliberately engage in various activities to control cognition (Efklides, 2008). An example would be to read a text more slowly if felt comprehension is low, or postponing the reading when too tired. *Metacognitive experiences* are feelings and judgements that occur during a cognitive activity and reflects aspects of this activity. For example, whilst solving a puzzle, one may experience a feeling of being close to or far away from the correct solution. Hence, metacognition ranges from knowledge about cognition and what could be regarded as higher order thinking skills (i.e., knowledge) and feeling states (i.e., experience), to regulation of cognition (i.e., strategies). (Flavell also introduced a fourth facet, namely *metacognitive goals (or tasks).* This refers to the objective of the cognitive activity in question. However, this facet has received less attention than the three others.) Importantly, Flavell (1979) emphasized the importance of possible *interactions* between the three facets. For example, metacognitive knowledge may concern which metacognitive skills are useful or not for a certain person conducting a certain cognitive task.

The concept of metacognition has been used to explore a variety of phenomena, from the study of the evolution of metacognition to self-regulated learning in school children. It has also been used to understand the development and treatment of various forms of psychopathology. However, what is still missing is a cross-disciplinary overview which points to similarities and differences in how metacognition is understood, as well as to methodological differences in how it is explored. This paper aims to give such an overview. Through this, we hope to provide those who are new to the field with an introduction to the

various ways in which metacognition is defined and measured, and to identify questions over which research fields agree as well as disagree.

We first provide a short historical perspective before we, in the second part, turn to how metacognition has been defined more specifically within selected sub-disciplines of psychology. For each of the sub-disciplines, we present key questions in the area, how metacognition is uniquely defined, and how it is measured. For each of these we also present some research findings, and point to their theoretical and applied impact.

The reader should be aware that due to the extensive amount of research within each of the psychological domains we have set out to cover, we are not able to provide a broad overview of each area. All that can be done within the limits of this review paper, is to touch upon some general trends and exemplify some theoretical and methodological approaches within each domain.

A historical perspective on metacognition

Metacognition as the act of "thinking about thinking" is as old as the human ability to reflect on their own cognitive experiences – what Socrates summarized as "I know what I do not know" (Plato, Apology). Ever since the advent of psychology as an independent science at the end of the 19th century, aspects of metacognition have been an integral part of it under many different names, including "vigorous thinking" (Gray, 1925). In memory research, for example, the feeling-of-knowing (FOK) experience (Hart & Kuhlen, 1965) and tip-of-the tongue (TOT) state (R. Brown & McNeill, 1966) were studied before the term metacognition was established. *Metacognition* became a hot topic, especially in cognitive and developmental psychology, after Flavell outlined a framework to distinguish between the three aspects of metacognition introduced above (Flavell, 1979; Flavell & Wellman, 1977). A. L. Brown (1977) applied and extended metacognition as being more than an epiphenomenon to educational psychology. Her studies on reading comprehension in typically developing as

well as children with varying degrees of intellectual ability and challenge, fall into developmental, educational, social and clinical psychology.

Whereas the focus in the 1970s was largely on metacognitive knowledge and experience, the focus shifted in the late seventies and eighties to a stronger emphasis on metacognitive control and strategy use (Dimmitt & McCormick, 2012). Since then, metacognition continued to be a topic of interest in cognitive psychology, especially in metamemory research. In clinical psychology, the importance of self-monitoring skills can be traced back at least to Ellis (1962), when therapists were encouraged to instruct the patient to monitor their cognition, and has since been more formalized by Meyers, Mercatoris, and Artz (1976). In comparative psychology, an early study of metacognition in non-human animals was conducted by Smith et al. (1995). This was a perceptual discrimination task with dolphins but which, as will be discussed later, raised some controversy over the extent to which this really was a case of metacognition. Around the same time, metacognition became a topic of study in cognitive neuroscience and clinical neurophysiology.

It should also be noted that a number of early studies of learning addressed phenomena that are arguably metacognitive in nature, even though they were not explicitly categorized as such. Examples include Harlow's "learning sets" (Harlow, 1949), learned helplessness (Seligman & Maier, 1967), and causal inferences in pigeons (Killeen, 1978).

Some decades later, Reder (1996) reviewed papers on metacognition from multiple research fields, including developmental psychology, neuropsychology, and educational psychology. She pointed to the fact that the different fields treated metacognition as a concept involving some degree of awareness of mental activity, but that the discrepancies between the various conceptualizations were of such magnitude that it was difficult to conclude that metacognition could be seen as a unitary concept.

A database perspective on metacognition

In the PsycINFO database today, almost 7 000 records are labelled with the 'Metacognition/' term from the Thesaurus of Psychological Index Terms (American Psychological Association, n.d.-b; we searched PsycINFO on Ovid, February 11 th, 2019 and August 7th, 2019). To get a rough sense of the extent to which metacognition is studied across the various sub-disciplines of psychology, we plotted the number of metacognition records against each of the most general PsycINFO Classification Codes (American Psychological Association, n.d.-a). The results are displayed in Figure 1.

Most notable, but not surprising, is that metacognition seems to be most frequently studied in the sub-disciplines of educational psychology and human experimental psychology (including, as its largest subclass, cognitive psychology). Next, a substantial proportion of metacognition studies belong to clinical psychology (cc's 3300 and 3200) and developmental psychology. While these four disciplines clearly account for the majority of metacognition records, metacognition is dealt with in a handful of other sub-disciplines too. It should be noted that two areas that have few citations in PsycINFO (although each above 100), namely animal psychology and neuroscience (i.e., "animal experimental & comparative" and "physiological psychology & neuroscience") seem to be represented with a larger number of citations when other databases are searched (e.g., Scopus, PubMed).

[Insert Figure 1 about here]

Based in part on this distribution, and in part on our own interests and areas of expertise, the remainder of this paper is organized into subsections from seven sub-disciplines. The selection criteria were that each sub-discipline should have more than 100 citations and that the sub-disciplines should also be complementary in terms of the content/perspective they represent. Thus, we chose the sub-disciplines of developmental

psychology, cognitive psychology, cognitive neuroscience, educational psychology, personality and social psychology, clinical psychology, and animal/comparative psychology.

To assess the function and facets within each of the sub-disciplines we extracted the number of records that mentioned metacognition and either knowledge, strategy*, experience*, monitor*, or control* in the title, abstract, subject headings or key concepts. We then expressed those occurrences relative to the total metacognition records. Figure 2 (upper) shows that over one-third of the articles in experimental cognitive psychology, educational psychology, and personality and social psychology deal with control aspects of metacognition. Control, more than monitoring, is more commonly studied across all disciplines. The sub-disciplines also vary in profile when it comes to how the three facets are investigated (see Figure 2, lower). In neurosciences and animal psychology, research is most often concerned with knowledge, followed by strategy, and with the least focus on experience. Developmental and educational psychology have the reverse profile. In these disciplines, the facet most often referred to is metacognitive experiences, followed by strategy, and then knowledge. In cognitive psychology, most research is concerned with metacognitive strategy. In clinical and personality/social psychology, the distribution of articles is fairly even across the three facets, but with slightly more on metacognitive strategy over the two other facets.

[Insert Figure 2 about here]

Metacognition as it is used in different fields

We now present brief introductions to how metacognition has been addressed in each of the chosen sub-disciplines. The introductions are meant as examples, and not as comprehensive overviews of all relevant research in the sub-disciplines. The distinctions between the chosen sub-disciplines are not absolute, and in some cases examples of research or methodology could perhaps equally well be placed under a different heading. As is evident

from the review, the different domains have also inspired each other, for example, by how paradigms from developmental and animal psychology are also used in studies of the neuroscience of metacognition.

Developmental Psychology

Central Questions. The developmental perspective asks when we first see evidence of metacognition, how it manifests itself across the lifespan, and which metacognitive milestones are typical during various phases of life (Brinck & Liljenfors, 2013; Sodian, Thoermer, Kristen, & Perst, 2012). Key questions in developmental psychology have therefore been (1) *when* do we begin thinking metacognitively, (2) practically speaking, *how* do we think metacognitively in relation to particular tasks and how does that influence our functioning, (3) does metacognition *change* across the lifespan, and (4) how can we *measure* these aspects of metacognition (Beran, Brandl, Perner, & Proust, 2012; Hertzog, 2016)?

Definition. The historical origin of research on metacognition in developmental psychology is Flavell's (1979) distinction between metacognitive knowledge, experience and strategies (Schneider, 2008).

One branch of developmental psychology research has focused on the degree to which metacognition is a pre-conscious, pre-reflective, non-representational or preverbal form of thinking. Insights from this research help determine *when* we begin thinking metacognitively in early childhood, perhaps even as early as infancy (Brandl, 2012; Brinck & Liljenfors, 2013; Kloo & Rohwer, 2012; Sodian et al., 2012).

A second branch in the developmental literature turns from *that* we can think metacognitively to *how* we think metacognitively and act proactively in relation to managing important tasks, like education and learning (Zimmerman, 2008).

A third branch in development psychology explores how metacognitive abilities evolve across the lifespan and particularly whether thinking about how metacognitive skills might decline with age as adults mark changes in cognitive fluency and cognitive processing time (Hertzog, 2016). However, since older adults can outperform younger adults on some metacognitive tasks and are able to adapt or learn metacognitive skills when needed (Pennequin, Sorel & Mainguy, 2010), the question as to whether decline more a developmental or learning matter remains unclear (Castel, Middlebrooks, & McGillivray, 2016; Hertzog, 2016).

Measurement. First, the focus on children in developmental research has inspired methods that are more task-oriented or observational with the idea that metacognitive activity becomes evident through how well people perform on tasks that require metacognition (Schneider, 2008). Of interest is then *that* we can think metacognitively from a very early age, and do so in varying ways throughout the lifespan (Palmer, David & Fleming, 2014).

Measures of growing awareness of cognition and the ability to monitor and regulate thought – essentially early measures of metacognitive experience – have been captured already at ages 2-4 months through observations of intersubjectivity (Brandl, 2012; Brinck & Liljenfors, 2013).

With preschoolers, pretense has been studied through observations of play (Esken, 2012), testing violations of expectations (Sodian et al., 2012), the nature of false beliefs, i.e. understanding that others have a more naïve knowledge than oneself and that they will act differently than we would (see Wellman et al., 2001 for a meta-analytical review), appearance-reality, i.e., understanding that something may be different from what it appears to be, level 2 perspective taking, i.e., understanding that the way something looks to me might be different than it looks to you who is looking at it from another angle, and through appropriate predictions about and responses to others' desires and emotions (Flavell, 2004).

In middle childhood and beyond, metacognitive studies focus more on measures of children's understanding that knowledge is malleable – active, interpretive and constructive (Flavell, 2004).

Second, to capture metacognition in older children and adults, self-report inventories have been used to measure metacognitive aspects of self-regulation related to metacognitive knowledge and skills (Mecacci & Righi, 2006; Schneider, 2008). Of interest is then *how* we think metacognitively in relation to particular tasks, and whether metacognition is domain or task specific (see also Cognitive Neuroscience section). In adult research, tasks that capture judgements of learning (JOL) and feelings of knowing (FOL) managing tip-of-the-tong (TOT) states with tasks as varied as managing math calculations and reporting metacognitive beliefs have also been used (Castel, Middlebrooks, & McGillivray, 2016; Mecacci & Righi, 2006).

Other methods have been developed since in order to complement self-report data (Zimmerman, 2008). Those include, for example, the use of monitoring traces of activity in computer-assisted learning environments, using think-aloud protocols in a hypermedia environment, structured online diaries that measure thinking before and after learning events in response to event questions directly related to student study sessions, and classroom observations in primary schools.

Findings and implications. Understanding where people of any age are at metacognitively can provide clues for how to tailor care and teaching to their needs, and facilitate self-regulated learning. Understanding what kinds of new cognitive realities need particular metacognitive attention is important for how we facilitate everyday life in all populations, including among older adults who report greater concern about their meatcognitive abilities than others (Mecacci & Righi, 2006).

When examining how metacognition develops in infants and preschoolers, for example, major growth occurs in terms of how well infants understand, through interactions with their caregivers, that actions are intentional and goal-directed. Infants also grow notably in how well they manage intentional focus and referential intent (Flavell, 2004). Through their preschool years, children metacognitively grow in their understanding of others' attentional focus, desires, emotions, knowledge and beliefs, role in pretense and thinking. From there on, children pass several metacognitive milestones that can influence their readiness for learning.

Between kindergarten and sixth grade, major growth occurs in strategy knowledge, while metamemory growth develops much slower into adolescence and beyond (Schneider, 2008). Metacognitive judgement grows even slower, often in cue-dependent ways. Younger children often overestimate how easy it will be for them to perform a new task yet improve in this area considerably by early elementary school. Skill at judging what they have learned (JOL) and feelings of knowing (FOK) both increase, though little, during elementary school. Likewise, when youth are asked to identify task difficulty and allocate study time thereafter, all elementary school children are able to distinguish easy from hard tasks, but only the older elementary children begin allocating more learning time to the harder tasks than the easier tasks.

During adulthood both objective task performance and metacognitive efficiency (as measured by meta-d') are high. Some report a decline of metacognitive efficiency with age (Palmer, David, Fleming, 2014) whereas others have not found notably reduced metacognition in older adults (Mitchell, Cam-CAN, and Cusack, 2018). For older who do experience decline, however, compensatory metacognitive control and monitoring strategies are important (Hertzog, 2016).

Cognitive psychology

Central Questions. Koriat (2007) has formulated five categories of questions that experimental cognitive psychology on metacognition has addressed, and which represent a good summary. These questions concern (1) the *bases* of metacognitive judgements during monitoring of cognitive activity, (2) the *validity* of such judgements and the variables that influence this validity, (3) the *processes* that influence their accuracy or inaccuracy, (4) how metacognitive *control* is influenced by the output of metacognitive monitoring, and (5) how *performance* is influenced by metacognitive monitoring and control (Koriat, 2007, p. 289). In addition, one might add that the inclusion of metacognitive ratings in experimental studies of consciousness has been used to infer the conscious status of the knowledge or process in question.

Definition. Metacognition is understood as "cognition about cognition", and is most often operationalized in terms of online ratings of varieties of metacognitive experiences, depending on the cognitive process in focus, e.g. confidence ratings. A central distinction here is between so-called information-based versus experience-based metacognitive feelings (Koriat, 2007). A metacognitive feeling that is influenced by the person's *conscious* beliefs, knowledge or past experiences, is said to be "information-based". For instance, when asked to estimate your confidence in the correctness of a decision, confidence may be influenced by estimates of skills in the particular domain. On the other hand, it may also be influenced by *non-conscious* factors, such as how quickly your answer came to mind, or the familiarity of the task domain. Metacognitive feelings that are influenced by such factors, are referred to as "experience-based". Thus, according to this perspective, metacognitive feelings can reflect both explicit/conscious and implicit/unconscious cognitive activity. Nevertheless, higher-order theories of consciousness would argue that the metacognitive state itself is conscious in

both cases, because metacognition involves higher-order mental representations which are indicative of consciousness (e.g., Rosenthal, 2000).

Measurement. Metacognition is most often measured by the use of introspective self-reports collected during a cognitive task – so-called “online” measures. The classic example is feelings of knowing (FOK) in memory situations (Hart & Kuhlen, 1965; Koriat & Levy-Sadot, 2001; Metcalfe, Schwartz, Joaquim, & Rayner, 1993). Here, the felt likelihood of future memory for unrecalled items is compared to actual later recognition accuracy for those items. Another classic example is tip-of-the tongue (TOT) ratings (Schwartz, 1999), in which the feeling of future recall is stronger and more imminent. Again, subjective ratings are compared to objective memory accuracy. In learning situations, metacognition has been measured with judgements of learning (JOL) (Schwartz, 1994). Within problem solving, the classic example of metacognition is warmth ratings. Metcalfe and Wiebe (1987) demonstrated how the relationship between warmth ratings and closeness to the correct solution differed for insight versus non-insight problem solving. This was used to argue that the underlying cognitive processes were different. Similarly, the degree of correspondence between confidence ratings and classification accuracy has been used to argue whether knowledge acquired in so-called implicit learning situations, is conscious or unconscious (Norman & Price, 2015).

Other ratings of metacognition in cognitive psychology include (but are not limited to) remember/know judgements (Yonelinas, 2002), ease-of-learning judgements (Jemstedt, Schwartz, & Jönsson, 2018), familiarity judgements (e.g. Whittlesea & Williams, 2000), post-decision wagering (Persaud, Peter, & Alan, 2007), and the related "no-loss gambling" method (Dienes & Seth, 2010).

Findings and implications. Metacognitive experiences predict memory, e.g. FOK (Koriat & Levy-Sadot, 2001), TOT states (e.g. A. S. Brown, 1991), and "feelings of

familiarity" (e.g. Whittlesea & Williams, 2000), both when metacognition occurs before or after the retrieval attempt has been initiated. In problem solving, the classic study by Metcalfe and Wiebe (1987) showed that warmth ratings predicted closeness to solution for incremental, but not insight problems. In implicit learning, metacognitive ratings of confidence distinguish cases of explicit learning where knowledge is conscious, from cases of pure implicit learning in which knowledge is inaccessible to consciousness (Norman & Price, 2015).

The discrepancy that sometimes occurs between metacognition and performance has not only been used to infer conscious availability, but has also itself been a focus of cognitive research, for instance on the Dunning-Kruger effect (Kruger & Dunning, 1999) and research on metacognitive calibration (Pieschl, 2009) where the focus is often how to reduce this discrepancy.

At a general level, research on metacognition in cognitive psychology has provided a conceptual and theoretical framework for understanding how people monitor and control their own cognitive processes. The applied implications of this are exemplified elsewhere in this paper. At a more theoretical level, it has contributed to our understanding of the relationship between cognitive processes and corresponding subjective experiences involved in, for example, learning and memory, as well as decision-making.

Cognitive Neuroscience

Central Questions.

Given that most cognitive tasks act like an intricate concert played by the instruments of different brain regions, one asks (1) whether there are brain regions that are *necessary* or *sufficient* for metacognitive processing, (2) whether metacognitive monitoring or control is a domain-general mechanism or a task-specific mechanism? That is, does the processing of the *meta* happen in brain regions activated according to the sensory modality of the task, in

(multiple) circumscribed brain regions, or is the meta a property of the neural network itself?

Originally, behavior was the only observable read-out. Fortunately, the tools of neuroscience allow us to monitor the readout *process* itself. We can thereby record neural populations and start formulating hypotheses about which brain regions are involved when we reflect upon our own thoughts and assesses our confidence in them.

Since information is encoded in neural population codes (Pouget, Dayan, & Zemel, 2000), where the variance of this code distribution is presumed to represent the precision of the percept, one further can ask (3) whether the precision is preserved in further processing stages, and (4) whether there is a readout mechanism for the precision or accuracy. If so, this could be used as a mechanism to access the confidence of internal states. More broadly, within neuroscience one asks, (5) which species possess a readout mechanism for uncertainty, and how good is the readout mechanism.

All and all, metacognition in the neurosciences focuses on the algorithmic and implementational level of explaining behavior (Marr & Poggio, 1976).

Definition. In cognitive neuroscience, the overarching definition of metacognition is cognition about cognition. That is, metacognitive processes are processes beyond the object-level and part of a hierarchy from sensory/object level to (a) meta level(s).

Measurement. Experimental tasks in neuroscience are often paradigms adapted from animal psychology (e.g., finding brain regions and decoding the neural firing that corresponds to monitoring how a monkey performs a task) and cognitive psychology (e.g., performing functional MRI or EEG/MEG when humans make confidence judgments or feeling of knowing (FOK) judgements). The field has also benefited from case studies based on patients with circumscribed lesions and their accompanied loss of function. Within behavioral neuroeconomics, as well as cognitive psychology, an increasingly popular paradigm is post-decisional wagering where one places a bet depending on one's certainty to have provided the

correct answer (Dienes & Seth, 2010; Persaud et al., 2007; Pfuhl & Biegler, 2012). The higher the stakes, the more confident we tend to be about our presumably correct answers. Many would regard varieties of post-decision wagering as a more reliable procedure for eliciting confidence ratings than more typically used verbal scales.

Another prominent method uses confidence ratings in a two-alternative forced-choice task. This is a recognition task based on discriminating previously seen sample stimuli from novel stimuli. By using Signal Detection Theory, one can calculate both a performance score, i.e., how well a person can discriminate between seen and not seen stimuli, and a bias score (see e.g. Barrett, Dienes, Seth, Appelbaum, & Harlow, 2013; Maniscalco & Lau, 2012).

Metacognition can also be measured by calculating a metacognitive sensitivity index: for example meta-d'. A signal detection statistic like meta-d' quantifies how well confidence ratings discriminate between correct (hits) and incorrect (false alarm) trials (Maniscalco & Lau, 2012). A well-calibrated person makes high-confidence judgements for correct trials, and low-confidence judgements for incorrect trials. Overconfident persons rate correct and incorrect trials with high confidence, and underconfident persons rate correct and incorrect trials with low confidence.

Experimental tasks can be combined with physiological measurements, e.g. fMRI, EEG, pupillometry, assessed in patients with prefrontal cortex lesions, across the lifespan including persons with dementia, or in persons with mental disorders known to compromise insight and self-awareness. These are useful for many other subdisciplines, too (e.g., studies within neuropsychology, computational psychiatry).

Findings and implications. Lesion and brain imaging studies have shown that metacognition is separable and distinct from other cognitive processes as well as from entities such as episodic memory, perception, decision-making. and reasoning. Furthermore, perceptual and mnemonic metacognition engage different brain regions (Rouault, Williams,

Allen, & Fleming, 2018). Not surprisingly, monitoring and controlling one's thoughts engage similar brain regions as those engaged by executive functions (Roebers, 2017).

Different kinds of metacognitive activity seem to be uniquely associated with particular brain regions. Based on brain imaging in healthy participants, there is evidence showing that prospective judgments engage the rostrolateral and dorsolateral prefrontal cortex whereas retrospective judgments engage the rostromedial prefrontal cortex (PFC) (Fleming, Dolan, & Frith, 2012). Confidence judgements of perceptual tasks engage more the lateral anterior PFC whereas confidence judgements in mnemonic tasks engage more the medial anterior prefrontal cortex (aPFC) (Baird, Smallwood, Gorgolewski & Margulies, 2013). Similarly, McCurdy et al. (2013) found that gray matter volume of the aPFC correlated with visual perceptual metacognition but not with memory metacognition. The anterior cingulate cortex, a region implicated in decision-making, is also activated during monitoring of choices (e.g. Baird et al., 2013). Furthermore, the anterior insula seems to be involved in meta-awareness of emotions (McCaig, Dixon, Keramatian, Liu, & Christoff, 2011) and also prospective metamemory (Le Berre et al., 2016). A study measuring meta-d' indicates two separable processes: a non-conscious statistical assessment of confidence and a conscious single-trial evaluation. The former recruits the dorsal anterior cingulate cortex whereas the latter recruits the posterior cingulate cortex (Charles, Van Opstal, Marti, & Dehaene, 2013).

When assessing metamemory, patients with amnesia (e.g. early Alzheimer) can have impaired episodic memory yet intact metamemory. They know they have problems remembering. Patients with PFC lesions, on the other hand, often have both poor memory and poor metamemory (Janowsky, Shimamura, Kritchevsky, & Squire, 1989). Similarly, aberrant metacognitive judgements are also found in a range of mental disorders, as psychosis, obsessive compulsive disorder (OCD), and depression (see clinical psychology section). Also, both dopamine and noradrenaline have been implicated in metacognition (Hauser, Allen,

Purg, Moutoussis, Rees, Dolan, 2017; Lak, Nomoto, Keramati, Sakagami, Kepecz, 2017) with the blocking noradrenaline having beneficial effects on metacognition.

Educational Psychology

Central questions. The central, and arguably most interesting questions related to metacognition in educational psychology are: (1) Does metacognition influence learning? And (2) can it be taught? Researchers have attempted to provide answers to them both at a general level, but also via specific education-related skills and processes such as reading and writing. In attempting to answer these questions, researchers have looked for associations between measures of metacognition and academic achievement, and for effects of metacognitively-oriented educational interventions.

Definition. Educational psychologists tend to see metacognition as part of the overarching concept of self-regulated learning (SRL). SRL can be construed as a framework for understanding how cognitive, metacognitive, emotional, motivational, and social aspects of learning interact (Panadero, 2017). According to Pintrich (2000), self-regulated learning "is an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features in the environment" (p. 453). Accordingly, a learner is considered self-regulated to the extent that she is metacognitively, motivationally and behaviorally engaged in her own learning process (Zimmerman & Schunk, 2011, p. 4).

Measurement. In educational psychology metacognition is most often measured by self-report, either through questionnaires or interviews, or by estimating the accuracy of metacognitive judgements of learning and/or feelings of knowing (JOL or FOK). Other

measures are also occasionally used, such as observations of student behavior (Dimmitt & McCormick, 2012, see also the section on Developmental psychology).

One of the most commonly used self-report inventories is the Metacognitive Awareness Scale, originally developed by Schraw and Dennison (1994). The MAI was designed to capture the two-components of the metacognition concept, with separate subscales for metacognitive knowledge and metacognitive regulation of cognition (i.e., metacognitive control). Since its initial introduction, several variations of the MAI have been used – both in the response scale format and in how scores are aggregated. Studies examining the scale's factor structure have been inconsistent in both the choice of analyses and in the resulting conclusions (Harrison & Vallin, 2018). This complicates the evaluation of the MAI's psychometric properties, though Harrison and Vallin's research does seem to indicate that a two-factor structure based on a subset of the original items provides a reasonable fit to the common, two-component knowledge and control conception of metacognition.

Mirroring the fact that educational psychologists tend to subsume metacognition under self-regulated learning, there are several instruments aimed at measuring self-regulated learning that contain metacognition subscales. These include: a) Learning and Study Strategies Inventory (LASSI, Weinstein, Schulte, & Palmer, 1987), b) the Motivated Strategies for Learning Questionnaire (MSLQ, Pintrich, Smith, Garcia, & McKeachie, 1993) where metacognitive self-regulation is one of the two MSLQ subscales, and measures planning, monitoring and regulating strategies, and c) the Self-Regulated Learning Interview Scale (Zimmerman, 2008; Zimmerman & Martinez-Pons, 1988).

All of these, including the MAI, are instances of offline, retrospective self-report measures. They are thus susceptible to memory distortions and unreliable introspections, and may not measure a student's actual *use* of metacognitive strategies. They also tend to associate with a conception of self-regulation as a relatively stable trait, varying little across

contexts. Recently, this conception has shifted towards one where self-regulation is seen as less stable and more contextualized, thus requiring online measures that are more closely associated with the performance of specific learning or cognitive tasks (see e.g. Panadero, Klug, & Järvelä, 2016; Veenman, 2011). Measuring metacognition through the use of introspective self-reports collected during the performance of a cognitive task is useful (and already covered in the sections on Cognitive neuroscience and Experimental cognitive psychology).

Findings and implications. An important contribution of educational psychology has been the examination of the link between metacognition, usually considered as part of SRL, and learning, typically measured as academic achievement. Considering the volume of research in this field, one might assume that this link is strong and firmly established. However, a recent meta-analytic review by Dent and Koenka (2016) found the association to be relatively modest, with a mean, weighted correlation (under a random effects model) of r = .20. Interestingly, the association was found to be significantly and substantially stronger when metacognition and self-regulation were measured by online self-report, rather than retrospectively.

Some degree of metacognitive knowledge and skills, both explicit and implicit, may develop as a natural part of growing up (see Developmental and Cognitive neuroscience sections of this article) or in our natural inclinations to think and act metacognitively (see Personality and Social Psychology section of this article). Another major contribution of educational psychology to our understanding of metacognition has been the study of whether and how task-specific metacognitive skills can be *taught*. While the association between self-regulation as measured by offline self-reports and academic achievement is relatively weak, it seems that metacognitively-oriented educational interventions can have a considerable impact. Dignath, Buettner, and Langfeldt (2008) meta-analysed 48 studies of primary school metacognition

training programmes, finding a mean standardized effect size (Cohen's *d*) on academic achievement across reading/writing and mathematics of .62. Similarly, Donker, de Boer, Kostons, Dignath van Ewijk, and van der Werf (2014) found an overall effect of learning strategies instruction on academic performance ($d = .66$) in primary and secondary education, with metacognitive strategies being more effective than cognitive strategies. Thus, there is convincing evidence that metacognitively oriented educational interventions may positively impact student learning.

Personality and Social Psychology

Central questions. Within the broad fields of personality and social psychology, metacognition encompasses processing and control of one's own or others mental states and processes. For one's own this include questions related to (1) attitudes, (2) self identity, (3) and interpersonal relationships. When applied to how others are thinking, metacognition is known as (4) mentalizing (Frith, 2012). Metacognitive monitoring and control might be involved in self-regulatory processes important for health, performance, well-being, and others. Accordingly, persuasion and social influence (Mercier and Sperber, 2011) as well as predicting people's behavior and reasoning (Briñol and DeMarree, 2012, Frith, 2012) involve metacognitive control (Fig 2). However, in these fields, metacognition as a theoretical concept is often assessed through related concepts such as self-efficacy (Bandura, 1977), cognitive control and need for cognition (Braver, 2012; Cacioppo and Petty, 1982, Shea et al. 2014), reflective mind (Stanovich, 2001), illusion of control (Langer, 1975), *belief* in one's knowledge and skills, attitude certainty and importance (Visser, Krosnick, Simmons, 2003), as well as behavioral game theory studies assessing social cooperation (Colman, 2003). Self-perception theory (Bem, 1972), emphasizing the role of inference from observation of own behavior in establishing and changing attitudes and self-beliefs, might also be regarded as a

metacognitive theory in the sense that attitudes and self-beliefs are summary inferences about past behaviors.

Moreover, in this broad field, metacognitive abilities are often treated as individual difference variables. Potential overlaps with other difference variables may occur (e.g. openness to experience), which may be one explanation for why metacognition is given a relatively modest role in personality research.

Definitions. Jost, Kruglanski, and Nelson (1998) suggested an expansive understanding of metacognition, including the metacognitive beliefs about others and their intentions (see also theory of mind research in the Developmental section of this article). Focusing on personality psychology, metacognition is sometimes challenged as a separate construct. For example, Batteson, Tormey, and Ritchie (2014) found evidence for a theoretical overlap between the conscientiousness and metacognition constructs. Although metacognition is often assumed to reflect conscious and controlled processes, Reder (1996) argued that the majority of self-regulative processes are actually automatic and nonconscious. The lack of direct and explicit access is overcome through discussion and collaborative decision-making, hence only humans might have acquired explicit metacognition (Frith, 2012, Shea et al., 2014).

Measurement. Metacognitive functioning in this context varies in how it is measured, depending on what aspect of metacognition is studied and who is being studied (e.g., children, adults). Indeed, the term social is broad, encompassing all kinds of social objects (relationship of other people), stereotypes, but also thoughts about institutions (Briñol & DeMarree, 2012). In 1982, Cacioppo and Petty developed the Need for Cognition scale, assessing an individual's willingness to engage in effortful cognitive activities. This spurred studies on motivation, reflection, and cognitive effort. Stereotypes and attitudes are assessed with a combination of implicit measures (e.g. implicit association test) and explicit measures

(questionnaires, e.g. Gawronski et al. 2017). Correlations are high, suggesting people are aware of their biases (Hahn & Gawronski, 2019).

Relations between personality traits and metacognition are commonly assessed by self-report instruments (see clinical and educational Psychology section).

Findings and implications. One way of exploring metacognition within personality research has been to focus on individual differences in metacognitive skills, which again are assumed to reflect differences in metacognitive ability. For example, Gernsbacher and colleagues (Gernsbacher et al., 1990) found evidence for individual differences in capturing and representing the structure of comprehensible information ("general comprehension skill"), supporting an assumption that metacognitive ability may vary in a trait-like fashion between individuals. Further, individual differences in cognitive control, as measured with, for example, the Need for Cognition scale, is related to cognitive effort in a range of tasks (Kool and Botvinick, 2018) and to overriding intuitive but wrong responses (Toplak, West and Stanovich, 2014).

Another approach has been to relate personality traits to metacognitive differences. For example, ÿz (2016) explored the relation between the Big Five personality traits and metacognitive awareness. The results indicated that Openness to experience and Extraversion demonstrated predictive power in determining both metacognitive knowledge and control.

Individual differences in metacognitive abilities may affect performance in subtle ways. For example, if competence is low, performance will suffer, but so will also the individual's ability to recognize it (Kruger & Dunning, 1999). Also, the metacognitive skill to recognize poor performance is dependent on the capacity that performance itself depends on. For example, participants low in competence on experimental tasks do not only overestimate their actual performance, but also fail to realize their poor judgment.

Clinical Psychology

Central Questions. Researchers in clinical psychology explore the influence of metacognition on mental states, and central questions circle around metacognition as a working factor in the development or treatment of psychopathology. For example, (1) If a metacognitive deficit is associated with psychopathology, how can therapists work with patients' metacognition to improve psychological functioning and mental health? Or (2) Does an assumed meta-cognitive deficit reflect the same construct in all psychopathology or does it differ from condition to condition?

Metacognition in the field of clinical psychology has been dominated by the work of Adrian Wells and colleagues since the 1990's (Wells, 2009; Wells & Matthews, 1994; Wells & Purdon, 1999). The focus has been especially on how individuals understand psychiatric symptoms and diagnoses and how they respond to them (Lysaker et al., 2011). The goal is to tailor therapeutic interventions that help people modify their dysfunctional thoughts and develop responses that are more functional (Matthews, 2015). A key purpose is thus to help patients identify, understand and repair dysfunctional metacognition.

According to the theory of Self-Regulatory Executive Function (S-REF), dysfunctional metacognitive beliefs are important contributors to the development and perseverance of psychopathology (Wells, 2009; Wells & Matthews, 1994). Worrying, rumination, threat-oriented thoughts and other poor coping strategies are seen to constitute a cognitive attentional syndrome (CAS). This syndrome is supposedly maintained by dysfunctional metacognitions. One example is when a depressed patient perceives worrying as an effective coping strategy, and therefore continues worrying. Ergo, it is not only the negative content of thoughts (*what* one thinks) that makes people develop psychopathology, it is also dysfunctional beliefs about these thoughts (*how* one thinks, Wells, 2009). These dysfunctional beliefs seem to be common processes associated with various

psychopathologies (Sun, Zhu, & So, 2017).

On the other hand, well-developed metacognitive skills may foster mastery and more functional coping strategies (Semerari et al., 2003). This is related to self-regulation and control – how patients may take action and implement strategies to alter an undesirable mental state and how they may learn to think critically and rationally about the problematic thoughts they experience.

Another related concept is *cognitive insight*, which is the capability to identify false beliefs and change these with the help of external feedback (Beck & Warman, 2004; Moritz et al., 2018).

Definition. Metacognition is conceptualized as skills that guide information processing and judgments about the thoughts and actions of oneself and others (Dimaggio & Lysaker, 2015).

Measurement. Metacognitive functioning is primarily measured with self-report scales (Semerari et al., 2003). One widely used scale is the Meta-Cognition Questionnaire (Semerari et al., 2003). Five dimensions of metacognition are represented in the scale: (1) Positive beliefs about worry, (2) Negative beliefs about the controllability of thoughts and corresponding danger, (3) Cognitive confidence, (4) Negative beliefs about thoughts in general, and (5) Metacognitive processes, or self-consciousness.

Behavioral measures are also increasingly used. Examples include computer-based tasks that involve attention-shifting (e.g. Callinan, Johnson, & Wells, 2015), cognitive reflection task (Mækelæ, Moritz, Pfuhl, 2018) or measuring implicit metacognition (Kreis et al., 2019, Pfuhl et al., 2015).

Findings and implications. Deficits in metacognitive abilities are associated with various psychiatric diagnoses and problems. Already in the 1980s, Baron-Cohen, Leslie, and Frith (1985) found deficits in autistic children's abilities to form theories about an other's

mind (see also the section on Developmental psychology). Similar patterns have been identified for some symptoms of schizophrenia (Brüne, 2005; Frith & Corcoran, 1996). Diagnoses where dysfunctional metacognition seems to play a role include schizophrenia (Lysaker et al., 2011), depression (Halvorsen et al., 2015; Papageorgiou & Wells, 2003), obsessive compulsive disorder (OCD) (Salkovskis, Richards, & Forrester, 1995), personality disorders (Dimaggio & Lysaker, 2015; Fonagy, 1991; Krueger, 2006), anxiety disorders (Spada, Nikcevic, Moneta, & Ireson, 2006), anorexia (McDermott & Rushford, 2011), hypochondriasis (Bouman & Meijer, 1999), dependencies (Saed, Yaghubi, & Roshan, 2010; Spada, Nikcevic, Moneta, & Wells, 2007), gambling (Lindberg, Fernie, & Spada, 2011), pathological procrastination (Spada, Hiou, & Nikcevic, 2006) and perceived stress (Roussis & Wells, 2008).

Since empirical research has shown associations between dysfunctional metacognition and psychopathology, metacognitive therapy has been proposed as a psychological treatment (Wells, 2001, 2009). Where cognitive therapy challenges the content of the patient's beliefs and thoughts, metacognitive therapy challenges the beliefs about the beliefs (Matthews, 2015). A cognitive therapist will be interested in the thought patterns that a patient has and try to change these into ones that are more constructive. A *metacognitive* therapist, on the other hand, will be interested in what the thoughts mean to the patient, which thinking strategies the patient uses, and the knowledge base that guides these strategies (Wells, 2001). For instance, a situation may elicit a certain thought in a person, for example "I am worthless", that makes the person feel depressed. Cognitive therapy will question the validity of the thought and try to alter it into something else, preferably something that yields a more positive consequence. Metacognitive therapy, on the other hand, will first address what the patient thinks and feels about the thought, how the patient deals with it and why, and then aim at altering the strategy in order to alter the thought.

Metacognitive therapy includes attention training, detached mindfulness and behavioral experiments. It has been successful in treating depression and anxiety disorders (Kahl, Winter, & Schweiger, 2012; Normann, van Emmerik, & Morina, 2014; Sadeghi, Mokhber, Mahmoudi, Asgharipour, & Seyfi, 2015) as well as psychosis (Vitzthum, Veckenstedt, & Moritz, 2014).

Animal Psychology

Central questions. Darwin's attention to difference of degree, not kind, provides a foundation for the understanding how metacognition may have evolved. Ethologists and comparative psychologists have built on this when tracing the phylogeny of metacognition and, if animals have it, determining what metacognition is good for. Specifically, key questions in ethology are (1) which species show metacognition, (2) did it evolve multiple times (convergent evolution), (3) how does it contribute to survival (functional argument), and (4) is episodic memory a prerequisite for metamemory.

Definition. Metacognition is defined as any behavior based on accessing internal states such as uncertainty or confidence about a memory or a decision. Since researchers in this tradition would argue that this does not require conscious awareness, it is referred to "implicit" as opposed to "explicit" metacognition (Frith, 2012).

Measurement. To assess whether animals can express their uncertainty in a perceptual judgment task, Smith et al. (1995) introduced a third answer option, a "don't know" response for opting out from difficult decisions. The use of this option might be learned through association (e.g. Hampton, 2009), but it spurred the development of assessing metacognition non-verbally.

A now classical paradigm involved measuring how well an animal appears to think it *will* remember (similar to a feeling of knowing measurement in humans) and how well it

appears to think it *has* remembered, i.e. assessing *prospective* and *retrospective* metamemory judgments (e.g. Goto & Watanabe, 2012; Hampton, 2001; Inman & Shettleworth, 1999, Suda-King, 2008). In a standard memory task, an animal is presented with a stimulus, and, after a delay, is given a task where it has to make a choice between stimuli. If the animal chooses the previously seen stimulus, it gets a reward (matching to sample).

In the prospective condition, to assess prospective metamemory, the animal chooses to take the memory test or to decline it. On some trials the animal proceeds directly to the memory test without having the option to decline taking the test, so called forced choices. Metamemory is thought to be indicated when the animal is better at self-chosen memory tests than on the forced tests.

In the retrospective condition, the animal first takes the test and then can indicate either “I think I was right”, or “I am not sure I was right” by e.g. an escape button. Asking for confidence after having taken the memory test has been criticized as it could be solved by associative learning, i.e. memory may not be a function of “meta” but of perceptual cues such as difficulty in retrieving or intertrial intervals (Hampton, 2009).

Betting (Son & Kornell, 2005) and the willingness to spend effort to access the reward (Pfuhl & Biegler, 2012) are cognitive judgements relying on internal cues. In post-decisional wagering, the animals are given opportunities to express their degree of uncertainty by wagering, for example with tokens, that they are willing to bet that they are correct (Kepecs & Mainen, 2012, Son & Kornell, 2005, Morgan et al., 2014, Ferguson et al., 2017). Metacognition is indicated by wagering more in easy trials than in difficult trials.

Choosing an option to collect more information before deciding, referred to as *information gathering*, is tested by hiding a treat either conspicuously or not. Primates as well as birds appear to request more information when they have not seen the baiting, indicating that they *know* that they do not know the location of the treat (Güntürkün & Bugnyar, 2016;

Mulcahy 2016; Perdue, Evans & Beran, 2018; Kornell, Son & Terrace, 2007). Knowing what others know, i.e. whether animals mentalize, has been studied in pilfering paradigms (Clayton, Dally, Emery, 2007).

Findings and implications. Results from metamemory and information gathering studies support the notion that a range of animals do, indeed, exhibit metacognition (Kornell, 2014; Smith, Zakrzewski & Church, 2016), although stimulus discrimination with an opt-out response option is seen as a low level form of metacognition (Hampton, 2009, Smith, 2009, Kornell, 2014). A non-exhaustive list of animals that have exhibited metacognition includes honey bees (*Apis mellifera*, Perry and Barron, 2013), pigeons (*Columbia livia*, Iwasaki, Watanabe, Fujita, 2018); ravens (*Corvus corax*, Bugnyar & Heinrich, 2005), dolphins (*Tursiops truncates*, Smith et al., 1995), rats (*Rattus norvegicus*, Templer, Lee, Preston, 2017), rhesus monkeys (*Macaca mulatta*, Hampton, 2001), *orangutans* (Suda-King, 2008).

By requesting rhesus monkeys to make low or high bets where the judgment is based on internal cues, and using transfer tasks, Morgan et al. (2014) addressed some of the critiques raised about previous task designs. They replicated the findings of Hampton (2001), and recently the same two monkeys fell for a metacognitive illusion the same way humans do (Ferrigno, Kornell, & Cantlon, 2017).

Of note, comparative studies suggest that human metacognitive efficiency can be explained by associative mechanisms, too (Pfuhl et al., 2013, Smith et al., 2019). This opens up a mechanistic understanding how the brain may derive metacognitive performance from simpler mechanisms. Indeed, animals, including humans, may use heuristic cues and judge the accuracy of their memory based on perceptual cues (Ferrigno et al., 2017, Hampton, 2009; Pfuhl et al., 2009). Furthermore, the behavioral paradigms have been combined with theoretical models (e.g. Kepecs & Mainen, 2012), and the tools of neuroscience such as multielectrode recordings, calcium imaging, optogenetics. These toolshave shed light on

where and how in the brain the “meta” is processed (see Neuroscience section). Studies in rhesus monkeys (*Macaca mulatta*), for example, implicate the primate frontal cortex in monitoring choices (Middlebrooks & Sommer, 2012). The parietal cortex has been implicated for certainty in perceptual decision-making (Kiani & Shadlen, 2009) and neural activity in a task-specific area, such as the supplementary eye field, has been found to be related to post-decisional wagering.

Current data suggest that metacognition may not have evolved linearly[1]. Metacognition could be understood as an emergent property of ecological necessities and computing capacity (Pfuhl et al., 2009, 2011). The extent to which these results from animal psychology can be regarded as indicative of metacognition, depends on the extent to which consciousness is considered a definitional property of metacognition. Nevertheless, knowing the minimal requirements for indicating what one might refer to as "implicit" metacognition (Frith, 2012; Hampton, 2009) can, indeed, advance our understanding of phylogenetic and developmental aspects of metacognition.

Discussion

Key components of metacognition addressed across disciplines

Our literature search shows that across the chosen psychological disciplines, there is consistently a stronger focus on metacognitive control than on metacognitive monitoring as measured in terms of number of records that included each of the concepts in the title, abstract, subject headings or key concepts. Because metacognitive monitoring is a prerequisite for metacognitive control, this does not necessarily imply that control is in reality given less weight than monitoring. Nevertheless, it suggests that authors are at least more likely to emphasize the role of control over monitoring.

Even though the different psychological disciplines showed similarities in terms of their common emphasis on function, there are some differences in terms of which facets of metacognition are referred to across the different psychological disciplines. In neuroscience and animal psychology, metacognitive knowledge is addressed more often than the two other facets. In developmental and educational psychology, the strongest emphasis is on metacognitive experiences whereas in cognitive psychology, metacognitive strategy is most frequently addressed. In clinical and personality/social psychology, the research focus is distributed fairly equally across all three facets.

It is our hope that the identification of functions and facets of metacognition that have been researched within and across psychological subdisciplines, together with our overview addressing key elements within each subdiscipline, can serve as a novel contribution to metacognition research. Comparative studies of metacognition are rare, and, to our knowledge, no previous studies have combined the type of systematic literature searches we have conducted, with a systematic overview of central questions, definitions, methods, and findings from the same set of subdisciplines.

Even if two subdisciplines have the same relative focus on a given facet of metacognition, this does not necessarily mean that metacognition is defined or measured in the same way in those subdisciplines. In other cases, the situation might be the opposite. What appears to be a diverging focus could sometimes conceal a largely overlapping research focus. We now turn to a closer discussion of similarities and differences across psychological disciplines in terms of central questions, definitions and measurement of metacognition.

Central questions

As is evident from our overview, the concept of metacognition has been addressed for different purposes and with different emphasis in different areas of psychology. Sometimes,

metacognitive issues have been addressed only indirectly and under other labels. The research questions show a large variation, ranging from the basic questions on when and how it develops in children (cf. developmental psychology), when and for what purpose metacognition once evolved and whether it is even restricted to our species (cf. animal research), which role it plays in learning and human functioning (cf. cognitive, educational, cognitive neuroscience and social/personality psychology), and to the more focused and applied questions of how teachers can improve metacognition in students (cf. educational psychology) and how therapists can modify dysfunctional metacognition in order to improve mental health (cf. clinical psychology).

It could even be argued that the research questions identified in our overview together represent such a wide range and target issues of such fundamental nature that they overlap with nearly all the foundational questions in psychology. Given that the ability for metacognitive reflection is often seen as characteristic of what makes us "human" (though this is challenged by findings from animal research, and from people who lack the cognitive resources for metacognition), it is perhaps not surprising that metacognition is increasingly often included as a component in models that attempt to understand a diversity of human thoughts and behaviors.

We are of course not the first to argue that metacognition is a fundamental ability with wide-ranging implications. As pointed out by Lempert, Chen, and Fleming (2015), “The ability to accurately appraise one’s uncertainty, known as 'metacognitive' accuracy, is thus crucial for guiding adaptive behavior, particularly when direct feedback from the environment is unavailable.”

So how differently is metacognition defined within and across the various sub-disciplines we have addressed?

Definition

Similarities across disciplines. One of the aims of this article was to present and compare definitions of metacognition from different fields of psychology. From this overview, it seems that most can agree on what metacognition is, broadly speaking. Most definitions either state or imply that metacognition has to do with *awareness* of one's own cognitive activity, that such awareness implies a form of *monitoring* which in turn increases the person's *control* over their own cognitive processes. Whereas this awareness is studied as a more implicit, preverbal or experience-based faculty in some disciplines (e.g., developmental psychology, some aspects of experimental cognitive psychology, neuroscience, and animal research), it is studied as a more explicit, verbal or information-based faculty in sub-disciplines more focused on how metacognition can be applied (e.g., developmental, social, educational and clinical psychology), although a thorough discussion of this is beyond the scope of this paper.

Moreover, there is wide agreement that metacognition has multiple facets, and the distinction between metacognitive knowledge, skills/strategies and experience (Flavell, 1979) is still applied in different domains, suggesting that this distinction is regarded as meaningful and useful. Interestingly, Flavell's fourth facet, "goals (or tasks)", which refers to the objective of the cognitive activity in question, is rarely mentioned explicitly. However, one might argue that a representation of one's goal would always be a necessary component (or premise) of metacognitive regulation. The lack of reference to this facet could therefore be due to its implicit role in metacognitive regulation. Indeed, Flavell was clear that person, task and strategies interact and rely on knowledge of cognition and the monitoring and regulation of cognition. Recent research on implementation intentions … (?)

Another recurring theme is that metacognition is useful, and that the acquisition of metacognitive skills should therefore be encouraged. Most seem to regard metacognition as

an activity that has important functions. In basic developmental, cognitive and educational psychology it is regarded as an integral part of various cognitive activities, for instance problem solving and learning. In those parts of clinical psychology that specifically address metacognition, it seems to be regarded as an important element for psychological well-being. Mental illnesses are understood to involve some kind of maladaptive metacognitive tendencies. Thus, therapy must address those insufficiencies and aim to improve metacognitive regulation, e.g., the ability to stop rumination.

It follows from this that most also seem to regard metacognition as something that, to some extent, develops naturally, can be developed further or learned through experience and reflection, learned, and/or refined. This is the case even though there is also agreement that there are relatively stable individual differences in people's basic sensitivity to metacognitive feelings (Fleming et al., 2012), and also that there is substantial variation in people's metacognitive strategies and knowledge by age, experience, personality, situation and task.

In spite of these differences, most researchers seem to agree that there is sufficient possibility for growth and change in metacognitive abilities, that this process follows some reliable patterns early in life, and that it is meaningful to address both in educational and therapeutic contexts. In fact, educational interventions targeting metacognition do seem to positively influence academic achievement (Dignath et al., 2008; Donker et al., 2014).

Also, after almost 50 years where cognitive therapy has been widely used for a range of psychopathologies, a third wave of cognitive behavioral therapies has emerged, trying to address the limitations in previous treatments (Kahl et al., 2012). Metacognition is a central and useful element in several of these new therapies (Moritz et al., 2014; Moritz et al., 2018; Vitzthum et al., 2014).

Inconsistencies and disagreements across disciplines. *What* is controlled and monitored by metacognition? The focus on what is studied and why varies in the different

perspectives we have presented here. Early childhood studies tend to focus much more on metacognitive activity related to managing human interactions and making accurate predictions about the environment children are learning to navigate. In experimental cognitive psychology, the focus is often on what kind of information-processing antecedents metacognitive feelings are based on (Koriat, 2007). In cognitive neuropsychology, studies focus more on which regions of the brain are involved in metacognitive processing (Fleming, Dolan & Frith, 2012). In personality psychology, the focus is more on individual differences and what that means for the expression of metacognition (Rouault et al., 2018), and in social psychology, the focus is also on moral decisions, and beliefs about other people and their intentions (Frith, 2012; Pfuhl, Haghish & Biegler. 2013). In more applied settings, research in educational psychology focuses more on metacognitive activity that helps people learn and function effectively in learning environments (Dimmitt & McCormick, 2012) while research in clinical psychology focuses more on helping people with their metacognitive activity related to identifying and repairing their dysfunctional beliefs (Matthews, 2015). Finally, animal studies are designed to capture evidence of feelings of knowing (Do I know enough to perform the task?) and evaluation judgements (Did I do the task well enough?) (Hampton, 2009; Kornell, 2014).

Measurement

Across different disciplines, there is large variation in the types of methods used to measure metacognition. These are commonly linked to the guiding definitions typical of the field.

Where research is more focused on awareness or management of implicit, preverbal or experience-based nature of metacognition, methods commonly used include, for example, observation of behaviors such as infant turn-taking and gaze, judgements of knowing based

on implicitly learned information, brain-imaging during feeling of knowing tasks or decision-making, and studies of animal metamemory or information gathering.

On the other hand, where research is more focused on awareness and/or management of explicit, verbal or more information-based aspects of metacognition, methods commonly used involve conscious thought about what one knows. These include interviews and think-aloud procedures, and self-report ratings/questionnaires.

The wide variety in methods used may be taken to indicate that we are perhaps dealing with different subcategories of the same phenomenon, if not outright different phenomena. Therefore, any researcher in the field of metacognition would need to be explicit about their working definition of metacognition and argue for the appropriateness of methodological choice -- using “online” measures that capture knowledge that may not be explicitly available to us, or using “offline” measures that capture what we allegedly have explicit access to through retrospection or reflection.

There is an interesting conundrum here. If our online behaviors or offline reports are about what we think we know about our cognitive processes, such measures should be regarded as reasonable measures of metacognition. Nonetheless, it could be argued that online observations are more telling of what is "really going on". However, if what we *think* is going on varies from what is *observed*, what is ultimately the better measure of metacognition? There is often no one accuracy test that distinguishes "real" or “accurate” metacognition from "fake" or “inaccurate” metacognition. Therefore, some metacognitive beliefs may be more functional and beneficial than others, essential for healthy behavior and development, while others may ultimately prove to be outright dysfunctional or get us in trouble. Hence, the value of measuring the outcomes of metacognitive approaches to learning (more proactive approaches to functional growth) and metacognitively motivated clinical therapies (more reactive approaches to dysfunctions). When researchers can assess performance “accurately”

(in terms of what is adaptive for any given situation), assessment of metacognitive skills may reveal inaccuracies or biases that can be more informative for when and how metacognition can be dysfunctional (Kruger & Dunning, 1999).

This leads us to an important point, namely that metacognitive ratings are not synonymous with the traditional notion of introspection. This was pointed out already by Nelson and Narens (1990), who stressed the fact that the most interesting aspect of metacognitive measures is that they allow us to compare the individual's perception of their own cognitive processes with objective measures of those same processes. This makes it possible to identify when the two correspond and when they deviate. Thus, metacognitive ratings are rarely of interest in and of themselves and should not be taken to accurately reflect cognitive processing. Instead of using people's introspections to draw inferences about how the mind works, then, metacognition researchers deliberately examine how people *think* the mind works and the role that those (faulty or accurate) beliefs play in their cognitive control.

Implications and conclusions

Based on the large variety in research questions, definitions and methodological approaches, one could draw a similar conclusion to Reder (1996), namely that the concept of metacognition has different meaning for different researchers, that some operationalizations have very little in common (Table 1), and that "metacognition" is no longer a unitary concept. When a theoretical concept becomes too broad it also risks losing its explanatory value, or losing some important nuance of the phenomenon.

However, depending on one's view on what should be the minimum requirement of a definition of an "umbrella" concept, a different conclusion could also be drawn — namely that the concept of metacognition is still meaningful and useful. Though Flavell galvanized this field of research within the domain of developmental psychology, it has roots in several fields and has borne fruit in even more. We suggest that the different operationalizations of

metacognition presented in this review all reflect the same class of experience, namely the ability to think about one's own thinking, whether consciously or not. With the wide range of questions/phenomena that metacognition is meant to address within a variety of research fields, it is perhaps most meaningful to think of it as a class of experience or a level of human functioning, rather than a specific mechanism or function, as often specified in educational or clinical settings.

Likewise, a topic we have touched upon in this paper, but not elaborated on, is the relationship between metacognition and neighbouring concepts like theory of mind, self-regulation, , self-efficacy, bodily awareness, and the like. One could argue that the lines between these concepts and metacognition are blurry. We leave that for future studies to address.

In sum, any theoretical explanation or intervention that addresses the "meta"-level of human cognition could potentially benefit from both general knowledge about the very core of metacognition, namely the human ability to reflect upon and let behavior be guided by knowledge about one's own mental states, as well as knowledge of metacognition derived from other psychological disciplines. As in other areas of psychology, differences in focus on the "basic" vs. more "applied" research fields may provide important insights for both practice-informed basic research as well as basic research-informed practice. Without basic research in developmental psychology, cognitive psychology, cognitive neuroscience, personality and social psychology, and animal studies, we might be less systematic in our conceptualizations and research methods than we could be. At the same time, without applied research, we might miss the needs, value and appropriate use of metacognition in order to function well in our everyday (as we grow, learn and lead mentally healthy lives). If we no longer used the umbrella concept of metacognition, this potential advantage may be lost. However, as argued above, the variety of approaches necessitates that researchers be specific

and explicit about their chosen angle in any given study – something that is perhaps easier when we have greater awareness of how it is approached in other fields.

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Footnote

1. We thank an anonymous reviewer for raising this point.

Figure captions

Figure 1. Number of ‘Metacognition/’ records by Classification Code in the PsycINFO database (searched on Ovid, February 11th, 2019).

Figure 2. The upper graph shows the proportion of records in each subdiscipline that mentioned metacognition and either monitor* or control* in the title, abstract, subject headings or key concepts. The lower graph shows the proportion of records in each subdiscipline that mentioned metacognition and either knowledge, strategy*, or experience* in the title, abstract, subject headings or key concepts.

Table caption

Table 1. An overview of how metacognition has been addressed in each of the chosen subdisciplines of psychology.