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Review

Executive function and metacognition: Towards a unifying framework of cognitive self-regulation

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ABSTRACT

Executive function and metacognition are higher-order cognitive processes that undergo steady improvements throughout childhood. They are highly relevant to daily functioning in various domains, including academic achievement. Both concepts have been intensively researched, but surprisingly little literature has sought to connect them theoretically and empirically. In the present review, I elaborate on the similarities between these concepts from a developmental perspective, including the definitions, developmental timetables, factors that lead to changes over time, and relations to academic achievement and intelligence. Simultaneously, the differences between these two domains of cognitive development are discussed. These include, in particular, the relative neglect of quantifying monitoring within research on executive functions and the disregard for the neuropsychological underpinnings of metacognition. Finally, this paper presents several avenues for future research and proposes a possible unifying framework of cognitive self-regulation that integrates executive function and metacognition and may lead to a better understanding of the emergence of cognitive self-regulation in development.

Introduction

One of the major milestones of a child's cognitive development is the ability to intentionally regulate his or her own behavior and thinking. This includes the ability to stop performing an action when asked to do so (e.g., clapping one's hands, talking, kicking the ball) and act in a goal-directed manner (e.g., getting out the right utensils for playing a certain game; remembering to do something at a certain time or place; selecting the best-suited strategy for solving a task). Further striking and far-reaching developments—for both the child and those in his/her environment (e.g., parents, teachers)—include the ability to stay focused despite distractions (e.g., going to fetch an object; finishing a task despite decreasing motivation) and to detect and correct errors.

This literature review focuses on so-called "higher-order cognitive processes," which play an important role in children's development of self-regulating behavior and mental operations. Such processes include the monitoring, steering, controlling, and adapting of "lower- or first-level information processes," such as encoding, storage, and retrieval of information. Two different bodies of the literature will be integrated: that focusing on "executive function" (EF) and that on "metacognition" (MC). In a previous brief report, some practically relevant similarities between EF and MC were outlined (Roebers & Feurer, 2016). The current paper aims to provide a more detailed review of the literature and a critical discussion of the avenues for future research. This review has been organized into two major sections: the first addresses the conceptual and theoretical issues related to EF and MC, while the second focuses on the developmental progression of these concepts, as well as their

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links to other variables and each other. The major aims of the present review are (a) to bring together two distinct bodies of cognitive and developmental literature related to the regulation of behavior and thinking, and (b) to elaborate on the many similarities and few differences between the concepts described therein. It is important to note that this review is not intended to be exhaustive; rather, the content was selected based on its subjective relevance to developmental theory and practice.

Conceptual and theoretical issues

Historical background

In 1971, John Flavell introduced the concept of "*metamemory*," and from the beginning linked it to developmental psychology. In discussing the potential factors that promote memory development in children, he referred to the concept of metamemory as "monitoring and knowledge of (memory) storage and retrieval operations" (p. 277). The essential aspects of metamemorial knowledge, nowadays commonly referred to as declarative metamemory, were described in detail by Flavell and Wellman (1977), and include an individual's knowledge about various person, task, and strategy-related variables. Concerning the procedural aspects of MC, Hart (1967) might have been the first to directly relate monitoring to performance by introducing a calibration curve. Such a calibration approach (still used today in metacognitive research) allows researchers to estimate the degree to which monitoring is commensurate with actual performance; in other words, it enables researchers to assess the realism of on-task monitoring. Calibration curves are determined by plotting subjective estimates of correctness (i.e., monitoring judgments) against the objective proportion of correct responses, revealing either over- or under-confidence in individuals.

Around the same time, Butterfield and colleagues (Butterfield, Wambold, & Belmont, 1973) suggested that memory improvements rely on two main factors: Namely, an individual's spontaneous and conscious access to memory monitoring and a task-unspecific executive control that allows for coordination of memory and memory monitoring. Together, these factors can improve memory performance—if applied in a sensible way during information processing. In a similar vein, Ann Brown (1975) explicitly added the concept of "knowing *how* to know" (i.e., "the ability to monitor and control," p. 146), which allowed a child to deliberately learn and memorize information, as well as to use self-initiated, goal-directed strategies. Later, Flavell (1979) proposed the broader concept of "metacognition" as the constant interplay between metacognitive knowledge, metacognitive experiences (i.e., essentially momentary to longer-lasting monitoring experiences), and metacognitive actions (e.g., selecting the best mode for learning, executing the best-suited strategy).

Conversely, researchers only became interested in *EF* in the late 1980s, with the emergence of various neuroanatomical, neurophysiological, and behavioral approaches to frontal lobe functioning in clinical neuropsychology (Welsh & Pennington, 1988). Initially, heterogeneous sets of behavioral deficits in adult patients with frontal lobe lesions were pooled under the term "executive function." This term captured patients' inability to inhibit a prepotent behavioral response, to mentally represent a plan, and to act in a goal-directed, self-determined, and flexible way in a variety of situations. Despite knowing of the rapid growth of the frontal lobes in primates' brain evolution (Fuster, 2008), researchers underestimated the impact of EF for typical development for a long time. The concept of executive function made a detour via developmental psychopathology before entering the field of developmental psychology: Pennington and colleagues (Pennington & Ozonoff, 1996; Welsh & Pennington 1988), in outlining the pronounced executive deficits in children with developmental disorders (especially those with attention deficit hyperactivity disorder [ADHD]), argued that EF is distinct from other information processing domains. Thus, as a "higher-order cognitive process," EF came to be seen as a primary driving force for typical development. Overall, despite being rooted in different research traditions, EF and MC are both factors now assumed to govern improvements in children's deliberate, goal-directed, and self-regulated information processing (Blair & Diamond, 2008; Kuhn, 1999).

Contemporary conceptualizations

Executive function

In the literature, "executive function" has been defined as a set of heterogeneous, higher-order cognitive processes involved in goal-directed, flexible, and adaptive behavior and the top-down regulation of cognition and behavior, that are particularly triggered in novel, challenging, and complex situations (Miyake et al., 2000). Zelazo (2015) noted that the situations in which top-down regulation through EF is necessary vary on a continuum from purely cognitive challenges (calling for "cool EFs") to motivationally significant situations (calling for "hot EFs"). Based on clinical observations of developmental disorders, the ability to inhibit automated responses and switch mental sets was also included in the concept of EF (Baddeley, 2000; Barkley, 1997). Although most researchers would agree that these different aspects of EF operate together and that a separation of the different processes is mostly impossible (Miyake & Friedman, 2012), separately measuring and investigating the various EF components can nevertheless shed light on differences in developmental timetables as well as the relative importance of the different EF components for various outcomes (Lee, Bull, & Ho, 2013).

Note that there is some conceptual overlap between research on EF and Mischel's framework of "hot" and "cool" "self-control" (Metcalfe & Mischel, 1999) and also with temperament-based approaches to children's self-regulation

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