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Investigating the relationship between self-regulated learning, metacognition, and executive functions by focusing on academic transition phases: a systematic review

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Abstract
The importance of self-regulated learning (SRL) for academic learning and achievement is already well established. In terms of developing a comprehensive understanding of SRL, executive functions (EFs), which are seen as an important influential factor for learning and goal-oriented behavior, should be taken into consideration. Some authors have linked SRL and EF via metacognition (MC), which forms a fundamental component of SRL, and like EF, represents higher-level cognitive processes. Therefore, this systematic review searched education and psychology databases to determine the natural development and current state of research on the three constructs. Academic transitional periods were brought into focus because of their influence on learners' well-being and academic achievement. An evaluation of 30 publications indicated that strong development of simple EFs occurs before the transition from preschool to primary school. Moreover, there is a decrease in the motivational component of SRL and the use of metacognitive SRL strategies during the transition from primary to secondary education but an increase in metacognitive awareness. Simple as well as complex EFs also increase during this transition, with a later developmental peak for complex EF. The transition from secondary to tertiary education is accompanied by positive developments in the cognitive and metacognitive components of SRL, with small increases for simple EFs, and larger increases for complex EFs. In conclusion, the findings suggest there is an early developmental maximum for EFs compared to SRL and MC, which supports the theory that EFs are the foundation for SRL and MC.

Keywords Self-regulated learning · Executive functions · Metacognition · Academic transitions · Developmental trajectories

Introduction

Self-regulated learning (SRL) describes "a process whereby learners activate and sustain cognitions, affects, and behaviours that are systematically oriented towards the attainment of personal goals" (Zimmerman & Schunk, 2011, p. 1). When learners proceed during their educational career, learning processes become more and more self-dependent, and external influences on learning continuously decrease (Taranto & Buchanan, 2020). Research has shown that SRL positively influences academic as well as vocational success (Perry, 2019). Despite its relevance for lifelong learning, SRL is often not optimally fostered within a school context, even though a direct focus on SRL would be highly promising for primary as well as secondary education (De Corte, 2019). Insights on the developmental trajectory and critical phases of SRL development could support the design of effective training programs for different target groups. Essential stages of human development are found during academic transitions, such as those from preschool to primary school, primary to secondary school, and secondary to tertiary (post-secondary) education. These transitions not only bring changes to the learning environment but can also affect personal development, which in turn, influences learning behavior and possibly SRL (Evans et al., 2018).

Research on SRL has mainly taken a pedagogical perspective, with a specific focus on psychology and educational sciences. Adopting a developmental psychological perspective by exploring executive functions (EFs) and their relationship to SRL (Effeney et al., 2013) could help

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to expand research on developmental changes of SRL. The term executive function (EF) is an "umbrella term" for several higher-order cognitive processes (Cirino et al., 2018; Diamond, 2016) that positively influence academic success (Diamond, 2016; Roebers, 2017). Moreover, some authors argue that EF plays an essential role in the execution of SRL skills (Hofmann et al., 2012), which accounts for the positive relationship that has been found between SRL and EF (Effeney et al., 2013; Petersen et al., 2006). This has also been demonstrated in a recent systematic review on the relationship between SRL and EF (authors, submitted). Both SRL and EF correlate with knowledge and control of one's cognitive processes and therefore with metacognition (MC)[1] (Folmer & Sperling, 2016). MC is a highly relevant construct on its own but it is also an important subcomponent of SRL.

In conclusion, this systematic review examines how the constructs of SRL (with a specific focus on MC) and EF are related by focusing on their development. As SRL is seldom analysed from a developmental perspective, a developmental lens was adopted by focusing on different transition phases: from preschool to primary school (ages five to seven), primary to secondary school (ages nine to 14 years), from secondary school to university education (ages 17 to 20 years). It analyses whether and how the developmental trajectories of all three constructs are related and overlap. Moreover, as SRL, MC, and EF are hypothesized to be interwoven, applying this developmental lens to SRL and MC and their relationship to EF can provide new insight into their causal relationship and can help to hypothesize which of the constructs forms the foundation for the others.

Self-regulated learning

Self-regulation is described as the active planning, control, and regulation of one's cognitions, emotions, motivations, and behaviors to achieve a specific goal (Zimmerman, 2000). Within a learning context, self-regulation is more narrowly defined as *self-regulated learning* (Perels et al., 2020). During an SRL process, learners set learning goals independently of external instruction and try to achieve them by planning, controlling, and regulating their learning behaviors (Garner, 2009). Although there exist many different SRL definitions, they all have three components in common (Perels et al., 2020): a *cognitive component* that comprises conceptual and strategic knowledge of learning strategies as well as the ability to use these strategies; a *motivational component* that includes the initiation and maintenance of the learning process through volitional internal (e.g., self-efficacy, Bandura, 1997) and external resources (Hoyle & Dent, 2018); and a *metacognitive component*, which is regarded as the planning, control, and regulation component of the learning process.

MC is a highly relevant subcomponent of SRL (see Boekaerts, 1999), although it is also seen as being a discrete construct. MC comprises personal knowledge about one's cognitive processes as well as the self-regulatory competencies that support using this knowledge in planning, monitoring, and reflection (Dinsmore et al., 2008; Folmer & Sperling, 2016). Following Flavell (1979), MC covers three categories: first, *metacognitive knowledge* is knowledge about persons, tasks, and strategies that is saved in long-term memory (e.g., how to solve a given problem); second, *metacognitive experiences* are conscious cognitive or affective experiences that refer to the learning situation (e.g., not having understood a given text) and are part of metacognitive knowledge; third, *metacognitive regulation* refers to goals and tasks that are attained using metacognitive control strategies or behavior (i.e., the application of metacognitive knowledge). In the context of SRL, metacognitive regulation is especially relevant as it comprises strategies such as planning, monitoring, control, and evaluation.

When describing SRL theoretically, one can distinguish between *component* and *process* models (for a review of SRL models, see Panadero, 2017): One prominent component model, which describes SRL as an ability made of different stable competencies, was proposed by Boekaerts (1999). This model describes three regulation layers (see Fig. 1a). The inner layer (regulation of process modes; cognition) comprises the selection and usage of cognitive learning strategies to control and regulate information processing. The middle layer (regulation of the learning process; metacognition) describes the organization and control of planning, using, and evaluating learning strategies through metacognitive knowledge and metacognitive skills. Within the upper layer (regulation of the self; motivation), learners regulate themselves by selecting their goals and resources and therefore their motivational processes (Boekaerts, 1999). In contrast, process models focus on identifying an optimal learning process and therefore divide learning into different phases. Probably the most recognized and cited process model (see Panadero, 2017) is that by Zimmerman (2000), which describes SRL as a cyclical sequence of planning, performance, and reflection (see Fig. 1b). During the planning phase, learners set individual goals after having performed a task analysis, and afterward, they plan the strategies that best fit this goal. Within the performance phase, learners monitor their cognitive information processing and, if necessary, they vary specific aspects of their learning behavior by adapting the usage of cognitive learning strategies. In the reflection phase, learners judge their performance by comparing the

[1] Metacognition shows conceptual overlap with SRL. We differentiate between procedural metacognition, considered here as comprehensive competence, and the usage of metacognitive strategies during specific learning processes.

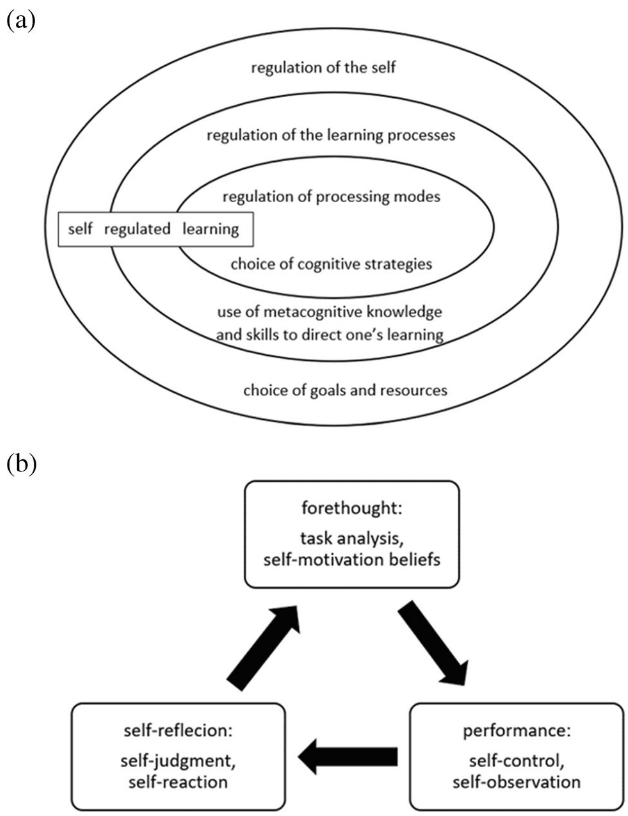


Fig. 1 **a** Three-layered model of SRL (Boekaerts, 1999) and **b** Cyclical model of self-regulation (Zimmerman, 2000)

Fig. 2 Developmental model based on Schunk and Zimmerman (2007)

results of their self-observations with their personal standards or goals; the consequences of optimizing subsequent learning processes can then be drawn (Zimmerman, 2000).

Early development of SRL

Concerning the general development of SRL, Schunk and Zimmerman (2007) present a social-cognitive model comprising four levels (see Fig. 2): during the first *observation level*, when a learner observes someone using and/or describing a competency or strategy, they learn to imitate the behavior (*emulation level*) and use it in a self-controlled way in similar contexts (*self-control level*). Learners evolve into self-regulated learners by adapting the competence or strategy to individual and contextual conditions (*self-regulation level*).

Regarding the age-related maturation of SRL, Hoyle and Dent (2018) argue that SRL development depends on the development of relevant components and constructs belonging to the SRL umbrella term. Therefore, for these authors, SRL development can only be described by examining the developmental processes of single SRL components. A highly relevant requirement for SRL development is the competence to control one's own emotions and behaviors (Perry, 2019). Within this context, two- and three-year-old children first show signs of self-regulated behavior when they resist an immediate reward in return for a delayed bigger reward by inhibiting an impulsive behavior (Mulder et al., 2019). Rapidly evolving verbal competencies support kindergarten children in understanding and expressing their emotions and internalizing rules, strategies, and plans for controlling their behavior (Bronson, 2000). During primary school, internalized speech, as well as improved cognitive functioning such as attentional and informational processing competencies, leads to a deeper understanding of one's own and others' perspectives, wishes, and emotions (Bronson, 2000). An increasing understanding of the relevance of interactions with peers comes along with a stronger awareness of one's self, social comparisons, and the development of internal and external success standards.

Concerning MC, preschool children are capable of using simple regulation strategies within the learning process and reflecting on their cognitions (Chatzipanteli et al., 2014). Through increasing age and accumulated learning experiences gained following school entry, effective learning strategy competencies evolve. Primary school students gain more and more insight into their cognitive processes and how to judge their own competencies, which is why the effortful control and monitoring of attention, strategy choice and usage, and goal setting and planning can further evolve (Bronson, 2000). Primary school students show higher controlling and monitoring competencies of cognitive and problem-solving processes than preschool students (Lai, 2011). Cognitive and metacognitive competencies, as well as SRL behavior, are further improved through increased learning experiences and practice using different learning strategies in differing contexts (Hoyle & Dent, 2018). By the age of twelve, children are able to estimate the effectiveness of different strategies and regulate the time and attention needed for their learning (Lai, 2011). With further development, effective strategies are acquired and used more frequently, and less helpful strategies are used less frequently (Kuhn, 2000). However, the monitoring and evaluation of these

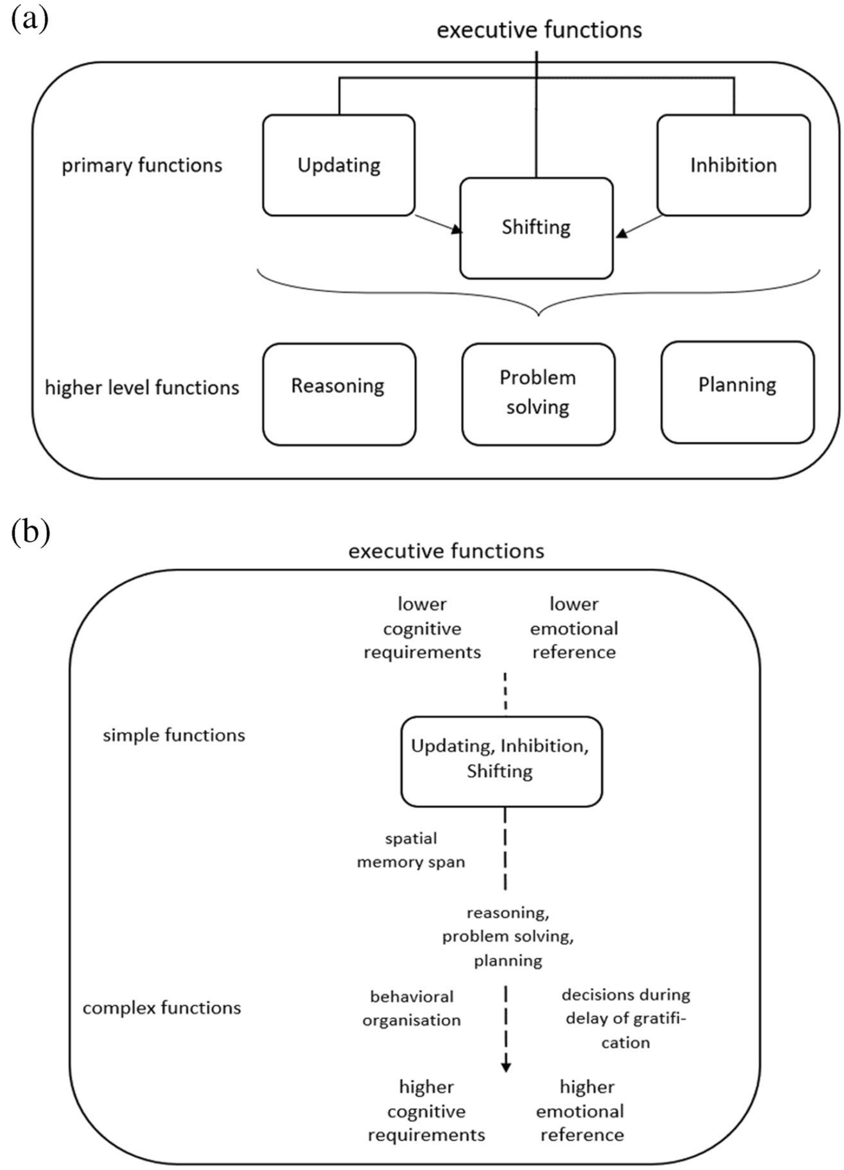


Fig. 3 Schematic (**a**) and extended (**b**) illustrative structure of EF. *Notes.* **a** The description is based on EF models by Miyake et al. (2000) and Diamond (2016). **b** The dotted arrow represents the link between the two continual models. Processes on the left correspond to a model by Luciana et al. (2005); processes on the right correspond to a model by Prencipe et al. (2011); processes placed on the arrow integrate the models by Miyake et al. (2000) and Diamond (2016)

strategies and the accompanying cognitive processes seem to slow down and may not even be fully developed in adulthood (Lai, 2011).

In summary, when students transition to secondary school, they have already established the foundation for SRL during preschool and primary education. However, key to strengthening and expanding their skillsets further are experiences throughout secondary and tertiary education. MC also shows important developments during primary education and continues to improve as students transition to secondary schooling. As with SRL, continuing experiences up to and beyond the transition to tertiary education are needed to further enhance MC.

Executive functions

Due to differing and inconsistent definitions and processes, the term *executive function* (EF) constitutes an "umbrella term" for a range of individual executive functions (Cirino et al., 2018; Welsh, 2001). In this review, EF is understood to be a collection of higher-ranked neurocognitive processes that control cognitive processing as well as behavior, and that enable independent and goal-oriented behavior (Garner, 2009; Petersen et al., 2006). They form the basis of competencies such as goal setting, planning, and the use and adaption of effective strategies.

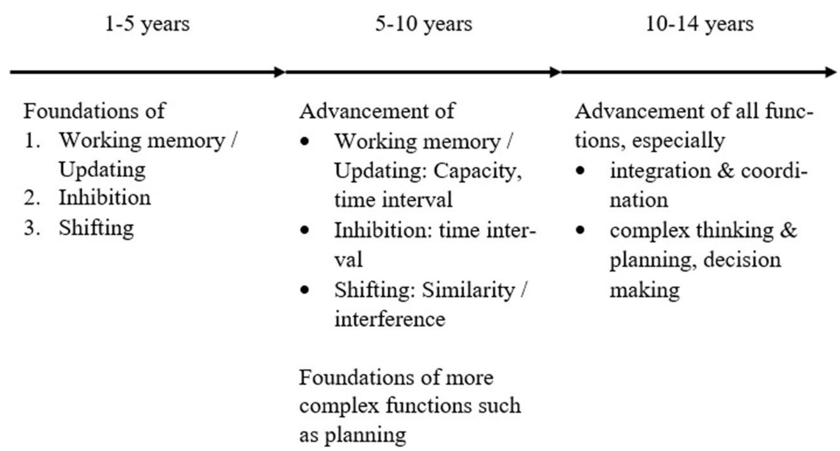


Fig. 4 Developmental trajectory of executive function components during childhood and adolescence. *Note.* This overview is primarily based on Welsh (2001) with additions from Hoyle and Dent (2018)

Three executive core processes are typically distinguished (Miyake et al., 2000; see Fig. 3a). *Updating* or *working memory* refers to the actualization and monitoring of task-relevant information so that it can be saved in working memory and adapt over time. The effortful *inhibition* of dominating or automatized reactions is another central executive process that helps to suppress behaviors such as motoric or verbal answers and enables individuals to focus on a certain goal and ignore distracting stimuli (Diamond, 2016). As Fig. 3a shows, the flexible change between different tasks and/or associated cognitive representations and behaviors is the third executive function: *shifting* or *cognitive flexibility*. This component is important for overwriting information and processes that are no longer relevant and activating new information and processes. Together, these three EF components build the basis for complex and higher-ranked functions such as reasoning, problem-solving, and planning (Diamond, 2016).

Due to the diversity of the individual EF components that sit with the global EF construct, some authors strive to systematically order them. Luciana et al. (2005), for example, examined different tasks that could be arranged on a continuum from simple to complex EF requirements. The authors name spatial memory span as a simple function with relatively low cognitive requirements, whereas they claim that behavioral organization during spatial selfordered search tasks is a complex function with relatively high cognitive requirements. Prencipe et al. (2011) follow a similar rationale, but their differentiation is not based on the complexity of functions but on their dominating involvement in different processes. While "cold" EFs, such as updating, are particularly responsible for abstract processes, "hot" EFs, such as decisions made during delay of gratification situations, respond more to affective and motivational stimuli. Therefore, cold EFs on a cognitive–rational level can be regarded as the regulation basis for hot EFs (Hofmann et al., 2012). An integration of both perspectives could be reached if hot EFs were seen as more complex than cold EFs due to their emotional relevance, as seen in Fig. 3b. Moreover, both perspectives assume different developmental trajectories for the single components. While simple EFs or cold EFs have relatively low emotional reference and reach their developmental peak earlier and remain stable, complex EFs or hot EFs can further evolve over a longer time frame (Luciana et al., 2005; Prencipe et al., 2011).

Early development of individual EF components

As mentioned above, some EF components build on one another and not all show similar developmental trajectories. Several studies hint at component-specific trajectories showing a common trend; many quantitative developmental milestones of basic functions are settled in childhood, whereas development in adolescence and early adulthood causes small qualitative changes in EF components. The development of EFs is often examined within the context of frontal brain region development, especially the prefrontal cortex (Hoyle & Dent, 2018). Accordingly, Welsh (2001) describes three phases for the development of EFs (see Fig. 4).

The first phase comprises the period from the first year of life to age five; it covers the beginning of working memory and updating development, and is followed by the first signs of inhibition and cognitive flexibility (Welsh, 2001). Garon et al. (2008) suggest that basic competencies evolve until the age of three, laying the cornerstone for quantitative developments in the following years. Regarding the shifting component, a delayed developmental trajectory is assumed due to its dependence on the updating and inhibition components (Hoyle & Dent, 2018). Working memory capacity evolves with age so that children can keep more information units within working memory over a longer time period; they are therefore better able to manipulate information in the updating component (Garon et al., 2008). This second phase, which lasts from ages five to ten, is the time period during which children learn to inhibit automatic reactions and reactions associated with incentives (Welsh, 2001). Following the development of updating and inhibition, children are increasingly able to switch between tasks that are similar or even in conflict with one another (Garon et al., 2008). Within the third phase from ages ten to 14 and beyond, many EF components show further improvements until they approximate the level of adults (Welsh, 2001). A long-term developmental trajectory until adulthood is especially assumed for the integration and coordination of different information units and processes, which are relevant for more complex cognitive and planning processes as well as decision-making behavior (Roebers, 2017). To reiterate, the fundamental components updating, inhibition, and shifting are already very well developed when students transition to secondary education. Within this time frame and beyond, the developmental focus seems to be on more complex EFs, with these mainly developing in early adulthood during the transition to tertiary education.

Relationship between SRL, MC, and EF

The three SRL, MC, and EF constructs are interwoven as they all focus on the goal-oriented monitoring of an individual's cognition and behavior to help them react and behave appropriately within a given environment (Dinsmore et al., 2008; Effeney et al., 2013). Nevertheless, and possibly because of this connection, it is not clear exactly how the constructs are related. Garner (2009) sees EF as a group of general competencies that support SRL and its development and are correlated with different SRL components. In line with this, Blair and Ursache (2011) assume that EF is the foundation for regulating one's own actions and that its development in early childhood lays the grounding for the core processes of planning, monitoring, and controlling learning behavior. Bailey and Jones (2019) also suggest that EF builds up core processes, resulting in three regulation domains that can be understood as (meta)cognitive and motivational SRL competencies. Hofmann et al. (2012) assume that working memory processes within SRL contexts represent learning goals and goal-related strategies and classify incoming information as goal-relevant or irrelevant. The capacity for engaging in this type of processing can be decreased by competing goals and wishes, or external distractions. In this case, inhibitory control must highlight goal-relevant information and suppress the activation of goal-irrelevant stimuli (Hofmann et al., 2012).

On a behavioral level, impulsive or usual behavior that has no goal-congruent effect must be inhibited (Hoyle & Dent, 2018). Based on Diamond's (2016) model, SRL is especially based on the inhibitory component as self-regulation primarily has a controlling and regulating function. Cognitive flexibility is relevant within the learning process if the learner wants to switch from a less optimal to a more helpful strategy or between short- and long-term goals (Hofmann et al., 2012). The higher-order functions of problem-solving and planning that result from the three basic EF components are seen as the foundation for SRL (Diamond, 2016; Perry et al., 2018). Within component and process models of SRL, EF seems to be relevant for information processing by using cognitive learning strategies during planning and reflection before and after the active learning phase. In line with this assumption, Effeney et al. (2013) suggest that SRL is a context-specific application of EF, having found that self-reported EF can predict self-reported SRL and the prediction was stronger with increasing age. Metacognitive processes can be found in the monitoring and control of the active learning phase as well as in the whole SRL cycle, such as during the planning and reflection phases. A recent review of the relationship between SRL and EF shows moderate correlations between the constructs (author, submitted).

Correlational analyses support the assumption that SRL, MC, and EF are related constructs (Effeney et al., 2013). EF and MC seem to be connected through their common involvement in SRL processes (Folmer & Sperling, 2016), and MC can be seen as the "conceptual middle ground between EF and SRL" (Effeney et al., 2013; p. 788). Both EF and MC are seen as higher-order cognitive control processes that enable adaptive and flexible actions. Due to their similar definitions and the assumed interaction between them, the differentiation of both constructs has been almost impossible (Roebers, 2017). Regarding the planning and performance phases of the SRL process, for example, it is not clear which proportion of the total process is influenced by which EF component. The entanglement of the three constructs is also obvious in a study by Cirino et al. (2018), who found a common second-order EF factor with five first-order factors, two of which were SRL and MC. In general, MC can be seen as the link between SRL and EF, especially when speaking of procedural MC, such as monitoring and control processes. Regarding the development of SRL and MC, it is evident that both constructs share common features, such as the role of the social environment (Hoyle, & Dent, 2018). This is also important for the development of EF, but neurocognitive changes predominate in the early development of this construct. A fundamental milestone for the development of all three constructs is the competence to inhibit goal-irrelevant impulses as this is responsible for emotional self-control (Hoyle & Dent, 2018), as well as delay of gratification, which is viewed as the first sign of self-regulation in toddlers (Mulder et al., 2019). In general, it is not totally clear how SRL, MC, and EF are interrelated but based on previous findings and theoretical assumptions, it seems likely that EF provides the grounding for SRL and that SRL is a context-specific application of EF.

The relevance of academic transition phases for learning

SRL is highly relevant for succeeding in academic contexts (Schunk & Greene, 2018) while educational settings themselves foster the development of SRL competencies. Nevertheless, academic trajectories are not constant and transition phases especially comprise a lot of changes. The first and maybe most drastic academic transition is from preschool to primary school and occurs at around five to seven years of age. Research has shown that a successful transition to primary school is linked to students' future success (Pianta & Cox, 2002) and that parental involvement and support as well as teachers' characteristics are relevant to the student adaptation process within the first year of primary education (Correia & Marques-Pinto, 2016). In addition, social skills, such as respecting rules and the play/work of other children, are seen as central to the smooth transition to primary school (Besi & Sakellariou, 2019). Moreover, self-regulation acts as a mediator between teacher–student conflicts and subsequent school adjustment (Li & Lau, 2018).

The second academic transition is from primary to secondary school and occurs at around ten to 13 years of age, depending on country and federal standards. Whereas in Germany, most students transition to secondary school (fifth grade) at the age of ten, this transition happens at eleven years of age at the earliest in the United States (Organisation for Economic Cooperation and Development [OECD], 2020). This academic stage is often seen as a phase of upheaval comprising many changes to environmental and individual factors. Regarding the environment, the transition to secondary school comes with larger schools and more classmates, as well as frequently changing teachers. Research has shown that peer relationships play a crucial role in mastering this critical academic transition. In a study by Waters et al. (2014), a high level of perceived peer support was the strongest predictor (as compared to school and family support) of students' expectations of an easy transition. In general, good peer relationships are critical for higher-level academic achievement, especially in early adolescence (Juvonen et al., 2012). Kiuru et al. (2020) examined the transition from primary to secondary school with regards to the quality of interpersonal relationships (parents, peers, teachers) and school well-being, including academic achievement, finding that high-quality relationships result in higher academic achievement through improvements in school well-being. Besides peer relationships, differing expectations from teachers and parents, a higher value placed on academic achievements, and greater competition within classes can be challenging for students (Evans et al., 2018). Environmental factors can also influence individual factors, such as social standards, academic self-concept, and learning behavior (Evans et al., 2018). In line with this, Robbers et al. (2017) found a decrease in motivation and deep informational processing that was present not only during the transition from primary to secondary school, but also one to two years before the transition and until the second year of secondary school. The aforementioned factors all reflect relevant SRL components and therefore have a significant effect on the development of SRL during the transition phase.

The transition from secondary school to college is also characterized by many (comparable) changes; college students need to be more independent and self-organized in their learning behavior than in school. Moreover, the new context combines differing teaching and learning content and new fellow students and can increase insecurities (Kyndt et al., 2015). A study by Wei et al. (2005) showed that college freshmen with attachment avoidance and attachment anxiety also lacked social self-efficacy and so experienced loneliness and depression within their first year of college. In general, peer interactions can enhance academic adjustment and transition experiences during this critical period (Owusu-Agyeman & Mugume, 2023). The significant influence of peer relationships also has been found for online social interactions, with deviant content posts by social network "friends" predicting lower grades and institutional attachment in first-year college students (Mikami et al., 2018). Besides these aforementioned challenges, the new learning environment can also increase motivational processes as students have more influence on their learning content and processes making SRL highly relevant (Kyndt et al., 2015). Vosniadou (2020) argues that although SRL has a significant influence on motivational and achievement differences between college students, most do not have adequate knowledge about appropriate strategies for delivering high-level independent learning behavior expectations when entering college.

Aim of the present review

Based on the relevance of academic transition phases for the well-being and learning behavior of students, the present systematic review aimed to generate new insights into the development of SRL and MC within these phases. By comparing the development of SRL and MC to that of EF within these phases, we aimed to draw conclusions about the nature of the relationship between SRL, MC, and EF and enrich previous findings on this issue. Due to the age periods of the transitions from preschool to primary school, primary to secondary school, and secondary school to college, the present review focuses on individual developmental trajectories in early to middle childhood, middle to late childhood, and adolescence. Concerning SRL, a developmental perspective was taken because previous research has mainly focused on interventions; therefore,

Table 1 Search terms

Topic	Label	Search term
SRL	n1	AB (self-regulated learning OR srl) AND (AB (development OR developmental stages OR trajectory) OR AB (elementary school OR primary school OR school age) OR AB (adolescence OR young adulthood OR high school) OR AB (higher education OR college OR university))
MC	n2	AB (metacognition) AND (AB (development OR developmental stages OR trajectory) OR AB (elementary school OR primary school OR school age) OR AB (adolescence OR young adulthood OR high school) OR AB (higher education OR college OR university))
EF	n3	AB (executive function OR executive functioning) AND (AB (development OR developmental stages OR trajectory) OR AB (elementary school OR primary school OR school age) OR AB (adolescence OR young adulthood OR high school) OR AB (higher education OR college OR university))
SRL, MC, EF	n4	(self-regulated learning OR srl) AND (executive function OR executive functioning) AND metacognition AND (development OR developmental stages OR trajectory)
EF subcomponents, relationship SRL, and EF	n5	(inhibition AND (SRL or self-regulated learning)) OR ((working memory OR updating) AND (SRL or self-regulated learning)) OR (switching AND (SRL or self-regulated learning))
Academic transition phases	n6	AB (self-regulated learning OR SRL OR metacognition OR executive function OR executive functioning) AND AB (transition OR school transition)
Transition to primary school	n7	AB ((self-regulated learning OR SRL) OR (executive function OR executive functioning) OR metacognition) AND AB (development OR developmental stages OR trajectory) AND AB (preschool OR kindergarten OR elementary school OR primary school)

there is relatively little knowledge on the development of SRL within the identified age periods and especially within these academic transition phases. Although it is assumed that the fundamental developmental phases of EF lie in early childhood, there are signs of its continual development until late adolescence. Based on the conceptual overlap of the three constructs (SRL, MC, and EF), the developmental trajectories were examined individually as well as in combination. This joint focus is rare in previous research, and even when executed, such research has only examined two of the three constructs. By taking a three-pronged approach and a developmental perspective, we aimed to uncover the interplay between these constructs.

Method

Search terms

Based on the theoretical aim of the study as well as on a first random search, we collected search terms and keywords upon which the systematic literature search was based (see Table 1). As we aimed at investigating the development of the three constructs in general without considering specific components, the search terms were phrased in a general way.

Since the review comprised three different constructs, we conducted a differentiated search for articles on the development of each construct (Table1, Labels n1–n3). To cope with the conceptual overlap in the three constructs, a further search simultaneously collated articles on the development of all three constructs (Table 1, Label n4). Label n5 considered the relationship between the two main concepts SRL and EF as well as the fact that EF is often referred to by its three main functions (updating, inhibition, shifting). Label n6 covered the focus on academic transition phases. To incorporate the transition into formal primary schooling, Label n7 was added to the search. The search terms were applied to the abstract of each publication, except those for Labels n4 and n6, which were not restricted in the hope of discovering additional publications.

Inclusion and exclusion criteria

To be considered for the systematic review, publications had to fulfill the following criteria:

- *Focus on the development of SRL, MC, and EF, especially during academic transition phases*. The search results were classified into preschool–primary transition, primary–secondary transition, and secondary–tertiary transition based on the relevance of these transitions for construct development.
- *Explicit information on school transitions within the given sample*. As mentioned above, the age of transition from primary to secondary school varies from country to country. If there was no information on the school transition age, the relevant age period was assessed following OECD (2020). Studies were excluded if they combined before and after academic transition students into one sample group. We focused on three age periods (five to seven years, nine to 14 years, and 17 to 20 years) to guarantee that the examined samples covered the

school transition time points and ideally, the year before and the year after the transition. This was predicated on the findings of Robbers et al. (2017), who suggest that motivational decreases and increases in surface information processing evolve one year before and one year after transitioning to secondary school, respectively. A similar pattern can be hypothesized for the transition from secondary school to university (Vosniadou, 2020). Regarding the secondary–tertiary transition, only studies with a discrete consideration of first-year college students fulfilled the age period requirement. We excluded studies in which students covering a wider age range before and after an academic transition were evaluated together as one group, as this would diminish the informative value.

- *Focus on general behavioral development and samples that were not restricted due to special criteria*. Studies were systematically excluded if they focused on development in specific populations, such as in children with learning disabilities or ADHD. In addition, we omitted intervention studies as the term "development" in this context does not refer to chronical development but to the development of competencies due to external support.
- *Accessibility to full-text at the time point of the literature search*.

Search strategy

To minimize missing studies due to publication practice we searched both APA PsycInfo and ERIC via EBSCO-Host. We considered all publications until and including August 2022, identifying 13,945 studies. To refine the search results, we omitted publications that were not written in English or German or that were not published in peer-reviewed journals. Studies published in German were included to broaden the possible search results. According to the above-mentioned criteria, the eligibility of the remaining 9,897 search results was judged at the abstract or full-text level by the second author; 25 publications were ultimately retained for systematic review. Inspection of the reference lists in these publications (Siddaway et al., 2019) revealed five more relevant studies, which gave 30 in total. All the studies were published in English. Figure 5 presents a schematic overview of the review process (according to the PRISMA statement, Page et al., 2021), and Tables 2 and 3 present background information on the selected studies. As the studies focused on different aspects of SRL, MC, and EF, and therefore did not use coherent measuring methods, the analysis was based on a qualitative summary of the results.

Results

Development during the preschool to primary school transition

Self-regulated learning

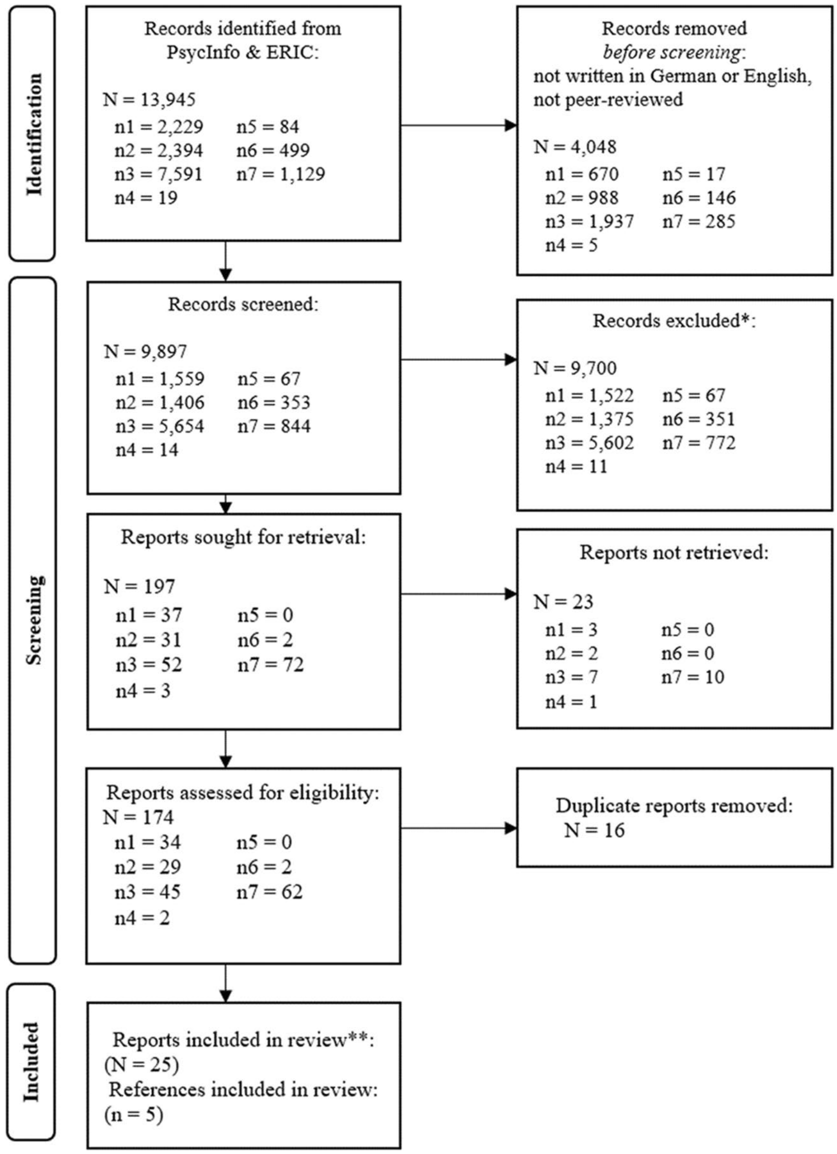
With regards to self-regulated learning, our search yielded no results for the transition from preschool to primary school; therefore, we were unable to present any results on this transition.

Executive function

The presentation of the development of EF results is oriented on the continuum models of Prencipe et al. (2011) and Luciana et al. (2005) that systematically order EF components on a continuum from simple to complex EF requirements (see Table 2 for overview of included studies). For the *updating* component, Matte-Gagné et al. (2018) found a quadratic model for the development of working memory (measured by a backward span task) with a significant decrease in the rate of growth. They interpreted the finding as a rapid development of working memory in preschool and the very first years of primary school that decelerates over time and levels off at about Grade 3. This is in line with the findings of Vandenbroucke et al. (2016), who revealed high increases in working memory capacity within a longitudinal study that focused on preschool and the first year of primary school. In relation to achievement, Kim et al. (2021b) found that working memory in preschool predicted achievement in first grade (but with a small effect size).

Regarding the *inhibition* component, Guy et al. (2012) found a linear developmental trend for auditory and visual inhibition using a cross-sectional comparison of three- to six-year-old children. Six-year-olds showed better performance than three-year-olds in all the variables of interest with moderate to high effect sizes. The authors concluded that there is "a period of intense developmental change between 3 and 5 years of age" (p. 533), i.e., before school entry. In contrast, Vandebroucke et al. (2016) only found a small improvement in inhibition between the ages of five and six. Gerstadt et al. (1994) also found a continuous age-related increase in the percentage of correct responses, but there was almost no further improvement in the decrease in response latency after 4.5 years of age. Matte-Gagné and colleagues (2018) found a consistent increase in inhibitory accuracy in a longitudinal study while children with better initial performance showed slower growth rates. McKay et al. (2022) compared same-aged children that

Fig. 5 Schematic overview of the review process. *Note.* * Based on applying the inclusion and exclusion criteria at the title and abstract levels. ** Based on applying the inclusion and exclusion criteria at the full text level. Labels n1–n6 refer to the topic related search terms (see Table 1 for label information)



enrolled in primary school or that stayed in preschool in a longitudinal design using brain activation data. They found a significant increase in accuracy for children that entered primary school but an insignificant increase for children that stayed in preschool.

Concerning the *shifting* component, Matte-Gagné et al. (2018) uncovered a linear model for the development of this component, while children with better initial performance values showed slower growth rates. In line with this, moderate improvements in fluency tasks have been found between the ages of five and six (Vandebroucke et al., 2016). For academic achievement, Kim et al. (2021b) found that cognitive flexibility in preschool predicted achievement in first grade (with a small effect size). Kim et al. (2021a) used the Head-Toes-Knees-Shoulder (HTKS), which measures updating, inhibition, and shifting. In a longitudinal study, the authors compared same-aged children that had reached the age cut-off for entering preschool and later on transitioned to primary school with children that had not reached this cut-off and did not transition to preschool and later on to primary school. They found a positive effect of preschool on HTKS task performance (small effect size) but not for first-grade students. However, the study was conducted in the United States, where preschool already represents a formal schooling environment.

Development during the primary to secondary school transition

Self-regulated learning

The presentation of the development of SRL results is divided into the three SRL components described by

Table 2 Overview of studies on executive functions

Author (Year)	Nation	Dependent value(s)	Transition phase [a]	Participants [b]	Academic transition between grades (age) [c]	Main results [d]
Anderson et al. (2001)	Australia	Updating / working memory; Inhibition / goal setting / problem solving; Shifting	PS	9–10 vs. 11–12 vs. 13–15 vs. 16–17 years ($n = 138$ (69), range 11–17.11 years)	Grades 5 or 6 (ca. 11 years) to Grades 6 or 7 (ca. 12 years)	No significant differences in updating; 11-year-olds poorer problem solving than 15–17-year-olds; poorer planning for 11-year-olds than 12+-year-olds; 11-year-olds poorer performance than 14-year-olds, and 11–13-year-olds poorer than 15-year-olds in working memory / shifting
Brocki and Bohlin (2004)	Sweden	Inhibition; Updating / working memory	PS	6–7.5 vs. 7.6–9.5 vs. 9.6–11.5 vs. 11.6–13.1 years ($n = 92$ (45), range 6–13.1 years)	Grade 6 (12 years) to Grade 7 (13 years)	Better working memory for 11–13-year-olds than younger; 7.6–9.5-year-olds poorer inhibition than 9.6–11.5-year-olds; 11–13-year-olds better working memory than all younger groups
Conklin et al. (2007)	USA	Updating / working memory; behavioral organization	PS	9–10 vs. 11–12 vs. 13–15 vs. 16–17 years ($n = 117$, range 9–17 years)	Grades 5 or 6 (ca. 11 years) to Grades 6 or 7 (ca. 12 years)	Working memory poorer for two youngest groups and better for oldest group compared to middle groups; behavioral organization poorer for 9–10-year-olds, better performance for older than younger groups with increasing difficulty
Crone and van der Molen (2004)	Netherlands	Decision-making	PS/ST	Experiment 1: 6–9 vs. 10–12 vs. 13–15 vs. 18–25 years ($n = 242$ (142), range 6–25 years) Experiment 2: 7–8 vs. 11–12 vs. 15–16 years ($n = 89$ (42), range 7–16 years)	Grade 6 (11 years) to Grade 7 (12 years)	Experiment 1: better decision-making improvement for two oldest groups with best performance for oldest group; Experiment 2: better improvement for oldest group
Gerstadt et al. (1994)	USA	Inhibition	PP	partially longitudinal: ages 3.5–7 years in 6-months-steps ($n = 160$)	preschool towards Grade 1 (ca. 6 years)	Correct performance improved significantly with age; response latency decreased significantly with age, primarily between 3.5 and 4.5 years

Table 2 (continued)

Author (Year)	Nation	Dependent value(s)	Transition phase [a]	Participants [b]	Academic transition between grades (age) [c]	Main results [d]
Guy et al. (2012)	Canada	Inhibition	PP	3 vs. 4 vs. 5 vs. 6 years ($n=68$ (34))	preschool towards Grade 1 (ca. 6 years)	Linear effect of age; significantly better response accuracy across visual and auditory task for 6- compared to 3-year-olds, significantly better auditory response accuracy for 4- compared to 3-year-olds; 3-year-olds more incorrect responses than all other age groups
Hooper et al. (2004)	USA	Updating / working memory; Inhibition; Decision-making	PS	9–10 vs. 11–13 vs. 14–17 years ($n=145$ (79), range 9–17 years)	Grades 5 or 6 (ca. 11 years) to Grades 6 or 7 (ca. 12 years)	Continuous improvements in updating with higher age; better inhibition with higher age; oldest group better improvement in decision-making than youngest group
Injoque-Ricle et al. (2014)	Argentina	Behavioral planning	PS	6 vs. 8 vs. 11 vs. 13 years ($n=270$ (157), range 6–13 years)	Authors: 13-year-olds in secondary education, Grade 6 (11 years) to Grade 7 (12 years)	Continuous improvement across age groups ($\eta^2=0.31$), with increasing difficulty; better performance for oldest group
Kalkut et al. (2009)	USA	Shifting	PS/ST	8–9 vs. 10–11 vs. 12–13 vs. 14–15 vs. 16–17 vs. 18–24 vs. 25–30 years ($n=649$ (347), range 8–30 years)	Grades 5 or 6 (ca. 11 years) to Grades 6 or 7 (ca. 12 years)	Improvements across age span, especially between the four youngest groups
Kim et al. (2021a)	USA	Flexibility / shifting	PP	Early Childhood Longitudinal Study, Kindergarten Class of 2010–2011 (ECLS-K:2011) spring of last preschool year (T1), fall (T2) and spring of first grade (T3) ($n=18{,}174$; mean range 73.4–85.3 months)	authors: preschool towards first Grade (ca. 6 years)	Improvements in working memory ($\beta=0.19$ / 0.08) and flexibility ($\beta=0.12$ / 0.14)

Table 2 (continued)

Author (Year)	Nation	Dependent value(s)	Transition phase [a]	Participants [b]	Academic transition between grades (age) [c]	Main results [d]
Kim et al. (2021b)	USA	Inhibition; Flexibility / shifting; Updating / working memory	PP	Longitudinal: 3 years in autumn and spring; children who reached or did not reach the cut-off for the last year of preschool resp. first grade of primary school (mean age T1 = 4.62 / 5.27)	authors: preschool towards first Grade (ca. 6 years)	Children who reached the cut-off for last year of preschool performed better than children who did not reach the cut-off ($f^2 = 0.08$), both groups improved from autumn to spring; children who reached the cut-off for first grade performed better than children who did not reach the cut-off ($f^2 = 0.11$), both groups improved from autumn to spring with children who did not reach the cut-off showing bigger improvement ($f^2 = 0.03$)
Luciana et al. (2005)	USA	Updating / working memory; Monitoring and organization	PS/ST	9–10 vs. 11–12 vs. 13–15 vs. 16–17 vs. 18–20 years ($n = 133$ (76), age range 9–20 years)	Grades 5 or 6 (ca. 11 years) to Grades 6 or 7 (ca. 12 years)	Working memory poorer for the two youngest groups compared to older groups ($\eta_p^2 = 0.06$ to 0.37); poorer organization for two youngest groups, better organization for 16–17-year-olds than younger groups ($\eta_p^2 = 0.28$)
Matte-Gagné et al. (2018)	Canada	Inhibition; Updating / working memory; Shifting	PP	Longitudinal: last year of preschool vs. first vs. second vs. third grade ($n = 106$ (60), mean range = 72–105 months)	Authors: preschool towards first Grade (ca. 6 years)	Inhibition accuracy followed a random linear model indicating continuous increase; working memory: performance followed a fixed quadratic model with decelerating growth; shifting: performance increased following a random linear model
McKay et al. (2022)	UK	Inhibition	PP	Longitudinal: same aged children in kindergarten, 40 proceeded into first grade, 40 remained in kindergarten for the following year ($n = 80$ (39), mean range = 53.5–65.5 months))	Authors: preschool towards first Grade	Children in first grade showed significant performance increase in between the time-points, children remaining in kindergarten showed no significant increase

Table 2 (continued)

Author (Year)	Nation	Dependent value(s)	Transition phase [a]	Participants [b]	Academic transition between grades (age) [c]	Main results [d]
Prencipe et al. (2011)	Canada	Updating / working memory; Inhibition; Decision-making	PS	8–9 vs. 10–11 vs. 12–13 vs. 14–15 years ($n = 120$ (52), range 7.98–15.88 years)	Grade 6 (11 years) to Grade 7 (12 years)	8–9-year-olds poorer updating than older groups; poorer inhibition for 8–9-year-olds than older groups; better decision making for 14–15-year-olds
Pureza et al. (2013)	Brazil	Updating / working memory; Inhibition, attention, and processing	PS	6–7 vs. 8–10 vs. 11–12 years ($n = 90$ (53), range 6–12 years)	Grade 5 (10 years) to Grade 6 (11 years)	Improvements in updating across age ($\eta^2 = 0.23$); poorer inhibition for youngest compared to oldest group ($\eta^2 = 0.09$ to 0.30)
Taylor et al. (2013)	England	Strategy generation, Planning	ST	17 vs. 18 vs. 19 years ($n = 98$ (77), range 17.0–19.8 years)	Secondary to tertiary schooling	Better strategy generation for 17-year-olds than 18-year-olds
Taylor et al. (2015)	England	Inhibition rule detection, strategy generation, planning, concept formation	ST	17 vs. 18 vs. 19 years (repeated measure after 12–16 months) ($n = 58$ (47), range 17–20 years)	Author: 17- and 18-year-olds studying for final exams, 19-year-olds university students	Improvements in inhibition and rule detection from T1 to T2 for 18- and 19-year-olds; improvements in strategy generation for 17-year-olds and better performance than 18-year-olds; 19-year-olds better planning at T2; decline in concept formation at T2
Vandenbroucke et al. (2016)	Belgium	Updating / working memory; Inhibition, flexibility / Shifting	PP	Longitudinal: kindergarten ($n = 107$, mean age $= 5.98$ years) and end of first grade ($n = 89$, mean age $= 6.95$)	Authors: preschool towards first Grade (6 years)	Children showed improvements in all EF measures ($0.05 < d < 1.20$)
Visu-Petra et al. (2007)	Romania	Inhibition; Planning; Shifting, category generation, monitoring and control	PS	5 vs. 6 vs. 7 vs. 8 vs. 9 vs. 10 vs. 11 vs. 12 ears ($n = 485$ (234), range 7–12 years)	Grade 4 (10 years) to Grade 5 (11 years)	6-year-olds same inhibition as 11-year-olds; 7-year-olds same planning as 12-year-olds; no differences in shifting / monitoring / control between 10–12-year-olds

Table 2 (continued)

Author (Year)	Nation	Dependent value(s)	Transition phase [a]	Participants [b]	Academic transition between grades (age) [c]	Main results [d]
Wu et al. (2011)	Hongkong	Updating / working memory; Inhibition; planning; Shifting	PS	7–8 vs. 9–10 vs. 11–12 vs. 13–14 years ($n=185$ (82), range 7.0–14.11 years)	China: Grades 5 or 6 (ca. 12 years) to Grades 6 or 7 (ca. 13 years)	7–8-year-olds poorer updating than 9–10-year-olds, which are worse than 11–12-year-olds; 13–14-year-olds better inhibition than 7–10-year-olds, 11–14-year-olds better than 9–10-year-old; 11–12-year-olds better shifting than younger groups ($\eta_p^2=0.09$ to 0.40)

[a] PP = preschool-primary transition, PS = primary-secondary transition, ST = secondary-tertiary transition. [b] n = number of participants (number of female participants), age range. If data points are missing, they were not reported in the publication. [c] Grades at which the transition from primary to secondary schooling usually occurs. Information following OECD (2020) unless stated otherwise. [d] Effect sizes are as reported in original studies

Boekaerts (1999): cognition, metacognition, and motivation. For the *cognitive component*, we could not identify any results, i.e., none of the studies reported changes in cognitive learning strategies. Regarding the *motivational component*, research consistently demonstrates negative development during the transition phase (see Table 3 for overview of included studies). Effeney et al. (2013) showed that learners from the age of 10.6 to 12.5 years show higher self-motivation values than older students and that scores on a self-motivational scale decreased with age (with moderate to high effect sizes). Similar results were found by van der Veen and Peetsma (2009), as students at the beginning of the first year of secondary education reported more SRL behaviors than they did one year later, especially regarding the delay of gratification, which is seen as belonging to the motivational component of SRL. This negative development of motivation is supported by findings of a decrease in self-efficacy beliefs regarding SRL strategies; from the fourth to the seventh grades there is a high loss of confidence in one's own SRL behaviors, which stabilizes in the eighth grade (Pajares & Valiante, 2002). This decrease in self-efficacy is supported by Usher and Pajares' (2008) research, which demonstrated that primary school students show higher self-efficacy beliefs than students in their first year of secondary education.

Concerning the *metacognitive component*, Effeney et al. (2013) found a decrease in learner goal setting and planning from 10.6 to 12.5 years; younger students scored higher than older students (with a low effect size). In contrast, a study on metacognitive awareness by Bakkaloglu (2020) examined learners from the third, fourth, and fifth grades in Turkish schools, where secondary education begins with the transition to fifth grade at age ten. Using the Metacognitive Awareness Scale for Children (Karakelle & Sarac, 2007), the authors found significantly higher metacognitive awareness for fifth graders than for third and fourth graders. These results suggest a developmental boost and increase in metacognitive awareness but a decrease in the use of goal-setting and planning strategies after the transition to secondary school.

Executive function

Concerning the *updating* component, Prencipe et al. (2011) found the highest performance increases for maintaining and manipulating several information units in working memory from age ten (see Table 2 for overview of included studies). Participants between nine and twelve years old showed a significantly lower spatial memory span than older participants (Luciana et al., 2005). A stable performance without further increases with age was found from the ages of 13 to 15 by Conklin et al. (2007). In line with this, Anderson et al. (2001) found better performance in students aged 15 compared to

Table 3 Overview of studies on self-regulated learning and metacognition

Author (Year)	Nation	Dependent value(s)	transition phase [a]	Participants [b]	Academic transition between grades (age) [b]	Main results [d]
Bakkaloglu (2020)	Turkey	Metacognitive awareness	PS	Grade 3 vs. Grade 4 vs. Grade 5 ($n=399$ (195))	Authors: Grade 3 and 4 primary school, Grade 5 middle school	Grade 5 significantly better than Grades 3 and 4, no significant difference between Grades 3 and 4
Coertjens et al. (2017)	Belgium	Processing and regulation strategies	ST	Longitudinal view: last year of secondary schooling until second year of tertiary schooling ($n=630$)	Secondary to tertiary schooling	Transition: improvement on all measured scales; transition period: growth in learning strategies and deep learning
Effeney et al. (2013)	Australia	SRL, EF	PS	10.6–12.5 years vs. 12.6–15.5 years vs. 15.6–17.5 years ($n=254$ (0), 10.6–17.5 years)	Grade 6 (11 years) toward Grade 7 (12 years)	SRL & EF closely related, strongest relationship for middle age group, both constructs decrease with age (EF $d=0.49$, SRL $d=0.10$–0.79)
Lawanto et al. (2013)	USA	Task understanding, self-regulatory strategies, cognitive strategies	ST	Grades 9–12 of secondary schooling, first year of tertiary schooling ($n=99$)	Secondary to tertiary schooling	First year of tertiary schooling higher level of SRL, overall gaps in SRL
Pajares and Valiante (2002)	USA	Self-efficacy concerning SRL	PS	Grade 4 (9 years) to Grade 11 (17 years) ($n=1{,}257$, range 9–17 years)	Authors: Grades 5 to 6	Self-efficacy decreased from Grade 4 to Grade 7, then stabilized with slight recovery in Grade 11
Radmehr and Drake (2020)	New Zealand	Metacognitive knowledge	ST	Grade 13 vs. first year of university ($n=17$ (2))	Secondary to tertiary schooling	First year in tertiary schooling better developed knowledge (esp. monitoring strategies)
Thibodeaux et al. (2017)	USA	Time planning and use	ST	Longitudinal view: beginning of first semester tertiary schooling until end of second semester ($n=589$ (63%))	Tertiary schooling	First semester planned and actual time on academics low, more time on academics in second semester; low SRL skills in first year
Usher and Pajares (2008)	USA	Self-efficacy concerning SRL	PS	Grades 3–5 vs. 6–8 vs. 9–12, age range 8–18 years ($n=3{,}670$ (1,849), range 8–18 years)	Authors: Grades 5 to 6	Continuously decreasing self-efficacy
van der Veen and Peetsma (2009)	Netherlands	Components of Pintrich's (2004) SRL model	PS	Longitudinal view: first year (12 years) until start of second year in secondary schooling ($n=735$ (42%))	Grade 6 (11 years) to Grade 7 (12 years)	Overall decrease in perceived SRL behavior (esp. delay of gratification)

[a] PS = primary-secondary transition, ST = secondary-tertiary transition. [b] n = number of participants (number of female participants), age range. If data points are missing, they were not reported in the publication. [c] Grades at which the transition from primary to secondary schooling usually occurs. Information following OECD (2020) unless stated otherwise. [d] Effect sizes are as reported in original studies

eleven- to 14-year-olds. A performance increase until age 17 was found by Hooper et al. (2004); 14- to 17-year-old participants performed better than eleven- to 13-year-olds, who in turn, showed performed better than nine- to ten-year-olds. In a study by Brocki and Bohlin (2004), participants between eleven and 13 years old showed significant performance increases in working memory compared to younger participants. The working memory component of the central executive function showed significant differences between six- to seven-year-olds, eight- to ten-year-olds, and eleven- to twelve-year-olds while performance increased with age, with a large effect size (Pureza et al., 2013).

Wu et al. (2011), demonstrated that seven- to eight-year-olds performed worse than nine- to ten-year-olds while both groups performed worse than ten- to 14-year-olds. Concerning the *updating* component, it can be concluded that, although the most reliable changes mostly already occur before the transition to secondary school, there is continuous improvement until 15 to 17 years of age.

Regarding the *inhibition* component, studies by Brocki and Bohlin (2004), Pureza et al. (2013), and Wu et al. (2011) found better performance in ten- to 14-year-olds than in participants of between six and ten years (with moderate to large effect sizes in both studies). In contrast, six-year-olds show the same inhibitory level as eleven-year-olds using a different measurement method (Visu-Petra et al., 2007). A comparison of students aged nine to 17 years revealed significant differences between all age groups with a higher discrimination ability for older students (Hooper et al., 2004). Prencipe et al.'s (2011) research indicates a significant performance increase for students older than ten years when compared to younger students. A similar performance pattern has been found for the Tower of London task (Wu et al., 2011); as this task requires different EF competencies, it is not only an indicator of inhibition but also a traditional task for measuring planning and problem-solving behavior.

When comparing students between six and 13 years old on the task, Injoque-Ricle et al. (2014) found that their general performance increased with age (with a large effect size). Moreover, the time needed to generate and organize a behavioral plan increased with higher task complexity, while older students needed less time than younger students. Injoque-Ricle et al.'s results contrast those of Visu-Petra et al. (2007), which show that seven-year-olds can plan their actions on a level similar to twelve-year-olds. A slow but continuous developmental trajectory of problem-solving behavior is suggested by Anderson et al. (2001), who found that eleven-year-olds required a significantly higher number of trials on a task compared to 15- to 17-year-olds. Nevertheless, single developmental leaps should not be ruled out, as demonstrated by the significantly lower accuracy values for the planning and organization activities of eleven-year-old students compared to those of twelve years and older (Anderson et al., 2001). In conclusion, most studies suggest a consistent increase in *inhibition* across the transition phase. Some significant comparisons of groups before and after the transitional period indicate small but continuous improvements across this broad time frame.

Concerning the *shifting* component, Kalkut et al. (2009) reported a general performance increase for the whole examined time period; they found significant and continuous performance development for different tasks that measured cognitive flexibility between the ages of eight twelve. Additionally, some tasks showed significant differences until age 15 (Kalkut et al., 2009). Visu-Petra et al. (2007) found no difference between ten- and twelve-year-olds in forming and changing competencies between semantic categories. One year later, the now eleven-year-olds reached the performance level of twelve-year-olds in a task on self-monitoring and control. Furthermore, Anderson et al. (2001) report that at around 14 to 15 years old, there seems to be a developmental leap in the common use of selective attention, working memory, and cognitive flexibility; in their study, 15-year-old students showed significantly faster performance than eleven- to 13-year-olds, while 14-year-olds were significantly faster than eleven-year-olds. In contrast, Wu et al. (2011) found significant differences up to the age of eleven to twelve years but no further increase in the shifting component for older students. To sum up, some studies have discovered improvements during the transition to secondary school for the *shifting* component, and are supported by other findings that indicate minor, steady changes when comparing students directly before and after the transitional period.

The aforementioned study by Luciana et al. (2005) suggests a later developmental boost in *complex EF* compared to *simple EF*; while the authors found no changes in spatial working memory from age 13 onwards, there were significant increases in complex EF on strategic self-organized behavior until age 17. This ongoing development of self-organization in spatial tasks until age 17 was also demonstrated by Conklin et al. (2007), although verbal task development was only found until age 13 to 15 years. In line with Luciana et al. (2005), Prencipe et al. (2011) found evidence to suggest the later development of hot EFs compared to cold EFs. In their study, 14- to 15-year-olds showed better performance than eight- to nine-year-olds regarding their competence to re-evaluate an immediate incentive in relation to a bigger, delayed incentive and make delay of gratification decisions. A similar pattern was found by Hooper et al. (2004): 14- to 17-year-olds showed more advantageous decision-making behavior compared to nine- to ten-year-olds. Crone and van der Molen (2004) revealed similar behavioral tendencies in adolescents: with increasing trials, students aged 13 to 15 showed increased performance in tasks comparing beneficial and damaging decisions, whereas younger participants did not show this increase. This development was confirmed in a second study in the same publication; adolescents made more long-term beneficial decisions throughout the examination whereas younger participants made more short-term beneficial decisions that were disadvantageous in the long-term. Overall, the findings indicate no significant changes for *complex EFs* during the transitional period, yet continuous smaller improvements across a broader time frame can be assumed. In contrast to simple EFs, complex EFs seems to improve more after the transition to secondary education.

Relationship between self-regulated learning and executive function

As discussed above, research indicates that SRL and EF change during the primary to secondary school transition, and the relationship between these constructs also follows this pattern. Effeney et al. (2013) found that EF (measured using the BRIEF-SR; Guy et al., 2004) predicted SRL competencies, especially the planning and organizing scales (as measured using the SSRLS; Purdie et al., 2004). When comparing three age groups, the youngest group (age 10.6 to 12.5 years) showed the least significant correlations between the constructs, whereas the oldest group (age 15.6 to 17.5 years) showed less significant correlations than the middle group (age 12.6 to 15.5 years). In the oldest group, there was almost no correlation between the EF scales of inhibition, shifting, and emotional control and the other scales. Based on these results it can be suggested that SRL and EF mainly are related in early adolescence and that their relationship decreases in later adolescence.

Development during the secondary to tertiary education transition

Self-regulated learning

Regarding the *cognitive* component of SRL, Coertjens et al. (2017) investigated the developmental trajectory of learning strategies using five measurement points, beginning with the last year of secondary education and ending in the first half of the second study year of tertiary education (college) (see Table 3 for overview of included studies). A questionnaire on learning strategies showed a positive trend towards deeper and more use of SRL over time. A comparison of the weeks before and after the academic transition showed a significant increase in self-regulation, memory, analysis, critical elaboration, structuring, and creating relationships. There was no change in self-regulation from the beginning to the end of the last year of secondary education, but there was a significant increase at the beginning of the first year of tertiary education and a following stagnation at the end of the same year. Concerning the second year of tertiary education, there was another, smaller, increase in self-regulation (Coertjens et al., 2017).

Increases in the *metacognitive* component are typically seen after the transition to tertiary education. For example, Lawanto et al. (2013) compared the coping process and strategy use in secondary school and freshmen college students during the course of a complex project. College students had higher self-reported self-regulation, planning, strategy choice, and monitoring, and more frequent and thorough use of explicit self-regulating processes, compared to secondary students. Nevertheless, the authors underline that both groups had developmental potential for enhanced SRL processing. With regards to time planning, Thibodeaux et al. (2017) found that college freshmen were not yet able to plan their time accurately as the time planned for study activities was higher than the actual time spent studying. Moreover, they planned too little time for their studies in comparison to that for their leisure activities. In their second semester, the college students adapted their planning based on their underestimations of the first semester and assigned more time to study activities. Nevertheless, they still used less time for their studies than they had planned. The authors also found a positive relationship between time planned and GPA after the first semester.

Concerning *metacognitive knowledge*, Radmehr and Drake (2020) demonstrated that college freshmen had higher knowledge scores than students in their last year of secondary education; this knowledge advantage was especially obvious for monitoring strategies such as problem-solving, planning, and evaluating results. However, the authors point out that metacognitive aspects are not optimally developed in either high school or college students and there is room for improvement in both groups. In general, the transition to tertiary education seems to be a favorable period for the development of cognitive and metacognitive SRL, as findings indicate significant improvements in self-regulatory strategies and planning and monitoring of one's learning process, especially at the beginning of the first semester of tertiary education.

However, for the *motivational* component, our literature search revealed no results.

Executive functions

Compared to early childhood and adolescence, there is less research on the development of EF in late adolescence and early adulthood (see Table 2 for overview of included studies). One reason could be that EF development, especially of simple EF, starts very early and most EF components have exceeded their developmental peak by late adolescence, so there are only marginal or no developmental changes after this age. Nevertheless, some research on this age group has

Table 4 Overview of the developmental trajectories

	SRL	EF
Preschool–primary transition	No studies detected	↑ Simple EFs: Updating (especially in preschool), Inhibition (especially in preschool), Shifting
Primary–secondary transition	↓ Motivation: Decrease in self-motivation, delay of gratification, perceived self-efficacy ↑↓ Metacognition: Increase in metacognitive awareness, decrease in goal setting and planning ↑ Increased correlation between SRL and EF	↑ Simple EFs: Updating, Inhibition, Shifting ↑ Complex EFs: Decision-making (but later developmental peak than simple EF)
Secondary–tertiary transition	↑ Cognition: Increase in deep learning strategy usage ↑ Metacognition: Increase in metacognitive knowledge, time planning, monitoring	↑ Simple EFs: Inhibition, planning strategies ↑ Complex EFs: Rule detection, beneficial decision-making

↑ increase, ↓ decrease

been conducted. This indicates that individuals of 15 years and older show no further increase concerning their spatial memory span, which is a simple EF component (*updating*) (Luciana et al., 2005). Furthermore, concerning *inhibition* performance (i.e., restraint from automatic reactions), Taylor et al. (2015) found higher values for 17- to 19-year-olds at the end of a one-year time frame than at the beginning, which indicates improved functioning over time. This age group also showed increased use of strategy planning over time and needed less time to begin task execution. Kalkut et al. (2009) did not find a significant change in the *shifting* component in late adolescents; 17-year-old students showed a significant increase in strategy generation but no further improvement over the age of 18. This result is somewhat supported by Taylor et al. (2013), who showed that 17-year-olds performed better than 18-year-olds.

Strategic self-organized behavior, which is categorized as a *complex EF* component, does not seem to develop differently across ages 16 to 17 and 18 to 20, even when different task difficulty levels are observed (Luciana et al., 2005). However, Taylor et al. (2015) showed that in 19- and 20-year-olds, competence to detect systematics improved over a one-year period. Despite this, in a concept-building task, all the age groups in Taylor et al.'s study showed lower performance at the end of the one-year period. Concerning decision-making behavior relative to short- and long-term positive and negative consequences, Crone and van der Molen (2004) showed that 18- to 25-year-olds are more competent than 13- to 15-year-olds; when comparing beneficial to disadvantageous decisions over the course of the study, the oldest group improved significantly more than the younger group.

Compared to complex EFs, during the transition to tertiary education, *simple EFs* seem to undergo little to no relevant changes. Only the *inhibition* component shows some evidence of improvement in behavioral planning contexts. *Complex EFs* such as decisionmaking seem to improve significantly until young adulthood.

Comparison of construct development

From the developmental trajectory descriptions, it is apparent that the components of both SRL and EF show changes during the age spans of interest to this study (see Table 4). Although the trajectories hint at some differences, they also show congruent and probably mutually supporting processes. Regarding the first academic transition, from preschool to primary school, we could not detect any studies referring to the development of SRL. For EF, it is clear that this period marks a time of extensive growth; updating seems to rapidly develop in preschool and the beginning of primary school, while there is less growth in later elementary years. In line with this, inhibition competencies also strongly increase during preschool and show only a slight increase once a child enters primary school. The shifting component typically shows a continuous improvement during the transition to primary school.

Concerning the transition from primary to secondary school, a decrease in the motivational component of SRL is obvious, especially with regard to motivation and self-efficacy (e.g., Effeney et al., 2013; Uhser & Pajares,2008). Although the development metacognitive of awareness seems to begin only after the transition from primary to secondary school (Bakkaloglu, 2020), the development of general SRL and metacognitive strategy use is regressive during this period (Effeney et al., 2013; van der Veen & Peetsma, 2009). During this period, final changes seem to take place regarding the simple EF competencies of updating, inhibition, and shifting; while these still show development after the primary–secondary transition, the largest developmental increases come before the transition. In relation to complex EF, strong changes are evidenced up to the age of 15 for two competencies—gratification delay (Prencipe et al., 2011) and decision-making (e.g., Crone & van der Molen, 2004)—which indicates a later developmental peak compared to simple EF. As mentioned above, the relationship between SRL and EF increases in middle adolescence; this is mostly driven by the goal-setting and plan-focused metacognitive aspects of SRL and EF (Effeney et al., 2013). The EF competencies of goal-setting and planning seem to be almost completely developed during the primary–secondary transition, as they show only marginal changes during this period and beyond (e.g., Injoque-Ricle et al., 2014). At the same time, there is a decrease in goal-setting, planning behavior, and self-motivation from an SRL perspective, with lower EF competencies being related to lower SRL behavior, although the developmental direction remains unclear (Effeney et al., 2013).

At the end of secondary education, some of the components of all three constructs (SRL, MC, EF) are not fully evolved: the metacognitive component of SRL shows further development after the transition to tertiary education with regard to metacognitive knowledge (Radmehr & Drake, 2020) as well as monitoring of the learning process and time planning (Lawanto et al., 2013; Thibodeaux et al., 2017). This increase is supported by an increase in cognitive strategy use to support deeper information processing during the first year of tertiary education studies (Coertjens et al., 2017). Concerning EF, decision-making competence regarding short-term and long-term consequences improves (Crone & van der Molen, 2004). This is in line with the development of simple EF processes, such as improved inhibition, at the beginning of college compared to the last year of secondary education (Taylor et al., 2015). There are parallels to the increase in time management competencies at the beginning of the second year of tertiary education studies compared to the first year (Thibodeaux et al., 2017). Nevertheless, it remains unclear why strategic self-organized behavior does not improve at the EF level (Luciana et al., 2005), although significant increases in self-organization are observed at the SRL level (Coertjens et al., 2017; Lawanto et al., 2013), and EF strategy development stabilizes (Taylor et al., 2013, 2015).

In summary, the development of basic EF mainly occurs in preschool years, seems to be finalized to a large extent with the transition from primary to secondary school, and only shows marginal changes after this period. There are still developmental changes in complex EFs during the transition from secondary education to college. This could explain the increased performance of the metacognitive SRL component during both transition phases, especially as inhibition is seen as relevant for metacognitive processes (Hofmann et al., 2012), and the metacognitive component is found to develop further after the transition to college. Although working memory is assumed to be important for goal-setting processes (Hofmann et al., 2012), goal-setting abilities decrease during the transition from primary to secondary education, although working memory performance increases. This could represent a methodological artifact; as SRL strategy usage (and therefore goal-setting, planning, etc.) are mostly assessed using self-report measures, the decreased performance after the transition to secondary school could be a result of the positive development of metacognitive awareness. If learners are more aware of their strategy usage and learning processes and learn to judge them more reliably, their self-reported strategy usage could decline because it is based on more realistic assessments (rather than overestimations).

Regarding motivation, the literature search only resulted in findings for the primary–secondary education transition, and these indicate significant decreases in motivation and self-efficacy. This is in line with previous research on motivation across this transition phase, which indicates non-favorable development for some types of students (Tuominen et al., 2020). The motivational component of SRL seems to be less connected to EF during this transition, which is something that has not been examined in previous research on SRL–EF link. For the cognitive component, the literature search only revealed findings for the transition from secondary education to college, and these support positive development. This is in line with research suggesting the positive development of both simple and complex EFs that help students choose appropriate cognitive learning strategies.

Summary and discussion

In the context of the research question regarding how SRL, MC, and EF are interwoven and develop during academic transition phases, 30 studies were analyzed and compared. SRL especially was investigated during school age as this time period is argued to be a particularly formative developmental phase. While we could not find any literature on SRL for the transition from preschool to primary school, the transition from primary to secondary education often comes with negative SRL development. In essence, there appears to be a decrease in SRL behaviors, self-efficacy beliefs, motivation, goal-setting, and planning. This trend continues into higher grades and potentially until the end of secondary education. A significant change in this trend comes with the transition to college; at the beginning of college especially, learners plan and monitor their learning processes much more intensively and use deeper learning strategies. In contrast to the development of general SRL, metacognitive awareness significantly increases during the primary–secondary education transition, especially with the transition to higher educational grades. This positive development also manifests during the transition from secondary to tertiary education. Freshmen college students show higher metacognitive knowledge than secondary school students and are able to better plan and monitor their learning process.

EF development is related to the development of the prefrontal cortex, and childhood and adolescence represent phases of very intensive change (Prencipe et al., 2011). EF development seems to be continuous during this period, although some components differ in their first emergence and developmental trajectories (Kalkut et al., 2009). With the end of primary education, *updating* and *inhibition* only show a slight increase because children's developmental focus is earlier, during the preschool years. In contrast, *shifting* seems to improve to a larger extent during this period. A similar development pattern can be seen for complex EFs, such as decision-making, which evidence significant change in the years after transition. The development of complex EFs such as rule-detection and decision-making also continues after the transition to tertiary education.

Comparing developmental trajectories suggests that developmental increases in EF seem to predate significant developmental changes in SRL and MC. Substantial changes occur in simple EF before the transition from primary to secondary school, while for SRL and MC, substantial changes occur during or after this transition. The subsequent significant developmental changes in complex EF align with the stabilization of SRL. With the transition to tertiary education, there are further developmental increases that are substantial for SRL and MC but less intensive for EF.

Limitations

Taking a critical view of this literature review reveals some shortcomings that should be discussed. Although we decided on an open methodical approach to consider as many publications as possible, an imbalance in publications on the three constructs was already evident when identifying possible studies (see Fig. 5 above). Whereas the search terms for SRL and MC resulted in a comparable number of studies (SRL: 2,229 studies; MC: 2,394 studies), we found almost three times as many studies for EF (7,591 studies). This imbalance was also reflected in the number of studies that were analyzed in the review: EF studies (22 studies) exceeded SRL studies (seven studies, and none for the preschool–primary school transition), and especially MC studies (only two studies in total). Therefore, the conclusions about SRL and especially MC must be taken with caution. Although there were more EF publications, there was also an imbalance regarding the transition phases: there was a smaller number for the secondary–tertiary transition than for the primary–secondary transition. As mentioned above, the early developmental peak plays a relevant role. Nevertheless, the results give reason to focus specifically on adolescence and early adulthood in future research, as overall, the current evidence base concerning changes during academic transition phases is scarce.

The characteristics of differing school systems should be considered when interpreting the results. This is especially true for the primary–secondary transition, as this occurs at different ages in different countries. Therefore, in this study, the age at which the transition occurred was rarely based on data from the individual studies, but instead, was based on OECD information (2020). Only ten studies (Bakkaloglu, 2020; Effeney et al., 2013; Kim et al., 2021a, b; Matte-Gagné et al., 2018; McKay et al., 2022; Pajares & Valiante, 2002; Usher & Pajares, 2008; Vandebroucke et al., 2016; van der Veen & Peetsma, 2009) made explicit statements about when the transition occurred. As the first step of the analysis of the studies was conducted at age level, spanning some years before to some years after the academic transitions, some studies had to be omitted due to inadequately defined sample age groups and overlapping developmental time periods. Moreover, students of the same age sometimes shared differing school levels; therefore, it was not clear whether the developmental differences were caused by age or the academic transition. Therefore, as age was not an appropriate variable for all the analyses, the second step of the analysis was based on the preschool–primary/primary–secondary transition. Concerning the secondary–tertiary transition, the presence of different educational systems was not considered to be that relevant since all the analyzed secondary school systems ended at 18 or 19, and tertiary education followed (OECD, 2020). For the college freshmen examined here, it was not clear whether they began their studies directly after graduating from school or whether they engaged in other experiences first (studied a technical subject or completed an apprenticeship, for example). However, based on previous analyses of the samples (e.g., Thibodeaux et al., 2017), we assumed that most first-year college students began their studies directly after graduating from school.

Another challenge when conducting this review was the multitude of differing assessment methods for SRL, MC, and EF that were used in the analyzed studies. As the Tower of London task shows, some methods can be utilized to assess different components (action planning vs. inhibition and problem-solving, for example). Regarding SRL, it would be helpful to integrate several assessment methods, consistent with studies on EF. Most SRL studies use self-report measures, such as questionnaires, diaries, and interviews that assess SRL as a whole but also enable the assessment of specific components such as motivational aspects (Wolters & Won, 2018). Nevertheless, self-reports collect retrospective data based on memory and are not aligned with the process character of SRL as they cover more of a trait perspective. Therefore, it would be helpful to use additional methods such as think-aloud protocols (Greene et al., 2018) or trace data (Bernacki, 2018), which measure real-time learning processes. Moreover, the development of innovative assessment methods could be helpful for studies that investigate SRL and EF conjointly, such as that by Effeney et al. (2013).

Implications for theory

Based on the definitions of SRL, MC, and EF, the three constructs obviously are interwoven as they all focus on the goal-oriented monitoring of an individual's cognition and behavior to help them react and behave appropriately within a given environment (Dinsmore et al., 2008; Effeney et al., 2013). Recently, several studies have investigated the relationship between SRL, MC, and EF and have found differing results mostly in dependence on which instruments were used to measure the constructs (e.g., Cirino et al., 2018, Folmer & Sperling, 2016). As no longitudinal studies exist to date, conclusions about the direction of the relationship between the three constructs cannot be drawn, although theoretically it is assumed that EF is a precursor for SRL (Bailey & Jones, 2019; Blair & Ursache, 2011). Therefore, the present systematic review is highly significant in summarizing previous results on the development of the three constructs in critical academic phases (i.e., transition phases) and by that aiming to deduce assumptions about the directional relationship. A comparison of the developmental trajectories during academic transition phases suggests that developmental increases in EF seem to predate significant developmental changes in SRL and MC. For (simple) EF, substantial changes occur before the transition from primary to secondary school, while for SRL and MC substantial changes occur during or after this transition. Subsequently, there are significant developmental changes in complex EF that align with the stabilization of SRL. With the transition to tertiary education, there are further developmental increases that are substantial for SRL and MC but less intensive for EF. Future studies should investigate the assumed directional relationship of EF preceding SRL and MC within longitudinal study designs as they could be helpful in detecting if for example changes in EF later on influences changes in MC and SRL.

With regard to theoretical contributions, the results of the present review (in combination with findings from longitudinal studies) could be used to build up a theoretical framework that connects both research lines: Based on the finding that EF may precede SRL, EF could build up the base of the model while SRL could be seen as a context-specific application of underlying EF (Effeney et al., 2013). MC could be conceptualized as the "conceptual middle ground between EF and SRL" (Effeney et al., 2013; p. 788), especially if longitudinal studies would undermine its function as a mediator between EF and SRL. One example of conceptualizing SRL as an application of EF stems from Bol and Garner (2011) for the context of learning in distance education environments with electronically enhanced texts. They position "executive functions as neurocognitive processes that promote self-regulation at both the basic cognitive (e.g., attentional control) and metacognitive (e.g., planning and self-monitoring) levels" (Bol & Garner, 2011, p. 114) and assume that variations in EF may impact the SRL cycle during interactions with such learning material. As the authors state, low EF can lead to difficulties in recognizing the need for goal setting and strategic planning, which in turn can lead to engagement with learning material without a specific goal in mind, and the inability to switch learning strategies when necessary. Supporting the interaction with electronically enhanced texts from an SRL and EF perspective can take place via help in selecting relevant information, facilitating students' management and self-regulation of task accomplishment, helping with the completion of tasks and use of learning resources, and helping with strategic learning choices. Further, EF support attentional control, which is imperative during the volitional stage of SRL, therefore, careful placement of visually appealing information (e.g., hyperlinks and other visual aspects of electronically enhanced text) is important to reduce distractions and helping to retain recently gained information. As this example only is hypothetical and only refers to one context (learning is distance education), it would be necessary to investigate how the application of EF during SRL processes would look like within empirical studies and differing domains (learning in school or college).

The findings of the present review additionally contribute to theory on developmental changes for EF, SRL, and MC. Concerning SRL, there is relatively little knowledge on its development in general and especially within academic transition phases. While we could not find any studies for the transition from preschool to primary school, we found a decrease in motivational factors and an inconclusive picture for the development of metacognition during the transition from primary to secondary school. For the transition into tertiary education, we found increases in cognitive and metacognitive SRL components. With regard to EF, the results suggest an increase in simple EF over the whole time period from preschool to tertiary education (with the biggest developmental changes happening during the transition from preschool to primary school and the magnitude of changes decreases with ongoing age) and an increase in complex EF mainly from secondary to tertiary education. Based on these findings, it could be hypothesized that the development of simple EF occurs as a precursor to the development of SRL and that complex EF and some parts of SRL develop simultaneously. With regard to the decrease in motivation and partly in metacognition after the transition to secondary education, more research has to be done yet as this decrease could reflect a methodological artefact. Most research on SRL is done by using questionnaires (Roth et al., 2016) and it could be assumed that children develop their competence of answering questionnaires with evolving age and therefore answer such measures in a more realistic way (due to lower overestimation of performance, Xia et al., 2023), providing lower ratings of questionnaire statements. In addition, after the transition to secondary education, the big-fish–little-pond effect kicks in (Becker & Neumann, 2018), which could lead to lower self-assessment of SRL competences in students. Besides that, while the results give a picture of developmental changes during the abovementioned transition phases, we cannot draw conclusion with regard to the general age-dependent development (independently from school transitions). In order to answer this question, longitudinal studies that focus on the development of SRL, MC, and EF in the interesting age periods are needed.

Implications for research

Besides the abovementioned implications for theory building, the present review also has implications for future research on the relationship between EF, SRL, and MC. As grade and age are highly related, it remains unclear which is responsible for the changes in the three constructs. Age is a biologic maturity-related factor, while grade involves social interactions and experiences, which highly influence the well-being of learners. Within a national comparison, Whitley et al. (2007) compared children and adolescents that had undergone academic transitions (across grades or school form groups) at different time points. They found significant performance decreases for math between the fifth and seventh grades that were consistent with those for students who had experienced a transition before Grade 7 as well as students that had experienced no transition before Grade 7. The academic transition had no additional influence on performance deterioration, therefore. The authors concluded that the missing effect was related to biological, cognitive, and psychological processes that occur during puberty. When comparing different school form groups, potential intervening factors must be considered because different form groups utilize varying curricula or foster programs that can affect developmental trajectories. Additionally, college student comparisons are influenced by their knowledge and experience. Based on a comparison of different nations, the results of the present review are not decisive on the influence of age or school grade. Considering the aforementioned theoretical models and the assumed developmental trajectories of SRL and MC from a socio-cognitive perspective, it is reasonable to hypothesize a stronger influence of experience and therefore school grades. From an EF perspective, both age as a neurological foundation for development and school grade as a relevant factor for the development of EF (Roebers, 2017), can be assumed to be highly influential. Cross-sectional and ideally longitudinal study designs utilizing close-meshed assessment measures before, during, and after academic transitions would help us to gain deeper insights into developmental changes and identify how much change can be ascribed to age, transition phase, or the interaction of both.

Given that we found no studies on the development of SRL within the transition from preschool to primary school, research in this area is needed. As formal education only begins in primary school, and measuring SRL in preschool is challenging due to missing literary language competencies (anonymized, year), research on SRL in preschool is generally scarce (anonymized, year). Future work should examine SRL longitudinally and focus on its development within the preschool to primary school transition. Another highly relevant area of research in this context is the investigation of causality between SRL and EF and their developmental trajectories. As discussed earlier, EF is seen as a necessary precondition for the development of SRL. This is validated by correlations between the constructs that suggest EF predicts SRL. In turn, clarification is needed on whether SRL use results in changes in EF. A specific hypothesis to be examined is that less SRL use after the transition to secondary education can cause stagnation of goal- and planning-related EFs. Analogously, it should be possible to improve EF through fostering SRL and vice versa. Research in this area is also necessary as the consequent improvement in EF decision-making competencies from late childhood to early adulthood (Crone & van der Molen, 2004) contrasts the decrease in delay of gratification at the SRL level (van der Veen & Peetsma, 2009); investigating the convergence between decision-making from an EF perspective and delay of gratification from an SRL perspective could help clarify this ambiguous finding. It could be possible that improved long-term decision-making at the EF level lays the foundation for implementing this competence in an SRL context. Deficiencies in decision-making could be viewed from a motivational perspective; following Zimmerman's (2000) process model, decreased motivation negatively impacts planning and usage of learning strategies. As an SRL component, motivation can have a moderating influence on the relationship between cognitive competencies and their actual use during learning processing, so that decision-making regarding learning could deteriorate despite given competencies. Arguments for a decrease in motivation during the primary–secondary transition come from Robbers et al. (2017) and Kurtz-Costest and Rowley (2012). In line with this, Effeney et al. (2013) hypothesize that adolescents feel pressured by concurring non-academic interests that come with the competence to make decisions and act freely.

Another finding that needs clarification is the contrasting development of metacognitive awareness and SRL as a whole during the primary–secondary transition. The increase in metacognitive awareness after the transition to secondary education may include a significant increase in knowledge of learning processes and their complexity, so that the prospect of the upcoming learning process is overwhelming for students (see Bakkaloglu, 2020). Additionally, higher metacognitive awareness could lead to more accurate self-perceptions; as learning strategy usage is mostly assessed using self-report measures, lower values could stem from more realistic self-reporting and less overestimation (which is mostly found in learners; Dunlosky & Rawson, 2012). Moreover, this can be influential in decreasing self-efficacy beliefs concerning learning success. In this context, academic self-concept is relevant; this is defined as beliefs about one's academic competencies and is highly influenced by performance and success in childhood (Wu et al., 2021). Therefore, an adequate judgment of one's competencies during primary school is possible through academic achievement scores, and the relevance of competencies increases with age and can reciprocally influence performance (Wu et al., 2021). Coelho et al. (2020) found a significant decrease in academic self-concept during the primary–secondary transition, which was assumed to be influenced by increasing challenges and possibly by increasing metacognitive awareness. In turn, this could negatively influence SRL. Future studies could consider academic self-concept when investigating the development of SRL and MC. While theory assumes that metacognitive functions are dependent on EFs, Roebers (2017) suggests that this dependence is only true for early developmental phases. The results of this review support a relationship between early and later developmental trajectories because metacognitive awareness shows a strong increase with the transition to secondary school while the foundations of EF are already developed in preschool. To investigate the causal relationship, an intervention study fostering EF and assessing the consecutive development of MC could be helpful. If the intervention was conducted at different academic education time points, the influence of academic transitions and stages could also be examined.

Implications for practice

Based on the results of this review, practical implications refer to educators' knowledge about SRL, MC, and EF, these constructs' importance for school transitions, their developmental changes as well as knowledge about interventions to foster these constructs. In a first step, teachers and parents should be educated in SRL, MC, and EF and their developmental trajectories, so that they can diagnose and understand learning problems better by integrating knowledge about these constructs. This goes hand in hand with the importance of parental involvement and teachers' support for a successful adaptation of learning processes after school transitions (Correia & Marques-Pinto, 2016). In-service trainings for teachers that encompass knowledge about how and when to foster SRL strategies could be especially useful (Karlen et al., 2023), as SRL strategies easily can be integrated into regular class (Andrzejewski et al., 2016).

As SRL shows a decrease after the transition from primary to secondary school, interventions that absorb the negative effects of this transition on SRL would be helpful. Generally, SRL support seems relevant to help students cope with the challenges of academic transitions, as they come with personal and environmental changes and require adapted learning processes (Coertjens et al., 2017). The results of the present review show that decreases after the transition to secondary school mainly occur in self-efficacy beliefs and motivational factors as well as goal-setting and planning. Therefore, interventions that aim at fostering motivational and metacognitive SRL strategies would be especially helpful. The meta-analysis of Dignath et al. (2008) shows that the combined training of motivational and metacognitive strategies leads to the highest effect sizes. In order to come up with stable effects of the intervention, it would be useful if it took place early on before the transition (end of next-to-last grade of primary school). Moreover, when aiming at an increase of SRL competencies, academic and social consequences have to be taken into account. Humphrey and Ainscow (2006) describe an acclimatization program in which students could visit secondary school some weeks before the transition to get used to the new environment and develop their social competencies, learning motivation, and self-confidence. Interventions at the beginning of secondary education can supplement such programs. Vosniadou (2020) reports on the "Learning Studies Programme," which supports students to acquire knowledge regarding the use of learning strategies. As SRL interventions also can be implemented into preschool and preschool can prepare children for learning in primary education, training for kindergarten teachers also could be helpful to diminish the negative effects occurring with regard to SRL (Dörr & Perels, 2020). In addition to preschool and primary school, programs to foster the learning competencies of freshmen college students could support them in coping with new challenges as they do not have an adequate and comparable knowledge base at the beginning of their studies (Radmehr & Drake, 2020). Interventions such as that by Dörrenbächer and Perels (2016) confirm that fostering SRL in this context could be profitable. For EF, it has also been shown that classroom-based interventions can be successful (Kavanaugh et al., 2019) and that such trainings positively influence academic achievement (Titz & Karbach, 2014). If further studies can reinforce the assumption that EF can be seen as a precursor of later SRL competencies, EF interventions would be especially helpful as they would both foster EF and, in an indirect way, SRL.

Conclusion

This systematic review aimed to summarize the current state of knowledge on SRL, MC, and EF development during academic transition phases and uncover the similarities with and relationships between the constructs. The analysis showed that the developmental trajectories of the three constructs differ but that there are also parallels. Moreover, academic transitions sit alongside significant changes in SRL and MC, and the development of these competencies should not be assessed without taking into account the influence of EF. Therefore, it seems highly relevant to foster SRL before and during academic transition phases and investigate further how SRL, MC, and EF are related and whether training in one of these competencies can positively impact the others. Future research should aim to investigate the causal relationships between the three constructs and uncover reciprocal links by conducting longitudinal studies during academic transition phases that ideally measure SRL, MC, and EF using multimethod assessment.

Author contributions Laura Dörrenbächer-Ulrich and Sabrina Dilhuit wrote the text of the review and Franziska Perels refined the text. Sabrina Dilhuit conducted the systematic literature search and review of the studies. All team members were involved in publication planning, reading of drafts and suggestions for changes, and feedback on the final publication draft. Laura Dörrenbächer-Ulrich and Franziska Perels were additionally involved in providing strategic advice on directions for the paper, and the role of the paper within the research team agenda. All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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Data availability Data is available upon request from the corresponding author.

Declarations

The Ethical Approval Statement and Informed Consent Statement sections do not apply to this study as it was based on previously published literature and no primary data were collected.

Competing interests The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

Anderson, V. A., Anderson, P., Northam, E., Jacobs, R., & Catroppa, C. (2001). Development of executive functions through late childhood and adolescence in an Australian sample. *Developmental Neuropsychology, 20*(1), 385–406. https://doi.org/10.1207/S15326942DN2001_5

Andrzejewski, C. E., Davis, H. A., Bruening, P. S., & Poirier, R. R. (2016). Can a self-regulated strategy intervention close the achievement gap? Exploring a classroom-based intervention in 9th grade earth science. *Learning and Individual Differences, 49*, 85–99. https://doi.org/10.1016/j.lindif.2016.05.013

Bailey, R., & Jones, S. M. (2019). An integrated model of regulation for applied settings. *Clinical Child and Family Psychology Review, 22*(1), 2–23. https://doi.org/10.1007/s10567-019-00288-y

Bakkaloglu, S. (2020). Analysis of metacognitive awareness of primary and secondary school students in terms of some variables. *Journal of Education and Learning, 9*(1), 156–163. https://doi.org/10.5539/jel.v9n1p156

Bandura, A. (1997). *Self-efficacy: Toward a unifying theory of behavior change*. W.H. Freeman and Company.

Becker, M., & Neumann, M. (2018). Longitudinal big-fish-little-pond effects on academic self-concept development during the transition from elementary to secondary schooling. *Journal of Educational Psychology, 110*(6), 882–897. https://doi.org/10.1037/edu0000233

Bernacki, M. L. (2018). Examining the cyclical, loosely sequenced, and contingent features of self-regulated learning: Trace data and their analysis. In D. H. Schunk, & J. A. Greene (Eds.), *Handbook of self-regulation of learning and performance* (2nd ed., pp. 370–387). Routledge.

Besi, M., & Sakellariou, M. (2019). Transition to primary school the importance of social skills. *SSRG International Journal of Humanities and Social Science, 6*(1), 33–36.

Blair, C., & Ursache, A. (2011). A bidirectional model of executive functions and self-regulation. In K. D. Vohs & R. F. Baumeister (Eds.), *Handbook of self-regulation: Research, theory, and applications* (pp. 300–320). Guilford Press.

Boekaerts, M. (1999). Self-regulated learning: Where we are today. *International Journal of Educational Research, 31*, 445–457. https://doi.org/10.1016/S0883-0355(99)00014-2

Bol, L., & Garner, J. K. (2011). Challenges in supporting self-regulation in distance education environments. *Journal of Computing in Higher Education, 23*, 104–123. https://doi.org/10.1007/s12528-011-9046-7

Brocki, K. C., & Bohlin, G. (2004). Executive functions in children aged 6 to 13: A dimensional and developmental study. *Developmental Neuropsychology, 26*(2), 571–593. https://doi.org/10.1207/s15326942dn2602_3

Bronson, M. B. (2000). *Self-regulation in early childhood: Nature and nurture*. Guilford Press.

Chatzipanteli, A., Grammatikopoulos, V., & Gregoriadis, A. (2014). Development and evaluation of metacognition in early childhood education. *Early Child Development and Care, 184*(8), 1223–1232. https://doi.org/10.1080/03004430.20-13.861456

Cirino, P. T., Ahmed, Y., Miciak, J., Taylor, W. P., Gerst, E. H., & Barnes, M. A. (2018). A framework for executive function in the late elementary years. *Neuropsychology, 32*(2), 176–189. https://doi.org/10.1037/neu0000427

Coelho, V. A., Bear, G. G., & Brás, P. (2020). A multilevel analysis of the importance of school climate for the trajectories of students' self-concept and self-esteem throughout the middle school transition. *Journal of Youth and Adolescence, 49*(9), 1793–1804. https://doi.org/10.1007/s10964-020-01245-7

Coertjens, L., Donche, V., De Maeyer, S., van Daal, T., & Van Petegem, P. (2017). The growth trend in learning strategies during the transition from secondary to higher education in Flanders. *Higher Education: The International Journal of Higher Education Research, 73*(3), 499–518. https://doi.org/10.1007/s10734-016-0093-x

Conklin, H. M., Luciana, M., Hooper, C. J., & Yarger, R. S. (2007). Working memory performance in typically developing children and adolescents: Behavioral evidence of protracted frontal lobe development. *Developmental Neuropsychology, 31*(1), 103–128.

Correia, K., & Marques-Pinto, A. (2016). Adaptation in the transition to school: Perspectives of parents, preschool and primary school teachers. *Educational Research, 58*(3), 247–264. https://doi.org/10.1080/00131881.2016.1200255

Crone, E. A., & van der Molen, M. W. (2004). Developmental changes in real life decision making: Performance on a gambling task previously shown to depend on the ventromedial prefrontal cortex. *Developmental Neuropsychology, 25*(3), 251–279. https://doi.org/10.1207/s15326942dn2503_2

De Corte, E. (2019). Learning design: Creating powerful learning environments for self-regulation skills. *Voprosy Obrazovaniya / Educational Studies Moscow, 4*, 30–46. https://doi.org/10.17323/1814-9545-2019-4-30-46

Diamond, A. (2016). Why assessing and improving executive functions early in life is critical. In J. A. Griffin, P. McCardle, & L. S. Freund (Eds.), Executive function in preschool-age children: Integrating measurement, neurodevelopment, and translational research (pp. 11–43). American Psychological Association. https://doi.org/10.13140/RG.2.1.2644.6483

Dignath, C., Buettner, G., & Langfeldt, H. P. (2008). How can primary school students learn self-regulated learning strategies most effectively? A meta-analysis on self-regulation training programmes. *Educational Research Review, 3*(2), 101–129. https://doi.org/10.1016/j.edurev.2008.02.003

Dinsmore, D. L., Alexander, P. A., & Loughlin, S. M. (2008). Focusing the conceptual lens on metacognition, self-regulation, and self-regulated learning. *Educational Psychology Review, 20*, 391–409. https://doi.org/10.1007/s10648-008-9083-6

Dörr, L., & Perels, F. (2020). Improving young children's self-regulated learning using a combination of direct and indirect interventions. *Early Child Development and Care, 190*(16), 2581–2593. https://doi.org/10.1080/03004430.2019.1595608

Dörrenbächer, L., & Perels, F. (2016). More is more? Evaluation of interventions to foster self-regulated learning in college. *International Journal of Educational Research, 78*, 50–65. https://doi.org/10.1016/j.ijer.2016.05.010

Dunlosky, J., & Rawson, K. A. (2012). Overconfidence produces underachievement: Inaccurate self evaluations undermine students' learning and retention. *Learning and Instruction, 22*(4), 271–280. https://doi.org/10.1016/j.learninstruc.2011.08.003

Effeney, G., Carroll, A., & Bahr, N. (2013). Self-regulated learning and executive function: Exploring the relationships in a sample of adolescent males. *Educational Psychology, 33*(7), 773–796. https://doi.org/10.1080/01443410.2013.78-5054

Evans, D., Borriello, G. A., & Field, A. P. (2018). A review of the academic and psychological impact of the transition to secondary education. *Frontiers in Psychology, 9*, 1482. https://doi.org/10.3389/fpsyg.2018.01482

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry. *American Psychologist, 34*(10), 906–911. https://doi.org/10.1037/0003-066X.34.10.906

Folmer, D. J., & Sperling, R. A. (2016). The mediating role of metacognition in the relationship between executive function and self-regulated learning. *British Journal of Educational Psychology, 86*, 559–575. https://doi.org/10.1111/bjep.1-2123

Garner, J. K. (2009). Conceptualizing the relations between executive functions and self-regulated learning. *Journal of Psychology, 143*(4), 405–426. https://doi.org/10.3200/JRLP.143.4.405-426

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin, 134*(1), 31–60. https://doi.org/10.1037/0033-2909.134.1.31

Gerstadt, C. L., Hong, Y. J., & Diamond, A. (1994). The relationship between cognition and action: Performance of children 3.5 –7 years old on a stroop-like day-night test. *Cognition, 53*(2), 129–153. https://doi.org/10.1016/0010-0277(94)90068-X

Greene, J. A., Deekens, V. M., Copeland, D. Z., & Yu, S. (2018). Capturing and modeling self-regulated learning using think-aloud protocols. In D. H. Schunk, & J. A. Greene (Eds.), *Handbook of self-regulation of learning and performance* (2nd ed., pp. 323–336). Routledge.

Guy, S. C., Isquith, P. K., & Gioia, G. A. (2004). *Behavior rating inventory of executive function–self-report version. Professional manual*. Psychological Assessment Resources.

Guy, J., Rogers, M., & Cornish, K. (2012). Developmental changes in visual and auditory inhibition in early childhood. *Infant and Child Development, 21*(5), 521–536. https://doi.org/10.1002/icd.1756

Hofmann, W., Schmeichel, B. J., & Baddeley, A. D. (2012). Executive functions and self-regulation. *Trends in Cognitive Sciences, 16*(3), 174–180. https://doi.org/10.1016/j.tics.2012.01.006

Hooper, C. J., Luciana, M., Conklin, H. M., & Yarger, R. S. (2004). Adolescents' performance on the Iowa gambling task: Implications for the development of decision making and ventromedial prefrontal cortex. *Developmental Psychology, 40*(6), 1148–1158. https://doi.org/10.1037/0012-1649.40.6.1148

Hoyle, R. H., & Dent, A. L. (2018). Developmental trajectories of skills and abilities relevant for self-regulation of learning and performance. In D. H. Schunk, & J. A. Greene (Eds.), *Handbook of self-regulation of learning and performance* (2nd ed., pp. 49–63). Routledge.

Humphrey, N., & Ainscow, M. (2006). Transition club: Facilitating learning, participation and psychological adjustment during the transition to secondary school. *European Journal of Psychology of Education, 21*(3), 319–331. https://doi.org/10.1007/BF03173419

Injoque-Ricle, I., Barreyro, J. P., Calero, A., & Burin, D. I. (2014). Tower of London: Planning development in children from 6 to 13 years of age. *Spanish Journal of Psychology, 17*(7), 1–7. https://doi.org/10.1017/sjp.2014.83

Juvonen, J., Espinoza, G., & Knifsend, C. (2012). The role of peer relationships in student academic and extracurricular engagement. In S. L. Christenson, A. L. Reschly, & C. Wylie (Eds.), *Handbook of research on student engagement* (pp. 387–401). Springer Science + Business Media. https://doi.org/10.1007/978-1-4614-2018-7_18

Karakelle, S., & Saraç, S. (2007). Validity and factor structure of Turkish versions of the metacognitive awareness inventory for children (Jr. MAI)-a and b forms. *Turkish Psychological Articles, 10*(20), 87–103.

Kalkut, E. L., Han, S. D., Lansing, A. E., Holdnack, J. A., & Delis, D. C. (2009). Development of set-shifting ability from late childhood through early adulthood. *Archives of Clinical Neuropsychology, 24*(6), 565–574.

Karlen, Y., Hirt, C. N., Jud, J., Rosenthal, A., & Eberli, T. D. (2023). Teachers as learners and agents of self-regulated learning: The importance of different teachers competence aspects for promoting metacognition. *Teaching and Teacher Education, 125*, 104055. https://doi.org/10.1016/j.tate.2023.104055

Kavanaugh, B. C., Tuncer, O. F., & Wexler, B. E. (2019). Measuring and improving executive functioning in the classroom. *Journal of Cognitive Enhancement, 3*, 271–280. https://doi.org/10.1007/s41465-018-0095-y

Kim, M. H., Ahmed, S. F., & Morrison, F. J. (2021a). The effects of kindergarten and first grade schooling on executive function and academic skill development: Evidence from a school cutoff design. *Frontiers in Psychology*, 11. https://doi.org/10.3389/fpsyg.2020.607973

Kim, M. H., Bousselot, T. E., & Ahmed, S. F. (2021b). Executive functions and science achievement during the five-to-seven-year shift. *Developmental Psychology, 57*(12), 2119–2133. https://doi.org/10.1037/dev0001261

Kiuru, N., Wang, M., Salmela-Aro, K., Kannas, L., Ahonen, T., & Hirvonen, R. (2020). Associations between adolescents' interpersonal relationships, school well-being, and academic achievement during educational transitions. *Journal of Youth and Adolescence, 49*, 1057–1072. https://doi.org/10.1007/s10964-019-01184-y

Kuhn, D. (2000). Metacognitive development. *Current Directions in Psychological Science, 9*(5), 178–181. https://doi.org/10.1111/1467-8721.00088

Kurtz-Costest, B., and Rowley, S. J. (2012). School transitions and african american youth. In S. Karabenick and T. C. Urdan (Eds.), Transitions across schools and cultures: Advances in motivation and achievement (Vol. 17, pp. 27–54). Emerald Group Publishing Limited. https://doi.org/10.1108/S0749-7423(2012)0000017005

Kyndt, E., Coertjens, L., van Daal, T., Donche, V., Gijbels, D., & Van Petegem, P. (2015). The development of students' motivation in the transition from secondary to higher education: A longitudinal study. *Learning and Individual Differences, 39*, 114–123. https://doi.org/10.1016/j.lindif.2015.03.001

Lai, E. R. (2011). *Metacognition: A literature review*. Pearson. http://images.pearsonassessments.com/images/tmrs/Metacognition_Literature_Review_Final.pdf. Accessed 01.02.2023.

Lawanto, O., Butler, D., Cartier, S. C., Santoso, H. B., Goodridge, W., Lawanto, K. N., & Clark, D. (2013). Pattern of task interpretation and self-regulated learning strategies of high school students and college freshmen during an engineering design project. *Journal of STEM Education: Innovations and Research, 14*(4), 15–27.

Li, J. B., & Lau, E. Y. H. (2018). Teacher–student conflict and preschoolers' adjustment in the transition to primary school: The role of child self-regulation and parents' positive relations with others. *Early Education and Development, 30*(3), 423–437. https://doi.org/10.1080/10409289.2018.1535227

Luciana, M., Conklin, H. M., Hooper, C. J., & Yarger, R. S. (2005). The development of nonverbal working memory and executive control processes in adolescents. *Child Development, 76*(3), 697–712. https://doi.org/10.1111/j.1467-8624.2005.00872.x

Matte-Gagné, C., Bernier, A., Sirois, M., Lalonde, G., & Hertz, S. (2018). Attachment security and developmental patterns of growth in executive functioning during early elementary school. *Child Development, 89*(3), e167–e182. https://doi.org/10.1111/cdev.12807

McKay, C., Wijeakumar, S., Rafetseder, E., & Shing, Y. L. (2022). Disentangling age and schooling effects on inhibitory control development: An fNIRS investigation. *Developmental Science, 25*(5), e13205. https://doi.org/10.1111/desc.13205

Mikami, A. Y., Szwedo, D. E., Khalis, A., Jia, M., & Na, J. J. (2018). Online social interactions predict academic and emotional adjustment in the transition to university. *Journal of Research on Adolescence, 29*(1), 210–224. https://doi.org/10.1111/jora.12377

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex frontal lobe tasks: A latent variable analysis. *Cognitive Psychology, 41*, 49–100. https://doi.org/10.1006/cogp.1999.0734

Mulder, H., van Ravenswaaij, H., Verhagen, J., Moerbeek, M., & Leseman, P. P. M. (2019). The process of early self-control: An observational study in two- and three-year-olds. *Metacognition and Learning, 14*(3), 239–264. https://doi.org/10.1007/s11409-019-09199-3

Organisation for Economic Co-operation and Development (OECD) (2020). Education GPS. http://gpseducation.oecd.org. Accessed 01.02.2023.

Owusu-Agyeman, Y., & Mugume, T. (2023). Academic adjustment of first year students and their transition experiences: The moderating effect of social adjustment. *Tertiary Education and Management, 29*, 189–209. https://doi.org/10.1007/s11233-023-09120-3

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., et al. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ, 71*, n71. https://doi.org/10.1136/bmj.n71

Pajares, F., & Valiante, G. (2002). Students' self-efficacy in their self-regulated learning strategies: A developmental perspective. *Psychologia: An International Journal of Psychology in the Orient, 45*(4), 211–221. https://doi.org/10.2117/psysoc.2002.211

Panadero, E. (2017). A review of self-regulated learning: Six models and four directions for research. *Frontiers in Psychology, 8*, 422. https://doi.org/10.3389/fpsyg.2017.00422

Perels, F., Dörrenbächer-Ulrich, L., Landmann, M., Otto, B., Schnick-Vollmer, K., & Schmitz, B. (2020). *Selbstregulation und selbstreguliertes Lernen* [Self-regulation and self-regulated learning]. In E. Wild & J. Möller (Hrsg.), *Pädagogische Psychologie* [Pedagogical Psychology] (3. Aufl., S. 45–66). Springer. https://doi.org/10.1007/978-3-662-61403-7_3

Perry, N. E. (2019). Recognizing early childhood as a critical time for developing and supporting self-regulation. *Metacognition and Learning, 14*(3), 327–334. https://doi.org/10.1007/s11409-019-09213-8

Perry, N. E., Hutchinson, L. R., Yee, N., & Määttä, E. (2018). Advances in understanding young children's self-regulation of learning. In D. H. Schunk, & J. A. Greene (Eds.), *Handbook of self-regulation of learning and performance* (2nd ed., pp. 457–472). Routledge.

Petersen, R., Lavelle, E., & Guarino, A. J. (2006). The relationship between college students' executive functioning and study strategies. *Journal of College Reading and Learning, 36*(2), 59–67. https://doi.org/10.1080/10790195.2006.10-8501

Pianta, R. C., & Cox, M. J. (2002). Transition to kindergarten. *Early Childhood Research and Policy Briefs, 2*(2), 2–4.

Pintrich, P. R. (2004). A conceptual framework for assessing student motivation and self-regulated learning in college students. *Educational Psychology Review, 16*(4), 385–407.

Prencipe, A., Kesek, A., Cohen, J., Lamm, C., Lewis, M. D., & Zelazo, P. D. (2011). Development of hot and cool executive function during the transition to adolescence. *Journal of Experimental Child Psychology, 108*(3), 621–637. https://doi.org/10.1016/j.jecp.2010.09.008

Purdie, N., Carroll, A., & Roche, L. (2004). Parenting and adolescent self-regulation. *Journal of Adolescence, 27*, 663–676.

Pureza, J. R., Gonçalves, H. A., Branco, L., Grassi-Oliveira, R., & Fonseca, R. P. (2013). Executive functions in late childhood: Age differences among groups. *Psychology and Neuroscience, 6*(1), 79–88. https://doi.org/10.3922/j.psns.20-13.1.12

Radmehr, F., & Drake, M. (2020). Exploring students' metacognitive knowledge: The case of integral calculus. *Education Sciences, 10*(3), 1–20. https://doi.org/10.3390/educsci10030055

Robbers, E., Donche, V., De Maeyer, S., & Van Petegem, P. (2017). A longitudinal study of learning conceptions on the transition between primary and secondary education. *Research Papers in*

Education, 33(3), 375–392. https://doi.org/10.1080/02671522.2017.1329337

Roebers, C. M. (2017). Executive function and metacognition: Towards a unifying framework of cognitive self-regulation. *Developmental Review, 45*, 31–51. https://doi.org/10.1016/j.dr.2017.04.001

Roth, A., Ogrin, S., & Schmitz, B. (2016). Assessing self-regulated learning in higher education: A systematic literature review of self-report instruments. *Educational Assessment Evaluation and Accountability, 28*(3), 225–250. https://doi.org/10.1007/s11092-015-9229-2

Schunk, D. H., & Greene, J. A. (2018). Historical, contemporary, and future perspectives on self-regulated learning and performance. In D. H. Schunk, & J. A. Greene (Eds.), *Handbook of self-regulation of learning and performance* (2nd ed., pp. 1–15). Routledge.

Schunk, D. H., & Zimmerman, B. J. (2007). Influencing children's self-efficacy and self-regulation of reading and writing through modeling. *Reading and Writing Quarterly, 23*, 7–25. https://doi.org/10.1080/10573560600837578

Siddaway, A. P., Wood, A. M., & Hedges, L. V. (2019). How to do a systematic review: A best practice guide to conducting and reporting narrative reviews, meta-analyses, and meta-syntheses. *Annual Review of Psychology*, 70. https://doi.org/10.1146/annurev-psych-010418-102803

Taranto, D., & Buchanan, M. T. (2020). Sustaining lifelong learning: A self-regulated learning (SRL) approach. *Discourse and Communication for Sustainable Education, 11*(1), 5–15. https://doi.org/10.2478/dcse-2020-0002

Taylor, S. J., Barker, L. A., Heavey, L., & McHale, S. (2013). The typical developmental trajectory of social and executive functions in late adolescence and early adulthood. *Developmental Psychology, 49*(7), 1253–1265. https://doi.org/10.1037/a0029871

Taylor, S. J., Barker, L. A., Heavey, L., & McHale, S. (2015). The longitudinal development of social and executive functions in late adolescence and early adulthood. *Frontiers in Behavioral Neuroscience*, 9. https://doi.org/10.3389/fnbeh.2015.00252

Thibodeaux, J., Deutsch, A., Kitsantas, A., & Winsler, A. (2017). First-year college students' time use: Relations with self-regulation and GPA. *Journal of Advanced Academics, 28*(1), 5–27. https://doi.org/10.1177/1932202X16676860

Titz, C., & Karbach, J. (2014). Working memory and executive functions: Effects of training on academic achievement. *Psychological Research Psychologische Forschung, 78*, 852–868. https://doi.org/10.1007/s00426-013-0537-1

Tuominen, H., Niemivirta, M., Lonka, K., & Salmela-Aro, K. (2020). Motivation across a transition: Changes in achievement goal orientations and academic well-being from elementary to secondary school. *Learning and Individual Differences, 79*, 101854. https://doi.org/10.1016/j.lindif.2020.101854

Usher, E. L., & Pajares, F. (2008). Self-efficacy for self-regulated learning: A validation study. *Educational and Psychological Measurement, 68*(3), 443–463. https://doi.org/10.1177/0013164407308475

van der Veen, I., & Peetsma, T. (2009). The development in self-regulated learning behaviour of first-year students in the lowest level of secondary school in the Netherlands. *Learning and Individual Differences, 19*(1), 34–46. https://doi.org/10.1016/j.lindif.2008.03.001

Vandenbroucke, L., Seghers, J., Verschueren, K., Wijtzes, A. I., & Baeyens, D. (2016). Longitudinal associations between objectively measured physical activity and development of executive functioning across the transition to first grade. *Journal of Physical Activity and Health, 13*(8), 895–902. https://doi.org/10.1123/jpah.2015-0708

Visu-Petra, L., Benga, O., & Miclea, M. (2007). Dimensions of attention and executive functioning in 5-to 12-year-old children: Neuropsychological assessment with the NEPSY Battery. *Cognition Brain Behavior, 11*(3), 585–608.

Vosniadou, S. (2020). Bridging secondary and higher education. The importance of self-regulated learning. *European Review, 28*(S1), S94–S103. https://doi.org/10.1017/S1062798720000939

Waters, S., Lester, L., & Cross, D. (2014). How does support from peers compare with support from adults as students transition to secondary school? *Journal of Adolescent Health, 54*(5), 543–549. https://doi.org/10.1016/j.jadohealth.2013.10.012

Wei, M., Russell, D. W., & Zakalik, R. A. (2005). Adult attachment, social self-efficacy, self-disclosure, loneliness, and subsequent depression for freshman college students: A longitudinal study. *Journal of Counseling Psychology, 52*(4), 602–614. https://doi.org/10.1037/0022-0167.52.4.602

Welsh, M. C. (2001). The prefrontal cortex and the development of executive function in childhood. In A. F. Kalverboer & A. Gramsbergen (Eds.), *Handbook of brain and behaviour in human development* (pp. 767–790). Kluwer Academic Publishers.

Whitley, J., Lupart, J. L., & Beran, T. (2007). Differences in achievement between adolescents who remain in a K-8 school and those who transition to a junior high school. *Canadian Journal of Education, 30*(3), 649–669. https://doi.org/10.2307/20466657

Wolters, C. A., & Won, S. (2018). Validity and the use of self-report questionnaires to assess self-regulated learning. In D. H. Schunk, & J. A. Greene (Eds.), *Handbook of self-regulation of learning and performance* (2nd ed., pp. 307–322). Routledge.

Wu, K. K., Chan, S. K., Leung, P. W. L., Liu, W. S., Leung, F. L. T., & Ng, R. (2011). Components and developmental differences of executive functioning for school-aged children. *Developmental Neuropsychology, 36*(3), 319–337. https://doi.org/10.1080/87565641.2010.549979

Wu, H., Guo, Y., Yang, Y., Zhao, L., & Guo, C. (2021). A meta-analysis of the longitudinal relationship between academic self-concept and academic achievement. *Educational Psychology Review*. https://doi.org/10.1007/s10648-021-09600-1

Xia, M., Poorthuis, A. M. G., & Thomaes, S. (2023). Why do young children overestimate their task. performance? A cross-cultural experiment. *Journal of Experimental Child Psychology, 226*, 105551. https://doi.org/10.1016/j.jecp.2022.105551

Zimmerman, B. J. (2000). Attaining self-regulation: A social cognitive perspective. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 13–35). Academic Press.

Zimmerman, B. J. & Schunk, D. H. (2011). Self-regulated learning and performance. An introduction and an overview. In D. H. Schunk & B. J. Zimmerman (Eds.), *Handbook of self-regulation of learning and performance* (pp. 1–12). Routledge.

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