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REVIEW ARTICLE

The Relationship Between Self-Regulated Learning and Executive Functions—a Systematic Review

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Abstract

Self-regulated learning (SRL) and executive functions (EF) are broad concepts stemming from different research areas. They have been defined and modeled in various ways and are repeatedly related to each other in the literature, but so far, no systematic analyses of these relations have been published. Therefore, a systematic analysis of their relationships described in the literature was conducted. Nineteen studies were synthesized concerning different categories (age groups, measurement methods, role of metacognition, relation to achievement, and longitudinal/intervention studies). In general, primarily low to moderate correlational relationships between SRL and EF were reported, with no detectable pattern depending on the age group. Measurement methods used to capture SRL and EF seem to influence the size of the correlations, with indirect measures correlating higher than direct/indirect measures. In addition, there is evidence that metacognition mediates the relationship between EF and SRL. In general, the notion that EF predicts SRL but not vice versa is supported. Following the systematic review, the results are critically discussed in the light of non-generalizable samples, measurement methods, and results interpretation issues. Suggestions for theory building and promising future research are given.

Keywords Self-regulated learning · Executive functions · Metacognition · Systematic review

Pursuing goals is essential to human life and is relevant to various contexts, such as academics, working, social life, well-being, and health behavior. Concerning academic goals, adaptive learning goal-related behavior is entitled to self-regulated learning (Boekaerts, 1999). Self-regulated learning (SRL) is a construct that describes how individuals actively initiate goal-directed learning processes and control and regulate their cognitive processes within academic contexts (Puustinen & Pulkkinen, 2001). As this definition discloses, metacognition is an essential part

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of SRL ("control and regulate") and is defined as encompassing higher-order cognitive processes that help to monitor, control, and adapt information processes on a lower level (Roebers, 2017). The term higher-order cognitive processes is also used to refer to executive functions (EF) as they describe the top-down regulation of cognitive and behavioral processes (Miyake et al., 2000). As the previous definitions made clear, several conceptualizations are highly relevant when describing goal-directed behavior (SRL, metacognition, EF), and it is not obviously clear how to differentiate between these concepts. In this context, Kim et al. (2023) speak of jingle-jangle fallacies, as the same terms are used for different conceptualizations resp. similar conceptualizations are named differently. Moreover, there is convincing evidence that SRL, metacognition, and EF are linked to academic achievement (e.g., Dent & Koenka, 2016; McClelland et al., 2013).

In order to disentangle the abovementioned conceptual overlaps, several reviews have delved into the literature and offered highly relevant insights: Dinsmore et al. (2008) carried out a review to shed light on the conceptual overlaps and differences between general self-regulation (execution of general goal-directed behavior; Hofmann et al., 2012), SRL, and metacognition, Kim et al. (2023) reviewed the literature on SRL and metacognition to integrate scientific views from cognitive and educational psychology. Referring to EF, Hofmann et al. (2012) wrote a pertinent review on the relationship between EF and general self-regulation, while Roebers (2017) illuminated the links between EF and metacognition within her seminal review. In order to complete the circle, the present systematic review aims to synthesize hitherto existing literature on the relationship between SRL and EF, as no review to date has focused on this conceptual overlap. We, therefore, explicitly do not integrate metacognition and general self-regulation into our search process, as such reviews already exist. Moreover, we aim to focus on self-regulated *learning* processes (and therefore representing an educational psychology perspective) and their relationship to EF. The review results should give new insights into and help structure associations between SRL and EF and uncover possible directional connections between both constructs. Summarizing and analyzing the current state of research is necessary to expedite theoretical work on this aim and stimulate empirical studies that further help disentangle both constructs.

Theoretical Background

Self-Regulated Learning: Background, Definition, Models

The well-known works of Bandura (1986) can be seen as the general theoretical foundation for research on self-regulation, introducing behavior, emotion, self-efficacy, and motivation as regulatory areas (Dinsmore et al., 2008). Although most of the articles on self-regulation were published in social psychology and personality journals (Boekaerts et al., 2000), from the 1990s on, the concept was applied to the academic domain, generating the term "self-regulated learning" (SRL). While there is no single widely accepted definition that would suffice all SRL research (Boekaerts, 1999), Perels et al. (2020) mention that even though numerous different

definitions exist, they are united by using three key components: A cognitive component (processing of information, strategic knowledge, and learning strategies), a motivational component (activities that serve to initiate and sustain the learning process, in addition to action-promoting attributions of successes and failures, and self-efficacy beliefs), and a metacognitive component (planning of the learning process, observing oneself in the learning situation, reflecting on and subsequently adapting the learning behavior by evaluating its usefulness for the learning goal). Following that, recent reviews describe SRL as incorporating cognitive, metacognitive, motivational, emotional, and behavioral aspects of learning (Panadero, 2017; Zeidner & Stoeger, 2019).

One definition of SRL that encompasses the aforementioned main components in a condensed manner and is meant when referring to SRL in this review comes from Pintrich (2000, p. 453): "self-regulated learning is … an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features in the environment". Pintrich (2000) makes several assumptions to come to this definition: Firstly, learners do not just passively receive information but actively use information coming from the environment and from their minds to construct their own meanings, set their own goals, and choose learning strategies. Secondly, there needs to be the assumption that learners can at least partially monitor, control, and regulate their cognition, motivation, and behavior. Thirdly, Pintrich argues that a criterion or goal must be set and worked towards, and the subsequent process can be regulated and adapted when one is in danger of missing one's goal. Lastly, self-regulatory endeavors are assumed to mediate between the described personal and contextual characteristics and eventual achievement.

SRL as a construct has been heavily researched over the last three decades. As a consequence of this and the fact that different definitions emphasize different aspects of the construct, a range of theoretical models have been proposed (see Panadero, 2017; Tinajero et al., 2024). However, Zeidner and Stoeger (2019) note that many commonalities between models emerge. According to most models, successful self-regulation in a learning context occurs when students actively engage in the learning process and take measures to actively adapt their behavior, personal processes, and external conditions to attain their goals. In his recent review, Panadero (2017) shows that Pintrich's (2000) and Zimmerman's (2000) models, which give a comprehensive overview of distinct SRL phases and areas of regulation, are most frequently used in the literature, with Zimmerman's model being the most cited (Panadero, 2017; Tinajero et al., 2024). Moreover, both models are based on the same theory (i.e., Bandura's (1986) social cognitive theory) and therefore bear resemblance (Puustinen & Pulkkinen, 2001). Besides such process models of SRL, component models focus on describing the competencies that positively impact SRL (Winne & Perry, 2000). To differentiate and provide a more thorough overview of the literature for the systematic analysis, Boekaerts' three-layered model of SRL (1999) will be examined in addition to Zimmerman's model (2000). In their review article, Tinajero et al. (2024) describe Zimmerman's model (2000)

as adopting a distant focus that established the process structure of SRL, while Boekaerts' model (1999) adopts a more task-focused approach. Therefore, both models are helpful to cover the whole SRL construct.

Zimmerman's Social Cognitive Model of Self-Regulation

By referring to self-regulation as "self-generated thoughts, feelings, and actions that are planned and cyclically adapted to the attainment of personal goals" (Zimmerman, 2000, p. 14), Zimmerman introduces a cyclical viewpoint that is not only essential to his social cognitive model of self-regulation but also to many other SRL models (Panadero, 2017). His process model explicitly focuses on describing process phases and the requirements to be met in the respective phase (see Fig. 1b). It is cyclical because the feedback resulting from prior behavior can influence or be used to adjust current behavior. This leads to a model that resembles a simple control loop in which a current actual status is compared with a target status, and depending on the difference, behavioral or cognitive adjustments will or will not be made (Perels et al., 2020). Zimmerman (2000) deems these reoccurring adjustments necessary because personal, behavioral, and environmental factors continuously change during learning processes.

The forethought phase splits into task analysis and self-motivation beliefs: task analysis involves goal setting, where students analyze task features and the requirements for performance. Goal setting is conditioned by essential self-motivational beliefs like self-efficacy (beliefs about one's ability to perform effectively), outcome expectations (what final result is expected), what value the task has, and how goal-oriented and interested the performer is. Considering these beliefs, the overall motivation for the task will be determined, as well as the effort and the activation of self-regulatory strategies. In the following performance or volitional control phase, the actual execution of the task takes place, including self-control and self-observation processes.

The self-control part reflects a process that aims to keep concentration and interest high with the help of various strategies (e.g., self-instructions or self-praise; Panadero & Alonso-Tapia, 2014). Self-observation can be described as a comparison between the expert model and what the student is doing and the assessment of one's performance (metacognitive monitoring) (Panadero & Alonso-Tapia., 2014). For the self-reflection phase, self-judgment and self-reaction are the two fundamental processes. They emerge after a task or performance has concluded and play an essential part in how a person responds to their (learning) experience. Judging oneself requires comparing the information gathered during the action with a standard or goal. During self-judgments, learners will also want to find causal attributions regarding the results of their learning session by analyzing their accomplishments or shortcomings and drawing conclusions about their abilities or invested effort (Puustinen & Pulkkinen, 2001). These attributions result in positive and negative emotions, which can impact motivation and regulation in future performances. Self-reaction includes satisfaction or dissatisfaction and adaptive or defensive

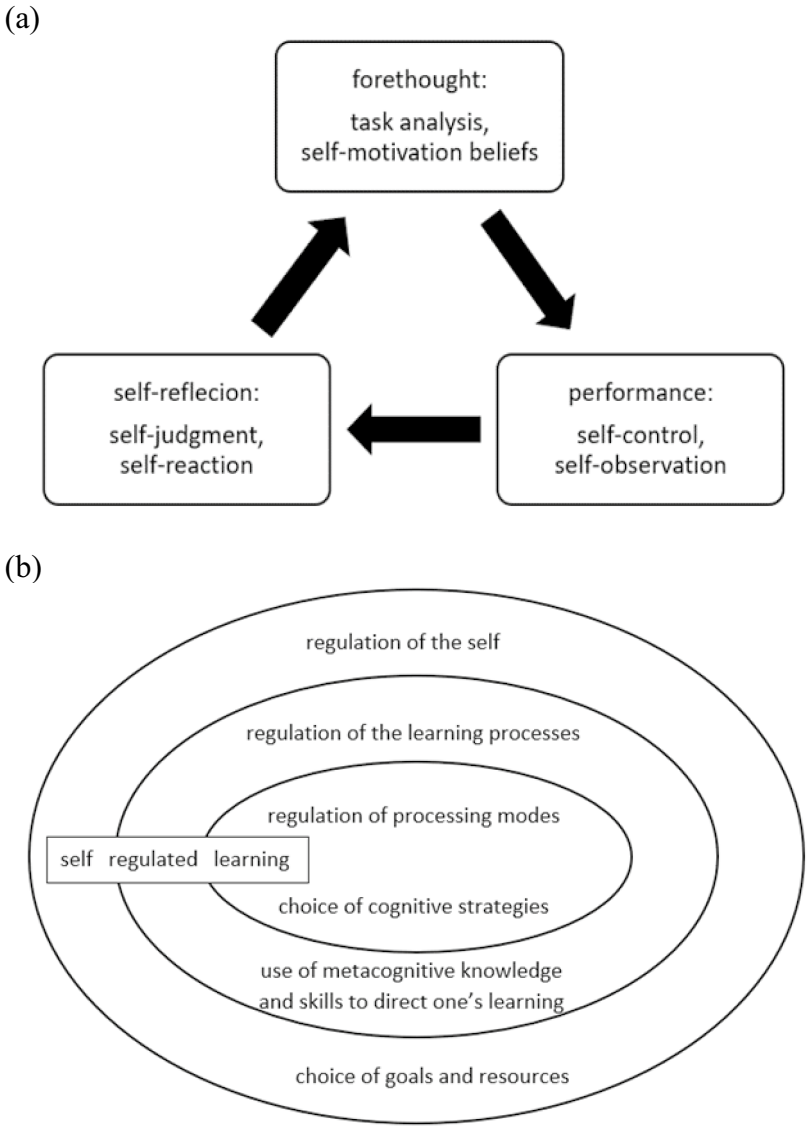

Fig. 1 **a** Cyclical model of self-regulation (Zimmerman, 2000) and **b** three-layered model of SRL (Boekaerts, 1999)

interferences. Returning to the cyclical aspect of Zimmerman's (2000) model, the late self-reflection phase prepares the next forethought phase.

Boekaerts' Three-Layered Model of SRL

The three-layered model of SRL (Boekaerts, 1999) consists of three concentrical ellipses (see Fig. 1a): The inner ellipse stands for the regulation of processing modes and is enclosed by the regulation of the learning process ellipse; both are encompassed by an ellipse that signifies the regulation of the self. The innermost ellipse can be seen as the typical way students learn. For self-regulation to occur on this level of the model, i.e., dealing adequately with a particular learning task by being able to adapt the course of action, the learner must perceive the choice between different cognitive strategies (Winne & Perry, 2000). The middle layer of the model represents the regulation of the learning processes, i.e. the learner guides and directs their learning process by monitoring whether they perform the task as planned in the inner ellipse. This is achieved using metacognitive knowledge and metacognitive strategies, including orienting, planning, executing, monitoring, evaluating, and correcting (Weinstein & Mayer, 1986). Regulation on this level is done internally when students can set their own goals, but some do need external regulation, for example, the guidance of a teacher or parent. The outer layer integrates the regulation of the self, including aspects like volition and motivation. If learning activities are self-initiated, they are more likely driven by personal goals compared to externally initiated learning, which is mainly imposed by the wishes and expectations of others. In general, the learner's overarching goals are potent drivers of behavior and can reveal how a learner regulates the self. The following section will give an overview of EF's definitions and model to lay this construct's theoretical foundation for the systematic review.

Executive Functions: Background, Definitions, Models

Executive functions (EF) describe a family of top-down or higher-order cognitive processes that are involved in goal-directed, flexible, and adaptive behavior and execute cognitive control through attentional, decision-making, and coordinative functions (Diamond, 2013; Miyake et al., 2000). Since the 1960s, Luria (e.g., Luria et al., 1967) systematically studied frontal lobe injuries and the accompanying effects (Suchy, 2009) and later described the functions of the frontal lobes as taking on an executive role (Goldstein et al., 2014a, b; Luria, 1980). Therefore, neuroanatomy and neuropsychology had a significant impact on the emergence of EF research. Overview articles on EF (Jurado & Rosselli, 2007; Suchy, 2009) often include clinical populations like patients who suffered brain damage from accidents or diseases in their concept assessment. Furthermore, Jurado and Rosselli (2007) list an extensive collection of neuroimaging research that links cognitive abilities associated with EF, like planning, attentional control, cognitive flexibility, and verbal/nonverbal fluency, to brain areas like the frontal lobes, different subcortical structures, and thalamic pathways. Additionally to neuropsychological research, other lines of research played an essential part in developing the EF construct: Broadbent (1958) contributed to the topic via the distinction between automatic and controlled

processes, and Shiffrin and Schneider (1977) proposed the concept of selective attention. Baddeley's (1992) influential working memory model includes a component named the central executive, which is assumed to have specific control over attention and cognitive processes. Norman and Shallice (1986) see evidence for a so-called supervisory attentional system that can replace automatic action with intentional behavior. As with SRL, EF has been approached in many ways, leading to different understandings of the concept.

EF has become an umbrella term for a whole collection of cognitive processes and abilities, including "stopping prepotent or automatic responses, resisting distraction or interference from irrelevant information in the environment or memory, switching between task sets, aspects of working memory processes, dual tasking, planning, monitoring, and verbal and design fluency" (Friedman & Miyake, 2017, p. 186). This, and the fact that Goldstein et al. (2014a, b) cited over 30 construct definitions from EF researchers, makes it not trivial to define the concept for general use in this work. Based on the approaches to define EF supposed by Suchy (2009), we consider it beneficial to include neurocognitive processes (like working memory, sequencing, inhibition, initiation, and response selection), use constructivist definitions, and consider a list of complex skills (like planning, reasoning, problem-solving, and judgment). Executive functions are directive capacities responsible for a person's ability to engage in purposeful, organized, strategic, self-regulated, goal-directed processing of perceptions, emotions, thoughts, and actions.

Although some models treat EF as a unitary construct, many EF researchers see evidence for EF being a multidimensional construct (Karr et al., 2018). In order to account for multidimensional models and the elementary neurocognitive processes approach, the well-established model of Miyake et al. (2000) will be explored in more detail. Miyake et al. (2000) build their model on three frequently proposed dimensions of EF: shifting, updating, and inhibition. The authors approach the topic via evidence for performance differences across executive tasks in clinical populations (e.g., Godefroy et al., 1999). Another consideration is that although the interrelations between different EF tasks are low, this does not necessarily indicate distinguishable EF because of the task impurity problem (Miyake & Shah, 1999). This means that when EF is being tested, the process requires other cognitive skills or functions that may be independent of EF-related brain structures but are reflected in the test results (Rabbitt, 1997).

To counter these challenges, Miyake et al. (2000) choose a latent variable analysis to explore EF's organization and cognitive role. The latent EF used in this model has the advantage that it is, compared to more complex proposed EF-like problem-solving, relatively elementary and limited in functionality and, therefore, can be operationalized more precisely (Miyake et al., 2000). *Shifting* requires switching between tasks or mental sets and results in different temporal costs that may stem from a differing ability to engage and disengage from tasks or handle interference from previous tasks (Miyake et al., 2000). *Updating* (or *working memory*) refers to a function that involves monitoring what kind of information is presented and relevant for the task at the moment and actively changing the information stored in the working memory by replacing old, irrelevant representations with new, relevant ones (Morris & Jones, 1990). Inhibition

is consciously suppressing prevalent, automatic, or prepotent responses when needed (Miyake et al., 2000). Using confirmatory factor analysis, the authors conclude that a three-factor model for shifting, updating, and inhibition fits the gathered data best when statistically compared to the various conceivable two-factor models and a one-factor model. However, further model comparisons showed that three completely separable factors were statistically unlikely, suggesting that the EFs assessed had at least some fundamental commonality.

Several other models build upon the model of Miyake and expand it: Diamond (2013) amplified these primary EF and hypothesized that they could build the basis for complex and higher-ranked functions such as reasoning, problem-solving, and planning. By arranging different tasks on a continuum from simple to complex EF requirements, Luciana et al. (2005) aimed at integrating both simple and complex EF within one model: While spatial memory span is seen as a simple function with relatively low cognitive requirements, behavioral organization during spatial self-ordered search tasks is seen as a complex function with relatively high cognitive requirements. In contrast, Prencipe et al. (2011) use a differentiation based on the dominating involvement of the EF processes in other processes. While "cold" EFs (e.g., working memory) are mainly responsible for abstract processes, "hot" EFs (e.g., decision-making during delay of gratification situations) are influenced more by affective and motivational stimuli. Cold EFs, therefore, can be seen as the regulation basis for hot EFs (Hofmann et al., 2012). Both perspectives could be integrated if hot EFs were seen as more complex than cold EFs due to their emotional relevance. Figure 2 illustrates how all three perspectives could be integrated within one model (author, year).

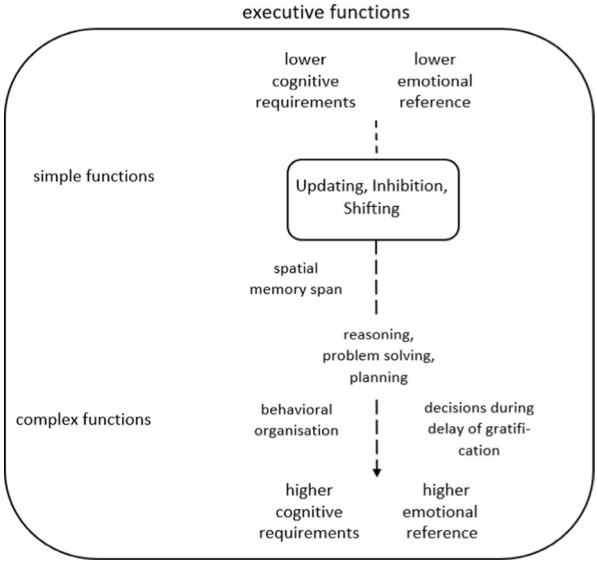

Fig. 2 Extended illustrative structure of EF. Processes on the left correspond to a model by Luciana et al. (2005); processes on the right correspond to a model by Prencipe et al. (2011), both integrating the primary EF functions of Miyake et al. (2000) and the higher-level functions of Diamond (2013) (adapted from author, year)

Similarities and Differences between SRL and EF

Based on the previous sections and the presented models, it can be resumed that SRL and EF have conceptual overlaps: Both constructs describe goal-related behavior and, therefore, higher-order cognitive processes with dynamic and regulatory functions that aim at monitoring, controlling, and regulating information processing and optimizing lower-level task processing (Roebers, 2017). Nevertheless, research histories of both constructs strongly differ as research on EF stems from frontal lobe functioning studies in clinical neuropsychology and also from developmental psychology (Roebers, 2017), while SRL is a concept of educational psychology that directly resulted from school studies (Dinsmore et al., 2008). In the following, we will describe several topics that help to uncover similarities and differences between SRL and EF.

Components of SRL and EF

When comparing SRL and EF on the component level, the review of Hofmann et al. (2012) can be very helpful as the authors proposed how EF components could be transferred to general self-regulation: while working memory is assumed to support the representation of goals, control of attention and shielding from distractions, inhibition is hypothesized to inhibit impulses and habitual behaviors that endanger goal achievement. Shifting could help individuals to switch flexibly between different strategies or multiple goals. As this transfer to self-regulation is not learning-specific, we illustrate how EF components could support SRL components (see also Hoyle & Dent, 2018): While working memory is necessary to process the information on the lowest level (cognitive component of SRL), it is also needed to monitor and control information processing (metacognitive component of SRL) as well as to actively represent goals and use these goals to control attention (motivational component of SRL). Inhibition is assumed to mainly support the motivational component of SRL as volitional strategies have to be used to maintain the motivation for goal achievement (and therefore shield learning processes from distracting thoughts). Shifting is hypothesized to mainly support metacognition, as the flexible adaption of the strategy used should result from monitoring and controlling learning processes. In line with this, Bol and Garner (2011) try to conceptualize SRL as an application of EF (for the context of learning in distance education environments with electronically enhanced texts). In general, they see "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). The authors suggest EF variations may influence the SRL cycle during interactions with electronic learning material. Low EF, therefore, could lead to difficulties in goal setting and strategic planning, resulting in the inability to switch learning strategies when necessary. Moreover, they assume that EF supports attentional control, which is imperative during the volitional stage of SRL. Referring to the categorization of Prencipe et al. (2011), cold EF seems more likely

to be related to the (meta-)cognitive component of SRL, while hot EF most likely are strongly related to the motivational component of SRL. For the differentiation between simple and complex EF (Diamond, 2013; Luciana et al., 2005), the transfer to SRL is not as easy as SRL strategies most likely can be seen as complex (due to their general reliance on metacognitive knowledge and skills).

In conclusion, regarding the theoretical component level of both SRL (cognition, metacognition, and motivation; referring to the model of Boekaerts, 1999) and EF (working memory, inhibition, shifting; referring to the model of Miyake et al., 2000), it can be assumed that EF components support the different SRL components in various ways with some EF components are likely to have a more substantial influence on SRL components than others (e.g., working memory seems to support all three SRL components, while inhibition and shifting mainly support one SRL component). Regarding process models of SRL, such as Zimmerman's model (2000), it is evident that SRL is more than the sum of the components: The cyclical nature of the model highlights that an optimal SRL process encompasses different phases (which all comprise several SRL components themselves). One phase can only be executed in an optimal goal-oriented way if the previous phase has been passed successfully. Each phase gives hints to the learners about whether the behavior is still goal-oriented and where they can regulate their behavior through strategy application. The feedback loop from the reflection to the following planning phase is enormously important as the learner can conclude previous learning cycles and the possible outcomes (success/failure). This cyclical nature is missing in the above-described EF models and helps to differentiate both constructs. In EF models, the different components are more collocated, and how they interfere with one another is not apparent nor theoretically deduced. This is also obvious when looking at the model of Miyake et al. (2000), who used a latent variables analysis approach. The three-factor model was the best-fitting model compared to the two-factor and one-factor models.

Metacognition

In general, metacognition is defined as "thinking about thinking" or, more specifically, as "knowledge and cognition about cognitive phenomena (Flavell, 1979, p. 906). In his seminal work, Flavell (1979) distinguished between metacognitive knowledge and metacognitive experiences: Metacognitive knowledge describes knowledge or beliefs about the interaction of different factors and their influence on the outcomes of cognitive processes. This knowledge can refer to persons (e.g., some people can better learn through hearing than through reading), task demands/goals (e.g., some tasks/goals are easier to accomplish/achieve than others), and strategies to achieve these goals (e.g., repeating is a valuable strategy to learn word lists but not to understand Maths). Metacognitive experiences are conscious reflections about cognition and primarily arise in cognitively challenging situations that require a lot of decisions, planning, and evaluation. Metacognitive experiences interact with and help to form and develop metacognitive knowledge. Besides metacognitive knowledge and metacognitive experiences, Veenman et al. (2006) introduce metacognitive

skills, which are about a "person's procedural knowledge for regulating one's problem-solving and learning activities" (e.g., planning a learning task; p. 4).

Besides Flavell's work, Nelson and Narens's (1990) model is essential when describing metacognition. Their conceptual framework on the relation of metacognition and cognition defines an object-level (basic information processing operations) and a meta-level (learner's model of the task and cognitive operations during performance). Metacognitive monitoring processes connect both levels cyclically as they transfer information about the object-level to the meta-level. Moreover, the meta-level can initiate control processes and regulate object-level processes to reach a specific goal. Pintrich et al. (2000) combine the work of Flavell (1979) and Nelson and Narens (1990) and state that metacognition comprises metacognitive knowledge, metacognitive monitoring and judgments, and metacognitive control. The authors describe that metacognitive knowledge can either refer to declarative ("What"), procedural ("How"), or conditional ("When" and "Why") strategy knowledge. In contrast, metacognitive monitoring refers to the learner's awareness regarding his/her current knowledge or learning process evaluation (Dunlosky and Metcalfe, 2008). It is deemed a "situation-specific and context-dependent" process that acts on the object-level and helps the learner regulate the learning process on the meta-level (Händel and Dresel, 2022, p. 2). Metacognitive judgments (i.e., a probabilistic judgment on performance quality) are indicators for metacognitive monitoring (Nelson and Narens, 1990). The process of selecting and using strategies for adapting learning processes is called metacognitive control.

For the overlap between general self-regulation, SRL, and metacognition, Dinsmore et al. (2008) report seven keywords within their review that unite all three constructs, which are "monitor, control, regulate, cognition, motivation, behavior, and knowledge" (p. 400). It is obvious that the first four keywords are also highly relevant when describing EF and that the overlap between EF and SRL mainly refers to the metacognitive component of SRL (Boekaerts, 1999). Metacognition, therefore, seems to play a special role in the relationship between SRL and EF as both correlate with knowledge and control of one's cognitive processes and with metacognition (Follmer & Sperling, 2016). Metacognition is a highly relevant construct on its own, but it is also an essential subcomponent of EF and SRL (Hoyle & Dent, 2018). The motivational component of SRL, which refers to initiating learning processes and pursuing goal achievement using volitional strategies, shows partial overlap with what hot EF means.

Developmental Aspects

Concerning developmental aspects, children have already established the foundation for SRL during preschool and primary education (Bronson, 2000; Chatzipanteli et al., 2014). However, their skill sets are further strengthened and expanded by experiences throughout secondary and tertiary education (Hoyle & Dent, 2018). For EF, essential development occurs before the age of six, as the foundations for working memory, inhibition, and updating are laid out at the preschool age (Welsh, 2001). These three core components and the advancement of complex thinking,

planning, and decision-making can be observed from elementary school to adolescence (Roebers, 2017; Welsh, 2001). Based on this somewhat earlier onset of development for EF than for metacognition, Roebers (2017) hypothesizes that EF has a causal role in the development of metacognition in early years, with this influence diminishing when domain-specific knowledge comes into play (which is important for metacognitive development). Karr et al. (2018) found a divergence of EF from preschool into adulthood. In contrast, Rheinberg et al. (2000) see a rising demand for SRL abilities with increasingly complex learning materials in higher grades. It could be argued that both concepts are subject to change throughout life. Thus, researchers could try to conclude their relationship from empirically observable parallel or divergent developments.

Measurement

Concerning measurement, SRL is mainly measured in authentic learning environments that ensure external validity, and the studies mostly show a cross-sectional or longitudinal instead of an experimental design (Kim et al., 2023). This is frequently done using self-report questionnaires that are sometimes very general (referring to learning tasks in general, e.g., Dörrenbächer & Perels, 2016) but sometimes domain- or course-specific (Roth et al., 2016). Using more context-sensitive measures such as microanalysis or trace data can help assess SRL in a task-specific and, therefore, more objective way (Dörrenbächer-Ulrich et al., 2021). In general, there is no clear answer on how to measure SRL optimally as all assessment methods show benefits and points of criticism (Rovers et al., 2019), so the choice of instrument often depends on the theoretical model or the aim of the study. In contrast, EF is mainly measured decontextualized using single tasks to assess specific components of EF or task batteries that assess more than one EF component (Chan et al., 2008). For example, the "Stroop Test" is probably the best-known test for assessing the inhibition component of EF. At the same time, the "Wisconsin Card Sorting Test" (Heaton & PAR Staff, 1993) is a prominent test to measure the shifting component, and the "Tower of London" (Shallice, 1982) is often used to measure the planning component. These tasks are primarily applied in laboratory and highly controlled studies. Besides task-based tests, there are also questionnaires to measure EF (impairment) in everyday situations, such as the "Naturalistic Action Test" (Schwartz et al., 2002).

Achievement Criteria and Intervention Studies

For achievement, it can be stated that both SRL and EF show substantial relations to academic performance measures. For SRL, meta-analyses show a positive relationship to achievement but with low effect sizes (e.g., Broadbent & Poon, 2015; Dent & Koenka, 2016). EF is a valid predictor for academic achievement (McClelland et al., 2013; Titz & Karbach, 2014) and can explain about 20–60% of school children's achievement variance (Roebers et al., 2014), while this has been shown for elementary up to high school students. As both SRL and EF are positively related to

academic achievement, it is helpful to look at the relationship of both constructs to achievement outcomes to find overlaps and differences between SRL and EF.

Literature addressing the fostering of SRL (e.g., Perels et al., 2020) or EF (e.g., Dawson & Guare, 2014) can serve as another indicator for concept overlaps. For example, if respective interventions aimed at fostering one of the concepts lead to qualitative changes in the other concept (defined as "far transfer"; see Kassai et al., 2019), this could indicate conceptual overlaps or entanglements. However, it is essential to consider how the interventions were designed and whether they exclusively foster one or both constructs, in this case, conclusions about conceptual relationships are challenging to draw.

Aims of the Present Systematic Review

The aim of compiling this theoretical background on SRL and EF was to explore the emergence and different definitions of the two concepts and the models that attempt to structure them. As has become evident, the two constructs are broad, defined, and modeled in many ways, and primarily grounded in different research fields. Moreover, we aimed to sum up the similarities and differences between the constructs by comparing their components, their development, ways of measuring both constructs and their relationship to achievement. In the systematic analysis, an effort will be made to structure associations between SRL and EF in a way that allows parallels to be drawn between different categories of relationships across studies. This way, findings from correlational associations could be compared with those from SRL-EF mediation modeling to reach more reliable conclusions about possible concept overlaps or entanglements. Another goal is to clarify whether SRL or EF is an application of the other or whether other directional connections can be found. Embedding these results in the thoroughly researched theoretical background may lead to insights regarding the shortcomings of the analyzed study designs, which may benefit future research. In conclusion, we aimed to investigate the following research questions:

RQ 1: How are SRL and EF related, and does this relationship depend on the age of the study sample or measurement methods?
RQ 2: What role does metacognition play within the relationship of SRL and EF?
RQ 3: How are SRL and EF related to academic achievement?
RQ 4: What are the results of longitudinal or interventional studies on the relationship between SRL and EF?

Method

To compile the literature and systematically compare SRL and EF, a search engine had to be chosen first, and search parameters had to be defined. EBSCO, a provider of research databases, electronic journals, journal subscriptions, e-books, and discovery services, was chosen as the literature source. On its search engine

EBSCOhost, the relevant databases "APA PsycArticles", "APA PsycInfo", "ERIC" and "PSYNDEX Literature with PSYNDEX Tests" were searched as follows: On January 31, 2024, the search string "TX (self-regulated learning OR srl) AND TX (executive function OR executive functioning)" resulted in 214 potential sources. No further restrictions were placed on the search criteria. Thus, non-peer-reviewed sources were also included, and no time limits regarding the date of publication were set. Of the 214 sources found, eleven exact duplicates were removed, leaving 203 sources to be studied in terms of content.

Inclusion and Exclusion Criteria

For this review, several inclusion and exclusion criteria were defined: as this review aims at giving a first overview of studies dealing with the relationship between SRL and EF and therefore aims to integrate both constructs on a general and conceptual level, sources that examined clinical populations, like individuals diagnosed with ADHD (e.g., Sibley et al., 2019) or autism spectrum disorder (e.g., Grainger et al., 2016) were excluded. Given that all studies were in English, none had to be excluded based on language. All papers that addressed any conceptual relationship or comparison between SRL and EF were considered to meet the inclusion criteria. For example, studies that described correlations (e.g., Effeney et al., 2013), mediation models (e.g., Follmer & Sperling, 2016), divergences, and convergences of the two concepts (e.g., Garner, 2009) were included. At this point, it should be reiterated that the goal is to systematically extract the researchers' results and conclusions on the relation between SRL and EF, not to compare results focusing exclusively on one of the constructs. Based on the abstracts, 161 papers were excluded according to the above criteria. In contrast, most papers were excluded as they did not focus on self-regulated learning (e.g., they mentioned the construct in the discussion but did not examine it in the main study) or as they did not investigate the relationship between both constructs. If the exclusion and inclusion criteria could not be applied without a doubt, the papers were retained in the literature pool for further analysis. In addition, six studies were excluded because they were not accessible through databases acquired by the University's libraries. Of the remaining 36 potential sources, an extra 19 were excluded after additional textual examination following the exclusion and inclusion criteria. Both authors made the analysis of these 36 sources, and in the case of non-convergence, the authors discussed why to keep or exclude a paper. As we detected two papers matching our criteria cited within the previously found texts, altogether 19 sources remained for in-depth analysis (see Fig. 3; Page et al., 2021).

Categorization Structure for the Analysis

To compile the researchers' results and conclusions and assess them systematically, first, a structure was designed to categorize them. The categories were formed based on the theoretical foundations and the abovementioned points in which the constructs show differences. We, therefore, categorize the results concerning the age or developmental stage, type of measurement, role of metacognition, relation to achievement, and

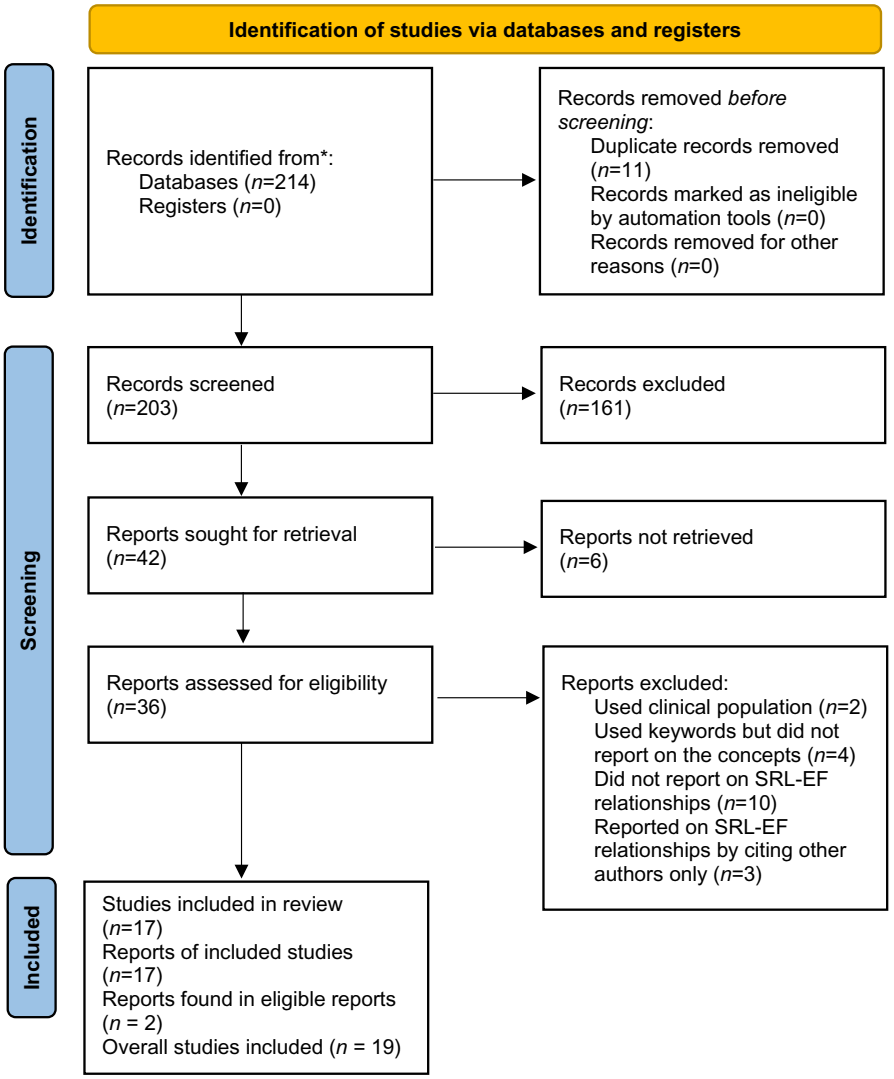

Fig. 3 PRISMA 2020 flow diagram. *APA PsycArticles ($n=113$), APA PsycInfo ($n=84$), ERIC ($n=13$), and PSYNDEX Literature with PSYNDEX Tests ($n=4$)

longitudinal studies/interventions. In order to classify the measures within single studies as referring to SRL or EF, we stuck to the classification used by the original study's authors.

Results

Correlations of SRL and EF

As it has been expected**,** most of the analyzed research papers examine relationships between SRL and EF or, more often, relationships between concept subcomponents. In order to categorize the findings and answer our first research question, if relations of SRL and EF differ depending on age or measurement methods, we will analyze the research papers concerning these two factors. For an overview of all studies and core results, see Table 1. As Bol and Garner's (2011) paper was theoretical, we did not integrate it into our results synopsis. The systematic review of Dörrenbächer-Ulrich et al. (2023) will only be integrated into our theory-building discussion section.

Comparison of Different Age Groups

Overall, we found five studies that examined the relation of SRL and EF in *preschoolers*, but only four included information on correlational coefficients. In general, the studies found low to moderate relations between SRL and EF in preschoolers: Davis et al. (2021) studied a sample of children at the end of kindergarten and again, 1 year later, at the end of their first school year. The SRL teacher rating correlated significantly moderately with the direct EF measures at T1 and low to moderate at T2. Using a direct, quantitative SRL measurement tool for preschoolers, Jacob et al. (2019b) found a significant, low correlation to an EF planning assessment task. In the study of Grüneisen et al. (2023), analyses showed a moderate correlation between hot EF and a composite SRL measure (strategy knowledge test + parent rating). In accordance, Vitiello's and Greenfield's (2017) study resulted in low to low-moderate associations between an EF task battery and a teacher rating scale for approaches to learning (which they equate with SRL).

Four studies dealt with the relationship between SRL and EF in *elementary school children*, but two used the same sample (Cirino et al., 2018, 2019). In general, correlations between measures of EF and SRL seem to be low in elementary school children. While Cirino et al. (2017) found the SRL and direct EF measures to be only weakly related to one another, Cirino et al. (2018) found low correlations between SRL scales and EF measures, with most correlations being non-significant. In a sample of third graders, measures for inhibitory control and cognitive flexibility correlated positively and moderately with SRL scores. In contrast, scores from the backward digit span task did not significantly correlate with SRL scores (Rutherford et al., 2018).

Only two studies analyzed the relation of SRL and EF in *adolescent learners* and partially showed moderate correlations. Effeney et al. (2013) conducted a study with children aged 10.5 to 17.5 years. They used both a self-report measure for SRL and EF. The EF total score and the SRL global score correlated moderately. Standard regression analysis resulted in the EF global score being a significant predictor of

Table 1 Overview of key study characteristics and results

Study	Aim	Age group/sample size	SRL/EF measurements[1]	Relevant core results (in addition to the results concerning correlations between SRL and EF measures, see right columns)	Correlations between indirect SRL / EF measures	Correlations between indirect SRL/direct EF measures
Bol and Garner (2011)	Theoretical work on self-regulation	N.A	N.A	• EF as processes that promote self-regulation at basic cognitive and metacognitive levels • Low EF can lead to difficulties in goal setting/planning, which can prevent switching learning strategies • EF supports attentional control (SRL: volition)	N.A	N.A
Cirino et al. (2017)	SRL/EF training study	Fourth graders/$n = 75$	HWD (SRL planning), HDD (reflection), SLQ/D-KEFS Verbal Fluency, Tower Task (planning)	• Tower Task and HWD weakly related • D-KEFS Verbal Fluency and HWD/HDD weakly related • Median correlation $r = 0.10$ • SRL/EF training group did not show better reading comprehension compared to the control group	N.A	• SRL and TOL: $-0.24 < r < -0.07$ • SRL and fluency: $-0.33 < r < 0.14$
Cirino et al. (2018)	Factor analytic EF study	Late elementary school children/$n = 846$	CLS (self-report SRL)/Working memory: WMTB-C, Corsi Blocks, n-back measures; Inhibition: Go-No-Go, Stop Signal; Shifting: D-KEFS; Planning: TOL, Woodcock-Johnson-III; Fluency: D-KEFS	• Correlations between SRL EF measures are generally low • Derived a bifactor model with a common EF factor and five distinguishable factors, among them an SRL factor	N.A	$-0.18 < r < 0.17$

Table 1 (continued)

Study	Aim	Age group/sample size	SRL/EF measurements[1]	Relevant core results (in addition to the results concerning correlations between SRL and EF measures, see right columns)	Correlations between indirect SRL / EF measures	Correlations between indirect SRL/direct EF measures
Cirino et al. (2019)	Impact of bifactorial EF model (Cirino et al., 2018) on reading	Late elementary school children/$n = 846$		• EF components added about 3% of explained variance to strong baseline models, with the SRL factor contributing 0.3% • Overall unique added contributions of 3% on two reading comprehension models, with the SRL factor contributing 0.3% to one model and minimally to the other	N.A	N.A
Davis et al. (2021)	Longitudinal study on the relationship between SRL/EF	Kindergarten to Year 1 transition pupils/$n = 176$	ChILD Cognitive Regulation subscale (teacher rating)/Working memory: Corsi Block Tapping task; Shifting: Verbal Fluency task; HTKS	• T1: SRL correlated significantly with all EF tasks • T2: SRL correlated significantly with all EF tasks • Cross-lagged panel analysis supports that children's EF longitudinally predicts future SRL to a moderate extent • A common factor model fitted the data as well	N.A	• T1: SRL and EF: $0.26 < r < 0.34$ • T2: SRL and EF: $0.17 < r < 0.38$
Dörrenbächer-Ulrich et al. (2023)	Review on SRL and EF in academic transitions	Primary/secondary/college students/$n = 30$ studies	— (systematic review)	• Findings support the hypothesis that EF is the foundation for SRL and metacognition	N.A	N.A
Effeney et al. (2013)	Relationship between SRL/EF	School-aged adolescent males/$n = 254$	SSRLS/BRIEF-SR	• Strongest correlations between SRL and BRIEF-MI and its subscales • BRIEF-GEC significantly predicted the SSRLS global score and explained a significant proportion of variance (18.8%)	• SRL and BRIEF-MI: $-0.61 < r < -0.15$ • SRL and BRIEF-BRI: $-0.29 < r < -0.10$ • SRL and BRIEF-GEC: $r = -0.44$	N.A

Table 1 (continued)

Study	Aim	Age group/sample size	SRL/EF measurements[1]	Relevant core results (in addition to the results concerning correlations between SRL and EF measures, see right columns)	Correlations between indirect SRL / EF measures	Correlations between indirect SRL/direct EF measures
Follmer (2021)	Role of college learners' monitoring of EF for their SRL	College students/$n = 189$	MSLQ-MS-R (metacognitive subscale)/EFI; ESQ; Inhibition: category and verbal fluency task; Updating: letter memory task; Shifting: plus-minus task	• Strong correlations between indirect EF measures and SRL (metacognition) • No correlation between the three direct EF measures and the MSLQ–MS-R	• EFI and MSLQ-MS-R: $r = 0.39$ • ESQ and MSLQ-MS-R: $r = 0.52$	• Category and verbal fluency task, letter memory task, plus-minus task, and MSLQ-MS-R: $0.02 < r < 0.06$
Follmer and Sperling (2016)	Relationship between EF, SRL, and metacognition	College students/$n = 117$	SRSI-SR; MSLQ-MS-R/ESQ; category and verbal fluency task; plus-minus task	• MSLQ–MS-R and SRSI composite score showed a strong correlation ($r = 0.56$) • EF (measured directly and indirectly) significantly predicted SRL and explained 27% of the variance in participants' beliefs about SRL • Two mediation models show that metacognition mediates the relationship between EF and SRL	• ESQ and MSLQ-MS-R: $r = 0.33$ • ESQ and SRSI overall: $r = 0.44$	• Direct EF score and MSLQ-MS-R: $r = 0.24$ • Direct EF score and SRSI total score: $r = 0.27$

Table 1 (continued)

Study	Aim	Age group/sample size	SRL/EF measurements[1]	Relevant core results (in addition to the results concerning correlations between SRL and EF measures, see right columns)	Correlations between indirect SRL / EF measures	Correlations between indirect SRL/direct EF measures
Garner (2009)	Mutual conceptual relationship between EF and SRL	College students/$n = 108$	MSLQ/EFI	• Numerous low to moderate correlations between the measures' components • All five subscales of the EFI correlated significantly moderate to high with the MSLQ Metacognitive Self-Regulation subscale and moderate with the MSLQ Effort Regulation subscale • MSQL subscales Critical Thinking and Control Beliefs did not significantly correlate with any of the EFI subscales	• EFI and MSLQ-MS-R: $0.20 < r < 0.52$ • EFI and MSLQ-Effort regulation: $0.24 < r < 0.35$ • EFI (motivational drive) and MSLQ (intrinsic goal orientation): $r = 0.34$	N.A
Gestsdottir et al. (2023)	Longitudinal study on the relation of SRL and EF	Secondary students/$n = 84$	SESRL/ANT	• Only working memory was related to SRL • SRL was a better predictor for Grade 6 outcomes than EF	N.A	EF (#correct) and SRL: $-0.20 < r < -0.04$ EF (reaction time) and SRL: $-0.36 < r < 0.18$
Grüneisen et al. (2023)	Analyses of SRL as a mediator for EF and achievement	Preschoolers/$n = 77$	SRL strategy knowledge test, COMPSCALE parent rating/Gift wrapping task	• SRL mediates the relationship between EF and academic competence	N.A	EF and SRL: $r = 0.32$
Jacob et al. (2019a)	Profile analyses: SRL precursor abilities, SRL training	Preschoolers/$n = 230$	SRL strategy knowledge test / Tower Task	• Effect of the SRL intervention is not significant • Descriptive results suggest that high speech competency, in combination with high self-regulation, plays an important part in the acquisition of SRL, but this advantage did not show up for EF	N.A	N.A

Table 1 (continued)

Study	Aim	Age group/sample size	SRL/EF measurements[1]	Relevant core results (in addition to the results concerning correlations between SRL and EF measures, see right columns)	Correlations between indirect SRL / EF measures	Correlations between indirect SRL/direct EF measures
Jacob et al. (2019b)	SRL diagnostic	Preschoolers/$n = 183$	SRL knowledge test/ Tower Task	• Total SRL score and EF performance correlated with low	N.A	EF and SRL: $r = 0.18$
Meijs et al. (2021)	Relationship between EF/SRL	Adult learners within distance education/$n = 889$	MSLQ adaption for online distance education/N-Back Test, Trail Making Test, Symbol Digit Substitution Test	• No correlation between basic EFs and SRL strategy use; negative relation between shifting and academic thinking; negative relation between processing speed and simple cognitive strategy use	N.A	Beta-values for the regression of SRL on EF: $-0.13 < \beta < 0.12$
Petersen et al. (2006)	Relationship between EF and study strategies	College students/$n = 81$	LASSI/EFRS	• Shared variance of both concepts was 33.2%	LASSI and EFRS: $-0.44 < r < -0.39$	N.A
Rutherford et al. (2018)	Relationship between EF/SRL/academic achievement	Elementary school children/$n = 211$	Teacher responses to student behavior questions; Inhibition and Switching. Hearts and Flowers task; Working memory: back-ward digit span	• Mediation models suggest that facets of EF can support SRL and, thus academic achievement	N.A	• Hearts and Flowers task and SRL: $r = 0.32$ • Digit span and SRL: $r = 0.05$
Said (2014)	Relationship between EF/SRL/meta-cognition	College students/$n = 45$	MAI; TMQ (time planning)/Planning: Tower of London; Working Memory: letter-number sequencing (LNS) test; BRIEF	• Many significant correlations among the measures • Factor analysis resulted in three factors with eigenvalues exceeding 1: Perceived Self-Regulation, Metacognitive Knowledge, and Executive Control Processes	• BRIEF-BRI and MAI: $0.17 < r < 0.32$ • BRIEF-BRI and TMQ: $0.22 < r < 0.28$ • BRIEF-MI and MAI: $0.27 < r < 0.31$ • BRIEF-MI and TMQ: $0.41 < r < 0.58$	• TOL and MAI: $r = 0.00$ • TOL and TMQ: $0.31 < r < 0.33$ • LNS and MAI: $0.11 < r < 0.13$ • LNS and TMQ: $0.02 < r < 0.27$

Table 1 (continued)

Study	Aim	Age group/sample size	SRL/EF measurements[1]	Relevant core results (in addition to the results concerning correlations between SRL and EF measures, see right columns)	Correlations between indirect SRL / EF measures	Correlations between indirect SRL/direct EF measures
Vitiello and Green-field (2017)	Relationship between self-regulation/EF/ approaches to learning (SRL)	Preschoolers/$n = 179$	• PLBS; inCLASS Task Orientation subscale (observational teacher rating)/Inhibition: spatial conflict and Go/No-Go; Shifting: something's the same; Working memory: pick the picture Go/No-Go	• Low to low-moderate associations between the EF and approaches to learning measure subscales ($0.07 < r < 0.23$) • The hypothesis that approaches to learning mediate the relationship between EF and change in school readiness was not strongly supported • Approaches to learning did not strongly predict gains in school readiness above and beyond EF	N.A	• Spatial conflict and PLBS: $0.13 < r < 0.15$ • Spatial conflict and inCLASS: $0.07 < r < 0.22$ • Go/No-Go and PLBS: $0.10 < r < 0.14$ • Go/No-Go and inCLASS: $0.09 < r < 0.20$ • Pick the picture and PLBS: $0.19 < r < 0.23$ • Pick the picture and inCLASS: $0.12 < r < 0.23$ • Something's the same and PLBS: $0.06 < r < 0.12$ • Something's the same and inClass: $0.08 < r < 0.23$

[1]Please see the Supplementary Material for references of measures used

BRI Behavioral Regulation Index; *BRIEF–SR* Behavioural Rating Inventory of Executive Function and Self-Report; *ChILD* Checklist of Independent Learning Development, *D-KEFS* Delis-Kaplan Executive Function System; *EFI* Executive Function Index; *EFRS* Executive Functioning Rating Scale, *ESQ* Executive Skills Questionnaire; *GEC* Global executive composite; *HDD* How Did I Do? task; *HTKS* Head-Toes-Knees-Shoulders; *HWD* How Will I Do? task; *MI* Metacognitive Index; *MSLQ* Motivated Strategies for Learning Questionnaire; *MSLQ–MS-R* Metacognitive Self- Regulation subscale of the MSLQ; *LASSI* Learning and Study Strategies Inventory; *PLBS* Preschool Learning Behaviors Scale; *SLQ* Student Learning Questionnaire; *SRSI-SR* Self-Regulation Strategy Inventory–Self-Report;*SSRLS* Strategies for Self-Regulated Learning Survey; *T1* first measurement/point in time; *T2* second measurement/point

the SRL global score and explaining a significant proportion of variance in the SRL global score (18.8%). The analyses of Gestsdottir et al. (2023) resulted in non-significant correlations between different EF measures and the Self-efficacy for Self-Regulated Learning questionnaire. Only the working memory reaction time showed a significant moderate correlation.

We identified four articles on the relationship between SRL and EF in *college students and adult learners*. In general, correlations between measures of SRL and EF tend to be low to moderate in college and adult learners. In a sample of undergraduate students, Follmer and Sperling (2016) found a significant moderate correlation between the SRL score and an indirect EF measure and a significant but lower correlation between the SRL score and the direct EF measures. Studying the relationship between self-reported SRL and self-reported EF, Garner (2009) reported low to moderate correlations between the constructs' components. The SRL subscale on intrinsic goal orientation showed the highest correlation with the EF motivational subscale. Meijs et al. (2021) measured self-reported SRL strategy use and utilized cognitive tests on working memory, shifting, and processing speed for EF. While time and effort management and complex cognitive strategy use were not predicted by any of the EF measures, simple cognitive strategy use was negatively predicted by processing speed, and critical thinking was positively predicted by shifting. In a sample of college freshmen, Petersen et al. (2006) used a self-report measure for SRL and EF. The analyses resulted in moderate correlations between the SRL self-report measure subscales and the EF total score (inversely scored). The authors found a shared variance between the SRL and EF measure of 33.2%.

Comparison of Different Measurement Methods

As EF can be measured using indirect (e.g., questionnaire) and direct (e.g., cognitive tasks) measures, we looked at differences in correlational patterns depending on the assessment method used. Table 1 overviews the SRL and EF measures used and the correlations found. We identified six studies that measured SRL and EF using indirect measures. In general, correlations between both constructs are higher if both are measured using indirect assessment methods (compared to EF measured directly). As can be seen in Table 1, the studies used differing indirect measures for SRL (e.g., SSRLS, MSLQ, SRSI-SR, LASSI, MAI, TMQ, observational teacher rating; see Supplementary Material for further details concerning the measurement methods) and for EF (BRIEF, EFI, ESQ, EFRS). Nevertheless, all studies found moderate to high correlations between both constructs and their components. The correlations ranged between $|.10| < r < |.61|$.

Concerning studies that measured SRL indirectly and EF directly, we identified twelve studies. These studies also used varying indirect measures for SRL (HWD, HDD, SLQ, CLS, CHILD, MSLQ, SRSI-SR, self-efficacy for SRL questionnaire, knowledge test, teacher ratings, parent ratings, MAI, TMQ, PLBS, inCLASS) and a large variety of direct measure for assessing EF processes (due to the high amount of different direct EF tasks, we do not repeat them here). In contrast to the correlations reported for indirect SRL and indirect EF measures, the correlations between

indirect SRL and direct EF measures turn out to be low to moderate and ranged between $|.02| < r < |.36|$, while it has to be stated that some studies also reported negative correlations between both constructs (e.g., Cirino et al., 2018).

The Role of Metacognition within the Relation of SRL and EF

Our search indicated five studies that took a closer look at the role of metacognition within the relationship between SRL and EF. In general, all three constructs are related moderately, and there is first evidence that metacognition acts as a mediator between EF and SRL. Effeney et al. (2013) used self-report measures for SRL and EF. The Behavioural Rating Inventory of Executive Function and Self-Report (BRIEF–SR, Guy et al., 2004) consists of the Behavioral Regulation Index (BRI; inhibition, shifting, emotional control, monitoring) and the Metacognitive Index (MI; working memory, planning, organization of materials, task completion) which both are inversely coded. The authors found higher correlations between the BRIEF-MI and SRL measures than between the BRIEF-BRI and SRL measures. Follmer and Sperling (2016) calculated two models to investigate if metacognition mediates the relationship between EF and SRL: The first model used self-reported metacognition as a mediator between indirect EF and SRL and between direct EF and SRL in the second model. For both models, they found metacognition to act as a mediator between EF and SRL. However, the direct effect of EF on SRL was not significant in the second model, suggesting that the effect of direct EF on indirect SRL was fully mediated by metacognition.

Follmer (2021) found moderate to high correlations between two indirect EF scores and an indirect metacognition measure. Nevertheless, three direct EF measures were not significantly correlated with the indirect metacognition measure. The moderate to high correlations between indirect metacognition and EF are in line with the result of Garner (2009), who found indirect metacognition and EF to be significantly correlated. Using exploratory factor analysis for the constructs of EF, SRL, and metacognition, Said (2014) found three factors that help to differentiate between high-achieving and low-achieving students: The first factor included metacognitive and behavioral EF scales, academic self-efficacy, and time management. Declarative knowledge, procedural knowledge, and knowledge monitoring ability are loaded onto the second factor. The direct EF measures are loaded onto the third factor.

Integrating Academic Achievement into the Relation of SRL and EF

We found five studies that integrated academic achievement measures into the examination of SRL and EF. In general, both constructs are positively related to academic achievement, and the first results hint at a mediating role of SRL in the relationship between EF and achievement. Vitiello and Greenfield (2017) tested the hypothesis that approaches to learning (which they adequate to SRL) mediate the relationship between EF and change in school readiness in preschoolers. Using structural equation modeling, the authors rejected their hypothesis but noted that the findings

link SRL and EF to gains in school readiness. In contrast, the study of Grüneisen et al. (2023) supports the hypothesis of SRL acting as a mediator for the relationship between EF and achievement within a preschool sample. While EF was not related to academic competence, SRL showed a moderate relation to academic competence, and there was a significant indirect effect from EF via SRL on academic competence.

Within a sample of elementary school children, Rutherford et al. (2018) investigated the shared associations between SRL, EF, and academic achievement. The direct EF measure was a statistically significant predictor of academic achievement and of the SRL measure, which suggests that facets of EF can support SRL. Additionally, SRL had its own statistically significant direct path to achievement in all mediation models and mediated the effect of EF on achievement (at least partially). The study's measurement timing supports the conclusion that better EF leads to more successful SRL, so improving EF may lead to higher performance scores via enhancing SRL. In a study with secondary school students (Gestsdottir et al., 2023), SRL showed a positive moderate relationship with grade measures of the same year, while none of the EF measures showed significant relationships with achievement. Nevertheless, for the grades of the following year, there was no significant relationship with the SRL measure but a significant negative relationship with reaction times for the shifting measures (lower reaction times indicate better performance). In a sample of college students, Said (2014) conducted an exploratory factor analysis to find factors that represent SRL, metacognitive strategies, and EF. The author found three factors in which high-achieving students differed significantly from low-achieving students.

Results from Longitudinal and Interventional Studies

We found four studies using a longitudinal or interventional design that could help to detangle possible causal relationships between SRL and EF. Until now, findings are too scarce to find a general pattern, but the first results hint at the predictive value of EF for SRL but not vice versa. Davis et al. (2021) conducted a longitudinal study with two measurement points and studied a sample of children at the end of kindergarten and their first school year. Using cross-lagged panel analysis, the author concludes that results support the assumption that children's EF longitudinally predicts future SRL to a moderate extent but not vice versa. The authors also tested a common factor model that fitted the data well, which they interpreted as indicating that SRL and EF measures could reflect the same underlying construct. Moreover, they tested different models that helped rule out alternative SRL-EF relationships (e.g., early SRL benefitting later EF or reciprocal relations).

Jacob et al. (2019a) examined how an SRL intervention influences SRL and EF in preschoolers with different SRL precursor profiles. Although the intervention showed no effect, their findings suggest that high speech competency, in combination with high self-regulation, plays an essential part in acquiring SRL. However, this advantage did not show up for EF. Gestsdottir et al. (2023) measured SRL and EF in Grade 6 and several outcome measures (e.g., achievement, depression,

anxiety, risky behavior) in Grade 6 and Grade 7. While they found EF deficits to be a stronger predictor for future development than for the concurrent state of risky behavior and internalizing symptoms of depression and anxiety, SRL was a stronger predictor for concurrent than future academic achievement. Even though Cirino et al. (2017) investigated the effects of SRL/EF training on reading comprehension, the experiment was designed so that SRL and EF training influences on reading comprehension could not be separated.

Discussion

Synthesis and Assessment of the Systematic Analysis Results

In general, it can be stated that until now, a relatively small number of studies have investigated the relationship of SRL and EF albeit the theoretical overlap of both constructs. In conclusion, a low to moderate correlational relationship between SRL and EF has been confirmed for many SRL and EF measurements, with indirect measures correlating higher. Treated as a subscale of SRL or EF self-report measures, metacognition regularly shows high correlations with other subscales of SRL or EF self-report measures, and there is evidence that it mediates the relationship between SRL and EF. Given these results and the directional models identified, the notion that EF predicts SRL but not vice versa is supported. The results will be synthesized and discussed in the following section, focusing on the single research questions.

How are SRL and EF Related, and Does This Relationship Depend on the Age of the Study Sample or Measurement Methods?

Of the 19 works analyzed, 14 reported correlations between SRL and EF measures or measurement subcomponents, representing the most comprehensive comparison category between the two constructs. Concerning *age differences*, there are no clear patterns recognizable as most studies report low to moderate correlations of SRL and EF, not depending on age group. This is unsatisfying as we cannot draw any conclusion about developmental trajectories using the results of the reviewed studies. Although we have separated the study results depending on age group and found no effect, the results of Effeney et al. (2013) confirmed that age impacts the correlation between SRL and EF. This is why, for example, SRL-EF correlations in college students can only be compared to a limited extent to SRL-EF correlations in preschoolers. This is also underlined by the fact that self-report measures for SRL and EF show high correlations, especially for self-report measures (see below). However, these measures strongly depend on the verbal abilities of the participants. It, therefore, is unclear how far self-reports can be compared for age groups that heavily differ concerning the requirements to answer such questionnaires (verbal abilities, metacognitive competencies). To gain deeper insight into age influences on the correlation of SRL and EF, studies are needed that investigate the relationship using comparable measures within different age groups. Multimethod assessment of both

SRL and EF using indirect and direct measures for different age groups could be very enlightening concerning age influences concerning the SRL-EF relationship.

What seems to make a more significant distinction regarding sizes of correlations of SRL and EF are the *measurement methods* used: While studies that measure both SRL and EF indirectly using questionnaires or teacher ratings result in moderate to high correlations between the constructs (e.g., Effeney et al., 2013; Follmer & Sperling, 2016), studies that measure EF directly instead show low to moderate correlations (e.g., Gestsdottir et al., 2023; Meijs et al., 2021). This pattern seems to reflect an underlying influence of common method variance (Söhnchen, 2009) and, therefore, must be treated cautiously. It could also result from an acquiescence tendency in self-reports (mainly found in younger children, e.g., Mehrani & Peterson, 2018), which questions the validity of such scales. Moreover, the finding aligns with the results of the meta-analysis of Duckworth and Kern (2011), who found that different self-control questionnaires correlated strongly with different executive function tasks, which showed low convergent validity. In addition, EF mainly was not analyzed using multiple individual measures for each latent variable shifting, updating, and inhibition as proposed by Miyake et al. (2000), which may have resulted in them not being fully represented. Likewise, measures such as performance on the Tower Task may not fully capture EF (see Complex Executive Tasks in Miyake et al., 2000). Another explanation may be that these low correlations result from direct and self-report measures capturing aspects of the constructs that show less overlapping. This seems consistent with the many different approaches to EF mentioned earlier. Notably absent from this review is work reporting correlations between EF self-report measures and SRL non-self-report measures, as well as both direct EF measures and direct SRL measures (e.g., microanalysis; Cleary & Callan, 2018). Therefore, permuting measuring instrument methods could help connect the dots, and studies using direct and indirect measures for both SRL and EF could help to detangle the influence of measurement methods and the actual conceptual overlap of both constructs.

In general, all studies used a broad range of differing measures, which complicated the comparison of results. Nevertheless, as there were primarily low to moderate correlations despite using different measurement methods, this seems to speak to the robustness of the relationship between these concepts and, at the same time, underlines the haziness that these constructs can have. This becomes more evident with the fact that in several studies, measures for SRL were constructed with a relatively simple subscale structure and showed low reliability (e.g., HWD in Cirino et al., 2017), were newly developed (Jacob et al., 2019b), or were constructed by selecting behavioral questions from a list, seemingly without prior evaluation trials (Rutherford et al., 2018). Concerning EF, a wide range of measures were used within the studies, and this became most evident in the study of Cirino et al. (2019), who used 27 measures to assess EF. Grouping all the different measures under the same SRL or EF construct exacerbates this fuzziness and limits the validity of statements about SRL-EF relationships. Moreover, the empirical overlap between SRL and EF strongly depends on how the measurement methods define the concepts: One of the highest correlations was found between a self-report questionnaire for SRL (SSRLS) and the BRIEF-SR for EF (Effeney et al., 2013; $|.15| < r < |.61|$). In this example, it is

evident that both questionnaires show comparable subscales (SSRLS: goal setting and planning, self-efficacy for goal achievement, using task strategies, self-motivation; self-monitoring and self-evaluation; BRIEF-SR: Inhibit, Shift, Emotional Control, Monitor, Working Memory, Plan/Organise, Organisation of Materials, Task Completion) although the SRL questionnaire focuses on academic goals and the EF questionnaires focuses on everyday life goals. Therefore, theoretical foundations of measurement methods must be considered when interpreting the results.

What Role Does Metacognition Play Within the Relationship of SRL and EF?

Studies investigating the mediating role of metacognition within the relationship of SRL and EF speak in favor of this hypothesis, although not many studies have yet examined such models. In the study of Follmer and Sperling (2016), the mediation effect was more pronounced in a model using direct EF measure scores (inhibition and shifting instead of indirect measure), where the effect of EF on SRL was transmitted fully by metacognition. Effeney et al. (2013) conclude that their findings lend "support to descriptions of SRL and EF that are couched in terms of metacognition … and give[s] rise to the notion that metacognition occupies the conceptual "middle ground" between EF and SRL" (pp. 787–788). Moreover, Effeney et al. (2013) see their results supporting the notion that EF shares the "conceptual core" outlined by Dinsmore et al. (2008), that is, the endeavors that individuals make to watch over their thoughts and actions and act accordingly to gain some degree of control over them. In line with this, Cirino et al. (2018) identified SRL and metacognition as components of EF. The model that fitted the data best was a bifactor model with a common EF factor and five specific factors for working memory span/manipulation and planning, working memory updating, generative fluency, SRL, and metacognition. Nevertheless, the generally high correlations between EF, SRL, and metacognition and the possible mediating effect of metacognition should also be seen in light of the influence of measurement methods (see above). It is further worth mentioning that the works of Garner (2009), Effeney et al. (2013), Follmer and Sperling (2016), and Follmer (2021) in a way build on each other, as they all refer to their respective predecessors. This might have led to adapting similar views, taking convergent approaches, using related measures, and obtaining similar results.

How are SRL and EF Related to Academic Achievement?

Concerning the integration of achievement, it can be stated that both SRL and EF are positively related to academic achievement. Said (2014) presents a three-factorial model of SRL (integrating EF) that can be used to differentiate between low-achieving and high-achieving students with high effect sizes. Concerning the predictive validity of SLR and EF for academic outcomes and achievement, the results pattern found in the included studies is unclear: While in the study of Gestsdottir et al. (2023), SRL was found to be correlated to academic outcomes with EF measures showing no significant correlations, EF seems to be a stronger predictor than SRL for reading outcomes (Cirino et al., 2019) and school readiness (Vitiello & Greenfield, 2017). Using mediation models, Rutherford et al. (2018) showed that

SRL mediated the relationship between EF and achievement, with both EF and SRL having their direct pathway to achievement. Grüneisen et al. (2023) found the same pattern of mediation in a sample of preschoolers, while EF was not related to academic competence in this study. It could be argued that academic achievement is closely linked to SRL, as SRL is usually assessed using academic tasks or contexts (Kim et al., 2023), while EF is mainly assessed decontextualized using cognitive tasks (Chan et al., 2008). Nevertheless, previous research results rather speak in favor of EF being a stronger predictor for academic achievement than SLR (Dent & Koenka, 2016; Titz & Karbach, 2014). However, these studies did not include both SRL and EF and, therefore, could not directly compare the predictive value of both constructs. Future studies should aim to specifically compare correlations of SLR and EF to academic achievement and further examine the previously found mediating role of SRL for the relationship between EF and achievement.

What are the Results of Longitudinal or Interventional Studies on the Relationship Between SRL and EF?

Concerning longitudinal and intervention studies, there is not much research yet that can be used to draw a conclusion. Evidence from cross-lagged panel analysis confirms that EF longitudinally predicts future SRL to a moderate extent in children (Davis et al., 2021). However, a common factor model allows for the interpretation that EF and SRL measures could equally well reflect the same underlying construct (Davis et al., 2021). We only detected one training study, which showed that SRL training did not influence EF (Jacob et al., 2019a). Unfortunately, the longitudinal study of Gestsdottir et al. (2022) did not report cross-lagged correlations of SRL and EF. Due to this small basis, we cannot draw valid conclusions regarding the longitudinal relationship between SRL and EF yet, albeit present results speak in favor of EF predicting SRL and not vice versa. Future research, therefore, should target longitudinal studies using cross-lagged panel designs. In doing so, mediation analysis could uncover whether metacognition (longitudinally) mediates the relationship between EF and SRL. Training studies investigating far transfer (Kassai et al., 2019) to examine if SRL training would influence EF and vice versa would be especially helpful in detangling possible causal relationships.

Limitations of the Systematic Review

With 19 works analyzed, this review accumulated a relatively small set of results, limiting the validity of results that have not been sufficiently replicated. This may be because there is little literature on the subject, but it could also result from the systematic search process. The age of the literature analyzed supports this assertion, as the concepts of interest have been described in detail for well over 20 years in the case of SRL and decades longer in the case of EF, but the bulk of the literature analyzed is from the last 5 years. One reason for this is that in older articles, links between SRL and EF have been discussed on a componential level without mentioning both superordinate constructs (e.g., Bjorklund & Kipp, 1996; Pintrich & Zusho,

2002). Another reason is using alternative names for SRL or related constructs like self-regulation in academic contexts, approaches to learning, or learning-related skills. In these cases, the search process did not include inclusion in the literature pool, which may have resulted in a significant number of results on this topic being omitted.

Another limiting factor of this work is that in synthesizing the studies to attain some conclusions, results from directly and indirectly measured EF and self-reported and teacher-reported SRL were combined. As discussed above, this could have led to inaccurate conclusions. With more data available, it could become more accessible to determine which measure results can be subsumed and which must be considered separately. Although concerns were raised above about the quality of some measuring instruments, it was not within the scope of this work to verify how well SRL and EF were operationalized in each study. Examining correlating subscales of SRL and EF measures at a more profound (e.g., item) level could help decide which measure results can be compared and synthesized and would increase the precision of conclusions. Besides this measurement-related criticism, several studies had quite specific samples in that they oversampled for struggling readers (Cirino et al., 2017, 2018), examined only male participants from a boys' private school (Effeney et al., 2013), or had participants from predominantly low socioeconomic background (Rutherford et al., 2018; Vitiello & Greenfield, 2017). It can be assumed that not all results of these studies apply to an average population.

Implications for Theory

As outlined in the theoretical background section, SRL and EF both describe goal-related behavior (Miyake et al., 2000; Pintrich et al., 2000), including metacognitive monitoring and regulating behavioral aspects (Roebers, 2017). Despite this theoretical overlap, SRL and EF have been investigated somewhat unconnectedly, as SRL is a construct of educational psychology. At the same time, EF stems from cognitive and developmental psychology. Building upon the results of the present review, it can be stated that both constructs are related, but the size of correlations found was lower than expected for concepts that show this amount of theoretical overlap. One reason for that probably is the differing contexts when measuring SRL and EF: while SRL is always measured contextualized, referring to learning tasks, EF primarily are measured decontextualized using laboratory tasks. When EF is measured using questionnaires, some contextual factors come into play, but these differ from SRL as they are more related to everyday life. Another possible explanation that deserves further examination comes from the study of Meijs et al. (2021): The authors partially found negative relations between EF tasks and SRL components (which were also found in the studies of Cirino et al., 2017, and Gestsdottir et al. 2023) and explain this by hypothesizing that students who can shift quickly and show high processing speed need less time for academic thinking and the execution of simple cognitive strategies (and therefore SRL). This would suggest an inverted U-shaped relationship, i.e., that students with relatively high EF show low SRL competencies (as they do not need them or do not frequently use

them). Students with relatively low EF competencies should also show low SRL competencies as they do not have the essential regulatory capacities for using SLR strategies. Future research could investigate if a high relationship between SRL and EF is only found for students with average EF competencies (and not for low and high EF competencies).

Referring to the models of SRL presented in the theoretical background, it can be assumed that the authors' concept definitions are reflected to some degree in the measures used: Fourteen studies refer to either Pintrich (2000) or Zimmerman (2000) when defining or describing SRL. Unfortunately, no study has investigated the phases of SRL, albeit using Zimmerman's cyclical model (2000). This would be especially interesting as it seems possible that some EF components show higher overlaps to some phase-specific SRL strategies (e.g., inhibition should be mostly relevant for the performance phase of learning when learning needs to be shielded from distractors). Concerning Boekaerts' (1999) SRL definitions or models, only two studies mentioned the three components in their theoretical introduction. Examining the components would be particularly helpful to detangle SRL and EF as it may be the case that some SRL components show higher overlap to some EF components (e.g., the metacognitive component of SRL should be highly related to working memory [needed for monitoring of goal progress] or complex EF like planning). We found that twelve studies referred to the EF model of Miyake et al. (2000) in some way, but few defined EF using this model. This is also obvious when looking at how EF was measured: Only a few studies measured all three components (inhibition, working memory, shifting), and if they did, these were always measured using cognitive tasks. If EF were measured using questionnaires, the components were not differentiated as the questionnaires assessed EF more broadly. In general, authors emphasized different aspects of SRL and EF, but definitions of SRL had more common ground than definitions of EF. This is in line with EF literature, as, for example, Miyake et al.'s (2000) model is not mentioned at all in some EF overview articles (e.g., Suchy, 2009) or only briefly touched upon in the *Handbook of Executive Functioning* (Goldstein & Naglieri, 2014), while in others (e.g., Diamond, 2013) it is treated as the standard of EF models. Future studies, therefore, should aim to use more comparable conceptualizations of SRL and EF and also investigate the relationship on a component level so that overlaps between the components of both constructs can be analyzed in more detail. At the moment, it is not possible to draw conclusions about the empirical relationships between the components of SRL and EF that are described in theoretical models as there are too less studies that investigate such component-based relationships.

We now try to compile our findings into a possible integrative framework uniting SRL and EF: Concerning the integration of EF and metacognition, Roebers (2017) has proposed to view EF and metacognition as being "expressions of the same underlying system of self-regulative processing" (p. 45) while this processing should be domain-general and acting on a second-order level. Monitoring processes are a core central and shared feature of EF and metacognition. Moreover, EF seems to be necessary for metacognitive processes and facilitates them (Roebers, 2017), while metacognitive monitoring is seen to be "slower, longer-lasting, more fine-tuned" (p. 46) and dependent on the first-order task. Therefore, the dependency on

domain-specific knowledge and prior experience leads to increased metacognitive competencies, differentiating metacognitive processes from EF processes. Concerning the broadness of constructs, Roebers (2017) argues that the EF framework is broader than the metacognition framework. Kim et al. (2023) integrate the metacognitive and the SRL framework by stating that metacognition is a more cognitive construct and SRL is an educational construct. While metacognition is measured using experimental tasks, SRL is measured in authentic learning situations and, therefore, reflects an application of metacognitive competencies. What additionally distinguishes SRL from metacognition is the importance of motivational aspects (Boekaerts, 1999). Integrating both frameworks of Roebers (2017) and Kim et al. (2023) and using the results of our review as support, it can be stated that SRL and EF show conceptual overlap but are not the same. It seems plausible that EF processes promote SRL at a rudimentary cognitive and metacognitive level (Bol & Garner, 2011), that metacognitive competencies mediate the relationship between EF and SRL (Effeney et al., 2013), and that SRL is a domain-specific application of EF and metacognitive competences (Kim et al., 2023). This is underlined by studies showing that SRL is a mediator for the relationship between EF and achievement (Grüneisen et al., 2023). From a developmental perspective, EF seems to be a precursor ability for SRL: The findings of a review of Dörrenbächer-Ulrich et al. (2023) support the hypothesis that EF can be seen as a foundation for SRL and metacognition as the developmental peak of (simple) EF lies in early childhood, while metacognition and SRL show relevant developmental changes in later childhood and adolescence. In conclusion, the present review gives the first indications for a possible theoretical framework describing the relations between EF, metacognition, and SRL. Nevertheless, as only a few studies have tested this relationship empirically, it would be helpful to first invest in theoretical work on possible theory-grounded directional pathways between the constructs. Future research should then experimentally test such theories and models to gain insights into vindicable theory components or to alter and adapt the models based on empirical results.

Implications for Future Research

Much criticism within this review revolves around measurement methods. One challenge future studies could tackle is a differentiated approach to SRL and EF by combining self-report and non-self-report measures for each construct to capture both more comprehensively. For EF, a combination of more complex EF tasks like the Tower Task, multiple basic tasks for shifting, updating, and inhibition like the plus-minus task, and self-report measures like the EFI could be used. Likewise, SRL could be captured by a combination of self-report measures like the MSLQ, teacher reports, and self-assessment through contextual self-regulation measures. The latter, in particular, was not well represented in this review and could be achieved through the use of think-aloud protocols (Greene et al., 2011), microanalysis (Cleary & Callan, 2018), or structured personal diaries (Schmitz et al., 2011). A greater variety of non-self-report SRL measures in studies on the SRL-EF relationship may provide further evidence as to why direct EF measures have lower correlations with the SRL

measures used in the studies analyzed here. Conducting such multimethod studies for different age groups could be very enlightening concerning age influences concerning the SRL-EF relationship.

As mentioned earlier, many measures seem to confirm some sort of relationship between SRL and EF, but their many differing subscales make it challenging to summarize correlations from different studies into precise statements. Intuitively, there is a need for the standardization of measuring instruments to increase precision. Of course, there are good reasons for different instruments to adequately capture the concepts in participants of different ages. However, if one wants to be more precise about the relationships between concepts, one needs more precise methods to measure those concepts (Dinsmore et al., 2008), and a plethora of measurement tools that represent authors' unique ways of looking at the concepts seems to run counter to this principle. Nevertheless, a follow-up study that could shed light on the results compiled here could narrow down the study area and systematically extract properties of correlating SRL and EF measure subscales by analyzing their operationalizations.

As the relationship between SRL and EF is not as high as expected based on their theoretical overlap, investigating influential third variables could be helpful. One such variable could be intelligence, as previous research has shown a moderate association between EF and intelligence (Lee et al. 2009), and the same holds for metacognition (van der Stel & Veenman, 2008). For the studies that used specific samples (e.g., Cirino et al., 2017, 2018; Rutherford et al., 2018), it would be instructive to see if their results can be replicated in studies with samples representing a more average population in the respective age group. Further studies in fostering SRL and EF would be informative as the studies analyzed (Cirino et al., 2017; Jacob et al., 2019a) did not report any appreciable effects. Because there is evidence that fostering EF (e.g., Blair & Diamond, 2008) and SRL (e.g., Theobald, 2021) is generally possible, work in this area should be able to contribute to the understanding of the SRL-EF relationship if they are linked as suggested in this review. These studies could help find overlapping areas of the constructs and confirm or refute the directional models proposed by Davis et al. (2021) and the mediating role of metacognition (Follmer & Sperling, 2016). Training studies investigating far transfer (Kassai et al., 2019) to examine if SRL training would influence EF and vice versa would be especially helpful in detangling possible causal relationships. In addition, understanding the SRL-EF relationship would benefit from previously underrepresented longitudinal study designs that can be used for SRL or EF training studies. In the context of longitudinal studies, comparing the predictive value of SLR and EF for academic achievement and examining the previously found mediating role of SRL for the relationship between EF and achievement would be very interesting.

Conclusion

Self-regulated learning (SRL) and executive functions (EF) are broad concepts that stem from different research areas and have been defined and modeled in various ways. In particular, it was noted that EF has a decades-long history in different research areas, which may explain the many different approaches to this construct

(Suchy, 2009). This systematic review examined literature from several databases that included the terms self-regulated learning and executive function for relationships between both constructs. It was found that most relevant research papers report on a low to moderate correlational relationship between SRL and EF. Metacognition, as measured by self-report instruments, regularly shows high correlations with EF or SRL self-report measure subscales, and there is evidence that it mediates the relationship between EF and SRL. The notion that EF predicts SRL but not vice versa is supported. Criticisms focus on non-generalizable samples, measurement methods that may not adequately capture EF or SRL, and the ease with which the literature on EF and SRL is interpreted in seemingly contradictory ways. Promising future research on this topic should include theory building on the relationship between EF and SRL and testing these theories experimentally. Using more SRL non-self-report measures, a more comprehensive collection of EF and SRL data per sample, and replicating the studies, focusing on longitudinal studies of SRL or EF training, would be very enlightening.

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Declarations

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