Metacognition Learning (2012) 7:151–173
DOI 10.1007/s11409-012-9089-9

Executive functioning, metacognition, and self-perceived competence in elementary school children: an explorative study on their interrelations and their role for school achievement

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Received: 16 January 2012 / Accepted: 17 September 2012 /
Published online: 29 September 2012

Abstract In the present study, associations between executive functioning, metacognition, and self-perceived competence in the context of early academic outcomes were examined. A total of 209 children attending first grade were initially assessed in terms of their executive functioning and academic self-concept. One year later, children's executive functioning, academic self-concept, metacognitive monitoring and control, as well as their achievement in mathematics and literacy were evaluated. Structural equation modeling revealed that executive functioning was significantly related to metacognitive control, both cross-sectionally and longitudinally, and that self-concept was substantially associated with metacognitive monitoring, both cross-sectionally and longitudinally. Individual differences in executive functioning and metacognitive control were significantly related to academic outcomes, with metacognitive control appearing to yield a more circumscribed influence on academic outcomes (only literacy) compared to executive functioning (literacy and mathematics).

Keywords Metacognition · Monitoring · Control · Executive functions · Self-concept · School achievement · Self-regulation

Individuals differ strongly in their ability to cope with emotions, resist temptations, regulate their thoughts, and/or monitor and control ongoing cognitive and motivational processes in learning and test situations. Factors explaining individual differences in and consequences of well-developed self-regulatory skills have been targeted by empirical research and theoretical developments alike. In the literature, there are two broader theoretical conceptualizations of self-regulation, and both lines of research describe self-regulatory skills as a heterogeneous set of cognitive and affective processes allowing the individual to continuously and flexibly adjust to changing

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situations and tasks (Best and Miller 2010). On the one side and within frameworks and research of "executive functions" (EF), processes such as goal-orientation and maintenance, inhibition of impulsive or automated responses, attentional and cognitive flexibility, as well as updating are typically integrated (Miyake et al. 2000; Munakata et al. 2012). On the other side, within frameworks of self-regulated learning, an individual's ability to set goals, to detect discrepancies between goals and the current state of mastery, to continuously and accurately monitor ongoing learning behavior, as well as to initiate regulatory processes to the benefit of task performance are included under the broader term of "metacognition" (Borkowski et al. 2000; Efklides 2011; Kuhn 1999; Winne and Hadwin 1998, 2008). However, empirical research directly linking these concepts to each other are still very rare (Best and Miller 2010; Fernandez-Duque et al. 2000; Garon et al. 2008). This paper presents an initial, developmentally motivated attempt in this direction.

Executive functioning

The term executive function (EF) is used to describe a variety of self-regulatory processes including goal-directed intentional behavior, cognitive processes that allow flexibility, error detection, and conflict resolution. Although there is no generally accepted definition of EF, most researchers would agree that EF comprises inhibition of attention and prepotent responses, attentional switching, and updating of information (Miyake et al. 2000). Especially in ontogeny, the ability of actively maintaining an abstract (verbally coded) goal or rule representation in working memory, constitutes an additional central aspect of EF (with verbal fluency tasks used to quantify the ability to access information stored in semantic memory, and to switch between semantic categories; see Munakata et al. 2012). This aspect is often overlooked in the adult literature, loads on the same EF factor as other tasks (e.g., Fisk and Sharp 2004; Unsworth et al. 2011), and is considered central for the development of self-regulation in general (Bunge and Zelazo 2006).

Individual differences in EF has consistent and substantial implications for everyday lives (e.g., Moffitt et al. 2011). Of special importance for the present study, EF has repeatedly been found to serve as powerful predictor of school readiness (e.g., Blair and Razza 2007), and of school achievement (e.g., Duncan et al. 2007). Although direct effects seem to be especially strong for mathematics (Bull et al. 2011; van der Ven et al. 2012; Lee et al. 2009), individual differences in EF are also substantially related to reading, writing, and science achievement (e.g., Monette et al. 2011; St. Clair-Thompson and Gathercole 2006).

Given that EF is a heterogeneously defined multi-faceted psychological construct, reliably measuring individual differences, especially in young samples, poses a serious problem for researchers. The single theoretical dimensions of EF cannot be measured in isolation as the targeted cognitive processes must be embedded in a certain task context that is likely to also trigger other EF and non-EF processes (i.e., "task-impurity problem"; e.g., Miyake and Friedman 2012). Moreover, when studying EF in children, the problem is exacerbated because the different EF processes are so closely intertwined that a clean measurement of subprocess-specific EF variance is very difficult to accomplish (Huizinga et al. 2006; Hughes et al. 2010; Wiebe et al. 2008). In order to deal with this problem and to appropriately account for the mainly common EF processes in young samples, we used a latent variable approach (including a confirmatory factor analysis) in the present study and included one latent EF variable as representing the shared EF processes of the included tasks (Friedman et al. 2011; Miyake and Friedman 2012).

Metacognition

The concept of *metacognition* is also broadly and mostly vaguely defined in the literature, referring to higher-order self-reflective cognitive processes that may be used for regulating information processing (Schneider 2011). In any of the different models of self-regulated learning, metacognitive processes hold an intermediate position between general achievement goals and task-bound, specific information processes triggered or activated in a given learning or test situation. In the earlier, traditional models of self-regulated learning (e.g., Boekaerts 1999; Pressley et al. 1989), metacognitive processes were conceptualized as "pure" higher-order cognitive operations (procedural metacognition) and knowledge structures (i.e., declarative metacognition; Flavell and Wellman 1977). According to the widely accepted conceptualization of Nelson and Narens (1990), two central dimensions of procedural metacognition, that is, monitoring (i.e., performance predictions: judgments-of-learning, performance postdictions: confidence judgments) and control (i.e., allocation of study time, error correction) enable a continuous exchange of information between the object-level (the task at hand) and the meta-level (a representation of the task at hand and its mastery).

In more recent models of self-regulated learning, however, multiple, bidirectional relations between cognitive and affective-motivational factors located on different levels of learning behavior are assumed: For example, Borkowski et al. (2000) extended the "good information processor" model (Pressley et al. 1989) by including learning experiences and related feedback loops that—through executive processes—gradually build up metacognitive functions. Such higher-order learning-related skills and knowledge can then be used in future learning situations. In a similar vein, Efklides (2011) assumes specific, learning-related "metacognitive experiences" to play an important role in the development, differentiation, and efficiency of metacognitive skills impacting subsequent learning-related behavior. Beside such conscious, explicit information processing, implicit metacognitive experiences arising from affective and motivational reactions to a given task will impact a learner's momentary self-perception of his or her task mastery. And in her developmental framework of metacognition, Kuhn (1999) also outlines that through associative processes during learning, both declarative and procedural metacognitive skills emerge, with these skills being initially implicit, then gradually becoming explicit, accessible to consciousness, to be finally and intentionally used during learning.

Importantly and of special interest for the present study, contemporary frameworks of self-regulated learning also integrate an individual's self-perceived competence as an important factor for both long-term achievement efforts and task-specific (online) micro-processes (Borkowski et al. 2000; Efklides 2011; Winne and Hadwin 2008). In fact, Winne and Hadwin (2008) distinguish two kinds of monitoring, with "cognitive monitoring" concerning the perception of one's general performance, and the term "metacognitive monitoring" being used for the monitoring of the self-regulatory learning processes specifically (Greene and Azevedo 2007).

Generally spoken, it is clearly established that metacognition directly and substantially influences an individual's academic outcomes. On the one side, declarative metacognitive knowledge, typically assessed with questionnaires, has a systematic long-term impact on school careers and a short-term impact on test performance (e.g., PISA studies, OECD 2005; Schneider et al. 1998). On the other side, procedural metacognitive skills, that is, metacognitive monitoring and control processes, explain substantial amounts of individual differences in test performance (e.g., Hacker et al. 2009b; Roebers et al. 2009; Schneider and Artelt 2010), even after controlling for psychometric intelligence (e.g., van der Stel and

Veenman 2008). Individuals who are better able to make accurate performance predictions or who are better able to estimate the correctness of provided answers, typically control more efficiently their study behavior (e.g., allocation of study time), and/or detect and correct more errors or comprehension difficulties (de Bruin et al. 2011; Koriat and Goldsmith 1996; Krebs and Roebers 2012). To our knowledge, long-term effects of procedural metacognition on children`s school careers have unfortunately not yet been investigated. Overall, it appears that the direct influence of metacognition on academic outcomes is relatively well established from grade 3 on, with a tendency of this influence to become closer as children grow older (Roebers et al. 2009; Schneider 2010).

Interrelations between EF, Self-Concept (SC), and metacognition

Empirical studies testing the assumption that EF, metacognition, and self-concept (SC) are significantly interrelated are still rare. However, a few neuro-imaging studies suggest that while performing either typical EF or certain metacognitive tasks, brain activation is especially pronounced in the prefrontal cortex (e.g., Kao et al. 2005). In samples with neurological disorders and frontal lobe lesions, both EF and metacognition may be impaired (Diamond 2000; Pannu and Kaszniak 2005), with a tendency of control processes rather than monitoring being associated with EF (Schwartz and Bacon 2008). On the behavioral level, a few studies provide evidence for a direct association between EF and metacognition, with these studies mainly focusing on updating. Better updating skills seem to be related to more efficient metacognitive functioning, both in adults (Dunlosky and Thiede 2004), and in children (e.g., DeMarie et al. 2004). However, other EF dimensions such as inhibition and cognitive flexibility are currently also discussed to be directly related to metacognitive processes. Kuhn and Pease (2010) argued that for adapting a flexible strategy use, an individual not only has to develop new strategic skills but must inhibit the use of previously used strategies and be able to flexibly shift between (meta-) cognitive subprocesses. And finally, from the theoretical viewpoint of metacognitive skills, an individual’s ability to access information stored in long-term memory, and to flexibly shift between the activated knowledge and the to-be-remembered information in order to monitor and control ongoing cognitive operations is crucial (for an integrative view on memory and metamemory see Dunlosky and Bjork 2008).

With respect to the relationship between self-perceived competence and metacognition, the two constructs have repeatedly been shown to be moderately interrelated in adult samples (Hertzog et al. 1990; Kleitman and Stankov 2007). As Hacker et al. (2009a) have outlined it is a sense of “agency” that emerges from an individual’s SC giving rise to self-regulated learning behaviors during learning. In other words, an individual’s belief in his or her self as an agent in an achievement situation may be related to the activation of metacognitive monitoring processes at the micro-level (see also Cornoldi 2010; Efklides 2011). It may thus be assumed that individual differences in EF may be related to metacognitive *control*, because both groups of processes are executive in nature (Best and Miller 2010; Fernandez-Duque et al. 2000). EF skills and metacognitive *monitoring*, in contrast, seem to share an individual’s ability to reflect and evaluate one’s performance (i.e., self-perceptions or self-concept), relying on the ability to introspect, that is, to form and activate mental representations about oneself that take past and ongoing activities as their content (Lyons and Zelazo 2011).

Developmental change in EF, metacognition, and Self-Concept (SC)

Undoubtedly, EF are observable (and measureable) early in development and continue to improve into adolescence (for a recent review see Best and Miller 2010): Pronounced EF improvements in early childhood are observed with respect to the accuracy of performance, likely reflecting children's growing ability to consciously select among different responses (including the ability to inhibit a prepotent response) by reasoning about available options, by switching between task demands while updating the tasks' goals and specifics. During elementary school years, further progression in EF performance is typically found, mirrored by the emergence of a speed-accuracy trade-off that corresponds to children's growing awareness of a discrepancy between tasks demands, on the one side, and their own performance, on the other side. As Lyons and Zelazo (2011) have elaborated, children become increasingly capable of integrating different mental representations (for example, with respect to changing rules) allowing a more accurate awareness of their performance as well as increasingly flexible adjustments of responses.

As to metacognitive development, most researchers agree that emerging metacognitive skills can be observed from an age of 3 years on. These early skills, however, have been found to be relatively undifferentiated (e.g., Moore et al. 1989; Lyons and Ghetti 2011). Between the age of 5 and 8 years, children's explicit awareness of certainty/uncertainty as well as the reliability and validity of monitoring increase gradually (Ghetti et al. 2011; Roebers et al. 2007; Schneider and Lockl 2008). Between the age of 7 and 8 approximately, a systematic association between item difficulty (in terms of ease of recall or recall accuracy) and monitoring judgments for incorrect responses (i.e., lower confidence judgments for harder items when item responses turn out to be incorrect) has been documented, indicating that from that age on individuals take recall properties into account, an important and useful heuristic for monitoring (Krebs and Roebers 2012; Serra and Metcalfe 2009). With a delay, children then also improve with respect to metacognitive control skills, (i.e., their ability to act upon monitoring). Age-related improvements in self-regulatory skills such as allocation of study time (Schneider and Lockl 2008), withholding uncertain responses (Roebers and Fernandez 2002), or revising answers in an achievement test (Roebers et al. 2009) are typically found during elementary school years. It should be noted, however, that research has so far mostly focused on developmental improvements while only marginally addressing individual differences. Moreover, findings stem mainly from experimental approaches and thus, the psychometric properties of the obtained measures were neither critical for the findings nor of central interest. In the present approach, an innovative method for quantifying metacognitive monitoring (i.e., confidence judgments) and control skills (i.e., detection and correction of errors) was developed aiming to obtain measures of metacognition in young elementary school children that would nevertheless have the psychometric qualities allowing the mapping of meaningful and shared metacognitive monitoring and processes separately (creating two latent variables that would converge with the data).

Self-concept development in children aged 6 to 8 years can best be characterized by a general and overoptimistic view, that is, by high levels of self-perceived competence with typically two distinguishable self-concept domains, a social and an academic SC dimension (for a recent and comprehensive review see Harter 2012). While the social SC of children around the transition to school typically slightly decreases, their academic self-perceptions tend to further increase due to the newly acquired skills in school (e.g., Aunola et al. 2002; Mantzicopoulos 2006; Marsh and Ayotte 2003). Measuring individual differences in children's SC (that yet exist) thus calls for an instrument that is highly sensitive in the upper half of its scale (Harter and Pike 1984; Nicholls 1978), with the nevertheless resulting non-normal and somewhat skewed distributions being the rule rather than an exception.

In the early school years, students' academic SC is only loosely related to their academic performance (e.g., Marsh et al. 2002; Spinath and Spinath 2005), and developmental psychologists have argued that this self-serving bias has a protective role by keeping children's motivation high despite failures (Bjorklund and Bering 2002; Shin et al. 2007). It is further assumed that through experiences with one's factual competences (including also unsuccessful task mastery attempts), this self-protective factor develops into a still positive but somewhat more realistic self-perception. In this view, task-specific experiences—similar to what has been outlined for metacognitive skills—give rise to more stable and generalized self-perceptions.

Developmental psychologists do increasingly target the question whether a source for developmental progression and individual differences in self-regulation may lie in children's growing ability to perceive (i.e., to introspect), evaluate, and control their cognitive activities and performance, including the ability to build mental representations about oneself (Ghetti et al. 2011; Lyons and Zelazo 2011; Moore 2010; Stoettinger et al. 2009). Several attempts have been made to document precursors of metacognition but these are mostly located in the domain of declarative metacognitive knowledge (Grammer et al. 2011; Lockl and Schneider 2007). Precursors of children's procedural metacognitions, however, remain widely unknown.

Theoretically, one might assume that early EF skills may be predictive for later metacognitive *control* in any learning situation. In this view, EF may fuel metacognitive control in that individuals with better EF can more competently adapt optimal learning strategies, can better coordinate retrieval, and can more efficiently avoid or correct errors (Best and Miller 2010; Fernandez-Duque et al. 2000; Kuhn 1999). As to developmental antecedents of metacognitive *monitoring*, SC seems to be a candidate factor: Performance predictions and performance post-dictions, as typically used for measuring metacognitive monitoring (i.e., judgments-of-learning, feeling-of-knowing, confidence judgments) reflect an individual's self-perception in a specific situation and can thus be considered as an aspect of SC at a very concrete level of operationalization (Shin et al. 2007). Against this background and considering the similarity of findings in the domain of early metacognitions and early SC, it may be assumed that young children's early SC is indeed linked to children's later monitoring skills.

The present study

The present longitudinal study aimed at pursuing two major research questions: First, interrelations between young elementary school children's metacognitive abilities, EF, and self-perceptions in the form of self-concept are explored. This was addressed cross-sectionally when children were in 2nd grade, but also longitudinally using data on these children's earlier EF and SC when they were in 1st grade. In order to tap emerging metacognitive monitoring and control skills, these processes were assessed in the context of a spelling task, a task known to trigger and facilitate exactly the processes we intended to target (Hacker et al. 2009a, b), and to have substantial ecological validity. Thereby, this study is among the first to investigate early elementary school children's procedural metacognitive skills on the level of latent variables (allowing error free estimation) and to relate these emerging skills to concurrent but also to earlier self-perceptions and EF. By these means, the present paper aims to contribute to theoretical issues, such as the positioning of EF, metacognition, and self-perceptions within an overarching theoretical framework of self-regulation.

Second, we intended to link individual differences in EF, metacognition, and SC simultaneously to school achievement. Despite the consistent, but mainly unrelated evidence for impacts of these constructs for scholastic achievement (when older children or adolescents are considered), a study in which EF, SC, and metacognition are assessed for explaining individual differences in young children's school achievement is still lacking. Theoretically, one might expect reliable influences of EF for mathematics and literacy, while metacognition may be expected to yield larger, but more task-specific effects on academic performance, in our case to literacy, as metacognition was assessed in the context of a literacy task.

Method

Sample

A total of N=209 children (N=109 girls) with a mean age of M=7 years and 6 months (M= 90.6 months; SD=4 months) at the beginning of the study were drawn from a larger longitudinal data set and were included in the present analyses. Children attended first grade (towards the end of the school year) at the first assessment (T_1) and were drawn from various public schools in urban, suburban, and rural areas of four different Swiss states. Only children who also completed the second assessment 1 year later (T_2; realized 11–12 months later) were considered. [Five additional children had been tested at T_1 but had moved out of the study's reach at T_2; they were therefore excluded from the analyses reported below; i.e., attrition rate<3 %]. The homogeneity of the sample in terms of ethnicity (>97 % White) reflected most parts of Switzerland; similarly, the diversity in terms of parental education was also typical for this area: only 4 % of the mothers and 5 % of the fathers reported to have finished their education after high school (9 years of obligatory schooling). In contrast, 61 % of the mothers and 36 % of the fathers described themselves having a college degree; 23 % of the mothers and 42 % of the fathers reported to have a university degree (12 % and 17 % of the paternal education information was missing for the mothers and fathers, respectively). As to children's native language, 76 % were reported by their parents to be native Swiss, 6 % were immigrants from the German speaking neighboring countries (Germany and Austria), and 7 % were non-native German speaking immigrants from Eastern and Southern European countries (11 % missing information), with all participants being sufficiently fluent in German. Informed parental consent was obtained prior to the study. Due to sickness or due to pragmatic reasons (time constraints of the schools) few tasks were not completed by all participants; the slightly varying numbers of data points in the analyses are indicated by the degrees of freedom.

Procedure and materials

Ethical approval for the present study was obtained from the Faculty's Ethics Committee. At both assessments, children were tested individually in a quiet room in their school by a trained experimenter. Each child participated in two sessions of approximately 30 min each, with the two sessions being 4 to 8 days apart. The order of the tasks was counterbalanced. At T_2, an additional small group testing of 3 to 6 children for the school achievements tests including the metacognitive monitoring and control measurement was realized. Table 1 gives an overview over the included tasks and provides descriptive statistics on the dependent variables.

Table 1 Means and standard deviations of included tasks as a function of time point (T_1 and T_2)

	Task	T_1	T_2
EF	Fruit-Stroop (Interference)	27.0 (10.1)	21.6 (6.8)
	Verbal Fluency	26.4 (6.7)	30.1 (7.3)
	Flexibility/Updating (Acc)	0.82 (0.12)	0.88 (0.11)
Self-Concept	SC Mathematics	20.9 (3.7)	19.7 (4.1)
	SC Language Arts	20.1 (4.2)	19.3 (4.3)
Mathematics	Sequences	–	12.1 (2.5)
	Equations	–	21.2 (5.5)
	Addition/Subtraction	–	7.9 (2.6)
Literacy	Spelling	–	24.6 (1.8)
	Reading Speed	–	71.8 (22.7)
	Reading Comprehension	–	25.8 (10.1)

EF executive functioning; *SC* self-concept; *SC Mathematics* SC Counting and SC Arithmetic; *SC Language Arts* SC Reading and SC Spelling; for the Descriptive Statistics of the Metacognition Variables see Table 3

Executive functioning In a first step, a principal component analysis including the EF tasks available in the data set for both measurement points was run in order to assess the factorial structure of EF given these tasks. Based on these results and based on theoretical considerations, the following tasks were selected: Fruit-Stroop task, Cognitive Flexibility, and Verbal Fluency (Lexical Access).[1]

The *Fruit Stroop* task (Archibald and Kerns 1999) consists of four different pages displaying 25 items each that are presented to the child: the first page displays 25 colored squares and children have to name the colors as quickly as possible. On the second page four different fruits in their original color are presented (congruent trial), followed by a third page displaying the same fruits in black and white and children are asked to name the original colors. The fourth and final page shows the fruits in incorrect colors and children are again asked to name the original color (incongruent trial). The (converted) dependent variable is a measure of inhibition/interference control according to Archibald and Kerns (1999) formula: time page 4 – [(time page 1 × time page 3)/(time page 1+time page 3)], with higher values indicating better inhibition/interference control. This measure accounts for individual differences in information processing speed, articulatory speed, and speed of lexical access and mirrors well an individuals' ability to inhibit prepotent responses (i.e., naming the fruits' names or naming the color of the stimuli).

For the *Verbal Fluency* task, children have to name animals and groceries. In the first trial, children are first asked to name as many "animals" as they could within 1 min. This same procedure is then repeated for the category "groceries" as a second trial. The dependent variable was the number of unique items named, excluding repetitions, produced within the 2 min (Luo et al. 2010; Milner 1964).

Finally, the C*ognitive Flexibility/Updating* task is a computerized task developed in our lab (e.g., Roebers and Kauer 2009). There are two categories of stimuli (two different kinds of fish) that are presented simultaneously on the right and left side of the computer screen.

[1] Unfortunately, the only relative pure updating task included in the study (Backward Color Recall task) proved to be unreliable (due to too few trials on one sequence length) and did not load substantially on the one resultant EF factor; one additional task of verbal fluency (Rapid Naming) was excluded in order to receive a well-balanced EF latent variable with the four dimensions being reflected by one task each.

Children are told that their task is to feed two families of fish consecutively, that is, to feed a member of one family in the first trial and a member of the other family in the next trial. Because each time two fish (one of each category) appear on the screen with randomly changing sides (switch and non-switch trials), it is the child's task to decide whose turn it is to be fed (updating). Fish are fed by pressing a button on the side corresponding to their appearance on the computer screen. There are $N=46$ trials (50 % non-switch trials), with a short break including positive feedback after half the trials. Inter-stimuli intervals vary from 300 to 700 msec. The dependent variable is the proportion of overall correct responses (i.e., accuracy).

At the second assessment 1 year later, the identical tasks for measuring *Inhibition* (*Fruit-Stroop)*, *Verbal Fluency*, and *Flexibility/Updating* were used as indicators of EF. As can be seen in Table 2, all three EF tasks proved to be stable over time, with one-year stability ranging from 0.51 to 0.56 ($p<.001$). Because developmental progression on these tasks is not the focus of the present paper, we just briefly report here that analyses of variance with repeated measures were performed on these EF tasks revealing that children underwent significant improvements in all three tasks between T_1 and T_2, F_{Stroop} (1, 207)=42.79, partial eta^2 ($\eta_p{}^2$) =0.17, $F_{\text{Verbal Fluency}}$ (1, 206)=66.70, $\eta_p{}^2$ =0.25, $F_{\text{Flexi/Updating}}$ (1, 205)= 46.43, $\eta_p{}^2$ =0.18, all *p*s<.001 (for the exact means see Table 1).

Self-concept A rating scale was used for measuring *Self-Concept* in mathematics and language arts at the first and second assessment (Nicholls 1978; Stipek and Daniels 1988; retest-reliability: 0.82). For this assessment, children are given a sheet of paper depicting vertical rows of 25 schematic faces and are explained that theses rows of faces represent their classmates. The experimenter further explicated that on top of each row, there is the student that is best in the specified area of interest (e.g., reading, spelling), on the bottom of that same row, there is the child that is worst in this school subject. Children are then instructed to mark the one face in each row that best represents their own rank, for each of the subjects separately. A numerical value is then assigned to each of the positions (1–25), with higher values indicating a more positive SC. Explorative factor analysis confirmed distinguishable albeit not independent SC factors of mathematics and language arts. SC Mathematics (reflecting counting and basic arithmetic) and SC Language Arts (reflecting reading and spelling) were therefore computed and were found to be fairly stable over the 1 year delay (group stability $SC_{\text{Math}}=0.34$; $SC_{\text{Language}}=0.41$ ($p<.01$). As can be seen in Table 2, these two domains of SC correlated in the range of $r=0.40$ to 0.57 ($p<.01$) with each other.

Metacognitive monitoring and control Metacognitive monitoring and control were measured using a multi-phase task in the context of spelling: In the first phase of this task, children are presented with 22 schematic pictures of simple objects and animals (e.g., "Hund"- dog; "Fahrrad"–bicycle) and instructed to write the corresponding word beside the picture. Items were selected based on intensive piloting ensuring varying degrees of item difficulty (averaged item difficulty=0.65; range: 0.24–0.90). Detailed item analyses revealed that there were 6 items each in three distinguishable subgroups of "easy", "average", and "difficult" words (18 items). [Four additional items turned out to be very easy, with 96 % and more participants spelling these words correctly, and were therefore excluded from the analyses]. After having completed the spelling test with a black pencil, children are given a blue pencil and were asked to indicate "*how sure they were that the word was spelled correctly*"; i.e., confidence judgments. Before they were allowed to start with the confidence ratings, children were familiarized with the 7-p oint-Likert confidence scale and practiced its

Table 2 Intercorrelations among the included variables

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
1. Inhibition $_{t1}$	–																			
2. Flexi/Updating$_{t1}$	0.31	–																		
3. Verb. Fluency$_{t1}$	0.29	0.20	–																	
4. Inhibtion$_{t2}$	0.56	0.23	0.28	–																
5. Flexi/Updating$_{t2}$	0.35	0.51	0.25	0.32	–															
6. Verb. Fluency$_{t2}$	0.22	0.19	0.56	0.23	0.19	–														
7. SC Language$_{t1}$	0.21	0.16	0.22	0.24	0.17	0.25	–													
8. SC Mathematics$_{t1}$	0.16	0.02	0.20	0.18	0.00	0.24	0.40	–												
9. SC Language$_{t2}$	0.15	0.03	0.04	0.09	0.04	0.16	0.41	0.12	–											
10. SC Mathematics$_{t2}$	0.21	0.00	0.08	0.17	0.01	0.17	0.28	0.34	0.57	–										
11. Monitoring_1$_{t2}$	0.08	0.03	0.14	0.04	-0.03	0.15	0.17	0.17	0.32	0.25	–									
12. Monitoring_2$_{t2}$	0.04	0.04	0.02	0.04	-0.04	0.13	0.21	0.17	0.33	0.26	0.60	–								
13. Control_1$_{t2}$	0.25	0.24	0.28	0.29	0.19	0.26	0.33	0.20	0.16	0.10	0.22	0.24	–							
14. Control_2$_{t2}$	0.01	0.08	0.14	0.01	0.05	0.10	0.14	0.05	0.16	0.04	0.24	0.19	0.26	–						
15. Control_3$_{t2}$	0.11	0.13	0.12	0.09	0.07	0.19	0.23	0.28	0.24	0.11	0.18	0.20	0.38	0.36	–					
16. Equations$_{t2}$	0.32	0.28	0.32	0.33	0.34	0.24	0.30	0.31	0.07	0.16	0.02	0.01	0.30	0.14	0.16	–				
17. Sequences$_{t2}$	0.33	0.33	0.30	0.32	0.35	0.27	0.27	0.22	0.13	0.21	0.00	0.02	0.25	0.08	0.20	0.51	–			
18. Addit/Subtr$_{t2}$	0.19	0.22	0.33	0.21	0.29	0.28	0.26	0.31	0.14	0.20	0.15	0.14	0.34	0.18	0.20	0.60	0.52	–		
19. Spelling$_{t2}$	0.27	0.31	0.24	0.11	0.30	0.19	0.25	0.06	0.11	0.08	0.12	0.06	0.47	0.16	0.27	0.28	0.30	0.32	–	
20. Reading Speed$_{t2}$	0.37	0.31	0.35	0.34	0.38	0.35	0.35	0.12	0.30	0.09	0.10	0.09	0.46	0.27	0.34	0.30	0.48	0.47	0.50	–
21. Reading Compr$_{t2}$	0.35	0.35	0.30	0.37	0.33	0.30	0.35	0.15	0.35	0.18	0.13	0.13	0.52	0.28	0.39	0.32	0.46	0.43	0.52	0.83

Correlations>0.13 are significant at the $p<.05$ level use (Krebs and Roebers 2010; Roebers et al. 2009). Then, children give confidence judgments to every word they had written down, resulting in 18 confidence ratings per participant. In order to control for the typical but problematic confound between confidence and performance (Kleitman and Stankov 2007), and because uncertainty monitoring skills (monitoring of incorrect responses) tend to be relatively undifferentiated in young children (Moore et al. 1989) leading to a lack of a substantial impact of item difficulty on the level of uncertainty and problems with their resulting psychometric properties (von der Linden and Roebers 2006), only confidence judgments for correctly spelled words were used as indicators of the latent variable "metacognitive monitoring". In the third and last phase of this task, the blue pencils are exchanged into red ones and children are allowed to cross-out previously written words if they believed they were spelled incorrectly. Children are not obliged to cross-out any word; however, they can do so if they wish. Control behavior is quantified through the number of words that are withdrawn (adequately vs. erroneously) or maintained (adequately vs. erroneously). As was expected based on previous studies, distributions of the resulting dependent variables revealed hints for floor effects and somewhat skewed distributions for inadequate control (correctly spelled but erroneously crossed-out; incorrectly spelled and erroneously maintained especially when easy and average items were considered, see Table 3). Therefore, the two indicators of adequate control (words that had been spelled *incorrectly* and were then *crossed-out* plus words that had been spelled *correctly* and had then been *maintained* in the control phase) were collapsed and used for mapping onto the corresponding latent variable in the structural equation modeling reported below. It is important to note that because of the multi-phase setup of the experimental paradigm chosen for the present study, monitoring processes can be investigated in terms of how and to what extent they influence subsequent control, but not *vice versa*.

School achievement tests School achievement in the domain of mathematics, reading and spelling was measured with standardized and curriculum-based school achievement tests administered at T_2. For *Mathematical Achievement* three subtests were administered (HRT1-4, Haffner et al. 2005). The first task, *Equations,* consisted of 40 items in which quantities have to be compared. For the second task, *Sequences*, children are presented with 20 sequences of numbers and have to continue these sequences. For the third task, *Addition/ Subtraction,* participants are given 12 basic arithmetic tasks containing between 2 and 5 operations. Retest-reliability of the mathematics tests as reported by the authors vary between 0.75 and 0.86. As can be seen in Table 2, the three tasks were significantly interrelated r=0.51–0.60 (p<.001)

Table 3 Descriptive statistics for metacognitive monitoring (confidence judgments) and control as a function of item difficulty

Monitoring		
(Min-Max=1–7)	Correct Spelling	Incorrect Spelling
Easy words	5.9 (0.8)	5.2 (1.6)
Average words	6.1 (0.9)	5.4 (1.4)
Difficult words	6.1 (1.0)	5.5 (1.1)
Control		
(Min-Max=1–6)	Adequate Control	
Easy words	4.5 (1.4)	
Average words	4.2 (1.2)	
Difficult words	3.1 (1.8)	

Adequate control=correctly spelled words maintained +incorrectly spelled words withdrawn (crossed-out); N=6 for easy, average, and difficult words, respectively

For *Literacy*, also three tasks were used. The first task, S*pelling*, children had to write down a sentence that was read aloud (max 27 correct graphemes; HSP; May 2002; short-term re-test reliability: 0.92). Additionally, there were two *Reading* tests (WLLP; Küspert and Schneider 1998; SLS, Mayringer and Wimmer 2003) in which children were asked to judge the meaningfulness of sentences (Reading Comprehension; parallel-test reliability as reported by the authors: 0.90) or to search for a pictorial match of a word's meaning out of a choice of 4 alternatives (Reading Speed; retest-reliability as reported by the authors: 0.75–0.81). Table 2 presents the significant intercorrelations among the three literacy tests.

Results

The following results section is organized in three subsections. In the first section, participants' metacognitive monitoring and control skills will be described. This is followed by presenting results from structural equation modeling investigating cross-sectional (T_2) links between executive functioning, self-concept, metacognitive monitoring and control, on the one hand, and school achievement in mathematics and literacy, on the other hand. In the third section, results of structural equation modeling will be presented that address a possible longitudinal link between earlier executive functioning and self-concept (T_1) on later metacognition (i.e., monitoring and control; T_2).

Metacognitive monitoring and control

A classical indicator of metacognitive monitoring is "resolution", defined as an individual's ability to metacognitively differentiate between correct and incorrect responses. In order to find out whether the young participants of this study were able to monitor, confidence judgments for correctly and incorrectly spelled words were contrasted. Because item difficulty has an additional and strong impact on monitoring (e.g., Krebs and Roebers 2010), confidence judgments were grouped together based on item difficulty. Table 3 presents these mean confidence judgments as a function of item difficulty and response correctness. Analyses of variance were conducted with correctness of response as within-subject factor for the easy, average, and difficult items, separately, revealing that for all three groups of items children's confidence judgments were significantly higher for correctly than for incorrectly spelled words, F_{easy} (1, 107)=15.85, $\eta_p{}^2$ =0.13, F_{average} (1, 166)=24.26, $\eta_p{}^2$ =0.13, and $F_{\text{difficult}}$ (1, 151)=32.52, $\eta_p{}^2$ = 0.18, all ps<0.001, indicative of relative adequate metacognitive resolution. As expected and of importance for the subsequent analysis, there was no systematic influence of item difficulty on children's confidence judgments (F< *1*, *ns*), revealing—especially for the monitoring of incorrect spellings—that these skills are not yet sufficiently developed in this age and therefore not optimally suited for the structural equation modeling reported below.

As to metacognitive control, Table 3 (in its lower part) presents the number of words children adequately maintained or withdrew (crossed-out). When systematically comparing adequate control as a function of item difficulty, an analysis of variance with item difficulty as within-subject factor revealed that adequate control differed substantially as a function of item difficulty (easy, average and difficult; $F_{\text{easy-average}}$ (1, 416)=61.82, $\eta_p{}^2$ =0.23, $F_{\text{average-difficult}}$ (1, 416)=64.09, $\eta_p{}^2$ =0.24), ps<0.001), with lower item difficulty resulting in more frequent adequate metacognitive control.

The importance of EF, SC, metacognitive monitoring and control for second graders' school achievement

In order to explore structural links between EF, SC, metacognitive monitoring and control, one the one hand, and academic achievement in terms of mathematics and literacy, on the other hand, structural equation modeling was realized using AMOS 18 software (Arbuckle 2009). For these cross-sectional analyses (but also for the longitudinal analyses reported in the section below), all variables were standardized. Table 2 presents the intercorrelations between all included indicators used for the structural equation modeling. To deal with missing data, we used the full information maximum likelihood approach because this method is widely considered as producing the least biased and most efficient estimates (Peugh and Enders 2004). The model's fit was assessed via Chi^2- value, the Tucker-Lewis index (TLI), the comparative fit index (CFI), and the root-mean-square error of approximation (RMSEA). A good fit of the model is thereby indicated by TLI- and CFI-values greater than 0.95, a RMSEA-value smaller or equal than 0.06, and a Chi^2-value that is ideally not significant (but may be significant in large samples as the present one; see Byrne 2001; Hu and Bentler 1998).

For investigating the direct effects of EF, SC, and metacognition on academic performance (prediction of academic achievement), cross-sectional data was used as all these variables of interest were available at the second measurement point. First, a fully recurrent measurement model was drawn, that is, all paths between any of the included latent variables were included. Next, because the initial path model did not converge with the data the two residuals between SC Mathematics and Mathematical Performance and between SC Literacy and Literacy Performance were allowed and estimated. This was done because theoretically, the residuals of these variables share common variance (e.g., school subject related interest, school subject specific motivation). This path model that then easily converged with the data was used as the final model and is presented in Fig. 1. In order to simplify the graphical presentation of the structural equation model, the standardized factor loadings onto the latent variables are presented in Table 4. Among the predictor variables, correlations were estimated; no covariances between the residuals were allowed. Fit indices suggested that this model had a very good fit to the data, $\chi^2(90, N=209)=115.42$, $p=0.02$, TLI=0.96, CFI=0.97, and RMSEA=0.04.

As to the *interrelations* between the four different predictors, inspection of Fig. 1 reveals that metacognitive control has significant correlations with all other three predictors (EF, SC, and metacognitive monitoring), and monitoring and self-concept were additionally and substantially interrelated. The other correlations among the predictors were not significant at $p<0.05$. As to the *structural links* between EF, SC, metacognitive monitoring and control, and the outcome variables, a school subject specific pattern of paths was found: EF and metacognitive control proved to be significant predictors of individual differences in *literacy*. In contrast, only EF was found to yield a direct effect on *mathematical* achievement in this model, with a total of 63 % of the individual differences in mathematics being explained through the included variables. Taken together, the cross-sectional model predicting academic achievement at the end of children's 2nd grade revealed substantial direct impacts of EF on mathematics and literacy achievement, and significant direct effects of metacognitive control on literacy explaining considerable amounts of variance in school achievement.

Relations between earlier EF and SC and later metacognitive monitoring and control

A core issue in developmental psychology and a specific research question in the domain of metacognitive development concerns the question of developmental antecedents of

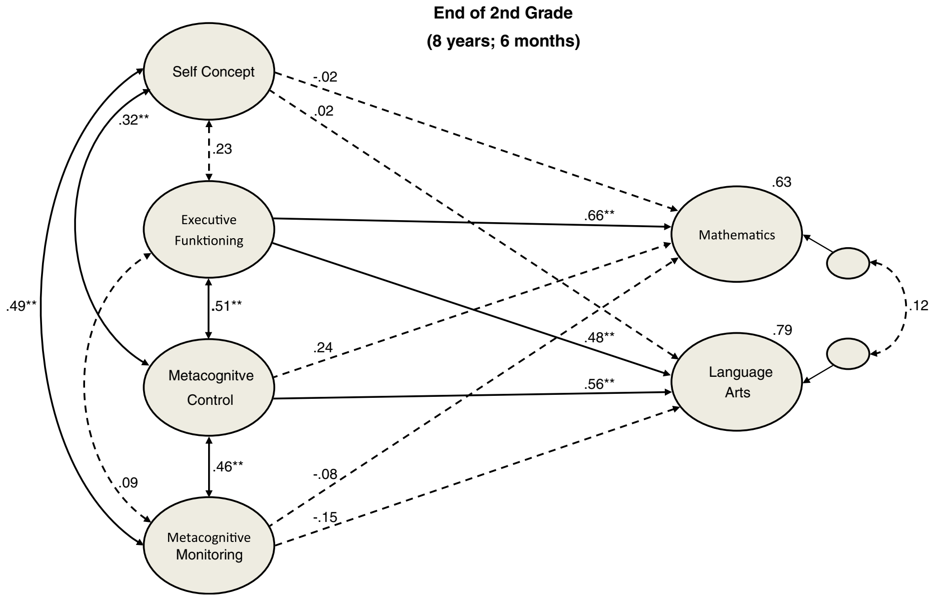

Fig. 1 Structural equation model explaining mathematics and literacy achievement with executive functioning, self-concept, metacognitive monitoring and control skills at the end of 2nd grade (cross-sectional analyses); *solid lines* represent significant paths, *dashed lines* represent non-significant paths

metacognitive monitoring and control skills. Therefore, we tested the hypothesis that there are substantial and direct associations between earlier EF, SC (assessed at the first

Table 4 Factor loadings of the predictors (indicators) on their corresponding latent variables depicted on the left side in Fig. 1

Latent variable	Indicator	Standardized factor loadings
Self-concept	Self-Concept Mathematics	0.67**
	Self-Concept Language	0.85**
Executive functioning	Inhibition	0.53**
	Flexi/Updating	0.55**
	Verbal Fluency	0.44**
Metacognitive control	Parcel 1	0.70**
	Parcel 2	0.44**
	Parcel 3	0.56**
Metacognitive monitoring	Parcel 1	0.80**
	Parcel 2	0.76**
Mathematics	Equations	0.77**
	Sequences	0.70**
	Addition/Subtraction	0.74**
Literacy	Spelling	0.57**
	Reading Speed	0.89**
	Reading Comprehension	0.92**

** $p<.001$

measurement point of this longitudinal study), and metacognitive monitoring and control assessed 1 year later when children were in the end of their 2nd grade. It was also explored whether there are direct effects from monitoring to control (but not *vice versa* because of the specific nature of the paradigm used). The measurement model was drawn fully recurrent (see above), and no covariances between any two residuals were allowed. EF and SC at the first measurement point were indexed through the identical set of tasks/measures as in the analyses reported above when predicting academic achievement (EF: Inhibition, Cognitive Flexibility/Updating, and Verbal Fluency; SC: rating scale for mathematics and literacy). As for the model depicted in Fig. 1, the latent variables of monitoring and control were indexed by item parcels (Little et al. 2002). Analyses revealed that the resulting model (Fig. 2) had an excellent fit to the data, $\chi^2(29, N=209)=33.98$, n.s., TLI=0.97, CFI=0.98, and RMSEA=0.03.

Figure 2 presents the final model with the estimated correlations and paths, as well as with the indicators and their standardized factor loadings onto their latent variables. As can be seen, all factor loadings of the indicators onto their latent variables were significant. Furthermore, EF and SC at the study's first measurement point proved to be substantially interrelated. Moreover, earlier EF had a significant direct effect on later control and earlier SC had a substantial direct effect on later monitoring. The direct path from earlier SC to metacognitive control just missed significance ($p>0.07$). Moreover, the indirect effect of SC on control via monitoring (0.115) was also non-significant when the mediation was tested for significance with the Sobel test (Sobel 1982). The direct path from earlier EF to later monitoring was not significant. Children's confidence judgments proved to have a significant direct effect on their control, for which 50 % of the total variance was explained. Thus, the hypothesis that EF and SC are associated with each other and with subsequently

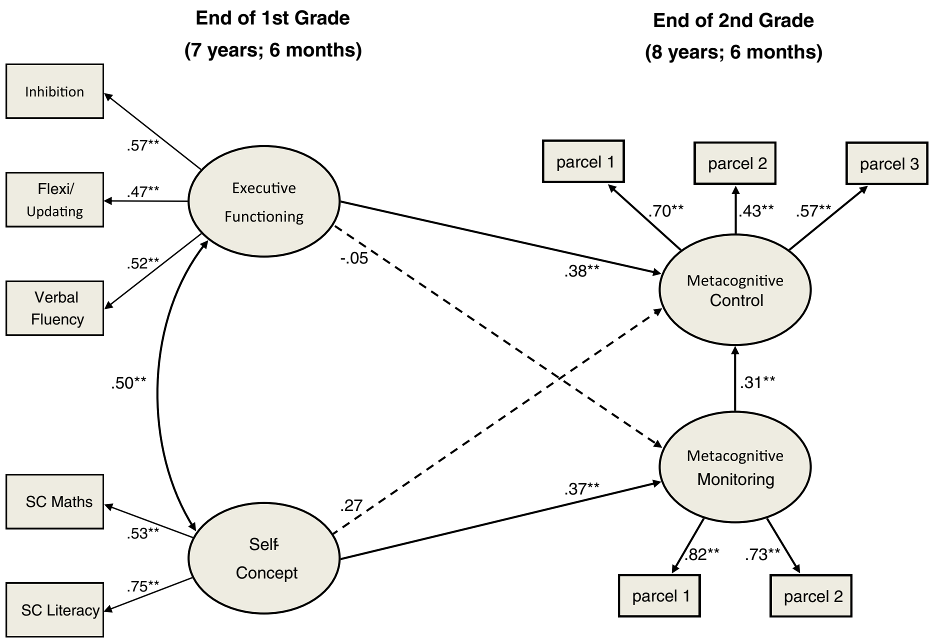

Fig. 2 Structural equation model predicting metacognitive monitoring and control at the end of the 2nd grade with executive functioning and self-concept at the end of 1st grade; *solid lines* represent significant paths, *dashed lines* represent non-significant paths

measured metacognitive monitoring and control in young children was confirmed and offered a picture suggesting domain-specific relations: earlier EF seems to more strongly predict control and SC appears to yield direct effects on monitoring. In other words, individual differences in early EF are associated with individual differences in later metacognitive control, and individual differences in young children's SC are related to their emerging ability to monitoring the correctness of their responses.

Discussion

One major aim of the present study was to explore the relation between executive functions (EF), self-concept (SC), and metacognition, as well as their relative impact for early academic performance. With a large data set including young elementary school children, cross-sectional direct effects on academic achievement in the end of children's 2nd grade were tested. As for these children, data on their earlier EF and SC (1st grade) were additionally available, the question of whether EF and SC may be potential developmental antecedents of procedural metacognition was also targeted.

Addressing the question of the relative importance of EF, SC, and metacognitive processes for 2nd graders' school achievement was realized by drawing a cross-sectional path model (Fig. 1). This approach constitutes an innovative contribution as the included constructs have mostly been studied separately. Results revealed that EF and metacognitive monitoring, and control processes are significantly related to children's academic outcomes. Beyond their influence, the included affective SC latent variable yielded no direct effects on the included academic outcome measures. But, this is not to conclude that SC is not influential for school performance, as the correlations between SC and achievement within the mathematical or literacy domain were substantial (see Table 2). These are important findings as they seem to suggest that executive functions and metacognitive control processes are predominant in the prediction of academic outcomes (e.g., Grissmer et al. 2009; Duncan et al. 2007). Moreover, the present study not only confirms the existing literature concerning both, the impact of EF for children's early school success (Blair and Razza 2007; Blair and Diamond 2008), and the importance of metacognitive skills for academic outcomes (e.g., Krebs and Roebers 2010), but extends our understanding as these two different lines of research were successfully integrated in the present approach allowing to simultaneously estimate their relative contribution.

At the same time, it appeared that EF (but not metacognitive monitoring and control) is significantly and directly related to both mathematics and literacy while metacognitive control was found to be directly associated to literacy only. One may argue that metacognitive control had been assessed within a task context similar to the measurement of spelling; however, these were independent measurements and Table 2 reveals significant correlations between metacognitive control and reading skills, too. Our findings therefore suggest that EF has a direct and substantial impact on mathematics and literacy whereas metacognitive control exerts either domain-specific influences or indirect effects. From a developmental perspective, it may be argued that the impact of EF and metacognitive control on academic outcomes may additionally change in the course of development through schooling, testing experience, and increasing cognitive resources, but also through increasing sophistication in these information processing skills. From this perspective, the present study provides only an age-dependent and focused spotlight on the interplay between EF, metacognition, and school achievement in early elementary school age children. At the same time, however, we tapped an important phase of children's school careers and were able to offer differentiated insights into higher-order cognitive information processes influencing academic outcomes just after school entry.

Noteworthy, over and beyond these shared cognitive information processes that positively impact young school children's academic outcomes, participants' self-perceptions of competence were not found to yield significant effects on early academic success. Against the bulk of evidence that a student's self-concept is related to her or his academic performance, this may be surprising (e.g., Harter 2012). However, the simultaneous consideration of strong and powerful cognitive predictors in addition to SC made direct effects of SC unlikely. Nevertheless, at the level of correlations and given the significant interrelations among the predictor variables, the present approach offers additional interesting new insights. It appears that young children's self-perceptions of academic competence influence the development of cognitive skills, in this case, metacognitive monitoring and control skills. A personality trait of "self-confidence" is being discussed in the adult literature (Kleitman and Stankov 2007), and contemporary frameworks of self-regulated learning also include motivational and affective aspects (Efklides 2011). A student with a positive self-concept may experience a new task as challenging (as opposed to threatening), may make more metacognitive experiences (more easily admitting to be unsure for some of the answers, and more courageously maintaining even uncertain answers), and through feedback occasions make stronger developmental advances. Thus, the documented associations between SC and metacognitive monitoring and control fit well into the literature addressing "cool" and "hot" aspects of self-regulation (Hongwanishkul et al. 2005; Efklides 2008), and may stimulate further research into this direction.

Turning now to the question of longitudinal links between EF, SC, and metacognitive processes, we found (a) EF assessed at the end of first grade to be significantly and directly linked to metacognitive control assessed 1 year later, and (b) earlier academic SC to be significantly and directly linked to later metacognitive monitoring (see Fig. 2). These substantial predictions of metacognitive control through earlier EF and of metacognitive monitoring through earlier SC still seem to suggests that there are important, specific, and shared processes that may in the long run further our theoretical understanding of processes involved in self-regulated learning situations. In the following paragraphs, we will discuss some possible interpretations.

As to the direct longitudinal link between EF and control, the executive nature of the involved processes, that is, an individuals' ability to act on monitoring or initiating adaptations, may be one of the shared and/or similar elements. With the documented empirical links the present study offers first empirical evidence for a relationship that has so far been hypothesized at the theoretical level (Best and Miller 2010; Fernandez-Duque et al. 2000). Unfortunately, we were not able to test for cross-lagged correlations between EF and metacognition as metacognitive skills were only assessed once at the end of 2nd grade. Thus, the exact nature of this relationship (i.e., EF proceeding control, *vice versa*, or a reciprocal relationship) remains to be studied in more detail. Nevertheless, the documentation of a substantial link between EF and metacognitive control is of great relevance, both for theory and practice. Theoretically, the consistently documented developmental lag between monitoring skills and their adequate translation into efficient metacognitive control is possibly in part due to immature executive functions (de Bruin et al. 2011; Krebs and Roebers 2010; Schneider 2010). In the educational field, the link between EF and metacognitive control may be informative for designing efficient interventions (e.g., a lack of transfer effects may stem from neglected EF), and deficits in EF are likely to lead to difficulties in metacognitive control, too.

As to the direct effect of earlier SC on later metacognitive monitoring, the present study may make a contribution for better understanding the ontogenetic emergence of metacognitive monitoring skills. A link between SC and monitoring has mostly been hypothesized on the theoretical level (Lyons and Zelazo 2011), and been documented mainly in adult cross-sectional samples (Hertzog et al. 1990; Kleitman and Stankov 2007). The present findings may be interpreted as suggesting that SC and monitoring skills share an individual's ability to introspect, that is, to take him- or herself as object of cognitive processing, with present but also past experiences being integrated (Ghetti et al. 2011; Moore 2010). Alternatively, one may also interpret the link between earlier SC and later monitoring skills as mirroring young children's positively biased view of themselves and their task-specific performance. From basic research on metacognitive development it is known that the measurement of task-bound monitoring processes is challenging in young children (Lyons and Ghetti 2011). Young participants are typically overconfident in the correctness of their responses (Shin et al. 2007), and it seems that this metacognitive overconfidence may root back to an overoptimistic view of their general skills, their self-perceptions. In the course of development, feedback in school, and "metacognitive experiences" during task mastery (Efklides 2011; for example, being confident in the correctness of an answer and then finding out it was incorrect) may give rise to both a more realistic self-concept and more differentiated task-specific metacognitive monitoring judgments. The importance of these shared processes and feedback loops for children's academic career and their self-regulated learning skills may not be underestimated as our results propose that important links to emerging metacognitive skills exist not only in cognitive but also in affective-motivational development, an aspect that has been widely overlooked in the developmental literature but that is integrated within recent and broader frameworks of self-regulated learning (Efklides 2011).

A number of limitations of the present approach need to be discussed. The reported findings may not generalize to other EF and metacognition, as the involved processes are to a certain degree "task-specific"; metacognitive processes only merge to a unified set of higher-order information processes later in development (van der Stel and Veenman 2008). Furthermore, since the study only included a limited number of EF tasks, it was not possible to investigate the unique contribution of, for example, switching or updating processes (Miyake and Friedman 2012), but only their shared processes. Further research into these issues is clearly needed. As mentioned above, an investigation of cross-sectional, longitudinal, and cross-lagged paths would have allowed a more comprehensive picture of interrelations among the included concepts. The present study is—from this perspective—exploratory in nature and may hopefully stimulate future work. Ideally, the longitudinal analyses (depicted in Fig. 2) should have been integrated in the prediction of academic achievement (depicted in Fig. 1). Although we had a sufficiently large sample, we were not able to converge such a complex model with the data; this was mainly due to an extremely high stability of the latent EF variable between the first and the second measurement (0.95) leaving no unexplained variance for the other included variables. Additionally, the somewhat biased distributions of the SC measures (mirroring a normative developmental phenomenon and not necessarily a methodological weakness) and the psychometric problem associated with uncertainty monitoring (confidence judgments following incorrect spellings) led to either improper solutions or unacceptable model fits. We preferred to limit and focus the research questions addressed rather than presenting problematic structural equation models.

Despite these limitations, some methodological advances of the present study should be mentioned. Metacognitive development has traditionally been studied either in strongly controlled experimental set-ups, or longitudinally with a focus on declarative metacognition (Grammer et al. 2011; Lockl and Schneider 2007). The paradigm used here is the one of the first documented attempts that allowed building a coherent and good fitting model including sensible latent variables of procedural metacognitive monitoring and control, with these measures mirroring true on-task processes (DeMarie et al. 2004). Structural equation modeling is advantageous because this approach allows explicitly considering measurement errors resulting in higher validity of the documented links. Especially against the background of the ongoing scientific discussion about the unity and diversity of executive functioning, building one latent EF variable allowed avoiding this problem and focusing on the shared EF processes only. Moreover, building latent variables also allows testing multiple relations between constructs rather than associations between single indicators increasing the relevance of the obtained results.

Taken together, the present investigation documented significant links between EF and metacognitive control and between SC and metacognitive monitoring, respectively, in a naturalistic, school-related task. Individual differences in metacognitive monitoring at the end of children's second school year were significantly related to their earlier, achievement related self-concepts suggesting important but understudied links between cognitive and affective-motivational aspects of development. Methodological advances in the measurement of metacognitive monitoring and control, as well as the application of structural equation modeling procedures shed light on the contribution of both EF and metacognitive processes for academic outcomes as well as on their interrelations when considered simultaneously.

Authors' Note The present study was partially financed by the Jacobs Foundation Zürich (project "Transition to School"; PI: Claudia M. Roebers). We wish to thank the participating children, and gratefully acknowledge the cooperation of the children's teachers and principals. We also wish to thank the student research assistants who helped with data collection and Uli Orth for teaching us structural equation modeling techniques.

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