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Prospective Memory, Executive Functions, and Metacognition Are Already Differentiated in Young Elementary School Children

Evidence from Latent Factor Modeling

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Abstract. This study investigated the empirical differentiation of prospective memory, executive functions, and metacognition and their structural relationships in 119 elementary school children (M = 95 months, SD = 4.8 months). These cognitive abilities share many characteristics on the theoretical level and are all highly relevant in many everyday contexts when intentions must be executed. Nevertheless, their empirical relationships have not been examined on the latent level, although an empirical approach would contribute to our knowledge concerning the differentiation of cognitive abilities during childhood. We administered a computerized event-based prospective memory task, three executive function tasks (updating, inhibition, shifting), and a metacognitive control task in the context of spelling. Confirmatory factor analysis revealed that the three cognitive abilities are already empirically differentiable in young elementary school children. At the same time, prospective memory and executive functions were found to be strongly related, and there was also a close link between prospective memory and metacognitive control. Furthermore, executive functions and metacognitive control were marginally significantly related. The findings are discussed within a framework of developmental differentiation and conceptual similarities and differences.

Keywords: prospective memory, executive functions, metacognition, cognitive development, cognitive differentiation, young elementary school children

Imagine an 8-year-old child being told by his teacher to return a library book on time. Remembering to do so requires *prospective memory*, that is, the ability to plan an intention, to retain it in memory, to retrieve it at the appropriate moment without an explicit reminder, and to execute the plan. Prospective memory has received increasing research attention over the past years, especially in adults (Brandimonte, Einstein, & McDaniel, 1996; Ellis & Kvavilashvili, 2000), and many factors that influence prospective memory performance have been identified (Brandimonte & Passolunghi, 1994; Einstein et al., 2005; Meier & Graf, 2000; Meier, Zimmermann, & Perrig, 2006; Smith, Hunt, McVay, & McConnell, 2007). However, a larger framework describing prospective memory and its relationships to other theoretically related cognitive skills is still missing. Especially from a developmental perspective, the positioning of prospective memory within cognitive development and the question of developmental differentiation of prospective memory and other related cognitive information processes that are executive in nature has been rarely addressed (e.g., Ford, Driscoll, Shum, & Macaulay, 2012; Kerns, 2000; Mahy, Moses, & Kliegel, 2014). To fill this gap, we examined the structural relationships between young school children's prospective memory, executive functions, and metacognition, and then investigated whether the three constructs are already empirically differentiable at this relatively young age (Martin & Kliegel, 2003; Schnitzspahn, Stahl, Zeintl, Kaller, & Kliegel, 2013). Since school entry places new demands on children's cognitive abilities, higher-order cognitive skills develop rapidly (Schneider, 2015). This potentially also stimulates the efficient orchestration and differentiation of cognitive abilities at that age (Bjorklund, 2011). Therefore, the early elementary school years seem to constitute an ideal window

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for studying the links between higher-order cognitive skills such as prospective memory, executive functions, and metacognition. In the following, we introduce the other two cognitive constructs, executive functions and metacognition, address the issue of their theoretical and empirical interrelationships and their development, and then briefly explain the analytical approach of this study.

The human cognitive abilities that are probably the most straightforwardly executive in nature are the *executive functions.* "Executive functions" is an umbrella term that refers to cognitive processes assumed to be activated in situations that require conscious, deliberate, and goal-directed behavior. Furthermore, because executive functions are strongly associated with the prefrontal cortex (PFC), they can be considered top-down processes (Miller & Cohen, 2001). In adults, executive functions have been subdivided into three components: updating, inhibition, and shifting (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). *Updating* refers to the maintenance and manipulation of relevant information, *inhibition* to the inhibition of predominant responses, and *shifting* to the flexible shift between mental sets. However, findings regarding the exact factorial structure of executive functions in children are still inconsistent. Some studies have suggested a one- or two-factor solution in young children (Miller, Giesbrecht, Müller, McInerney, & Kerns, 2012; Wiebe, Espy, & Charak, 2008). In a recent large-scale study, Lee, Bull, and Ho (2013) reported that, in children up to 13 years, a two-factor solution fit the data best, and a three-factor solution only emerged in the 15-year-olds. Overall, these results suggest a slow developmental differentiation of executive functions during childhood. Against the background of these findings concerning executive functions, the issue of differentiation of a larger range of cognitive abilities is not only interesting, but also theoretically innovative.

Metacognition is another cognitive ability that has executive features and is related to prospective memory and executive functions. This third construct of the present study's interest has been described as cognition that reflects on, monitors, or regulates first-order cognition (Kuhn, 2000). It also reflects higher-order self-reflective cognitive processes that may be used for regulating information processing (Schneider, 2011). Metacognition has been divided into *declarative metacognition*, the declarative knowledge about (one's own) cognitive processes, and *procedural metacognition* (Flavell & Wellman, 1977). Nelson and Narens (1990) further distinguished between the two procedural metacognitive processes monitoring and control. Whereas *monitoring processes* serve to update the mental representation of one's task performance and are considered bottom-up processes (e.g., expressed by confidence judgments), *control processes* implicate some action. Hence, control process are more regulative and executive, and thus top-down in nature. Adequate metacognitive control abilities allow an individual to adjust task performance, for instance, through the correction of errors, the allocation of more study time, or by switching between strategies. Because of this executive feature and also because first signs of efficient metacognitive control can be observed in the early elementary school years (Schneider & Lockl, 2008), this study focused on metacognitive control.

Theoretical and Empirical Interrelationships Between Prospective Memory, Executive Functions, and Metacognition

Not only do prospective memory, executive functions, and metacognition reflect cognitive processes that are relevant for many of our everyday life activities, especially for children in school (Krebs & Roebers, 2010; Neuenschwander, Röthlisberger, Cimeli, & Roebers, 2012), they also seem to be theoretically related. First, executive functions are assumed to be involved in prospective memory (Burgess, Quayle, & Frith, 2001), that is, prospective memory and executive functions share several important characteristics on the level of involved cognitive processes. For instance, prospective memory retrieval is assumed to be highly self-initiated (Craik, 1986), and self-initiated retrieval is associated with deliberate, conscious, or goal-directed actions, which are assumed to be a key feature in executive functions, too (Zelazo, Carlson, & Kesek, 2008). Around the age of 8 years, children's ability to proactively control their cognitive processing increases, allowing self-initiated goal-directed behavior (Munakata, Snyder, & Chatham, 2012), and possibly fuelling self-initiated retrieval in prospective memory tasks as well. Moreover, prospective memory tasks are executive in nature as they involve shifting between two tasks (ongoing and prospective memory task). Updating abilities in the sense of interim storage of rules, instructions, and plans while performing a distracting action are also clearly needed. Likewise, inhibitory abilities are needed when a practiced predominant action must be inhibited and replaced by a new action (Van den Berg, Aarts, Midden, & Verplanken, 2004).

Second, metacognitive control is considered to be related to executive functions, as it reflects processes that build on metacognitive monitoring and ideally put executive functions into action (Fernandez-Duque, Baird, & Posner, 2000; Roebers, Cimeli, Röthlisberger, & Neuenschwander, 2012). Some authors have argued that, for instance, flexible strategy use in children may in part rely on inhibitory control skills (Best & Miller, 2010). This is because one needs to inhibit a previously used strategy when one realizes that it is no longer adaptive in a given task context (Kuhn & Pease, 2010; Siegler, 1996). In addition, as under investigation in the present study, one may experience uncertainty concerning a specific answer and decide to revise or withdraw the answer.

Third, prospective memory and metacognition have so far only rarely been linked to each other. In those few studies, the focus has been on metacognitive monitoring (viz., on performance predictions; Kvavilashvili & Ford, 2014; Meeks, Hicks, & Marsh, 2007; Meier, von Wartburg, Matter, Rothen, & Reber, 2011; Schnitzspahn, Zeintl, Jäger, & Kliegel, 2011), rather than on metacognitive control. Since the relationship between metacognitive monitoring and control is much more complicated than previously assumed (Nelson & Narens, 1990), and since monitoring processes are highly task-bound, the focus in the present study was put on metacognitive control. From a theoretical perspective, successful prospective memory and efficient metacognitive control both rely on the execution of intentions and on accurate monitoring and involve higher-order cognitive operations. Moreover, based on the subjective evaluations of ongoing task mastery, prospective memory tasks and metacognitive control behaviors have to be adapted. Therefore, we expected to find a specific link between prospective memory and metacognitive control.

Although they are theoretically related, only a very few empirical studies have specifically focused on the relationship between prospective memory and executive functions, predominantly aiming to explain individual differences in prospective memory. Mahy and Moses (2011), for example, examined the role of executive functions in prospective memory in 4- and 5-year-olds. They used a prospective memory task and two executive function tasks; their results indicated that updating, but not inhibition, predicted prospective memory performance. Further, Yang, Chan, and Shum (2011) investigated the developmental trajectory of prospective memory in 7- to 12-year-olds by administering different prospective memory tasks, an n-back updating task, and an attention and response inhibition task. They reported moderate relationships between prospective memory and updating, and between prospective memory and inhibition; these links remained significant when they controlled for age. Their results call attention to the role of the two executive function components in children's prospective memory performance (see also Ford et al., 2012; Kerns, 2000; Mackinlay, Kliegel, & Mäntylä, 2009; Mäntylä, Carelli, & Forman, 2007; Van den Berg et al., 2004). Together, executive processes seem to be involved in prospective memory.

Concerning the link between executive functions and metacognitive control, findings from neuroimaging studies document PFC involvement in both kinds of processes and deficits executive functions and metacognition typically co-occur in patients with prefrontal brain lesions (Kao, Davis, & Gabrieli, 2005; Pannu & Kaszniak, 2005). On the behavioral level, individual differences in executive functions seem to explain a substantial amount of variance in adults' and children's metacognition abilities (Dunlosky & Thiede, 2004; Kuhn & Pease, 2010). Moreover, Roebers et al. (2012) reported evidence for a substantial empirical (cross-sectional and longitudinal) relationship between executive functions and metacognitive control in second-graders. Finally, empirical studies that relate prospective memory to metacognitive control in children are lacking, emphasizing the need to make first exploratory research efforts in this direction.

Development in Prospective Memory, Executive Functions, and Metacognition

Recently, the body of research on prospective memory has been accumulating (Ellis & Kvavilashvili, 2000), but most studies have focused on prospective memory abilities in adults (Henry, MacLeod, Philips, & Crawford, 2004; Smith & Bayen, 2006; Zimmermann & Meier, 2010; Zöllig, Martin, & Kliegel, 2010). Comparatively little research has been conducted on prospective memory abilities in children and developmental studies are still scarce (Guajardo & Best, 2000; Kerns, 2000; Kliegel et al., 2013; Kvavilashvili, Messer, & Ebdon, 2001; Mackinlay et al., 2009; Mahy & Moses, 2011; Rendell, Vella, Kliegel, & Terrett, 2009; Voigt, Aberle, Schönfeld, & Kliegel, 2011; Yang et al., 2011). However, there is accumulating evidence that prospective memory performance increases gradually during childhood (Kvavilashvili et al., 2001; Ward, Shum, McKinlay, Baker-Tweeney, & Wallace, 2005; Yang et al., 2011; Zimmermann & Meier, 2006). Similarly, executive functions are known to improve considerably during childhood (Best & Miller, 2010; Best, Miller, & Jones, 2009; Huizinga, Dolan, & van der Molen, 2006; Zelazo et al., 2008). Finally, metacognitive control skills also seem to improve substantially during the elementary school years (for an overview, see Roebers, 2013).

Given that these cognitive abilities undergo substantial developmental improvement during the same period of childhood, that is, around the age of 7 years, one might suggest that a stable, global, maturational, or intellectual factor underlies these improvements, fuelling the development in different cognitive domains. In this sense, the different cognitive functions may not (yet) be empirically distinguishable in early development, for example, as has been found for executive functions (Lee et al., 2013). We therefore address this question.

Latent Variable Approach

Our use of confirmatory factor analysis (CFA) was motivated by two reasons: First, this technique allows us to compare different theoretical models by means of empirical data. Basically, CFA estimates the amount of shared variance between different constructs and explicitly excludes error variance between the links (Kline, 2005; Little, Cunningham, Shahar, & Widaman, 2002). Thus, this approach can provide empirical evidence regarding the relationships between different constructs by shedding light on the shared – and unshared – underlying processes. Second, CFA may account for the "task-impurity problem" (Miyake & Friedman, 2012; Miyake et al., 2000): Especially in (younger) children, the three components cannot be measured in isolation because they are closely intertwined, simultaneously triggered in many tasks, and consequently share a considerable amount of variance (Garon, Bryson, & Smith, 2008; Hughes, Ensor, Wilson, & Graham, 2010; Huizinga et al., 2006; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Wiebe et al., 2008). Mapping observed variables onto a latent variable is one way to deal with this problem, enabling one to work with only the shared processes inherent in different tasks.

The Present Study

In summary, prospective memory, executive functions, and metacognitive control reflect cognitive processes that are relevant for success in everyday activities. From a theoretical perspective, they appear to share executive features, fueling the assumption of a potential link. Further, the three cognitive abilities are known to improve considerably during childhood, with marked improvements at similar ages. However, empirical findings addressing the question of whether and to what extent they are empirically distinguishable in young elementary school children, are still rare. Therefore, this study investigates whether the three theoretically closely related constructs are empirically separable in second grade school children and quantifies the degree of overlap on the level of latent variables using CFA. This issue is of general theoretical interest as it may help to better position prospective memory, executive functions, and metacognition in a broader framework of higher-order cognition. Based on the existing literature, we expected the three cognitive abilities to be substantially interrelated, but beyond that, to be clearly empirically distinguishable, even in elementary school children. We hypothesized that a differentiated three-factor model would fit the data better than a one-factor model.

Method

Participants

A total of N = 119 children (51 boys, 68 girls, M_{age} = 95 months, SD_{age} = 4.8 months, range: 80 to 109 months) were recruited from 10 public schools in the agglomeration of Bern, Lucerne, and Aargau (Switzerland). Parents gave written informed consent, and the children provided oral assent. Thereof, 20 children (16.8%) were nonnative Swiss-German speakers, but all had a sufficient level of language skills to follow the task instructions. Permission to conduct the study was obtained from the university's Ethics Committee.

Materials and Procedure

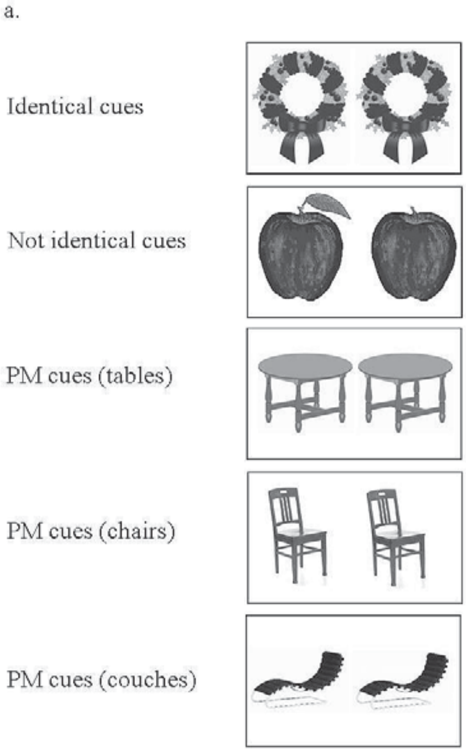
Data were collected at the beginning of the second school year. Experimenters visited the classes for two individual sessions that lasted about 30 min each for one group session that lasted about 25 min. Task order was identical for all participants. After the last test session, participants received positive feedback and a small gift.

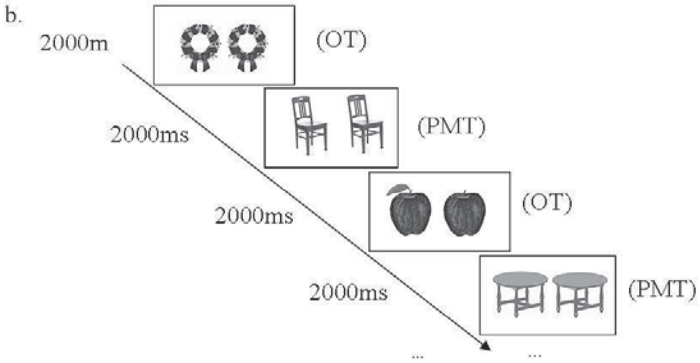
Prospective Memory

Prospective memory was assessed using a computerized event-based prospective memory task adapted from Zimmermann and Meier (2006). Laptops were equipped with Windows 7 and Eprime 2.0. A green sticker highlighted the X-key, a red sticker highlighted the M-key. The stimulus material (easy-to-name pictures) was identical to that used in the Zimmermann and Meier study. Figure 1 shows stimulus exemplars (1a) and a schematic task description (1b, 1c). The task incorporated three phases: practice (ongoing task only), instruction (no activity), and test (prospective memory task embedded in the ongoing task). In the practice phase, children were to put their left index finger on the green X-key and their right index finger on the red M-key. Thirty-two pairs of pictures subsequently appeared on the screen. Participants were asked to press the green key when the stimuli were identical and the red key when the stimuli were not identical. This comparison activity reflects the ongoing task in the test. Of the 32 pairs of pictures 16 were identical and 16 were nonidentical. The stimuli were presented for 2000 ms; the task did not continue until the participant responded.

The practice phase was followed by the instruction phase during which participants were given instructions for the subsequent test phase. We explained to the children that they would be doing the picture comparison task again at a later point in time, but that they would need to press the 1-key with the left index finger whenever furniture pictures appeared (prospective memory task). Tables, chairs, and couches served as prospective memory cues. To check their category knowledge, children were to name members of the furniture category. If they named incorrect category members, they were corrected. If they named correct category members, but particularly missed tables, chairs, and couches, the experimenter gave positive feedback, but mentioned table, chair, and couch ("Yes, that's correct, a cupboard is a piece of furniture, and so are tables, chairs, and couches"). We thereby made sure that all participants were aware of the critical types of furniture that would appear in the test.

After the instructions, a distractor task (here: Stroop) lasting approximately 5 min was administered to introduce





c.

Block	Number of Pairs	Task	Cues
1	20	OT	Identical / not identical cues
2	1	PMT	PM cue
3	20	OT	Identical / not identical cues
4	1	PMT	PM cue
…	…	…	…
17	20	OT	Identical / not identical cues
18	1	PMT	PM cue
19	8	OT	Identical / not identical cues

Figure 1. (a) Examples of stimuli presented in the prospective memory task. (b) Schematic sequence of the test with the prospective memory task embedded in the ongoing task. (c) Stimulus order in the test. PM = Prospective memory. OT = Ongoing task. PMT = Prospective memory task.

Table 1
Descriptive statistics of all dependent (observed) variables

Observed variable	*M*	*SD*	Minimum	Maximum
Prospective memory overall	0.29	0.30	0.00	1.00
Prospective memory 1	0.29	0.34	0.00	1.00
Prospective memory 2	0.28	0.32	0.00	1.00
Prospective memory 3	0.30	0.36	0.00	1.00
Updating	8	3	2	16
Inhibition	–26.98	–7.67	–57.40	–14.20
Shifting	28	7	10	45
Metacognition overall	0.57	0.13	0.24	0.95
Metacognition 1	0.60	0.17	0.14	1.00
Metacognition 2	0.53	0.18	0.14	1.00
Metacognition 3	0.56	0.17	0.14	1.00

Note. Overall prospective memory performance and overall metacognition performance were split into 3 parcels for CFA: Prospective Memory 1–3 (parcels) represent the mean percent accuracy of 3 items. Metacognition 1–3 (parcels) represent the mean percent accuracy of 7 items. Inhibition (in s) was originally reverse-coded with higher values indicating poorer performance; the polarity of the scores was reversed for analysis. Updating and shifting are given in frequencies.

a retention interval (see Einstein & McDaniel, 1990; Zimmermann & Meier, 2006). The distractor task was followed by a test lasting between 10 and 15 min which incorporated the prospective memory task into the ongoing task. Children were asked to perform the task explained in the instruction phase. The prospective memory task (pressing the 1-key whenever they encountered furniture pictures) was not mentioned again. The test consisted of 197 pairs of pictures, whereby 188 were used for the ongoing task (94 identical, 94 nonidentical) and 9 were used for the prospective memory task (4 identical, 5 nonidentical). The stimuli were presented for 2000 ms; the task did not continue until the participant responded. Stimulus order was identical for all participants. We measured response accuracy for the nine prospective memory cues: Pressing the 1-key when the participant encountered a prospective memory cue was scored as *correct* (score = 1), pressing the X- or M-key when the participant encountered a prospective memory cue was scored as *incorrect* (score = 0). Overall prospective memory performance was reflected by the proportion of correct responses (in %) in the test.

Typicality of the prospective memory cues was manipulated (see Brandimonte & Passolunghi, 1994; Nowinski & Dismukes, 2005; Penningroth, 2005), with some stimuli being more (or less) prototypical for the category, resulting in a manipulation of item difficulty: Typical items were assumed to be recognized more easily than less typical items and thus result in higher accuracy rates. For the CFAs, we built three parcels following the recommendations of Little et al. (2002). Three prospective memory cues of varying typicality were assigned to each parcel, resulting in three parcels of approximately equal difficulty (see Table 1).

Executive Functions

Executive functions were measured with three tasks, assumed to capture updating, inhibition, or shifting, respectively (Miyake et al., 2000). In order to assess updating, we administered the letter-number-sequence subtest of the German version of the Wechsler scale (Hamburg Wechsler Intelligenztest für Kinder, HAWIK-IV; Petermann & Petermann, 2010). Children listened to mixed sequences of letters and digits, and were then asked to reproduce the items immediately afterward and in the following manner: First, digits from the smallest to the largest; then, letters in alphabetical order. The number of items increased by one if the child correctly recalled 50% of the items of a sequence, starting with a three-item sequence. There were six trials per sequence length, and the task was terminated if a child reproduced less than 50% of the items of a sequence. The dependent variable was the total number of correct trials (see Table 1).

In order to assess inhibition, we administered an adapted version of the Fruit Stroop task used by Archibald and Kerns (1999). Test-retest reliability for this test is between $r = .71$ and $r = .87$ (Archibald & Kerns, 1999; Roebers, Röthlisberger, Cimeli, Michel, & Neuenschwander, 2011). Stroop-like tasks are used to measure inhibitory control as they produce a conflict between overlearned and novel responses (Brocki & Bohlin, 2004) and as they appear to correlate with other inhibitory tasks such as go/no-go tasks (Archibald & Kerns, 1999). Furthermore, inhibitory control was assumed to be particularly involved in prospective memory (Kerns, 2000). In our Stroop task, children were faced with four pages of 25 stimuli (5 lines, 5 columns) each. On page 1, 25 yellow, green, blue, or red squares were presented. On pages 2 to 4, 25 fruits and vegetables (strawberry, plum, banana, or lettuce) were presented in a congruent color (page 2; e.g., yellow banana), in black and white (page 3), or in an incongruent color (page 4; e.g., red banana). As quickly as possible, children were to name the correct color of the stimulus (pages 1 and 2) while inhibiting the natural response of naming the fruit and ignoring the incorrect color (page 3 and 4). We measured reaction times for each page and used the Archibald and Kerns (1999) interference control measure as a dependent variable (see Table 1). This score (in s) results from the formula: time page 4 – [(time page 1 × time page 3)/(time page 1 + time page 3)]. To ease interpretation, we reversed the polarity of the score so that higher values indicate better performance.

In order to assess shifting, we administered a verbal fluency task as this task has been found to load on factors labeled as shifting (Brocki & Bohlin, 2004; Lehto et al., 2003). The version used in this study was similar to that used in Munakata et al. (2012) and consisted of two parts: In Part 1, children were asked to orally generate as many animals as possible within a time period of 1 min; in Part 2, children were asked to orally generate as many things to eat as possible within a time period of 1 min. Split-half reliability for the two parts was $r = .60$, $p < .001$. The total number of items generated (without repetitions), aggregated across both parts, was the dependent variable (see Table 1).

As outlined above, the three tasks are expected to share a considerable amount of variance and executive function tasks rarely measure one component in isolation (Garon et al., 2008; Hughes et al., 2010; Huizinga et al., 2006; Miyake & Friedman, 2012; Wiebe et al., 2008). As we were specifically interested in the common processes underlying the construct, we specified one latent executive function variable consisting of the three dependent variables mentioned above. In other words, the three dependent (observed) variables served as indicators and were regressed onto the latent executive function variable (Little et al., 2002).

Metacognition

Metacognitive control was assessed using a paper/pencil task that has successfully been used elsewhere (Roebers et al., 2012). The task consisted of a total of 22 items (i.e., schematic pictures of simple objects and animals, e.g., snail, mouse, candle), and the children were to spell every word describing the depicted object or animal, even when they were unsure about the correct spelling. The words differed in spelling difficulty (range: .10 – .90 proportion of correct spelling). After the spelling part was completed, children were to indicate on a 7-point Likert scale how sure they were that they had spelled the word correctly (monitoring). Finally, children were informed that they had the opportunity to cross out previously written words that they believed were incorrect (i.e., metacognitive control). For data analysis, the words were coded according to whether they had been spelled correctly/incorrectly, and whether

Table 2
Significant correlation coefficients between all study variables

	1	2	3	4	5	6	7	8	9
1. Prospective memory 1	–								
2. Prospective memory 2	.68***	–							
3. Prospective memory 3	.72***	.74***	–						
4. Updating	.27**	.21*	.23*	–					
5. Inhibition				.21*	–				
6. Shifting		.26**	.21*	.19*	.21*	–			
7. Metacognition 1	.27**	.27**		.22*		–			
8. Metacognition 2							.31**	–	
9. Metacognition 3				.22*			.39***	.42**	–

Note. Prospective memory and metacognition performance were split into 3 parcels for CFA: Prospective Memory 1–3 (parcels) represent the mean percent accuracy of 3 items. Metacognition 1–3 (parcels) represent the mean percent accuracy of 7 items. *$p < .05$, **$p < .01$, ***$p < .001$.

they had been crossed out/not crossed out. Metacognitive control was indexed by the percentage of correctly spelled words that had not been crossed out plus the percentage of incorrectly spelled words that had been crossed out. One very easy item (spelled correctly by 92% of the children) was excluded from subsequent analyses, resulting in a final total of 21 items. To model a latent variable representing metacognition, we randomly assigned seven items to each of the three different parcels, following the recommendations of Little et al. (2002). Table 1 shows the means and standard deviations for the three parcels.

Results

Preliminary Analyses

Since the study variables were measured on different scales and for ease of interpretation of the results, we conducted *z*-standardizations and ran all analyses with *z*-scores. The raw scores of all observed variables and parcels are shown in Table 1. Clearly, none of the scores were at floor or at ceiling, and they showed considerable variance, thereby meeting the preconditions for the subsequent confirmatory factor analyses (CFAs).

Pearson correlations (two-sided, pairwise) were calculated to ensure that the observed variables representing each latent variable in the subsequent CFAs were correlated. Table 2 presents all significant correlation coefficients; reported effect sizes are in accordance with Cohen (1992). As can be seen, the variables within each construct were all significantly interrelated. The three prospective memory parcels were significantly interrelated and effect sizes were large ($r > .68$). The three executive functions (updating, inhibition, shifting) were all significantly interrelated, but effect sizes were relatively small ($r > .19$). The three metacognition parcels were significantly interrelated and effect sizes were medium ($r > .31$). As for the correlations between the three constructs, both updating and shifting were significantly related to prospective memory and effect sizes were small to medium (*r*s = .21 – .27). Updating was also significantly associated with metacognition, and effect sizes were small ($r > .22$). Single prospective memory parcels and metacognition parcels were significantly related, and effect sizes were medium ($r > .27$).

One-Factor Model vs. Three-Factor Model

Against the background of the significant correlations between the construct variables, we conducted CFAs using the AMOS 20 software (Arbuckle, 2011). This procedure allowed us to estimate correlations between latent variables, which were represented by observed variables. The full information maximum likelihood approach was administered, as it is thought to produce the least biased and most efficient estimates in case of missing data (Peugh & Enders, 2004). The fits of the models were assessed using the chi-square value (χ^2), the Tucker-Lewis index (TLI), the comparative fit index (CFI), and the root-mean-square error of approximation (RMSEA). A good model fit is indicated if the χ^2 value is not significant, the TLI and CFI values are greater than 0.95, and the RMSEA value is less than or equal to 0.06 (Hu & Bentler, 1998). The models' fits were compared by means of a χ^2 difference test.

To test whether, and if so the extent to which, prospective memory, executive functions, and metacognition are empirically separable in second graders, we examined whether a one-factor model or a differentiated three-factor model better fit the data. In the one-factor model, all observed variables were regressed onto a single latent variable, reflecting the assumption that general cognitive ability is a unitary factor. In the three-factor model, the observed variables of each construct were regressed onto three latent variables, reflecting the assumption that there are three separable cognitive abilities. The CFAs revealed that the fit of the one-factor model was clearly unsatisfactory, χ^2 (27) = 74.99, $p < .001$, normed χ^2 = 2.78, TLI =

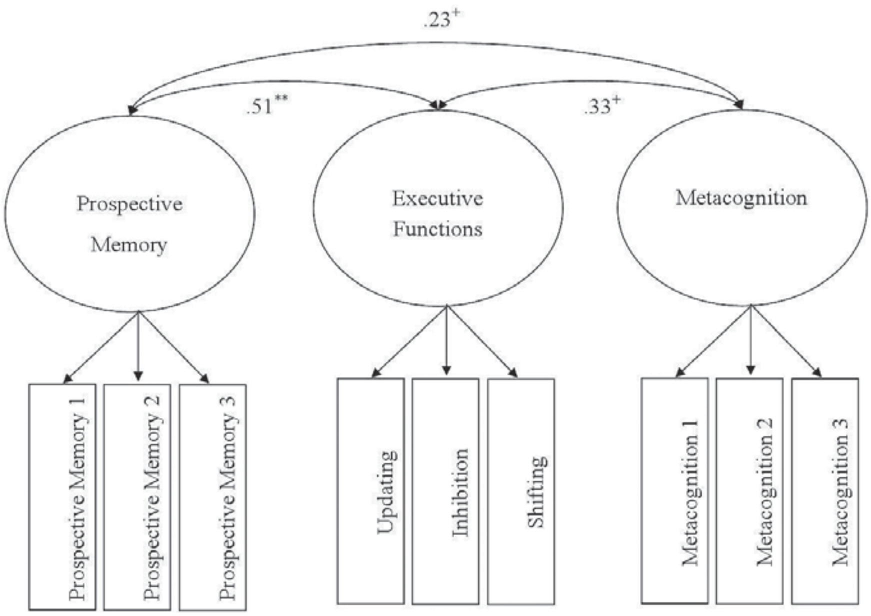


Figure 2. Three-factor model. Fit indices according to Hu and Bentler (1998): χ^2 (24) = 27.67, p = .27, normed χ^2 = 1.15, TLI = .973, CFI = .985, RMSEA = .036. Regression weights from the indicators onto the latent variable are shown in Table 2. $^{**}p$ < .01, $+p_{(r=.23)}$ = .07; $+p_{(r=.33)}$ = .08.

.683, CFI = .810, RMSEA = .123. In contrast, the fit of the three-factor model was good, with all criteria proposed by Hu and Bentler (1998) clearly met, χ^2 (24) = 27.67, $p < .27$, normed χ^2 = 1.15, TLI = .973, CFI = .985, RMSEA = .036. The chi-square difference test between the two models was highly significant, $\Delta\chi^2$ (3) = 47.32, $p < .001$, indicating that the three-factor solution is clearly preferable. Therefore, in the following section, we explore only the more differentiated three-factor model.

Relationships Between Prospective Memory, Executive Functions, and Metacognition

Figure 2 presents the theoretical model including the three presumably separate factors prospective memory, executive functions, and metacognition. Table 3 shows the regression weights of the observed variables on the corresponding latent variables (single-headed arrows). The correlations between the latent variables (double-headed arrows) are depicted in Figure 2. As can be seen, the regression weights were all significant (ps < .05), meeting the required statistical condition and allowing the interpretation of the latent variables (Kline, 2005). The regression weights of the prospective memory indicators were large (> .82), those of the executive function indicators were small to medium (> .35), and those of the metacognition indicators were medium to large (> .54).

As for the links between the latent variables, the CFA revealed a strong and significant correlation between prospective memory and executive functions (r = .51, p < .01) and marginally significant correlations between executive functions and metacognition (r = .33, p = .08) as well as between prospective memory and metacognition (r = .24, p = .07).

Table 3
Parameter estimates for three-factor model shown in Figure 2

Latent variables	Indicators	Regression weights
Prospective memory	Prospective memory 1	.82***
	Prospective memory 2	.83***
	Prospective memory 3	.88***
Executive functions	Updating	.56*
	Inhibition	.35*
	Shifting	.41*
Metacognition	Metacognition 1	.56***
	Metacognition 2	.54***
	Metacognition 3	.73***

Note. Prospective memory and metacognition performance were split into 3 parcels for CFA: Prospective memory 1–3 (parcels) represent the mean percent accuracy of 3 items. Metacognition 1–3 (parcels) represent the mean percent accuracy of 7 items. $^{*}p$ < .05, $^{**}p$ < .01,$^{***}p$ < .001.

Discussion

Prospective memory, executive functions, and metacognition are relevant in many daily activities, including school, and they show substantial improvements during elementary school years. They are theoretically related and share strong executive demands, supporting the idea of a close link, especially in this age group when developmental differentiation is still to be expected (Lee et al., 2013). However, no empirical study has ever studied the relationships among the three cognitive constructs on the latent level. The present study therefore explores, first, whether second graders' prospective memory, executive functions, and metacognition are already empirically distinguishable and, second, the extent of their structural relationships on the latent level. These two goals were pursued by means of confirmatory factor analyses.

By and large, our assumptions were confirmed. First, CFA revealed that the three-factor model better fit the data than the one-factor model. The fit of the differentiated model was good, with all criteria according to Hu and Bentler (1998) clearly being met. Second, we found a strong and significant association between prospective memory and executive functions and a weaker, albeit marginally significant, link between prospective memory and metacognition as well as between executive functions and metacognition. Overall, our findings provide empirical evidence that prospective memory, executive functions, and metacognition considerably overlap with respect to their cognitive demands, but that, at the same time, they are clearly empirically distinguishable in young elementary school children. Our findings are discussed within a framework of developmental differentiation and conceptual similarities and differences.

First, we showed that a three-factor model with prospective memory, executive functions, and metacognition as distinct factors provides a better fit to the data of the second graders than a one-factor model. This indicates that, although the three abilities have many features in common, they are clearly already empirically differentiable in this age group. This is not trivial as our tasks all had a strong executive, top-down component and required the children to deliberately carry out actions while inhibiting other actions, thus hypothetically also promoting a general cognitive factor. Furthermore, developmental research has shown that, especially in children, the structure of cognitive abilities is anything but clear. Research on the structure of executive functions revealed inconsistent results (Lee et al., 2013; Miller et al., 2012; Wiebe et al., 2008). In addition, developmental progress during childhood has been assumed for both metacognitive abilities (Schneider & Lockl, 2008), and prospective memory (Zimmermann & Meier, 2006), supporting the existence of differentiation processes in children.

The finding that there is a considerable amount of nonshared variance between prospective memory and executive functions reflects two clearly separable and empirically distinguishable groups of information processes, also in this relatively young age group. The updating demands in the prospective memory task were clearly longer-term in nature compared to the updating demands of the executive function tasks during which rules and goals needed to be refreshed and updated trial by trial. In the prospective memory task, the children had to be more proactive in controlling their cognitive operations, and these differences – especially in young elementary school children – may underlie the nonshared variances (Munakata et al., 2012). Whether the link becomes stronger or weaker with age is an empirical question. Overall, our findings suggest that the three abilities are already separable at a relatively young age, providing important information for the development of prospective memory, executive functions, and metacognition. Of course, because of its cross-sectional design and because we only had one age group, our study does not allow us to draw firmer conclusions about development per se. Comparing the empirical structure of different related cognitive abilities at different ages (e.g., before and after school entry) or longitudinally would be advisable in order to explore the potential impact of academic challenges on cognitive differentiation. Nevertheless, the present study constitutes an important first step toward a better understanding of the development of different higher-order cognitive processes that imply self-regulated behavior.

Furthermore, in addition to the clear differentiation of prospective memory, executive functions, and metacognition, CFA also revealed considerable relationships between the three constructs. Especially the finding that prospective memory and executive functions were substantially interrelated agrees with theoretical accounts (Burgess et al., 2001) as well as with some of the few existing empirical findings supporting such a link (Mahy & Moses, 2011; Yang et al., 2011). Thus, our study strongly points in the expected direction, thereby extending the current body of knowledge to the early elementary school years. Moreover, our study goes beyond previous individual differences approaches by taking advantage of CFA, which mirrors only shared processes between observed variables in the latent variable (Little et al., 2002). This approach provides insight into the factorial structure of the two information-processing skills. A candidate-shared process is the ability to keep the task rule and goal in mind while responding to other task demands. It suggests that the updating component inherent in any of the applied executive function tasks and also involved in the prospective memory task (updating the rule of pressing one key if a piece of furniture appears, rather than comparing the two pictures) is fuelling the link (see also Table 2).

The link between metacognition and executive functions was weaker than expected, although in the expected direction (r = .33, p = .08). Based on previous findings, one might expect to find a significant link within this age group, not only theoretically, but also empirically (De Marie, Miller, Ferron, & Cunningham, 2004; Kao et al., 2005; Roebers et al., 2012). Our finding may indicate that executive function tasks and metacognitive control tasks recruit different cognitive processes, resulting in unrelated individual differences. In other words, children who do well in executive function tasks may still have underdeveloped metacognitive control skills; or, children who are able to metacognitively control their test performance well are not necessarily good at executive function tasks. Whether or not such a nonsignificant link gets stronger with increasing experience or is already the result of the advanced differentiation of cognitive processes is an open question. Executive functions may also serve as a driving force in the development of metacognitive control, as metacognitive control is more task-bound as well as domain-dependent (Roebers et al., 2012) and develops relatively late in ontogeny compared to executive functions.

As mentioned above, we found a weak, but marginally significant link between prospective memory and metacognition. One might suggest that the metacognitive control abilities targeted in our study were relatively distant to the metacognitive processes involved in prospective memory. At the same time, while prospective memory abilities call for updating processes, metacognitive control in many cases (including our own paradigm) additionally requires access to long-term memory (knowledge base). These additional processes, including their successful orchestration, appear to follow a different developmental trajectory, possibly impeding the detection of individual differences.

From a neuropsychological perspective, our findings agree with studies that emphasize that prospective memory tasks (and a wide range of other cognitive tasks or abilities such as multitasking, theory of mind, or mentalizing) depend on the functionality of the PFC (see Burgess, Gonen-Yaacovi, & Volle, 2011; Dumontheil, Burgess, & Blakemore, 2008). The PFC is known to develop in a protracted manner, presumably prolonging the differentiation of the cognitive abilities that rely on this particular structure (Dumontheil et al., 2008; Gogtay et al., 2004). Our empirical findings support the view that close links exist between these constructs, but also that clear differentiation between prospective memory, executive functions, and metacognition is possible on the latent level.

More broadly, prospective memory, executive functions, and metacognition could be considered to be related to foresight (i.e., episodic future thinking). Nigro, Brandimonte, Cicogna and Cosenza (2014), for instance, found that episodic future thinking significantly predicted prospective memory performance in 4- to 7-year-olds. Being able to imagine or anticipate future events may help to initiate behaviors that enable individuals to achieve a particular goal. Moreover, foresight also involves metacognitive control, for example, when inhibiting a prepotent, but maladaptive response.

To summarize, our study documents the empirical differentiation of the theoretically related cognitive abilities prospective memory, executive functions, and metacognition in elementary school children. This work provides information about the similarity and differences between the three cognitive constructs and indicates that there are common grounds as well as distinct processes involved. In other words, despite their considerable overlap, the three processes are already differentiable in elementary school children.

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