Developmental Psychology
2014, Vol. 50, No. 10, 2393–2404

0012-1649/14/$12.00 http://dx.doi.org/10.1037/a0037491

The Development of Time-Based Prospective Memory in Childhood: The Role of Working Memory Updating

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This large-scale study examined the development of time-based prospective memory (PM) across childhood and the roles that working memory updating and time monitoring play in driving age effects in PM performance. One hundred and ninety-seven children aged 5 to 14 years completed a time-based PM task where working memory updating load was manipulated within individuals using a dual task design. Results revealed age-related increases in PM performance across childhood. Working memory updating load had a negative impact on PM performance and monitoring behavior in older children, but this effect was smaller in younger children. Moreover, the frequency as well as the pattern of time monitoring predicted children's PM performance. Our interpretation of these results is that processes involved in children's PM may show a qualitative shift over development from simple, nonstrategic monitoring behavior to more strategic monitoring based on internal temporal models that rely specifically on working memory updating resources. We discuss this interpretation with regard to possible trade-off effects in younger children as well as alternative accounts.

Keywords: prospective memory, time monitoring, working memory, executive functions, childhood

Prospective memory (PM) refers to the ability to remember to carry out an intended action at an appropriate time in the future while being actively engaged in an unrelated ongoing activity (Einstein & McDaniel, 2005). For example, a child may have to remember to return homework or remember to wish a friend a happy birthday. The appropriate context for the initiation and execution of the intended action can be linked to a specific time point in the future (time-based PM) or to the occurrence of a specific cue (event-based PM). Importantly, it has been suggested that PM plays a key role in independent daily functioning, with most memory failures in everyday life being prospective rather than retrospective in nature (e.g., Kliegel & Martin, 2003).

One important question is how and when PM improves over childhood. In the last 15 years, an increasing body of research has examined the development of this ability in children (e.g., Kerns, 2000; Kliegel & Jäger, 2007; Kvavilashvili, Messer, & Ebdon, 2001). Developmental increases in both event- and time-based PM performance across childhood have been documented, with some evidence that PM capacities are present at 3 years of age (e.g., Kliegel & Jäger, 2007; Somerville, Wellman, & Cultice, 1983) and show considerable growth during the preschool years, middle childhood, and even into adolescence (e.g., Ford, Driscoll, Shum, & Macaulay, 2012; Kerns, 2000; Kliegel & Jäger, 2007; Kvavilashvili et al., 2001; Shum, Cross, Ford, & Ownsworth, 2008; Voigt, Aberle, Schönfeld, & Kliegel, 2011; Ward, Shum, McKinlay, Baker-Tweney, & Wallace, 2005).

One limitation of the current body of research on children's PM development is that studies have typically examined narrow age ranges spanning a period of 2 to 5 years. No study has examined PM development over the entirety of the childhood years from preschool to adolescence. A second limitation is that despite a clear descriptive picture of the development of event-based PM in

This article was published Online First August 11, 2014.

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This research was supported by a grant from the Deutsche Forschungsgemeinschaft to Matthias Kliegel. Caitlin E. V. Mahy wishes to acknowledge a Swiss Government Scholarship.

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childhood, much less is known about time-based PM, particularly in early childhood. Moreover, few studies have examined the cognitive mechanisms that drive developmental changes in time-based PM.

There seems to be a consensus that one promising candidate for a developmental mechanism underlying changes in PM performance is the maturation of working memory (e.g., Kerns, 2000; Kretschmer, Voigt, Friedrich, Pfeiffer, & Kliegel, 2013; Mahy & Moses, 2011). The construct of working memory describes a system that allows for the simultaneous maintaining, updating, and active manipulation of information in mind. Working memory is involved in a wide range of complex cognitive processes such as reading, learning, and fluid intelligence (e.g., Engel de Abreu, Conway, & Gathercole, 2010; Nevo & Breznitz, 2011) and is associated with cognitive deficits such as attention disorders (Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005). According to Baddeley (2003), working memory comprises two storage buffers that temporarily store visual–spatial and auditory information, as well as the central executive that coordinates these systems. Working memory updating is one of the main functions of the central executive (i.e., the continuous manipulation of stored information in response to new, relevant information).

The hypothesis that working memory plays an important role in PM development in children is supported by five lines of evidence: (a) theoretical frameworks of PM that assume controlled processes are necessary for PM, at least under some circumstances; (b) the similar developmental trajectories of working memory updating and PM; (c) clinical studies with adults that show prefrontal cortex lesions are associated with both executive dysfunction and PM deficits; (d) correlational studies showing positive relations between individual differences in PM and working memory in children; and (e) experimental studies documenting an impact of working memory manipulations on PM performance in adults.

Both the multiprocess framework (McDaniel & Einstein, 2000) and the preparatory attentional and memory model (PAM; Smith & Bayen, 2004) predict that controlled processes such as working memory may play a role in PM. The PAM model posits that such processes must be operating for the PM cue to be detected. In contrast, the multiprocess framework predicts that such controlled processes are only recruited under demanding cognitive conditions (e.g., low PM cue salience). Despite differences in the proposed role of automatic processes between these two models, there is consensus that controlled executive processes play an essential role in many PM tasks. Specifically, working memory is believed to support monitoring and updating information relevant to the appropriate time point of intention execution, and to enable the coordination of the ongoing task and PM task (Kliegel, Martin, McDaniel, & Einstein, 2002).

In a second line of evidence, working memory also shows rapid development over the preschool years with smaller age-related increases during middle childhood (e.g., Gathercole, Pickering, Ambridge, & Wearing, 2004; Huizinga, Dolan, & van der Molen, 2006; for a review see Pickering, 2001) similar to PM (Kliegel & Jäger, 2007; Mahy & Moses, 2011).

Third, lesion and neuroimaging studies with adults have revealed that the right prefrontal region is associated with PM performance, specifically time-based PM (Volle, Gonen-Yaacovi, de Lacy Costello, Gilbert, & Burgess, 2011). Moreover, working memory recruits similar neural correlates in frontal regions (e.g., Olesen, Westerberg, & Klingberg, 2004). Further, studies with children and adolescents with traumatic brain injury in the prefrontal region have revealed worse performance on PM tasks as well as the self-ordered pointing task, a measure of visuospatial working memory (Ward, Shum, McKinlay, Baker, & Wallace, 2007). Therefore, current neuropsychological evidence suggests that PM and working memory ability rely on similar neural networks.

Individual differences in working memory and event- and time-based PM have been shown to be associated in children as young as 4 years (e.g., Aberle & Kliegel, 2010; Mahy & Moses, 2011), and this relation seems to persist into middle childhood (e.g., Kerns, 2000; Mackinlay et al., 2009; Shum et al., 2008; Ward et al., 2005; Yang, Chan, & Shum, 2011). For example, in 6- to 12-year-old children, PM was related to visual working memory and updating (Kerns, 2000; Mäntylä, Carelli, & Forman, 2007; Yang et al., 2011). In 8- to 9-year-old and 12- to 13-year-old children, working memory significantly predicted PM above and beyond age (Shum et al., 2008). Moreover, studies with 4- to 6-year-old children have observed positive relationships between PM and working memory, as measured by backward span tests (Ford et al., 2012; Mahy & Moses, 2011). In sum, available evidence supports the conclusion that there is a general relation between working memory and PM early in childhood; however, it remains unclear whether working memory is driving developmental increases in PM.

In children, only one experimental study has attempted to manipulate working memory load by assigning children 4 to 6 years old one or two intentions to carry out (Mahy & Moses, 2011). Results showed that the number of intentions had no impact on PM, although it is difficult to know whether this null result was due to the number of intentions or the number of visible external reminders as children in the dual intention condition received two visual reminders of their intentions, whereas they only received one reminder in the single intention condition. Therefore, the evidence for the role of working memory in PM development is extremely limited. Adult experimental studies, however, suggest that working memory resources impact PM performance (Kidder, Park, Hertzog, & Morrell, 1997). Together, these five lines of evidence indicate that there may be a link between working memory and PM and that working memory could play a mechanistic role in PM development.

Besides testing this prediction across childhood, a second conceptually important question remains virtually unanswered: How might working memory influence PM development? In time-based PM, working memory may be important in time monitoring. The literature on time-based PM distinguishes at least two distinct time monitoring strategies: *adaptive time monitoring*, which relies on an internal time model, and *simple time monitoring*, which is based on the observation of an external time-keeping device such as a clock.

Whereas simple reliance on external time-keeping devices is apparent by a pattern of constantly high or low frequency of clock checking, adaptive monitoring behavior is characterized by a functional increase in external clock checking with approaching target time (e.g., J-shaped pattern on a single PM trial, Kerns, 2000; or a saw-toothed pattern across many PM trials, Voigt et al., 2011). This functional increase may indicate that children use their internal representation of time to initiate the checking of an external time-keeping device when more specific temporal information is needed close to the target time. It seems reasonable that working memory updating is one critical factor in creating as well as continuously updating and flexibly retrieving the underlying temporal model (Carelli, Forman, & Mäntylä, 2008; Ogden, Salominaite, Jones, Fisk, & Montgomery, 2011). Thus, individuals with higher working memory updating resources may be more likely to benefit from adaptive time monitoring, while individuals with more limited updating abilities may more heavily rely on external time-keeping devices.

Interestingly, older children tend to demonstrate more adaptive patterns of time monitoring than younger children, whereas younger children seem to have problems in maintaining an adaptive time-monitoring strategy (Mackinlay, Kliegel, & Mäntylä, 2009; Voigt et al., 2011). Moreover, there is empirical evidence that time monitoring behavior, indicated by the total number of clock checks, is linked to PM accuracy, thereby underlining its functional role in the PM process (e.g., Voigt et al., 2011). However, previous studies have failed to examine the link between PM and the pattern of time monitoring across the time course of a task. For example, a high number of clock checks overall can result from both adaptive and simple time monitoring and thus is less informative with regard to the process of PM. Therefore, the comparative examination of the link between PM and an increase of clock checking with the approaching target time (as an indicator of adaptive monitoring) as well as the total number of clock checks within one study may reveal whether age-related changes in the use of different monitoring strategies contribute to processes involved in PM development.

Current Study

The present study had three goals. First, at a descriptive level, it examined time-based PM in children from 5 to 14 years old. Second, at an explanatory level, it examined the role of working memory in the development of time-based PM by using an experimental dual-task design. We predicted that (a) there would be developmental growth in time-based PM performance within this age range; (b) working memory and time-based PM performance would be positively related—that is, dual-task interference would occur when a working memory task is performed concurrently with a PM task; and (c) age-related differences in PM performance would be more pronounced when a working memory task had to be executed in parallel with a time-based PM task compared to the execution of a PM task alone. As younger children have more limited resources in working memory compared to older children and PM also requires working memory resources, we hypothesized that PM performance in younger children would be impaired when both tasks had to be executed at the same time. Third, at a process level, this study examined time monitoring as a subcomponent of PM to explore the developmental role of time monitoring. As the first study to address these questions, the present study examined both the quality and quantity of monitoring (the increase in time checks at the end of trial vs. the cumulative number of clock checks) and their functional role in time-based PM performance.

Method

Participants and Design

The sample was composed of 197 children aged 5 to 14 years (M = 9.04, SD = 2.79; 33 five- to 6-year-olds; 39 seven- to 8-year-olds; 40 nine- to 10-year-olds; 38 eleven- to 12-year-olds; 27 thirteen- to 14-year-olds). All children were German speaking and drawn from local kindergartens, primary, and secondary schools in the urban area of Dresden, Germany. The majority of mothers (60%) held a high school degree or equivalent. According to predefined inclusion criteria, we excluded data from 17 children because of parental reports of developmental problems such as attention-deficit/hyperactivity disorder (n = 3), retrospective memory failure for the PM task instruction (n = 6), or technical problems with the computer equipment (n = 8). In the present study, we used a mixed design with age as a continuous variable varying between subjects and load on working memory updating manipulated within subjects (low load vs. high load condition). Order of conditions of was counterbalanced.

Materials and procedure

Prospective memory task.

Ongoing task. The ongoing task was embedded in the Dresden Cruiser (Voigt et al., 2011), a driving game adapted from Kerns (2000). The ongoing task was to drive a target vehicle on a road without crashing into other cars. Specifically, participants had to drive a car on a two-dimensional road displayed vertically on the monitor that had three parallel lanes with other vehicles driving in the same direction. The car was controlled by a gamepad (Thrustmaster FireStorm Digital 3 Gamepad) on the horizontal (left–right) axis only. The number of car crashes was the measure of ongoing task performance.

Prospective memory task. The time-based PM task was embedded in the Dresden Cruiser and required children to remember to refuel the car only when [1/4] tank or less fuel was left. The fuel level was displayed on a gauge that children had to monitor as a time equivalent. This gauge appeared for 3 s in the lower left corner of the screen after pressing a specific button on the gamepad. By pressing a second button on the gamepad, participants could refuel the car when the needle of the gauge indicated that the tank was less than [1/4] full by moving into a red area. If the car ran out of gas, the tank was refilled automatically, without giving any signal to indicate that there was a failure to refuel. The number of correct, 'on-time' refuels served as the measure of children's PM performance. One test block consisted of four 1-min trials. In each trial the car had to be refilled once after 50 s of driving and within 10 s of the fuel gauge indicating the tank was only [1/4] full (PM target time). Thus, the PM target time point approached within a predictable period as is standard in time-based PM tasks. Monitoring the decreasing distance of the fuel gauge needle to the red area (i.e., the expiration of time left to the next time-based PM target time) enabled children to calibrate their own psychological clock and to form an internal time model of the schedule of time-based PM target times, both precursors for the use of adaptive monitoring. This regularity is in direct contrast to a typical event-based PM task, where the cue preceding the PM target time is an unpredictable, distinct event, and it is usually not possible to monitor its approach. In the present study, children were not given any information about the temporal characteristics of the task. Time monitoring was measured by recording the number of times the children checked the fuel gauge. Following the standard procedure in analyzing time monitoring patterns (e.g., Kerns, 2000), the number of gauge checks across the length of one PM trial (including one PM target time) was analyzed. Therefore, the number of gas checks was tallied within each of the four separated intervals (of equal length), with the fourth interval being nearest (and just prior) to the PM target time. This was done for all four trials, resulting in 16 single intervals over the course of one test block.

The described paradigm followed the guidelines for research on PM in children as suggested by Kvavilashvili, Kyle, and Messer (2008). First, to increase children's motivation a game score was permanently displayed in the lower right corner of the screen during the game. Second, to prospectively account for differences in ongoing task performance, the difficulty of the driving game was adapted to each participant's individual performance level (number of car crashes) during a dual-task baseline trial. There were five difficulty levels of the Dresden Cruiser that varied the number of other cars presented on the road per minute (ranging from 25 to 65 cars per minute). Assignment of the difficulty levels to children's specific skill level was based on a large data pool that originated from three earlier studies in our lab (Kliegel et al., 2013; Kretschmer et al., 2013; Voigt et al., 2011) using the Dresden Cruiser under various experimental conditions.

Third, to ensure retrospective memory for the PM task, children were asked to recall the instructions after the game. Only children who could recall the PM task instructions were included in the data analysis.

Experimental manipulation of working memory updating. A dual-task manipulation was used to vary demands on working memory updating. All participants performed the Dresden Cruiser in two consecutive test blocks (low load vs. high load condition). In the low load condition, participants worked on the time-based PM task only. In the high load condition they completed the time-based PM task while concurrently executing a one-back task (a task that taps working memory updating processes). Whether children received the low load or high load condition first was counterbalanced, and participants were randomly assigned to order conditions.

An auditory one-back task was used to manipulate resources for working memory updating in the high load condition. Children heard familiar words (e.g., *cat, book, apple, jacket*) belonging to different categories (e.g., animals, objects, food, clothes). All words were presented consecutively via earphones, lasted for 1 s and were followed by a response time window. Participants had to indicate if the current word matched the previous word by a verbal "'yes'" response (20% target trials, 80% nontarget trials). The percentage of missed target trials served as indicator of children's working memory updating performance. The experimenter recorded the number of missed target trials during task administration. In a pilot study ($n = 41$), task difficulty of the working memory updating task was calibrated to reach a similar baseline accuracy of approximately 80%–90% for children of all ages. Therefore, difficulty adjustment applied the following parameters: (a) matching criterion (same word for 5- to 6-year-olds, e.g., *cat* followed by *cat* vs. same category for the older age-groups, e.g., *cat* followed by *horse*); (b) the number of word categories (two for 5- to 8-year-olds, three for 9- to 10-year-olds, and four for 11- to 14-year-olds); (c) the length of the allowed response time window after stimuli presentation (2 s for 13- to 14-year-olds vs. 4 s for all younger children). In the pilot study, a target performance of 75% was reached for 5- to 6-year-old children using the final version of the one-back task after pretesting had shown that children of this age performed far below target performance (<44%) when asked to make a categorical decision in a one-back task. All other age groups performed at about target level in the first step of pretesting using the final version of the one-back task (7- and 8-year-olds: 79%; 9- to 10-year-olds: 91%; 11- and 12-year-olds: 87%; 13- and 14-year-olds: 88%). In parallel with the duration of the PM task, the working memory updating task lasted 4 min in each test block (81 trials for 13- to 14-year-olds and 49 trials for all younger children).

General ability. Performance (standardized score) on the Vocabulary subscale of the German version of the Wechsler Preschool and Primary Scale of Intelligence-III (HAWIVA–III; Ricken, Fritz, Schuck, & Preuβ, 2007) and the Wechsler Intelligence Scale for Children-IV (HAWIK–IV; Petermann & Petermann, 2008), for children aged 5 or 6 years and older, respectively, served as an indicator for crystallized intelligence. In this subtest, children have to orally provide definitions of words of increasing difficulty. The performance (standardized score) in the "Matrix Reasoning" subscale in these tests was used as a measure of fluid intelligence. Here, participants have to select an item that correctly completes the pattern in a partially filled grid.

Procedure

Children were tested individually in 60- to 80-min sessions. First, the experimenter introduced the working memory updating task and familiarized participants with what the words would sound like. Then, participants received the task instructions and the experimenter demonstrated them with two examples. Children performed the working memory updating task in a training block (16 trials for 13-year-olds, nine trials for all younger children) followed by a baseline block (4 min). Performance in this baseline block was used as a measure of children's baseline working memory updating performance. Next, children were introduced to the Dresden Cruiser game. When children could accurately repeat the instructions for this task, they played a 1-min practice trial (ongoing task without refueling). Children then completed a dual-task baseline, performing the ongoing task of the Dresden Cruiser and the working memory updating task simultaneously (4 min) without the PM task. Based on ongoing task performance in this dual-task baseline, the difficulty of the Dresden Cruiser was adapted to the appropriate level.

Subsequently, the experimenter provided the PM task instructions and children had to demonstrate understanding of these PM task instructions by verbal recall of the rules. To implement a delay between the task instructions and subsequent execution of the PM task (see Ellis & Kvavilashvili, 2000), the experimenter administered the Vocabulary scale of the HAWIVA–III or the HAWIK–IV. After completing the Vocabulary scale, children were asked to play the first test block, either the low load condition (ongoing and PM of the Dresden Cruiser) or the high load condition (ongoing and PM task of the Dresden Cruiser as well as the working memory updating task), without further reminding on the need to refuel. Afterward the experimenter repeated the instructions for the PM task, and a second delay phase involving the Matrix Reasoning subscale of the HAWIVA–III or the HAWIK–IV followed. Children then completed the second test block. With the completion of both test blocks, retrospective memory for task instruction was confirmed. Children were thanked and received a €5 voucher for a local toy store.

Data Analysis

Statistical analyses focused on the examination of age-related differences in (a) working memory updating performance, (b) ongoing task performance, (c) PM performance, and (d) time monitoring behavior. For all analytic steps we implemented two-level hierarchical linear models (HLM) in SPSS 19. In each of these models two task blocks (Level 1) were nested within subjects (Level 2). Besides the fixed effects of age and block, all models included an age by block interaction and a random intercept. However, they did not include a random slope, as there were only two Level 1 units (blocks). Effect sizes (ES) are presented in terms of standardized beta coefficients reflecting the number of standard deviations the dependent variable changes when the independent variable increases one standard deviation. We used simple slope analyses, following the approach suggested by Preacher, Curran, and Bauer (2006), to explore the nature of possible interactions. Simple slope analyses allow for examining how the effect of a regressor variable on a dependent variable varies across specified levels of a moderator variable (i.e., moderated regression). For interactions involving age as a moderator, we evaluated simple slopes at three designated levels: 5 years (lower end of age range), 9.5 years (middle of age range) and 14 years (upper end of age range in our sample). *Z* values falling outside the region of significance [lower bound, upper bound] correspond to a significant simple slope (effect of the regressor variable).

Results

Appendix A shows means and standard deviations for all dependent measures and Appendix B shows Pearson's correlations between independent and dependent variables. The positive correlation between age and general cognitive abilities indicated that older children achieved higher scores in the standardized measures of general cognitive ability; thus, these general cognitive abilities were included as an additional predictor in all subsequent analyses. General cognitive abilities failed to predict PM performance or ongoing task performance in both conditions.

Working Memory Updating

We tested the variability of working memory updating performance (percentage of missed *n*-back trials) as a function of age, condition (baseline working memory updating task only vs. working memory updating and PM task), an interaction between age and condition as well as general cognitive abilities in a two-level HLM model (as described above; see Figure 1). Results showed a fixed main effect of age, $\beta = -0.05$, $SE = 0.01$, $t(341) = -10.09$, $p \leq .001$, 95% CI [–0.07, –0.04], $ES = -0.53$, 95% CI [–0.64, –0.43], indicating that older children performed more accurately

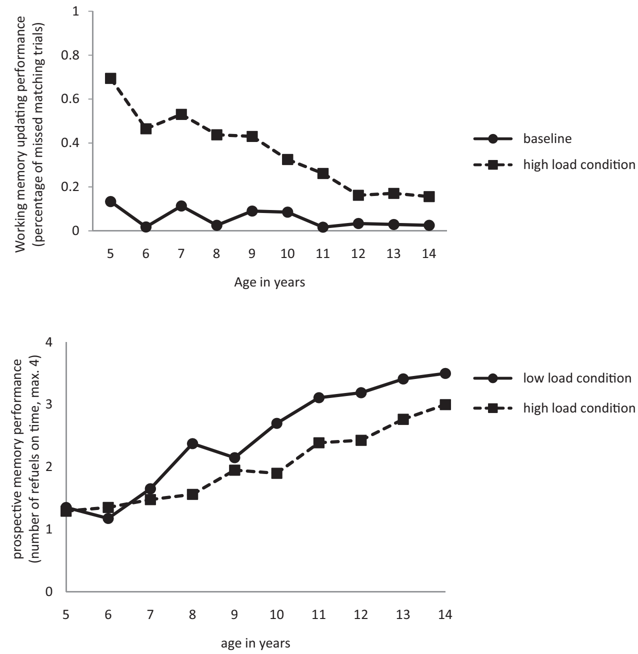

Figure 1. Upper panel: Working memory updating performance (in terms of percentage of missed *n*-back trials) as a function of age for the baseline (working memory updating task only) and high load condition (working memory updating task and prospective memory task). Lower panel: Prospective memory performance as a function of age for the low load condition (prospective memory task only) and high load condition (working memory updating task and prospective memory task).

than younger children in the working memory updating task. There was also a fixed main effect of condition, $\beta = -0.32$, $SE = 0.02$, $t(181) = -17.65$, $p \leq .001$, 95% CI [–0.35, –0.28], $ES = -1.15$, 95% CI [–1.28, –1.03], showing that participants solved the working memory updating task more accurately in the baseline (6% error rate) compared to the high load condition (37% error rate). Further, there was a fixed Age × Condition interaction, $\beta = 0.05$, $SE = 0.01$, $t(184) = 7.93$, $p \leq .001$, 95% CI [0.04, 0.07], $ES = 0.52$, 95% CI [0.39, 0.65]. In simple slope analyses (Preacher, Curran, & Bauer, 2006), we explored the nature of this interaction by evaluating the significance of the simple slope for (a) the regression of working memory updating performance on age as a function of condition and (b) the regression of working memory updating performance on condition at several conditional values of age: at 5 years, 9.5 years, and 14 years. Importantly, age-related effects were restricted to the high load condition ($b = -0.05$, $SE = 0.01$, $z = -10.13$, $p \leq .001$), while the baseline performance in the working memory updating task was independent of age ($b = 0.00$, $SE = 0.01$, $z = -0.21$, $p = .830$) as intended by the a priori difficulty adaptation of the working memory updating task. In turn, performance differences between the baseline and the high load condition were more pronounced for 5-year-old ($b = -0.54$, $SE = 0.03$, $z = -15.94$, $p \leq .001$), and 9.5-year-old children ($b = -0.30$, $SE = 0.02$, $z = -17.03$, $p \leq .001$), compared to 14-year-old children ($b = -0.07$, $SE = 0.04$, $z = -1.91$, $p = .056$, region of significance [13.97, 17.41]). Further, higher general cognitive abilities predicted better performance in working memory updating, β = −0.02, *SE* = 0.01, *t*(181) = −4.22, $p \leq .001$, *ES* = −0.17, 95% CI [−0.25, −0.09].

Ongoing Task Performance

We analyzed differences in ongoing task performance (number of car crashes in the Dresden Cruiser game) depending on age, condition (low load vs. high load on working memory updating resources), and the interaction between age and condition, as well as general cognitive abilities in a two-level HLM model as described above. Results revealed a fixed main effect of age, β = −0.02, *SE* = 0.01, *t*(285) = −9.71, $p \leq .001$, 95% CI [−0.02, −0.01], *ES* = −0.63, 95% CI [−0.75, −0.50], indicating that across the two test blocks older children's ongoing task performance was higher than younger children's even after the a priori calibration of the ongoing task difficulty to children's individual performance level in the dual-task baseline (ongoing task and working memory updating task). Hence, it seems likely that these age-related differences in the ongoing task resulted from adding the PM task. Further, ongoing task performance was higher in the low load condition compared to the high load condition, β = −0.01, *SE* = 0.01, *t*(176) = −2.14, *p* = .033, 95% CI [−0.02, −0.01], *ES* = −0.14, 95% CI [−0.27, −0.01]. However, no Age × Condition interaction emerged (*p* = .097), indicating that the relation between age and ongoing task performance did not vary across test blocks.

Prospective Memory Performance

We analyzed the variability of PM performance (number of correct on-time refuels) as a function of age, condition (the low load and high load on working memory updating resources), and the interaction between age and condition, as well as general cognitive abilities. A fixed main effect of age indicated better PM in older compared to younger children, β = 0.18, *SE* = 0.04, *t*(276) = 4.81, $p \leq .001$, 95% CI [0.11, 0.25], *ES* = 0.33, 95% CI [0.20, 0.47] (Figure 1). Moreover, children had better PM in the low load condition (*M* = 2.44, *SD* = 0.10) compared to the high load condition (*M* = 1.98, *SD* = 0.10) as reflected by a fixed main effect of condition, β = 0.46, *SE* = 0.10, *t*(176) = 4.78, $p \leq .001$, 95% CI [0.27, 0.65], *ES* = 0.32, 95% CI [0.19, 0.46]. However, these main effects were qualified by an interaction between age and condition, β = 0.09, *SE* = 0.04, *t*(176) = 2.49, *p* = .014, 95% CI [0.02, 0.16], *ES* = 0.17, 95% CI [0.04, 0.30]. According to post hoc simple slope analyses, there were performance differences between low load versus high load condition for older children (9.5 and 14 years of age: *b* = 0.47, *SE* = 0.10, *z* = 4.75, and *b* = 0.89, *SE* = 0.20, *z* = 4.52, $ps \leq .001$), but not for younger children (5-year-olds: *b* = 0.05, *SE* = 0.18, *z* = 0.26, *p* = .793), region of significance [–15.95, 6.96], as illustrated in Figure 1. In turn, age-related effects were found in both the low load and the high load condition (*b* = 0.18, *SE* = 0.04, *z* = 4.81 and *b* = 0.27, *SE* = 0.04, *z* = 7.22, $ps \leq .001$, respectively).

In two additional analyses we explored (a) whether there were age-dependent trade-off effects between the updating and PM task when both tasks were performed simultaneously (high load condition) and (b) whether the higher impairment of older children's PM performance in the high load condition was a result of trade-off effects in the high load condition or age-related differences in ongoing task performance. The first analysis exploring trade-off effects was a standard multiple regression analysis predicting PM in the high load condition from age, updating task performance (in the high load condition), and a possible interaction with age as well as general cognitive abilities. Results revealed evidence that children of all ages traded off attention in favor of the PM task to a similar extent, indicated by a significant effect of updating performance in the high load condition, β = −0.94, *SE* = 0.44, *t*(172) = −2.13, *p* = .034, $r_{\text{partial}}(172) = -.169$, and a nonsignificant interaction of updating performance with age (*p* = .837). In the second analysis, we explored whether taking into account differences in updating task engagement and ongoing task performance did affect the age-dependent effect of updating condition on PM by entering performance in the ongoing task (in both conditions) and the updating task (in the high load condition) into the initial HLM analysis of PM performance. This is the analytical approach taken in most previous studies to deal with differences in ongoing task performance (e.g., Kliegel & Jäger, 2007, instead of a priori difficulty calibration as implemented in the present study). Importantly, this additional analysis showed that, after taking ongoing task, β = −2.32, *SE* = 0.94, *t*(352) = −2.46, *p* = .014, 95% CI [–4.17, –0.46], *ES* = −0.14, 95% CI [–0.25, –0.03], and updating task performance, β = −0.77, *SE* = 0.33, *t*(175) = −2.36, *p* = .020, 95% CI [–1.41, –0.12], *ES* = −0.16, 95% CI [–0.29, –0.03], into account, older children's PM performance was still more affected by updating condition compared to younger children, as indicated by a significant interaction of age and updating condition on PM performance, β = 0.11, *SE* = 0.04, *t*(166) = 2.80, *p* = .006, *ES* = 0.29, *95% CI* [0.09, 0.50], *ES* = 0.32, 95% CI [0.19, 0.46]. This suggests that neither the observed trade-off effects nor the higher ongoing task performance of older children can explain the age differences in the working memory updating manipulation.

Time Monitoring

To gain insight into the processes underlying PM we analyzed two aspects of time monitoring behavior (see Figure 2). First, as in previous studies (e.g., Mäntylä et al., 2007), analyses focused on the cumulative number of fuel gauge checks within a test block. Second, we examined the increase in time monitoring frequency during the fourth (and final) interval by averaging the difference between the number of fuel gauge checks in the fourth interval and the number of fuel gauge checks in the third interval across the four trials of a test block. We implemented a random intercept HLM model with two hierarchical levels. Independent variables in this model were age, working memory updating condition (low load vs. high load on working memory updating resources), an interaction between age and condition, and general cognitive abilities.

Results for the cumulative number of fuel gauge checks revealed no main effect of age (*p* = .183), but a significant effect of condition emerged, β = 1.79, *SE* = 0.52, *t*(176) = 3.46, *p* = .001, 95% CI [0.77, 2.81], *ES* = 0.24, 95% CI [0.11, 0.38], such that the frequency of fuel gauge checks was higher in the low load condition (*M* = 11.25, *SD* = 0.55) compared to the high load condition (*M* = 9.43, *SD* = 0.55). Further, we observed a significant Age × Condition interaction, β = 0.59, *SE* = 0.19, *t*(176) = 3.10, *p* = .002, 95% CI [0.21, 0.97], *ES* = 0.21, 95% CI [0.08, 0.35]. Post

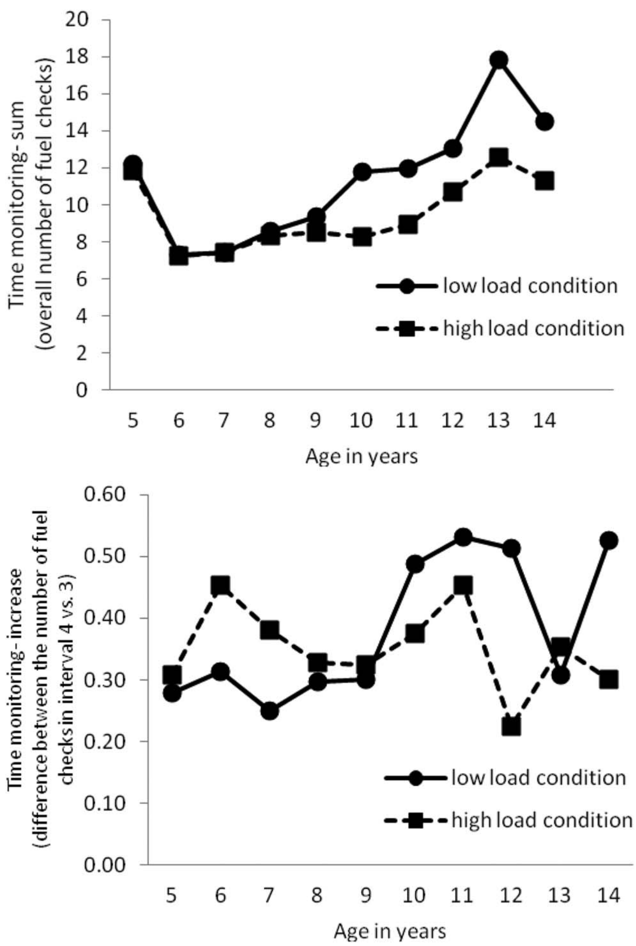

Figure 2. Time monitoring (upper panel: cumulative number of time checks vs. lower panel: increase in the number of time checks in the fourth interval) as a function of age for the low load condition (prospective memory task only) and high load condition (working memory updating task and prospective memory task).

hoc simple slope analyses indicated that the monitoring differences between low load condition and high load condition were greater for older children (aged 9.5 years: $b = 1.91$, $SE = 0.52$, $z = 3.69$, and 14 years: $b = 4.57$, $SE = 1.03$, $z = 4.44$, $p\text{s} \leq .001$), compared to younger children (aged 5 years: $b = -0.76$, $SE = 0.98$, $z = -0.78$, $p = .440$), region of significance [0.29, 8.15]. In turn, the frequency of fuel gauge checks depended on age in the low load condition ($b = 0.87$, $SE = 0.21$, $z = 4.16$, $p \leq .001$), but not in the high load condition ($b = 0.28$, $SE = 0.21$, $z = 1.34$, $p = .182$).

Results for the increase in time monitoring frequency during the fourth (last) interval of a trial showed no fixed main effect of age ($p = .490$) or condition ($p = .588$) but revealed a significant interaction between age and condition, $\beta = 0.04$, $SE = 0.02$, $t(176) = 2.03$, $p = .044$, 95% CI [0.01, 0.07], $ES = 0.20$, 95% CI [0.01, 0.40]. Post hoc simple slope analyses revealed that there were no performance differences in time monitoring increase between the low load condition and high load condition for younger children (5-year-olds: $b = -0.13$, $SE = 0.10$, $z = -1.42$, $p = .157$, and 9.5-year-olds: $b = 0.03$, $SE = 0.05$, $z = 0.69$, $p = .488$), but that older children increased monitoring more in the low load condition compared to the high load condition (14-year-olds: $b = 0.20$, $SE = 0.10$, $z = 2.04$, $p = .041$), region of significance [–18.98, 12.88]. In turn, age did not relate to the increase in time monitoring under high load conditions ($p = .490$), but there was an association at trend level under low load conditions ($b = 0.03$, $SE = 0.01$, $z = 1.93$, $p = .054$).

Function of Time Monitoring

Next we examined the function of both aspects of time monitoring behavior for PM performance. We compared two HLM models focusing on the predictive role of (a) the cumulative number of fuel checks and (b) the increase in monitoring frequency prior to the end of a trial. The first model followed the approach of previous studies. In a random intercept HLM model with two hierarchical levels we tested the cumulative number of fuel checks as a predictor of PM performance. Further independent variables in this model were age, condition (low load vs. high load on working memory updating), and general cognitive abilities. Several interaction terms were included to consider the conditional effects of the cumulative number of fuel checks depending on age, condition (two-way interactions), and on age as well as condition (three-way interaction). Respective results showed a fixed main effect for the cumulative number of fuel checks, $\beta = 0.09$, $SE = 0.02$, $t(239) = 4.52$, $p \leq .001$, 95% CI [0.05, 0.12], $ES = 0.44$, 95% CI [0.25, 0.64], indicating that children who checked the fuel gauge more often were more successful in their PM performance, and the effect of age, $\beta = 0.22$, $SE = 0.05$, $t(279) = 4.07$, $p \leq .001$, 95% CI [0.11, 0.32], $ES = 0.41$, 95% CI [0.21, 0.61]. However, the role of the cumulative number of fuel checks for PM performance depended on age, $\beta = -0.02$, $SE = 0.01$, $t(244) = -2.40$, $p = .017$, 95% CI [–0.03, –0.01], $ES = -0.21$, 95% CI [–0.38, –0.04], and marginally on condition, $\beta = 0.02$, $SE = 0.01$, $t(217) = 1.89$, $p = .061$, 95% CI [–0.01, 0.05], $ES = 0.12$, 95% CI [0.00, 0.25]. The positive relation between the number of fuel checks and PM performance held for 5- and 9.5-year-old children ($b = 0.15$, $SE = 0.03$, $z = 4.58$, and $b = 0.08$, $SE = 0.02$, $z = 3.31$, $p\text{s} \leq .001$, respectively) but was not observed for 14-year-olds ($p = .675$), region of significance [2.34, 34.34]. A three-way interaction showed that the predictive value of the cumulative number of fuel checks was significant for younger and older children in the high load condition ($b = 0.12$, $SE = 0.02$, $z = 8.08$, and $b = 0.10$, $SE = 0.02$, $z = 4.98$, $p\text{s} \leq .001$), whereas in the low load condition the cumulative number of fuel checks predicted PM performance for younger but not for older children ($b = 0.15$, $SE = 0.03$, $z = 5.06$, $p \leq .001$vs. $b = 0.01$, $SE = 0.04$, $z = 0.21$, $p = .861$), $\beta = 0.01$, $SE = 0.01$, $t(219) = 3.21$, $p = .002$, 95% CI [0.01, 0.02], $ES = 0.18$, 95% CI [0.07, 0.28].

The second model was similar to the first but included the increase in monitoring frequency prior to the end of a trial (instead of the cumulative number of monitoring frequency) as well as the number of fuel checks in the third trial interval (to serve as baseline frequency before the fourth interval increase) and the interaction between these two factors. This second model also comprised all possible two-way, three-way and four-way interactions between increase, Interval 3, age, and condition. We obtained a main effect of increase, $\beta = 1.35$, $SE = 0.26$, $t(297) = 5.29$, $p \leq$

.001,95% CI [0.85, 1.85], $ES = 0.46$, 95% CI [0.29, 0.63], and time monitoring frequency in the third interval, also = 0.36, $SE = 0.02$, $t(344) = 15.7$, $p \leq .001$, 95% CI [0.31, 0.40], $ES = 0.50$, 95% CI [0.44, 0.57]. Children who showed a steeper increase during the fourth (final) interval and who checked the fuel gauge more often during the third interval showed better PM performance. There were no other significant effects ($ps \geq .128$).

Discussion

The current study had three aims: (a) to describe the developmental course of time-based PM in childhood in a wide age range from preschool to adolescence (descriptive aim), (b) to examine the role of working memory updating resources in the maturation of PM abilities by investigating time-based PM and time monitoring performance under low or high working memory updating demands while calibrating ongoing task performance according to individual skills level (explanatory aim), and (c) to examine time monitoring as one important component that is assumed to be functionally related to successful time-based PM using both the typical measure of the cumulative number of time checks (quantitative aspect) and the increase in time checks during the final interval before the target time (qualitative aspect; process aim).

Effect of Age on Prospective Memory

Findings revealed a constant, linear increase in time-based PM between 5 and 14 years of age consistent with many studies that have documented age effects in narrower age ranges of 5 years or less (e.g., Kerns, 2000; Mackinlay et al., 2009; Mäntylä et al., 2007; Yang et al., 2011; Voigt et al., 2011). Although many studies have established that children as young as 3 years old can succeed on event-based PM tasks (e.g., Guajardo & Best, 2000; Kliegel & Jäger, 2007; Kvavilashvili et al., 2001; Mahy & Moses, 2011; Somerville et al., 1983), this is one of the first studies to indicate that children as young as 5 years old can succeed on a time-based PM task (see also Aberle & Kliegel, 2010).

Working Memory Updating as a Mechanism of Prospective Memory Development

In accordance with our hypothesis concerning the role of working memory updating as a mechanism of PM development, there was an increase in time-based PM with age, and imposing a working memory load negatively affected time-based PM performance. The link between working memory updating and PM is generally in accordance with the predictions of the multiprocess framework and the PAM that controlled executive processes play an essential role in many PM tasks. However, working memory load interacted with age, but in the opposite direction from our expectation. Our prediction was that working memory load would have a larger impact on young children's PM performance based on the fact that younger children have lower working memory updating resources to fulfill task demands compared to older children. In direct contrast, the results showed that a high load on working memory resources affected PM and time monitoring performance of older children more strongly than that of younger children. The opposite pattern was found for working memory updating performance: While younger children's updating performance was much worse in the high load condition compared to the baseline condition, this difference was much smaller for older children.

Several explanations may account for the age differences in the influence of the dual-task condition on PM and working memory updating performance. First, children of different ages may have applied different cognitive strategies to solve the PM task. Specifically, younger children may have generally applied highly demanding controlled processes, whereas older children may have relied mostly on automatic processes. This account is referred to as the "low control account" going forward.[1] Consequently, younger children may have had fewer resources left for completing the updating task in parallel with the PM task, and thus their working memory updating performance may have suffered much more compared to older children. In the context of this low control account, there are two possible reasons why the manipulation of working memory updating may have affected younger children's PM performance much less than that of older children. One possibility is that if younger children recruited highly demanding controlled processes, their limited working memory updating resources may have been overwhelmed by the PM task alone in the low load condition; hence, the dual-task manipulation did not have a greater impact on PM. A second possibility is that younger children showed a selective or pronounced trade-off between PM and working memory updating in favor of the PM task, and therefore the external manipulation of working memory updating did not affect their PM performance in the dual task situation. Several of the results seem to be out of line with this possibility in the context of the low control account. First, younger children's performance on the working memory updating task suggests that they were sufficiently engaged in the task when simultaneously completing the PM task. This suggests that the experimental manipulation tapped young children's working memory updating resources, yet they still had some free working memory updating resources left in the low load condition. Second, we found evidence that all children focused their attentional resources on the PM task at the expense of updating task performance in the high load condition. The clearly nonsignificant interaction ($p = .837$) in the respective model shows that this was equally true for younger and older children. Third, even after taking into account differences in working memory updating performance in the high load condition, results remained the same. Thus, older children's PM performance was clearly more affected by the working memory updating manipulation.

Finally, the low control account proposes that older children may have relied mostly on low-demanding, automatic processes when working on the PM task. Based on this assumption, one would expect that older children's PM performance should remain unaffected by adding a secondary task that relied on working memory updating resources. In this respect, the low control account cannot explain why older children's PM performance was negatively affected by increasing working memory updating demands and why their working memory updating performance was impaired by the addition of the PM task in the high load condition (although to a lesser extent than for younger children).

[1] We thank an anonymous reviewer for raising this point.

A second competing view that these data support is that children of all ages relied on working memory updating resources in PM. However, older children may have done so to a greater extent. Conceptually, this assumption is in accord with recent suggestions by Chatham, Frank, and Munakata (2009) who found that school children are generally more likely to apply high-demanding proactive control strategies in cognitive control tasks while preschool children mainly rely on less resource demanding reactive control strategies. As this account assumes a high involvement of controlled processes in PM in older children, it is termed the "high control account" in the following. In the present study, this account is in line with the observation that older children outperform younger children in the PM task, indicating the use of a more effective (possibly proactive control) strategy, and that they are also more affected by the addition of a task that requires working memory updating resources (possibly because they relied on a highly demanding, proactive control strategy). Also consistent with the high control account, younger children did worse on the PM task compared to older children, suggesting that they used a less effective (possibly reactive control) strategy and that their PM performance only slightly decreased when simultaneously completing a task that required working memory updating resources (possibly because they relied on a low-demanding, reactive control strategy). Importantly, our analyses clearly showed that this pattern of results was not based on age-related differences in ongoing task performance or trade-off effects between the PM and the updating task, further supporting the high control account.

Additional empirical support for the high control account comes from the results on time monitoring (detailed below in the next section) as well as a recently published study comparing differences in time-based PM between children aged 5 to 6 years ($n = 22$) and 7 to 8 years ($n = 25$), using a shorter version of the same PM task as the present study. In this correlational study, Kretschmer et al. (2013) conducted a mediation analysis showing that age-related variability in working memory (here indexed by the digit span backward task) accounted for the higher PM performance of older children (higher number of correct refuels in the Dresden Cruiser); this held true even after statistically accounting for differences in ongoing task performance (the number of car crashes in the Dresden Cruiser).

Conceptually, it is possible that working memory updating may not be the mechanism most critically responsible for age-related increases in PM performance. Perhaps other executive components play a more important developmental role in PM, such as inhibition (e.g., Mäntylä et al., 2007; Kerns, 2000; Mahy, Moses, & Kliegel, in press) or shifting (e.g., Mackinlay et al., 2009), as recently found explaining declines in PM during healthy aging (e.g., Schnitzspahn, Stahl, Zeintl, Kaller, & Kliegel, 2013). Similarly, other research has suggested that the retrospective memory component may play an important role in age-related increases in PM (Smith, Bayen, & Martin, 2010). It is also possible that one executive function alone cannot account for age-related changes in PM performance, but rather that distinct executive processes are critical for PM at different developmental stages in childhood similar to previous findings in adults (Mattli, Zöllig, & West, 2011).

The Functional Role of Time Monitoring

The present study extends prior research with two further important results. First, only the increase in clock checks at the end of a trial (an indicator of adaptive monitoring), but not the cumulative number of time checks in a trial, predicted PM for older children when the load on working memory updating resources was low. Second, although these two indicators of time monitoring behavior were differentially related to PM performance, both measures were similarly affected by age and limited working memory updating resources: Children of different ages similarly monitored the time in the high load condition, whereas only older children showed a higher overall number of clock checks and a steeper final increase in the low load condition. In turn, we found that these two characteristics, a higher overall number of clock checks in a trial and a steeper increase in the final interval of a trial, predicted better PM performance.

At the process level, these observations suggest that older children's monitoring behavior is more dependent on working memory updating resources and dovetails with the high control account. When sufficient working memory updating resources are available, older children seem to recruit an adaptive (or one might say proactive) time monitoring strategy more often than younger children. Specifically, older children seem to rely on a self-generated internal time model that predicts the appropriate time of intention execution. This makes them more independent of continuous externally provided temporal cues as indicated by a more pronounced increase in clock checks. This adaptive strategy used by older children is assumed to require a high amount of working memory updating resources and seems to be critical for older children's superior PM performance. However, when working memory updating resources are experimentally limited, older children's time monitoring seems to become less adaptive, as indicated by a smaller increase in clock checks at the end of a trial, and the role of the overall number of clock checks becomes a significant predictor of PM performance.

Compared to older children, younger children seem to adapt a less effective, less adaptive, and less resource-demanding monitoring strategy indexed by a fewer overall clock checks and a smaller increase in clock checking at the end of a trial resulting in worse intention execution. Younger children seem to rely more heavily on external indicators of time (fuel gauge) to ensure successful prospective remembering, which is in line with a more reactive time monitoring strategy (cf. Voigt et al., 2011).

The higher likelihood of a strategy shift in the face of high external demands with increasing age may also account for the finding that older children's working memory updating performance was less affected by the high load condition compared to younger children. Older children shifted from an effective and highly resource-demanding strategy (indicated by adaptive monitoring in the low load condition) to a low resource-demanding but also less effective strategy (indicated by simple monitoring in the high load condition). This seems to not only have resulted in a lower PM performance in the high load condition but may also have freed attentional resources that the older children could have used to maintain their performance level in the working memory updating task, while younger children did not have this opportunity to compensate. Thus, the high control account is not only in line with the present results in the PM task but may also explain the opposite age-related pattern of results in the working memory updating task.

Conclusion

In sum, the current study provides evidence that time-based PM develops continuously from preschool to adolescence. The experimental manipulation of working memory updating resources affected the PM performance of older children more than that of younger children suggesting that the maturation of working memory updating may be linked to the developmental improvements in PM. In contrast with younger children, older children's monitoring became more adaptive when working memory updating resources were not limited and this adaptive monitoring was linked to a superior PM performance. This suggests that the maturation of working memory updating may foster PM development by allowing for a qualitative shift in monitoring behavior, as suggested by current accounts of cognitive control development. Alternative interpretations discussed include possible trade-off processes in younger children or the possibility that younger children may have relied on controlled processes, while automatic processes contribute to the PM performance of older children. However, these accounts only explain some parts of the present results and conflict with other aspects of our findings. Future research will need to examine the role of working memory updating in PM performance compared to other executive abilities like shifting, inhibition, or planning, as well as the involvement of abilities in temporal processing that have been suggested to contribute to PM processes and that also seem to rely on working memory capacities (Forman, Mäntylä, & Carelli, 2011).

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(*Appendices follow*)

Appendix A

Means (and Standard Deviations) for All Dependent Measures

Variable	5–6 y (n = 33)	7–8 y (n = 39)	9–10 y (n = 40)	11–12 y (n = 38)	13–14 y (n = 27)
OT (0–1)[a]					
Low load	0.28 (0.08)	0.24 (0.06)	0.21 (0.06)	0.17 (0.06)	0.16 (0.09)
High load	0.30 (0.07)	0.27 (0.10)	0.21 (0.07)	0.17 (0.05)	0.16 (0.06)
PM (0–4)[a]					
Low load	1.36 (1.39)	1.95 (1.34)	2.43 (1.48)	3.13 (1.02)	3.44 (1.01)
High load	1.36 (1.25)	1.51 (1.23)	1.93 (1.51)	2.37 (1.28)	2.85 (1.06)
TM					
Low load	9.61 (10.72)	7.79 (5.81)	8.38 (5.67)	10.00 (5.23)	12.11 (6.32)
High load	9.82 (10.17)	7.87 (5.93)	10.55 (6.45)	12.74 (6.56)	16.59 (7.28)
TM Interval 3					
Low load	2.03 (2.37)	1.90 (2.09)	2.45 (1.80)	2.89 (1.91)	4.37 (2.22)
High load	2.06 (2.87)	1.63 (1.53)	1.40 (1.61)	2.24 (1.60)	2.37 (1.67)
Increase TM					
Low load	0.30 (0.46)	0.27 (0.47)	0.39 (0.56)	0.52 (0.49)	0.39 (0.47)
High load	0.38 (0.56)	0.36 (0.49)	0.35 (0.43)	0.30 (0.48)	0.33 (0.50)
WM updating (0–1) [a]					
Baseline	0.07 (0.11)	0.08 (0.12)	0.09 (0.10)	0.03 (0.07)	0.03 (0.07)
High load	0.59 (0.35)	0.49 (0.28)	0.38 (0.27)	0.21 (0.18)	0.16 (0.16)
General cognitive abilities	10.99 (1.95)	11.04 (1.92)	11.06 (2.48)	12.74 (1.99)	12.94 (2.69)

Note. y = years old; OT = ongoing task; PM = prospective memory; TM = time monitoring; WM = working memory updating.
[a] Range of possible scores.

Appendix B

Pearson Correlations Between All Measures in the Low Load vs. High Load Condition

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Age													
2. OT performance, low load	−.54*												
3. OT performance, high load	−.60*	.62*											
4. PM performance, low load	.51*	−.47*	−.43*										
5. PM performance, high load	.36*	−.32*	−.31*	.58*									
6. TM performance, low load	.31*	−.37*	−.35*	.70*	.49*								
7. TM performance, high load	.12	−.18*	−.14	.36*	.63*	.55*							
8. TM performance third interval, low load	.30*	−.33*	−.35*	.61*	.46*	.85*	.53*						
9. TM performance third interval, high load	.22*	−.17*	−.18*	.33*	.53*	.48*	.87*	.47*					
10. Increase of TM during the fourth interval, low load	.15*	−.19*	−.12	.45*	.21*	.28*	−.02	−.15*	−.02				
11. Increase TM during the fourth interval, high load	−.05	−.14	−.08	.21*	.49*	.16*	.39*	.16*	.01	.09			
12. WM updating performance, baseline	−.21*	.13*	.18*	−.15*	−.09	−.04	−.06	−.03	−.04	−.04	−.10		
13. WM updating performance, high load	−.54*	.34*	.42*	−.40*	−.33*	−.28*	−.16*	−.28*	−.21*	−.12	−.01	.40*	
14. General cognitive abilities	.33*	−.17*	−.18*	.21*	.16*	.16	.04	.20*	.06	.04	.01	−.37*	−.36*

Note. OT = ongoing task; PM = prospective memory; TM = time monitoring; WM = working memory updating.
* $p < .05$.

Received May 7, 2013
Revision received March 18, 2014
Accepted April 19, 2014 ■