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Short article

The rise and decline of prospective memory performance across the lifespan

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In the present study, the trajectory of prospective memory across the lifespan was investigated in a total of 200 participants from five age groups (4- to 6-year-old children, 13- to 14-year-old adolescents, 19- to 26-year-old adults, 55- to 65-year-old adults, and 65- to 75-year-old adults). In an event-based prospective memory task the prospective and the retrospective components were assessed separately. For the prospective component, the results showed better performance for adolescents and young adults than for children and 65- to 75-year-old adults. In addition, participants belonging to the latter group were more likely to forget the retrospective component after having noticed the prospective memory targets. Overall, these results indicate that across the lifespan prospective memory performance follows a similar inverted u-shape function as is well known for retrospective episodic memory.

Prospective memory is the ability to remember an intention at the appropriate occasion. It is highly functional in everyday life, from childhood to old age. In childhood, this ability can be considered as a cornerstone of cognitive development. There is evidence that already preschool children show reliable prospective memory performance and that there is a continuous performance increase in childhood (e.g., Kvavilashvili, Messer, & Ebdon, 2001). In adulthood, intact prospective memory is critical for leading an autonomous life, and there is evidence that prospective memory performance decreases in old age (e.g., Dobbs & Rule, 1987). However, so far no study has investigated prospective memory performance across the lifespan, and the goal of this study is to fill this gap.

A prospective memory task always consists of two distinct components (Einstein & McDaniel, 1990): a *prospective component*, which refers to remembering *that* something has to be done, and a *retrospective component*, which refers to *what* has to be done (i.e., the contents of the intention). The prospective component can be either a specific time or a specific event, and accordingly a distinction between time-based and event-based prospective memory tasks can be made. In the present study we focus on the latter.

There is evidence that already 4-year-old children are able to carry out prospective memory

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tasks and that an age-related performance increase occurs in childhood (Guajardo & Best, 2000; Kvavilashvili et al., 2001; Passolunghi, Brandimonte, & Cornoldi, 1995). However, the specific trajectory varies between studies. Maylor, Darby, Logie, Della Sala, and Smith (2002) suggested that these variations occurred as a result of different methodologies with different processing requirements. The question of whether there is an age-related decline in prospective memory performance is more controversial. While some studies did not find age effects (e.g., Einstein & McDaniel, 1990), many other studies found an age-related performance decrease (Dobbs & Rule, 1987; Mäntylä, 1994; Maylor, 1990). There is evidence that age effects are more likely to occur when the ongoing activity is demanding, when the prospective memory load is high, and for participants with low scores in verbal abilities, lower education, and a lower social status (see Henry, MacLeod, Phillips, & Crawford, 2004, for a meta-analytic review).

Overall, the findings suggest that under many conditions event-based prospective memory performance increases in children and decreases in old age. However, the reasons for these performance differences are not fully understood. For example, there is little empirical evidence of whether the differences are due to failures to identify the target event (i.e., the prospective component), failures to disengage from the ongoing task despite having noticed the target event, or a lack of resources to switch to the prospective memory task, or whether the differences might be based at least partly on forgetting the intended action (i.e., the retrospective component). Despite the effort to keep the retrospective component as simple as possible, evidence from posttest interviews suggests that retrospective forgetting occurs quite frequently in old age. For example, Einstein, Holland, McDaniel, and Guynn (1992) reported that nearly half of the older adults were not able to recall any of the four prospective memory targets in a debriefing interview at the end of the experiment. However, age-related declines in the retrospective component are usually smaller than those in the prospective component, and they cannot explain the whole magnitude of age-related differences in prospective memory performance (Cohen, West, & Craik, 2001; Mäntylä, 1994; Smith & Bayen, 2006; West & Craik, 2001).

In order to assess the two components of prospective remembering separately, we developed a new paradigm, which is based on typical behaviours of participants in prospective memory experiments. Upon recognition of a prospective memory target participants frequently move backwards in their chairs, sometimes accompanied by exclamations like "oops", "aha", "now I have to do something". At this point of time participants do not seem to have the immediate knowledge of what they have to do. These observations are consistent with the noticing plus search model, which distinguishes processes related to the detection of prospective memory targets and processes related to retrieving the contents of the intention (cf. Einstein & McDaniel, 1996). Our paradigm was designed such that these natural occurrences are part of the experimental procedure. We used a test arrangement, in which an ongoing task requirement was to continuously press a specific key (i.e., the shift-key). If participants stopped pressing the key, the ongoing task was interrupted. The prospective memory task was to press a different key with the same finger (i.e., the "y"-key) as soon as a prospective memory target was encountered. To do this, participants had to release the shift-key first. Therefore, the release of the shift-key is mapped to the backwards movement as described above, and it is considered as the prospective component indicating detection of the prospective memory target. Pressing the "y"-key is similar to the requirements of a conventional prospective memory task, which involves retrieval of the retrospective component. In conventional tasks the retrospective component is kept as simple as possible (i.e., pressing a key) to allow for a pure measurement of the prospective component. However, in these types of task it is still possible that participants detect a prospective memory target and correctly interrupt the ongoing task, but then fail to initiate the retrospective component. If this happens, the prospective memory measure is contaminated by retrospective memory failure. We hypothesized that this type of failure would occur more often in old age.

As an ongoing task we used a picture comparison task during which pairs of identical or nearly identical pictures were presented. Participants had to indicate whether the pictures were identical. The prospective memory targets were defined as pictures of animals. In order to keep ongoing task difficulty constant across age groups the pace of presentation was individually adjusted. In addition, to make sure that all participants understood the instructions, a practice trial of the prospective memory task was administered.

Method

Participants

A total of 40 kindergarten children between 4 and 6 years (M = 5.5, SD = 0.56), 40 adolescents between 13 and 14 years (M = 13.3, SD = 0.46), 40 adults between 19 and 26 years (M = 21.2, SD = 1.75), 40 adults between 55 and 65 years (M = 58.7, SD = 3.16), and 40 healthy older adults between 65 and 75 years (M = 70.4, SD = 3.62) participated voluntarily in this study. Kindergarten children were recruited from local nurseries, adolescents were recruited from local schools, young adults were undergraduate students, the 55- to 65-year-old adults were parents or other relatives of undergraduate students, and 65- to 75-year-old adults were recruited from a senior education programme of the University of Bern.

Materials

For the picture comparison task a total of 139 pictures were required; 42 pictures were used for practice and for adjusting ongoing task difficulty, and 92 pictures were used for the ongoing task in which the prospective memory targets occurred. An additional 5 pictures were used as prospective memory targets. Pictures of easy-to-name common objects were downloaded from the Internet (most of them from http://www.cheries-welt.com/downloads). First, they were standardized in size and resolution. Then they were duplicated such that each picture occurred twice, side by side on a computer screen. Half of the copies were slightly modified such that they differed from the original in one prominent feature. The prospective memory targets consisted of 2 different pictures of cats and 3 different pictures of dogs. One picture of a dog was used to explain the prospective memory task. The other 4 animal pictures were embedded in the ongoing task.

Procedure

First, participants were instructed for the prospective memory task. They were informed that we were interested in how well they could remember to carry out an activity in the future. The activity was to press a particular key on the keyboard. Specifically, they were instructed to press the "y"-key on the keyboard with the left index finger every time they saw a picture of an animal. Then they were instructed for the ongoing task. They were told that they would see a pair of pictures and that some picture pairs were identical but some were slightly different. They were instructed to indicate for each pair whether the pictures were identical or not by pressing the "b"-key or the "m"-key with the index finger of the right hand. They were also informed that in order to keep the task going the shift-key had to be pressed continuously with the index finger of the left hand. They were informed that they should not release this key until a picture of an animal was presented. If they mistakenly released the shift-key, the task did not continue until they pressed the shift-key again. The instructions were explained until participants understood and were able to repeat them.

Next, five practice trials were administered. For the first four trials, each pair of pictures was presented for 4 seconds or until a response was given. Then, a pair of an animal picture that was a prospective memory target (i.e., a dog) was presented until the prospective memory response (releasing the shift-key and pressing the "y"-key) was given. With this arrangement, we made sure that all participants understood the instructions and were able to carry them out. Next, 38 trials of the picture comparison task were administered to adjust presentation time for the ongoing task. For each trial, a pair of pictures was presented until the participant responded. Individual mean reaction time (RT) for correct responses was used for each participant as presentation time in the following ongoing task. On average these RTs were 4,655 ms, 3,372 ms, 2,967 ms, 3,864 ms, and 6,156 ms for children, adolescents, 19- to 26-year-old adults, 55- to 65-year-old adults, and 65- to 75-year-old adults, respectively. A univariate analysis of variance (ANOVA) with age group as between-subject factor was significant, $F(4, 195) = 24.373$, $p < .001$, $MSE = 2{,}605{,}734$. Post hoc Tukey HSD tests showed that adolescents, 19- to 26-year-old adults, and 55- to 65-year-old adults were significantly faster than both kindergarten children and older adults. Children were faster than the older adults (all $ps < .01$). All other groups did not differ.

Next, an unrelated questionnaire was administered to create a filled retention interval, which lasted approximately 5 minutes (cf. Einstein & McDaniel, 1990). Then, the ongoing task with the embedded prospective memory task was started without mentioning the prospective memory task again. Pairs of pictures were presented with individually adjusted presentation times (see above). Order of presentation was random. A total of 96 picture pairs were presented with a prospective memory target at the 23rd, 47th, 71st, and 95th position, respectively. Order of prospective memory targets was pseudorandomized such that each target occurred equally often at each position. A schematic example of three consecutive trials is presented in Figure 1.

Whenever a prospective memory target was presented participants had to press the "y"-key with their left index finger, thereby releasing the shift-key first. After pressing the "y"-key a screen with the instruction to "press the shift key to continue" appeared. At the end of the experiment, participants who failed to perform the prospective memory task were asked whether they remembered that they were instructed to perform an additional task under specific conditions and what they had to do. As all participants remembered both components, these data are not further discussed.

Results

Prospective memory performance was measured as proportion of correct responses. For the

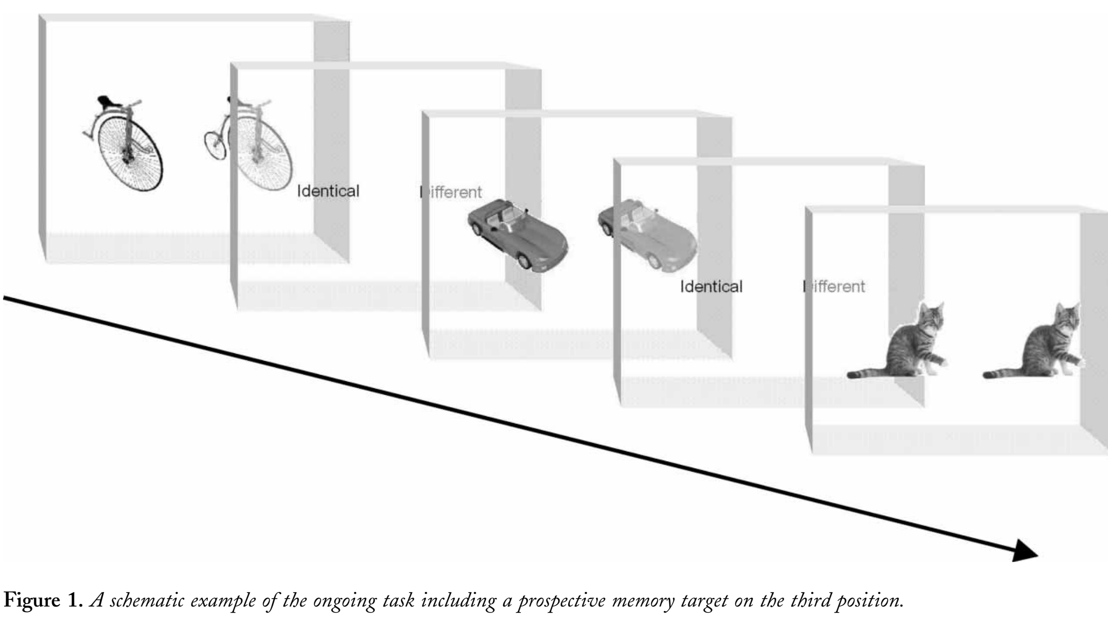

Figure 1. *A schematic example of the ongoing task including a prospective memory target on the third position.*

prospective component, a response was scored as correct when the shift-key was released at the appropriate occasion. Proportions of correct responses for the prospective component are shown in Figure 2. A one-factorial ANOVA revealed a significant quadratic effect, $F(4, 195) = 10.88$, $p < .001$, $MSE = 0.103$. Post hoc Tukey HSD tests showed that the group of adolescents and the 19- to 26-year-old group scored significantly higher than the group of children and the 65- to 75-year-old group (all ps < .05), whose performance was not statistically different. The 55- to 65-year-old group scored significantly better than the 65- to 75-year-old group ($p < .001$), but did not differ from all other age groups.

Overall, 31 children, all adolescents, all 19- to 26-year-old adults, 38 of the 55- to 65-year-old group, and 29 of the 65- to 75-year-old group correctly interrupted the ongoing task at least once. The retrospective component was analysed as conditional probability and was scored as correct when the "y"-key was pressed after the release of the shift-key. Proportions of correct responses across age groups are also shown in Figure 2. A one-way ANOVA revealed a significant effect, $F(4, 173) = 6.817$, $p < .001$, $MSE = 0.032$. Post hoc Tukey HSD tests showed that 65- to 75-year-old adults scored significantly lower than all other age groups (all ps < .05). All other comparisons were not significant.

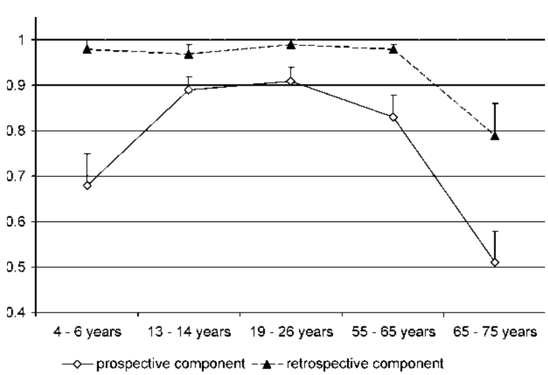

Figure 2. *Prospective memory performance across the lifespan. The prospective component is based on mean proportion of correct responses out of 4; the retrospective component is presented as conditional probabilities for participants who responded correctly to at least one prospective memory target. Bars represent standard errors.*

We also checked whether it occurred that participants incorrectly released the shift-key. The mean number of false alarms for the prospective component was 2.03 for children, 0.77 for adolescents, 0.15 for the 19- to 26-year-old group, 0.17 for the 55- to 65-year-old group, and 1.15 for the 65- to 75-year-old adults. A one-factorial ANOVA revealed a significant effect, $F(4, 195) = 3.885$, $p < .01$, $MSE = 6.413$. Post hoc Tukey HSD tests showed that children displayed significantly more false alarms than did 19- to 26-year-old adults and 55- to 65-year-old adults (ps < .05). All other comparisons were not significant. We also checked whether it occurred that participants pressed the "y"-key after having mistakenly released the shift-key. Interestingly, this never happened. This result indicates that the incorrect releases of the shift-key may be due to fatigue or clumsiness rather than reflecting errors related to prospective memory task performance.

Discussion

The goal of this study was to examine the lifespan trajectory of prospective memory. We tested 4- to 6-year-old kindergarten children, 13- to 14-year-old adolescents, 19- to 26-year-old adults, 55- to 65-year-old adults, and 65- to 75-year-old adults with a paradigm that allowed the separate assessment of the prospective and the retrospective component. Overall, the results revealed an inverted u-shaped trajectory with a performance increase from childhood to adulthood and a decline in performance in older adulthood. This data pattern indicates that prospective memory performance follows a similar lifespan trajectory as retrospective explicit episodic memory. However, our results suggest that different processes might underlie performance in the prospective and retrospective components, and these underlying processes might be affected differently across the lifespan.

Our results indicate that the ability to identify prospective memory targets (i.e., the prospective component) rises in childhood and declines in older age. As processing resources increase with development and decrease with age a straightforward interpretation is that a difference in available processing resources has caused this trajectory. Our results also showed that even when the prospective memory targets were noticed, and the ongoing task was interrupted as planned, older adults more often failed to remember the retrospective component. Several processes may be responsible for these failures.

First, older adults may have simply forgotten what they were supposed to do, and consequently failures to execute the retrospective component would be identical to retrospective memory failures. But as all participants were able to recall the retrospective component in the postexperimental interview, this possibility is unlikely. However, this result indicates that by probing participants at the end of the experiment, the retrospective memory for the target or the prospective memory task might be overestimated. Second, it might be that older adults lack the resources to switch from the ongoing task to the prospective memory task. Results from task-switching studies consistently show an age-related decline; however, similarly a rise in performance in development is also documented (Kray, Eber, & Lindenberger, 2004). Therefore this possibility cannot explain the differential effect for kindergarten children and older adults. Another possibility is that interrupting the ongoing task is sufficient to interfere with retrospective remembering. Older adults may have more difficulties in disengaging from the ongoing task despite having noticed the target event, which implies a deficit in inhibition. There is consistent evidence that inhibition accounts for age-related performance decline, and there is evidence that inhibition plays a more important role in older adulthood than in childhood (De Ribaupierre, 2002; Hasher & Zacks, 1988).

Our results are consistent with many studies that investigated developmental or age effects in prospective memory. However, it is important to note that different results may occur with different kinds of test arrangement. For example, our ongoing picture comparison task required perceptual rather than semantic processing of the pictorial objects. In contrast, for recognizing a pictorial object as an animal (i.e., as a prospective memory target) semantic processing is required. As a consequence there was no concurrent overlap between ongoing task and prospective memory task requirements (cf. Meier & Graf, 2000). Performance in our task might have been less resource demanding if there had been a processing overlap. In addition, we have used categorical rather than specific prospective memory targets. Previous research has shown a performance benefit for specific targets, and it is possible that with specific targets age differences across the lifespan would be reduced. Therefore, the specific trajectory of prospective memory performance across the lifespan may vary for different types of prospective memory test. According to Einstein and McDaniel's (2005) multiprocess framework, the extent to which a prospective memory task requires resource-demanding monitoring is determined by whether the ongoing task requires focal processing of the target event, and a test arrangement as ours would clearly enhance monitoring-related age differences.

To summarize, our results demonstrate that prospective memory abilities develop early in life, and it seems that their rise and decline follow a similar pattern as retrospective memory abilities. However, our results also suggest that different underlying processes are responsible as indicated by the differential trajectory of the prospective and the retrospective component. Future research will further disentangle these underlying processes.

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