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Neural correlates of prospective memory across the lifespan

Jacqueline Zöllig[a,*], Robert West[b], Mike Martin[a], Mareike Altgassen[a], Ulrike Lemke[a], Matthias Kliegel[a]

[a] *Department of Psychology, University of Zurich, Binzmühlestrasse 14/24, CH-8050 Zurich, Switzerland*
[b] *Department of Psychology, Iowa State University, USA*

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Abstract

Overview: Behavioural data reveal an inverted U-shaped function in the efficiency of prospective memory from childhood to young adulthood to later adulthood. However, prior research has not directly compared processes contributing to age-related variation in prospective memory across the lifespan, hence it is unclear whether the same factors explain the 'rise and fall' of prospective remembering from childhood to later adulthood. The present study examined this question using a paradigm that allowed us to consider the behavioural and neural correlates of processes associated with the prospective and retrospective components of prospective memory.
Methods: We compared 14 adolescents, 14 young adults, and 14 old adults in a paradigm where the prospective memory task was embedded in a semantic categorization task.
Results: The behavioural data revealed an inverted U-shaped function with adolescents and old adults performing poorly relative to young adults. Analyses of the error data revealed that different processes may have contributed to failures of prospective memory in adolescents and older adults. This finding was supported by age differences in ERP-components for cue detection and post-retrieval processes. Additionally, source localization using LORETA revealed different patterns of neural recruitment for adolescents and older adults relative to younger adults.
Conclusion: Our findings demonstrate that adolescents and older adults show different patterns of behavioural errors and neural recruitment for successful prospective remembering indicating that different processes may contribute to the 'rise and fall' of prospective memory across the lifespan.

Keywords: Prospective memory; Lifespan development; ERPs; LORETA

Prospective memory requires the formation and later realization of intentions that must be delayed for minutes, hours, or days (Brandimonte, Einstein, & McDaniel, 1996). Remembering to post a letter, to take medication with a meal, or to switch off the stove after cooking are all examples of prospective memory tasks. Given these examples, it is clear that prospective memory is an important and pervasive aspect of memory outside of the laboratory, and may be regarded as one of the main factors supporting the attainment and maintenance of autonomy across the lifespan (Guajardo & Best, 2000; Meacham & Colombo, 1980; Rendell & Craik, 2000). Consistent with this idea, deficits of prospective memory account for unique variance in understanding cognitive impairment associated with attention deficit/hyperactivity disorder in children (ADHD, Kliegel, Ropeter, & Mackinlay, 2006), dementia in older adults (Duchek, Balota, & Cortese, 2006; Jones, Livner, & Backman, 2006), and depression (Rude, Hertel, Jarrold, Covich, & Hedlund, 1999). Motivated by this evidence, the goal of the current study was to examine the neurocognitive processes underlying variation in the efficiency of prospective memory across the lifespan.

1. Components of prospective memory

There is typically agreement in the prospective memory literature that the realization of delayed intentions is facilitated by prospective and retrospective processing components (Guynn, McDaniel, & Einstein, 2001; McDaniel & Einstein, 1992; Simons, Scholvinck, Gilbert, Frith, & Burgess, 2006). Generally, the prospective component entails processes that support the detection or recognition of prospective cues and the retro-

* Corresponding author. Tel.: +41 44 635 74 29; fax: +41 44 635 74 19.
E-mail address: j.zoellig@psychologie.unizh.ch (J. Zöllig).

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spective component entails processes that support the retrieval of an intention from memory following the recognition of a prospective cue (Einstein & McDaniel, 1996; Smith & Bayen, 2004). Evidence from studies using behavioural, mathematical modelling, and electrophysiological methodologies has been used to distinguish the processes underlying the prospective and retrospective components of prospective memory. Behavioural evidence indicates that the prospective component is more sensitive to changes in the perceptual characteristics of the cue than to the semantic relationship between the cue and intention; in contrast, the retrospective component appears to be more sensitive to variation in the semantic relationship between the cue and intention than to variation in the perceptual characteristics of the prospective cue (Cohen, West, & Craik, 2001). Evidence from studies using a variety of methods has revealed that the prospective component is more sensitive to individual differences in working memory capacity (Smith & Bayen, 2005) or variation in the working memory demands of the ongoing activity (Marsh & Hicks, 1998; West, Bowry, & Krompinger, 2006) than the retrospective component. Together these data led to the suggestion that in many cases the prospective component is supported by attention demanding processes that serve to monitor the environment for prospective cues (Guynn, 2003; Smith, 2003; although for an alternative view see Guynn et al., 2001). The retrospective component shares many of the processes that support explicit episodic memory in recognition and cued-recall tasks that facilitate the retrieval of contextual information from long-term memory (Einstein & McDaniel, 1996; Guynn et al., 2001; Smith & Bayen, 2004; West & Krompinger, 2005).

The general division between prospective and retrospective processing components is also supported by evidence from studies examining the neural basis of prospective memory. Patients with damage to the medial temporal lobe can exhibit deficits in both prospective memory tasks and episodic memory tasks (Palmer & McDonald, 2000) and there is some evidence indicating that the regions of the medial temporal lobe are activated by the realization of delayed intentions (Okuda et al., 1998). These findings are consistent with the idea that there is overlap between the processes underlying the retrospective component of prospective memory and forms of explicit episodic memory including recognition and cued-recall (Einstein & McDaniel, 1996; West & Krompinger, 2005). In contrast to the retrospective component, processes underlying the prospective component may be more heavily dependent on the functional integrity of the prefrontal cortex. Evidence from a number of patient studies indicates that damage to the prefrontal cortex can result in significant impairment in prospective memory in individuals who possess largely intact explicit episodic memory when measured in the form of new learning (Burgess, Veitch, de Lacy Costello, & Shallice, 2000; Cockburn, 1995; Palmer & McDonald, 2000). Converging with the patient data, studies using functional neuroimaging methods reveal that activation of anterior prefrontal cortex may be associated with strategic monitoring that facilitates the recognition of prospective cues (Burgess, Quayle, & Frith, 2001; Burgess, Scott, & Frith, 2003; Simons et al., 2006).

2. Development of prospective memory

A limited number of studies have explored the development of prospective memory in childhood and adolescence (e.g. Kvavilashvili, Messer, & Ebdon, 2001; Martin & Kliegel, 2003). These studies have revealed some competence in prospective memory as early as the pre-school years (Guajardo & Best, 2000; Kliegel & Jäger, 2007; Somerville, Wellman, & Cultice, 1983) that continues to develop through adolescence as children become increasingly skilled at using external reminders to cue prospective remembering (Beal, 1988; Mantyla, Carelli, & Forman, 2007; Meacham & Colombo, 1980). Other evidence indicates that improvements in prospective memory between 7 and 12 years of age reflect an increase in the efficient use of strategic monitoring associated with the prospective component of prospective memory (Ceci, Baker, & Bronfenbrenner, 1988; Kerns, 2000). In contrast to this evidence, other findings indicate that improvements in prospective memory between 7 and 10 years of age may arise from an increase in the efficiency of processes underlying the retrospective component of prospective memory (Smith, Bayen, Martin, & Metzroth, 2006). In light of this apparent inconsistency across studies, the current investigation utilized a task that allowed us to estimate the contribution of the prospective and retrospective components to improvements in prospective memory from adolescence to early adulthood.

The development of prospective memory from young adulthood to older adulthood has been investigated in a number of studies using extreme group and cross sectional designs (for an overview see Henry, MacLeod, Phillips, & Crawford, 2004). Here, evidence from studies using behavioural and mathematical modelling methodologies indicates that the effects of aging may be greater on the prospective component than the retrospective component of prospective memory (Cohen et al., 2001; Smith & Bayen, 2004; West & Craik, 2001). With some evidence indicating that age-related declines in the prospective component may result from a reduction in the likelihood that older adults engage in preparatory processing that facilitates the recognition of prospective cues (Kidder, Park, Hertzog, & Morrell, 1997; Logie, Maylor, Della Sala, & Smith, 2004; Smith & Bayen, 2006). There are however other findings from studies using electrophysiological methods that reveal clear differences between younger and older adults in the neural correlates of processes associated with both the prospective and retrospective components of prospective memory (West & Bowry, 2005; West, Herndon, & Covell, 2003). Based on these data it seems that processes underlying both the prospective and retrospective components may contribute to age-related declines in prospective memory across the adult lifespan.

3. ERPs and prospective memory

Work using event-related brain potentials (ERPs) to examine the neural correlates of prospective memory has revealed two modulations of the ERPs that are differentially related to the prospective and retrospective components of prospective memory (i.e., N300 and prospective positivity). The *N300* reflects greater negativity for prospective cues than for ongoing activity