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Age-related differences in the temporal dynamics of prospective memory retrieval: A lifespan approach

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ABSTRACT

The efficiency of prospective memory (PM) typically increases from childhood to young adulthood and then decreases in later adulthood. The current study used event-related brain potentials (ERPs) to examine the development of the neural correlates of processes associated with the detection of a PM cue, switching from the ongoing activity to the prospective task, retrieval of the intention from memory or task set configuration, and strategic monitoring of the environment. The study included 99 participants that were 7.5–83 years of age. Slow wave activity related to strategic monitoring was reliable across the lifespan suggesting that all ages were able to allocate attentional resources to facilitate PM. Additionally, components of the ERPs related to cue detection, switching, and task configuration were reliable across the lifespan, suggesting that similar processes contribute to PM at all ages. In children, PM errors may have resulted from a decoupling of processes supporting cue detection and switching from the ongoing activity to the prospective element of the task. In younger and older adults, PM errors appeared to result from the failure to detect PM cues in the environment. These findings lead to the conclusion that different processes may contribute to variation in PM across the lifespan.

1. Introduction

The ability to form, retain and later execute an intention without an explicit external agent that prompts a memory search when the retrieval context occurs, constitutes prospective memory (PM, Brandimonte, Einstein, & McDaniel, 1996; Kliegel, McDaniel, & Einstein, 2008). Successful PM is supported by two fundamentally different components (i.e., retrospective and prospective, Einstein, Holland, McDaniel, & Guynn, 1992; Einstein & McDaniel, 1990, 1996; Kliegel, Mackinlay, & Jäger, 2008; Martin, Kliegel, & McDaniel, 2003). The retrospective component allows the individual to retrieve the content of the intention (i.e., retrieval context and intended action) from memory when a relevant cue is encountered in the environment (Einstein & McDaniel, 1996). There is significant overlap between the processes contributing to the retrospective component of PM and those contributing to other forms of explicit episodic memory (Einstein & McDaniel, 1996; West & Krompinger, 2005). The processes underlying the prospective component are more closely aligned with executive control and support the detection of PM cues in the environment, the coordination of the ongoing activity and execution of the intended action, and monitor the outcome of an action (Marsh, Hicks, & Watson, 2002; West, 2011). Studies examining the development of PM reveal an inverted U-shaped distribution in the efficiency of PM across the lifespan, with PM improving from childhood to young adulthood and then declining from young adulthood to later adulthood (Kliegel et al., 2008a; Zimmermann & Meier, 2006; Zöllig et al., 2007). Evidence from behavioral and electrophysiological levels of analyses lead to the suggestion that somewhat different processes may contribute to the development of PM across the lifespan (Zöllig et al., 2007). The current study examined age-related differences in the neural correlates of PM in individuals 7.5–83 years of age to determine whether similar or distinct processes contribute to variation in PM across the lifespan.

1.1. The development of PM

The success of PM typically increases from young childhood to about the mid-twenties (e.g., Ceci, Baker, & Bronfenbrenner, 1988; Guajardo & Best, 2000; Kliegel & Jäger, 2007; Kvavilashvili, Messer, & Ebdon, 2001; Martin & Kliegel, 2003; Smith, Bayen, & Martin, 2010) and then starts to decline in middle adulthood (Maylor & Logie, 2010) with an acceleration of decline in later adulthood (Kliegel & Jäger, 2006). There is some debate regarding whether age-related differences in PM across the lifespan result

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from variation in the efficiency of the prospective or retrospective component of PM. Some investigators have argued that the development of executive control processes associated with the prospective component (e.g., strategic monitoring of the environment) represents the primary locus for improvement in PM between 7 and 12 years of age (Ceci et al., 1988; Kerns, 2000; Zimmermann & Meier, 2006). In contrast, Smith et al. (2010) provide evidence demonstrating that processes associated with the retrospective component may represent the critical factor in understanding the development of PM from childhood to young adulthood. Consistent with this view, Zöllig et al. (2007) found that the development of PM between adolescence and young adulthood reflected a reduction in both the number of confusion errors for PM cues and false alarms for PM lures. Both types of errors could be considered indices of the retrospective component, since for each the content of the intention (i.e., the intended action in confusions and the retrieval context in false alarms) does not appear to be remembered correctly (West & Craik, 1999, 2001; Zöllig et al., 2007). Alternatively, false alarms to PM lures could also result from inefficient executive control processes that give rise to impulsive PM responses before the appropriate response is retrieved from memory. Zöllig et al. (2007) also found non-significant differences in the number of prospective misses between adolescents and younger adults, indicating that the efficiency of the prospective component may be similar at these two points of development.

Work examining the nature of age-related differences in PM between younger and older adults also reveals inconsistencies across studies. Some evidence indicates that aging has a stronger effect on processes associated with the prospective component than the retrospective component of PM (Cohen, West, & Craik, 2001; Smith & Bayen, 2004; West & Craik, 2001). Furthermore, other evidence indicates that this effect may result from a decrease in the efficiency of preparatory attentional processes that facilitate the detection of PM cues in older adults (Smith & Bayen, 2004). In contrast, other findings reveal that aging can be associated with a decline in processes associated with the retrospective component of PM (Einstein et al., 1992; Zimmermann & Meier, 2006). As an example, Zöllig et al. (2007) reported an increase in PM confusion errors and false alarms to PM lures in older adults relative to younger adults. Both of these types of errors could be attributed to failures of the retrospective component of PM; although, as noted above false alarms to PM lures might also result from impulsive responses associated with inefficient executive control processes.

1.2. The ERP correlates of PM and development

Studies using event-related brain potentials (ERPs) to investigate the neural correlates of PM have revealed ERPs that are associated with the prospective and retrospective components of PM. The prospective component is associated with processes related to the detection of PM cues (N300), switching from the ongoing activity to the prospective response (frontal positivity), and configuration of the prospective task set (prospective positivity); and the retrospective component is associated with processes related to retrieval of an intention from memory (parietal old-new effect, for a review see West, 2011). These studies have also revealed sustained neural activity over the frontal and parietal regions of the scalp that are associated with strategic monitoring of the environment for a PM cue (West, 2007; West, McNerney, & Travers, 2007). The effects of development from adolescence to young adulthood on some of these ERP components have been examined in a study by Zöllig et al. (2007), and the effects of aging have also been considered in a small number of studies (West & Bowry, 2005; West & Covell, 2001; West, Herndon, & Covell, 2003; Zöllig et al., 2007).

The N300 reflects greater negativity for PM cues than ongoing activity trials over the occipital–parietal region of the scalp between 300 and 500 ms after stimulus onset (West, 2007; West, Herndon, & Crewdson, 2001). The amplitude of the N300 is greater for PM hits than for PM misses and ongoing activity trials, and may be similar for PM misses and ongoing activity trials (West, 2007; West & Krompinger, 2005; West & Ross-Munroe, 2002). These findings have led to the suggestion that the N300 is associated with the detection of an event-based PM cue in the environment. Evidence from three studies reveal that the amplitude of the N300 is attenuated in older adults (West & Bowry, 2005; West & Covell, 2001; West, Herndon et al., 2003). Some evidence indicates that the effect of age on the N300 may result from the reduction in the efficiency of executive processes that facilitate the detection of PM cues (West & Bowry, 2005); although, it is also possible that differential task-related recruitment in younger and older adults or greater within person variability in the timing of the ERPs between older than younger adults also contributes to this effect. In contrast, other data reveals that there may be relatively little effect of age upon the amplitude of the N300 from adolescence to later adulthood (Zöllig et al., 2007). The failure to find age-related differences in the amplitude of the N300 by Zöllig et al. (2007) appears to be related to differential neural recruitment early and later in life that may obscure developmental trends in the N300 when measures of mean voltage are considered.

The frontal positivity reflects greater positivity for PM cues than for ongoing activity trials over the midline frontal region of the scalp between 300 and 500 ms after stimulus onset (West, 2007, 2011). Like the N300, the frontal positivity distinguishes between PM hits and PM misses and ongoing activity trials (West, 2007). Based upon similarities between the frontal positivity and components of the ERPs related to task switching, some investigators have proposed that the frontal positivity is associated with an executive control process that supports switching between the ongoing and prospective elements of the task (Bisiacchi, Schiff, Ciccola, & Kliegel, 2009; West, 2011). The amplitude of the frontal positivity may be attenuated in older adults relative to younger adults (West, Herndon et al., 2003), and the effect of development from childhood to young adulthood on the frontal positivity has not been investigated.

Beginning around 400 ms after stimulus onset, PM cues are associated with a sustained positivity over the parietal region of the scalp relative to ongoing activity trials (West et al., 2001). The parietal positivity represents three distinct components of the ERPs. The P3b contributes to the parietal positivity (West & Wymbs, 2004). The influence of the P3b on the parietal positivity can be minimized by using PM cues that are perceptually similar to the ongoing activity stimuli (West, Wymbs, Jakubek, & Herndon, 2003). The recognition old-new effect also contributes to the parietal positivity and is associated with the retrieval of an intention from memory (i.e., the retrospective component of PM, West & Krompinger, 2005). The third component that contributes to the parietal positivity is the prospective positivity (West & Krompinger, 2005). The prospective positivity tends to emerge later than the P3b (West, Wymbs et al., 2003) or the old-new effect (West, 2007), and may be associated with an executive control process that supports configuration of the prospective task set (Bisiacchi et al., 2009; West, 2011). The amplitude of the parietal positivity decreases from adolescence to younger adulthood to later adulthood (West & Bowry, 2005; West & Covell, 2001; Zöllig et al., 2007). This finding indicates that there is age-related variation in the amplitude of ERP components that contribute to the parietal positivity. Based upon available evidence it is difficult to determine which of the three components contributes to age-related differences in the parietal positivity from childhood to young adulthood; in contrast, in older adults it appears that age-related reduction in the amplitude of the P3b (West & Covell, 2001) and prospective positivity (West & Bowry, 2005) contribute to the age-related effect on the parietal positivity.