Neuropsychologia 49 (2011) 2147–2155

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

The neuropsychology of prospective memory in normal aging: A componential approach

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ARTICLE INFO

Article history:
Received 2 August 2010
Received in revised form
30 November 2010
Accepted 14 December 2010
Available online 28 December 2010

Keywords:
Prospective memory
Aging
Prefrontal processes
Hippocampal processes

ABSTRACT

To guide understanding of the neuropsychology of prospective memory and aging, we highlight several components of prospective memory, including planning an intended action, retrieving the action at the appropriate moment, and executing the action. We posit that frontal systems are particularly important for prospective memory tasks that require planning, that require strategic monitoring to detect the appropriate moment for executing the prospective memory intention, or for which execution of the retrieved intention must be delayed briefly. Drawing from a variety of approaches, including neuroimaging (with young adults) and studies examining individual differences relating to frontal functioning, we assemble preliminary evidence that supports this hypothesis. Further, because aging especially disrupts frontal functioning, the above noted prospective memory tasks would thus be expected to display the greatest age-related decline. The available literature confirms this expectation. A second key hypothesis is that some prospective memory tasks—those requiring minimal planning and supporting spontaneous retrieval—do not rely extensively on frontal processes but instead rely on medial-temporal structures for reflexive retrieval. These prospective memory tasks tend to show minimal or no age-related decline. The literature, though sparse with regard to the neuropsychological underpinnings of this kind of prospective memory task, is consistent with the present hypothesis.

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Understanding the neuropsychology of prospective memory in normal aging hinges on an appreciation of a key behavioral finding in the literature on prospective memory and aging. In some situations, older adults display impaired prospective memory performance, whereas in other situations older adults show relatively small or no declines in prospective memory performance (see Kliegel, Jager, & Phillips, 2008, for a metaanalysis, and McDaniel & Einstein, 2007, for a review; see also West, 2005). In this paper we adopt a componential analysis of prospective memory that helps organize the above behavioral findings, and we apply that analysis to organize and leverage the nascent literature on the neuropsychological underpinnings of prospective memory in healthy older adults.

As many theorists have noted, prospective memory can involve several components that include planning an intended action, retrieving the action at the appropriate moment, and executing the action (e.g., see Dobbs & Reeves, 1996). Further, we assume that the processes involved in these components may rely differentially on several neuropsychological systems, most prominently prefrontal systems and medial temporal systems, as well as different areas within these systems (West, 2005). Importantly for understanding prospective memory in healthy aging, we suggest that the degree to which these components are challenged or involved in prospective memory can vary widely across different prospective memory situations, and accordingly, our review will focus on the particular neuropsychological systems that we believe are relied upon in different prospective memory tasks. Critically, because the literature suggests that aging may disproportionately penalize some relative to other of these neuropsychological systems, delineating the particular prospective memory situation is paramount to characterizing the neuropsychological underpinnings of both spared and impaired prospective memory in older adults.

More specifically, on the view that normal aging preferentially disrupts prefrontal systems (Raz et al., 1997; West, 1996; see Braver et al., 2001, for a review of converging evidence from neuroimaging and neurophysiological results), the hypothesis proposed by Glisky (1996) is that prospective memory will be impaired in healthy older adults to the degree that the prospective memory task is heavily dependent on frontally mediated processes. Glisky's formulation provided an initial sketch on the processes involved in prospective memory tasks that may rely more or less on frontal processes. In this article, we further develop the Glisky hypothesis by reviewing the

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doi:10.1016/j.neuropsychologia.2010.12.029

aging and neuropsychological literature through the lens of a more detailed characterization of prospective memory tasks and theoretical assumptions regarding the functions subserved by frontal and medial temporal (and other) systems in these tasks. Our approach will be an additive one, in which we first consider prospective memory tasks in which planning and execution components are minimally challenged, thereby isolating the retrieval processes involved in prospective memory. We then examine paradigms in which the execution component is demanding, and finally, examine situations in which the planning component is added.

1. Retrieval

Most of the laboratory prospective memory research has focused on event-based prospective memory. In event-based prospective memory, subjects are instructed to perform a particular action (e.g., press the F8 key) whenever they encounter a particular target event (e.g., the word *spaghetti*) during an ongoing activity. Under these typically simple prospective memory instructions, subjects need not form their own intention nor construct elaborate plans for executing the prospective memory task (as noted by Dobbs & Reeves, 1996). The major challenge for subjects is remembering the intended action at the appropriate moment, i.e., when the target event appears, and theoretical work in prospective memory has focused primarily on this remembering process. One current theory suggests that people can rely on (1) a spontaneous retrieval process, in which the occurrence of the target event spontaneously triggers retrieval of the intended action from long-term memory, or (2) a strategic monitoring process, in which the subject actively monitors the environment for the target event (McDaniel & Einstein, 2000). Further, characteristics of the prospective memory target event in conjunction with the demands of the ongoing activity will influence the degree to which strategic monitoring is required for prospective remembering as opposed to spontaneous retrieval.

Briefly, when the ongoing task encourages processing of the attributes of the target event that were processed during initial encoding (during the prospective memory instructions), then prospective remembering can be relatively spontaneous (for convenience and in keeping with the literature we will label this a *focal-cue* prospective task; for further details see Einstein & McDaniel, 2005). This view emanates in part from the encoding specificity principle, which proposes that retrieval is more likely when the features of the target that were processed at retrieval match those that were processed at encoding (Tulving, 1983). Another important facet of this idea is that the critical attributes of the target are somewhat *integral* to the information processed for the ongoing task. As an example, for an ongoing task in which pairs of words are presented in the middle of a computer monitor and subjects decide whether one word is a member of the category represented by the other word, specifying a particular word as a target event (*tortoise*) would be a focal prospective memory task. As an everyday example, you might form the intention to give your friends, who you are meeting later for dinner, the message that you have switched restaurants and now plan to meet at the new restaurant in town. As you form your intention, you assume that you will be encountering your friend Tom, thereby encoding his name and perhaps some of his facial features. When you later directly encounter Tom, your processing of these features encoded during intention formation is integral to your processing of Tom (i.e., saying his name and perceiving his facial features). In this situation, Tom serves as a focal cue.

By contrast, when the ongoing task does not require processing of the attributes of the target event, then prospective remembering is assumed to depend on monitoring of the environment for the target event (we label this a *nonfocal* task). For example, for the above category decision task, specifying a particular syllable as a target event (*tor*) would create a nonfocal prospective memory task. For the everyday example, after envisioning encountering Tom (as specified in the above paragraph), you might be wondering about the percentage of people who wear belts these days (perhaps you are on the dress-code committee), and accordingly as you pass people you are primarily attending to people's waists. In this case, the initially encoded features (of Tom) are unlikely to be extracted when you encounter him (because you would be noticing Tom's waist). In other words, the features encoded as part of the prospective memory intention are peripheral to those being extracted when you subsequently encounter the target event. Consequently the prospective remembering (to tell Tom about the change of restaurant) depends on a nonfocal cue. We acknowledge that this theoretical distinction may be most clear cut in the laboratory, where it is easier to infer and to control the overlap between the processing at prospective memory encoding and at retrieval. Also, it may be more apt to think of the distinction between focal and nonfocal tasks as reflecting a continuum, rather than as discrete categories (see Knight et al., in press).

With this theoretical groundwork in place, we can begin to specify the neuropsychological systems involved in various prospective remembering tasks. Theoretically, one proposed mechanism for spontaneous retrieval (see McDaniel, Guynn, Einstein, & Breneiser, 2004, for another mechanism) is that it is supported by a reflexive–associative memory subsystem that is linked to medial temporal structures such as the hippocampus (Moscovitch, 1994; see also Cohen & O'Reilly, 1996, for a similar idea). On the other hand, there is high agreement that strategic monitoring should be associated with frontal functioning (Burgess, Scott, & Frith, 2003; Reynolds, West, & Braver, 2009; Simons, Scholvinck, Gilbert, Frith, & Burgess, 2006). Accordingly, focal prospective memory tasks should be related to medial temporal processes, whereas nonfocal prospective memory tasks should be related to frontal processes. In the following sections we review neuroimaging evidence, behavioral work focused on individual differences related to the neuropsychological systems just mentioned, and neuropsychological studies that bear on these hypotheses; and we relate these findings to the age-related patterns in prospective memory. To align with the theoretical orientation adopted here, we consider nonfocal and focal prospective memory tasks in turn.

1.1. Neuropsychological processes in nonfocal prospective memory tasks

1.1.1. Frontal processes revealed by neuroimaging

As far as we know all of the published neuroimaging studies, with at most one exception, have used prospective memory tasks that could be considered to rely upon nonfocal cues. Though this work is limited to younger adults, we briefly consider it to provide initial glimpses of the neuropsychology of prospective memory. In Burgess et al. (2003) there were different domains of ongoing tasks (numbers, letters and pictures). In the number condition, a pair of numbers was presented on each trial, and subjects had to decide whether the higher number was on the left or the right (and then press the appropriate key). In the letter condition, subjects had to decide which of two letters came first in the alphabet. For the prospective memory task, subjects were instructed to try to remember to press both keys if two even numbers appeared on the trial (number ongoing task) or if two vowels appeared on the trial (letter ongoing task). Note that determining the parity of the numbers or the type of letters requires extracting information that was not required for the ongoing task, and thus these prospective memory cues would be classified as nonfocal. And, by our analysis, prospective remembering on this task should be highly dependent on monitoring processes.

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