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Short Communication

Episodic future thought: Contributions from working memory

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ABSTRACT

The ability to imagine hypothetical events in one's personal future is thought to involve a number of constituent cognitive processes. We investigated the extent to which individual differences in working memory capacity contribute to facets of episodic future thought. College students completed simple and complex measures of working memory and were cued to recall autobiographical memories and imagine future autobiographical events consisting of varying levels of specificity (i.e., ranging from generic to increasingly specific and detailed events). Consistent with previous findings, future thought was related to analogous measures of autobiographical memory, likely reflecting overlapping cognitive factors supporting both past and future thought. Additionally, after controlling for autobiographical memory, residual working memory variance independently predicted future episodic specificity. We suggest that when imagining future events, working memory contributes to the construction of a single, coherent, future event depiction, but not to the retrieval or elaboration of event details.

1. Introduction

Recent years have seen a growing theoretical and empirical interest in the ability to mentally simulate imagined future events, or *episodic future thought* (for reviews, see Schacter, Addis, Hassabis, Martin, Spreng, & Szpunar, 2012; Szpunar, 2010). Much like episodic memory, episodic future thought is believed to be a constructive process in which disparate pieces of information are retrieved from long-term memory and flexibly recombined into a coherent imagined event (Schacter & Addis, 2007a). Episodic memory and future thought are therefore often thought to serve as complementary functions at opposite ends of one's temporal narrative and are together viewed as comprising the broader faculty of *mental time travel* (Suddendorf & Corballis, 2007).

Converging evidence from a variety of research domains lends support for this view. For example, a number of clinical populations associated with impaired memory function have been observed to exhibit corresponding deficits in the ability to imagine the future, including amnesic (Hassabis, Kumaran, Vann, & Maguire, 2007; Klein, Loftus, & Kihlstrom, 2002; Tulving, 1985), suicidally depressed (Williams et al., 1996), autistic (Lind & Bowler, 2010), and schizophrenic populations (D'Argembeau, Raffard, & Van der Linden, 2008). Likewise, lifespan developmental patterns of memory functioning parallel the emergence (Busby & Suddendorf, 2005; Suddendorf & Busby, 2005) and decline (Addis, Wong, & Schacter, 2008) of future thought abilities. The phenomenological characteristics of past and future thought have also been reported to be constrained by similar factors, with positive and temporally close events being more richly recalled or imagined (D'Argembeau and Van der Linden, 2004). Furthermore, a number of brain imaging studies have demonstrated striking functional overlap in the neural regions underlying episodic memory and future thought, including prefrontal, medial temporal, and parietal cortices (Addis, Wong, & Schacter, 2007; Okuda et al., 2003; Spreng, Mar, & Kim, 2009; Szpunar, Watson, & McDermott, 2007).

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Although there are considerable similarities between autobiographical recall and future event construction, there are also some important differences. Unlike past episodic recall which requires reconstructing elements of a previously experienced event, future thought depends on a novel recombination of episodic details into a hypothetical event (Addis & Schacter, 2012; Addis et al., 2007). This requirement for novel recombination suggests that future event construction may involve additional cognitive and neural processes that are not as involved in autobiographical memory reconstruction.

For example, an early study by Addis et al. (2007) found that some brain regions were more active during future than past event construction. In particular, regions of the prefrontal cortex, including right frontopolar and left ventrolateral areas, and the right hippocampus were more active for future than past events during the event construction phase, when participants were forming a single plausible event (e.g., "Two weeks from now I will be standing in front of a classroom teaching the first class of the semester"). During the event elaboration phase, when participants were asked to elaborate on the event by providing as many episodic details as possible, there was considerably more overlap between the regions activated for past and future events. The additional involvement of both prefrontal and hippocampal regions in the construction of future events suggest that a combination of executive and memory binding functions may contribute to this novel constructive process. If this is the case, it points to a potential role for the working memory (WM) system in imagining future episodes, above and beyond the contributions provided by access to the autobiographical memory base.

The WM system may be broadly conceptualized as a workspace where information is temporarily held in an active state, such that it can be manipulated, integrated, or accessed in service of higher order cognitive thought. Although there are many theoretical conceptualizations of the WM system (e.g., Baddeley, 2000; Cowan, 1999; Engle, Tuholski, Laughlin, & Conway, 1999; Unsworth & Engle, 2007), each share the notion that maintaining information in an active state requires contributions from both long-term memory and executive processes, the same two processes that have been implicated in constructing future events. Perhaps the most well-known conceptualization of the WM system is Baddeley & Hitch's (1974) multiple component model and its more recent modifications (Baddeley, 2000; Baddeley, Allen, & Hitch, 2011). This model posits two domain-specific temporary stores, the visuo-spatial sketchpad and the phonological loop, that hold information taken in from the environment or retrieved from long-term memory. These stores have been joined in recent years by the episodic buffer, which is thought to store bound multimodal constructions kept in consciousness through interaction with the central executive.

The episodic buffer component of WM has previously been suggested to act as the "stage" on which episodic details are recombined into a hypothetical scenario (Schacter & Addis, 2007b; Suddendorf & Corballis, 2007). This is consistent with the idea that imagining the future involves combining information from multiple modalities, including past experiences, visualization processes (Szpunar, Chan, & McDermott, 2009; Szpunar et al., 2007), and semantic personal information (D'Argembeau & Mathy, 2011; Viard et al., 2011). In addition, the executive function (EF) subcomponent of the WM system has been linked to a number of other future oriented behaviors, such as prospective mind wandering (Baird, Smallwood, & Schooler, 2011; Smallwood, Nind, & O'Connor, 2009), autobiographical planning (Spreng, Stevens, Chamberlain, Gilmore, & Schacter, 2010) and future oriented decision making (Bickel, Yi, Landes, Hill, & Baxter, 2011). It might therefore be hypothesized that the WM system should be particularly involved with the construction of novel future events. This hypothesis, however, has not previously been directly tested.

Although not designed to look specifically at the relationship between WM and episodic future thought, two previous behavioral studies provide some support for this hypothesis. In one study (D'Argembeau, Ortoleva, Jumentier, & Van der Linden, 2010), young adults were administered a variety of neuropsychological tests, including one test of WM (Letter-Number Sequencing) and several tests of one subtype of EF, fluency (phonemic, semantic, and figural fluency). Participants' performance on a composite of the WM and EF measures was then used to predict performance on three different components of future event construction and elaboration: fluency (e.g., how many unique future events can a person generate in 1 min), specificity (e.g., whether a person can construct a unique potential future event, similar to the event construction phase in Addis et al. (2007)), and details (e.g., how many specific episodic details can a person produce about a possible future event, similar to the event elaboration phase in Addis et al. (2007)). The composite WM and EF factor was a consistent predictor of episodic future thought, particularly for specificity and details. Because the composite factor, however, was primarily composed of fluency tasks, it is difficult to determine whether WM capacity itself was involved in episodic future thought, or whether the correlations were driven primarily by performance on the fluency tasks.

In a second, smaller study of 17 older adults (Addis et al., 2008), measures of WM (Digit Span Backwards), relational memory (Verbal Paired Associates), phonemic fluency, and EF (Wisconsin Card Sort) were used to predict the number of episodic and semantic details produced during a task combining the event construction and elaboration phases. The number of episodic details produced for both past and future events was significantly correlated with both Verbal Paired Associates and Digit Span Backwards. Because the outcome measure in this study did not distinguish between different phases of future thought, however, it is unclear whether WM was related to the initial construction or subsequent elaboration of an event. Moreover, because of the small sample size and the fact that the WM/Future Thought correlation was only examined in older adults, the generalizability of this result is not clear.

Finally, in both the D'Argembeau et al. (2010) and Addis et al. (2008) studies, the measures involving WM appear to be slightly higher for the future measures than for the past, though this was not directly tested in either study. If constructing a novel future event requires greater WM resources than does re-constructing an experienced past event, then WM capacity should be a significant predictor of future event construction even after controlling for past event construction.