



## Retro- and prospection for mental time travel: Emergence of episodic remembering and mental rotation in 5- to 8-year old children<sup>☆</sup>

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### ABSTRACT

We investigate the common development of children's ability to "look back in time" (retrospection, episodic remembering) and to "look into the future" (prospection). Experiment 1 with 59 children 5 to 8.5 years old showed mental rotation, as a measure of prospection, explaining specific variance of free recall, as a measure of episodic remembering (retrospection) when controlled for cued recall. Experiment 2 with 31 children from 5 to 6.5 years measured episodic remembering with recall of visually experienced events (seeing which picture was placed inside a box) when controlling for recall of indirectly conveyed events (being informed about the pictures placed inside the box by showing the pictures on a monitor). Quite unexpectedly rotators were markedly worse on indirect items than non-rotators. We speculate that with the ability to rotate children switch from knowledge retrieval to episodic remembering, which maintains success for experienced events but has detrimental effects for indirect information.

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### 1. Introduction

We naturally speak of "looking back on past events" or "looking forward to the future." Clearly, we cannot literally look back or forward in time (Martin, 2001). We cannot see the future or the past in the same way as we see an event unfolding in front of us or behind us. The best we can do to capture past or future experiences of an event is to re-experience the event (retrospection), or imagine experiencing a future event (prospection).<sup>1</sup>

The ability to retrospect in this sense has become a central feature for episodic memory with Tulving's (1985) introduction of "autonoetic consciousness", namely the awareness that remembering consists of "calling back into consciousness a seemingly lost state that is then 'immediately recognized as something formerly experienced' (Ebbinghaus, 1885, p. 1)." Philosophers spoke of "experiential memory," at least since Locke (Owens, 1996). Although the different terms all capture the phenomenon adequately, and "retrospection" does so in nice juxtaposition to "prospection," we prefer "episodic remembering" as our standard term. The choice of "remembering", rather than "memory" is to emphasise that it is more than just

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<sup>1</sup> In response to an anonymous reviewer we need to point out that the precise form of how the future is addressed in different prospection studies varies. Sometimes it is a concern about a specific future event (e.g., on the way to the puzzle room I have to think taking the needed implement with me; Suddendorf & Nielsen, 2009) but sometimes a timeless assumption suffices that one can treat as placed in the future (e.g., When(-ever) I go to a hibernal resort (tomorrow) I will take my coat and not the swimsuit; Atance & Meltzoff, 2005). In both cases the events one imagines experiencing (into which one projects oneself) are imagined possibilities (i.e., although one intends to do the puzzle, it is not a fact that one will) in contrast to retrospection, where one re-experiences (projects oneself into) a past event that has actually taken place. By precedent and due to this commonality we keep using the term "prospection" for experiencing imagined events in contrast to retrospection for re-experiencing actual events.

retrieval of knowledge about a past episode. It is a re-experiencing of that episode. This distinction is also brought out by the notion of “mental time travel” (MTT: Suddendorf & Corballis, 1997; Wheeler, Stuss, & Tulving, 1997): one has to not just retrieve information about the past or think about the likely future. It requires projecting oneself as an experiencing agent into the past or future. This distinction is also akin to the difference between having a theory of mind (Churchland, 1984; Gopnik & Astington, 1988) as opposed to simulating one’s own (or other people’s) mental processes (Goldman, 2006; Gordon, 1986; Heal, 1986).

There is the strong and widespread, but not uncontested, intuition that these three abilities, theory of mind, episodic remembering, and prospection belong together. They may be uniquely human abilities (Gilbert & Wilson, 2007; Roberts, 2002; Roberts et al., 2008; Suddendorf & Busby, 2003; Suddendorf & Corballis, 1997, 2007; Wheeler et al., 1997). There is now also fast growing empirical evidence from different quarters that episodic remembering (often investigated under the label or as part of autobiographical memory), prospection, and theory of mind share a developmental schedule, and common neural substrate as shown in coactivation patterns and in common deficits in clinical cases.

### 1.1. Brain imaging

Spreng, Mar, and Kim (2008) meta-analyzed, among other areas, all available brain imaging studies on theory of mind ( $n = 30$ , as a random selection of 50), autobiographical memory ( $n = 19$ ), and prospection ( $n = 6$ ). Direct overlap was observed in the medial temporal lobe (left parahypocampal gyrus: BA 36), medial parietal regions (precuneus, posterior cingulate, bilaterally: BA 31), left temporo-parietal junction (BA 39, touching on BA 19), medial prefrontal cortex (frontal pole: BA 10). Convergence within same Brodmann areas were also observed in right TPJ, left ventrolateral prefrontal cortex (BA 47), medial prefrontal cortex, and rostral anterior cingulate (BA 32), and lateral temporal lobe (BA 21, 22) especially left. All these regions tend to also be activated by navigation problems and default processing (areas that tend to be more strongly activated in the absence than in the presence of external stimulation). Two theories have been proposed as to the common denominator underlying these common activations. Hassabis and Maguire (2007) suggested that all these tasks require scene-construction and Buckner and Carroll (2007) that they all require projection of self into different time points or spatial locations.

### 1.2. Brain injury

Patients without auto-noetic consciousness in Tulving’s sense, i.e., amnesics with a special impairment of episodic remembering and autobiographical memory, have been reported to also have severe deficits of prospection, Patients K.C. (Tulving, 1985), R. (Stuss, 1991), M.L. (Levine et al., 1998), and D.B. (Klein, Loftus, & Kihlstrom, 2002). Loss of auto-noetic consciousness does, however, not lead inevitably to an impairment in theory of mind (patients K.C. and M.L.: Rosenbaum, Stuss, Levine, & Tulving, 2007). This finding does not preclude theory of mind being necessary for auto-noetic consciousness and episodic remembering, in particular, it may be crucial as a developmental requirement or linkage. In fact, there is growing evidence that theory of mind development around 4 and 5 years is linked to both, episodic remembering as well as prospection.

### 1.3. Development

There are studies showing a specific relationship between advances in theory of mind and free recall as a measure of episodic remembering in relation to cued recall (Tulving, 1985). Perner and Ruffman (1995) were able to show that between 3 and 5 years, children’s improvement on free recall correlates significantly with their understanding of how knowledge depends on experience. Even when cued recall and verbal intelligence were partialled out, correlations stayed above .30. Tasks used included children’s ability to explain why they know the contents of a box (How-do-you-know test: Wimmer, Hogrefe, & Perner, 1988a; Wimmer, Hogrefe, & Sodian, 1988b), to distinguish a lucky guess from proper knowledge (Miscione, Marvin, O’Brien, & Greenberg, 1978), and to understand which sense modality to use to find out about colour or weight of an object (O’Neill et al., 1992). These results were largely replicated by Naito (2003) on a Japanese sample. She also found a relationship between free recall and children’s ability to understand when they had learned a fact (Taylor, Esbensen, & Bennett, 1994).

Perner, Kloof, and Gornik (2007) used a different measure of episodic remembering. They contrasted recall of *experienced* events with recall of *indirectly conveyed* events. In the experience condition children put cards with drawings of simple objects into a box. In the indirect-information condition they were blindfolded and so could not see which cards they put inside. They were afterwards shown on a monitor the pictures that were on these cards (information about individual cards was thus indirectly conveyed). The reasoning was that children can have an episodic memory of putting a particular card inside the box only when they experienced putting that card into the box. Only with this experience can they later re-experience their action. When blindfolded, they cannot experience which card they had put inside. When later shown what was on these cards, they can only infer that they put that card inside the box. Hence there is no experience of putting that card inside, which they could re-experience. Free recall of experienced events correlated with performance on various theory of mind tasks (How-do-you-know, When-did-you-learn, and the modality-specificity test). Sprung (2008) and Sprung and Harris (2009) found that theory of mind abilities (especially introspective understanding) modulates children’s ability to report

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