CORTEX 63 (2015) 271–281

Available online at www.sciencedirect.com

ScienceDirect

Journal homepage: www.elsevier.com/locate/cortex

Research report

Sharing mental simulations and stories: Hippocampal contributions to discourse integration

Elizabeth Race [a,*], *Margaret M. Keane* [a,b] *and Mieke Verfaellie* [a]

[a] *Memory Disorders Research Center, VA Boston Healthcare System and Boston University School of Medicine, Boston, MA, USA*

[b] *Department of Psychology, Wellesley College, Wellesley, MA, USA*

ARTICLE INFO

Article history:
Received 21 April 2014
Reviewed 17 June 2014
Revised 7 August 2014
Accepted 4 September 2014
Action editor Asaf Gilboa
Published online 19 September 2014

Keywords:
Amnesia
Hippocampus
Binding
Language
Memory

ABSTRACT

Accumulating evidence suggests that mental simulation of the future and past relies on common processes supported by the hippocampus. However, it is currently unknown whether the hippocampus also supports the ability to share these mental simulations with others. Recently, it has been proposed that language and language-related structures in the brain are particularly important for communicating information not tied to the immediate environment, and indeed specifically evolved so that humans could share their mental time travels into the future and the past with others. The current study investigated whether processes supported by the hippocampus are necessary for effectively communicating the contents of one's mental simulations by examining the discourse of amnesic patients with medial temporal lobe damage. In Experiment 1 we tested whether patients can produce integrated discourse about future and past events by measuring lower-level discourse cohesion and higher-level discourse coherence. Striking reductions in both measures were observed in amnesic patients' narratives about novel future events and experienced past events. To investigate whether these deficits simply reflected concurrent reductions in narrative content, in Experiment 2 we examined the status of discourse integration in patients' verbal narratives about pictures, which contained an equivalent amount of narrative content as controls'. Discourse cohesion and coherence deficits were also present when patients generated narratives based on pictures, and these deficits did not depend on the presence of neural damage outside the hippocampus. Together, these results reveal a pervasive linguistic integration deficit in amnesia that is not limited to discourse about the past or the future and is not simply secondary to reductions in narrative content. More broadly, this study demonstrates that the hippocampus supports the integration of individual narrative elements into coherent and cohesive discourse when constructing complex verbal accounts, and plays a critical role in the effective communication of information to others.

* *Corresponding author*. Memory Disorders Research Center, Boston VA Healthcare System and Boston University School of Medicine, 150 S. Huntington Avenue (151-A), Boston, MA 02130, USA.
E-mail address: race@bu.edu (E. Race).

http://dx.doi.org/10.1016/j.cortex.2014.09.004
0010-9452/

1. Introduction

The ability to mentally project into the future and past supports a range of adaptive behaviors and allows us to build predictions and plans for the future based on prior experience. Recent evidence suggests that mental simulation of the future is compromised in medial temporal lobe amnesia. Specifically, amnesic patients with adult-onset hippocampal damage have difficulty not only projecting back in time to mentally simulate the past (retrospection), but also projecting forward in time to mentally simulate novel and specific future scenarios (prospection) (Andelman, Hoofien, Goldberg, Aizenstein, & Neufeld, 2010; Hassabis, Kumaran, Vann, & Maguire, 2007; Klein, Loftus, & Kihlstrom, 2002; Race, Keane, & Verfaellie, 2011; Race, Keane, & Verfaellie, 2013; Tulving, 1985). Interestingly, patients' impairments in retrospection and prospection are strongly positively correlated (Race et al., 2011), suggesting that common hippocampal mechanisms support both functions. Candidate hippocampal mechanisms include the retrieval and recombination of mnemonic details and the integration of these details into coherent mental representations (Addis & Schacter, 2011; Hassabis & Maguire, 2007; Schacter & Addis, 2009).

While mental simulation of the future and past has been closely linked to hippocampal function, it is currently unknown whether the hippocampus also supports the *communication* of these mental simulations. The ability to effectively communicate one's mental simulations of the future and past confers important adaptive advantages, enabling experiences, plans, and ideas to be shared so that others may benefit (Corballis, 2009, 2013). Recently, it has been proposed that language and language-related structures in the brain are particularly important for communicating information not tied to the immediate environment, and indeed evolved so that humans could share their mental time travels into the future and the past with others (Corballis, 2009, 2013; Gardenfors, 2004; Suddendorf, Addis, & Corballis, 2009). Specifically, Corballis (2009) has argued that events in the present are shared by mutual experience and can be communicated through simple signals that direct attention or convey the importance of visible referents. In contrast, conveying information about the past and future requires symbolic linguistic elements and the combination of these elements into integrated discourse units that can be easily understood (Corballis, 2009). The link between language and mental simulation, and their co-evolution in humans, has been related to the development of brain regions such as the hippocampus that allow events to be situated in different points in time (Suddendorf et al., 2009). However, many aspects of language production are intact following hippocampal damage (Kensinger, Ullman, & Corkin, 2001; Milner, Corkin, & Teuber, 1968; Race et al., 2011; Skotko, Andrews, & Einstein, 2005) and it is currently unknown whether functions supported by the hippocampus are particularly important for creating integrated discourse about the past and future.

Preliminary evidence supporting the role of the hippocampus in discourse integration comes from a handful of prior studies that have investigated whether amnesic patients with medial temporal lobe damage can construct integrated verbal narratives about the past. Discourse cohesion and coherence are two linguistic measures that have been investigated, and serve to index lower-level and higher-level aspects of narrative integration, respectively. Discourse cohesion is a measure of the connection of individual narrative elements using linguistic devices (e.g., grammatical and lexical links), whereas discourse coherence is a measure of the overall continuity and organization of the narrative into a unified, integrated whole (Caspari & Parkinson, 2000; Louwerse & Graesser, 2005). MacKay, Burke, and Stewart (1998) were the first to suggest that the hippocampus may play an important role in creating coherent discourse about the past (MacKay et al., 1998). They found that the amnesic patient H.M. produced verbal narratives about childhood events (as well as verbal narratives about ambiguous sentences) that were less coherent and less focused compared to the narratives produced by controls. Based on these results, MacKay and colleagues proposed that the hippocampus supports discourse-level integration through its role in linguistic binding (MacKay et al., 1998; MacKay, James, Hadley, & Fogler, 2011; MacKay, James, Taylor, & Marian, 2007). Specifically, they proposed that the same hippocampal binding processes that support episodic memory also enable the rapid formation of new connections between disparate lexical, semantic, or phonological representations during verbal discourse. Congruent with this hypothesis, recent neuroimaging evidence suggests that the hippocampus plays a role in syntactic integration during language comprehension (Meyer et al., 2005) and discourse-level semantic integration of pictures (West & Holcomb, 2002). It has also been suggested that the hippocampus plays a role in linking sentence information across event boundaries in the service of memory (DuBrow & Davachi, 2013; Ezzyat & Davachi, 2011; Swallow et al., 2011).

While these results support the hypothesis that the hippocampus enables the integration of individual narrative elements into cohesive and coherent discourse when describing the past, prior results have not always been consistent across studies. In particular, Caspari and Parkinson (2000) found evidence for cohesion reductions in the autobiographical discourse of the amnesic patient M.R., but did not find evidence for reductions in M.R.'s discourse coherence. More recently, Kurczek and Duff (2011) found suggestive evidence for impairments in both discourse cohesion and discourse coherence in amnesic patients' narratives about the past, but these impairments did not reach significance. Thus, important questions remain about the presence and nature of discourse-level integration impairments in amnesia and whether processes supported by the hippocampus are particularly critical for creating cohesive and coherent discourse about the past.

In addition, it is currently unknown whether hippocampal damage impacts amnesic patients' ability to create cohesive and coherent discourse about the future. Describing novel future events that have yet to occur places high demands on combinatorial processes to form new linguistic connections and to integrate elements from past experience in new and creative ways (Schacter & Addis, 2009). Hippocampal binding processes have been proposed to be particularly critical when creating new linguistic connections that do not have pre-existing internal representations that can be automatically