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A LORETA study of mental time travel: Similar and distinct electrophysiological correlates of re-experiencing past events and pre-experiencing future events

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ABSTRACT

Previous studies exploring mental time travel paradigms with functional neuroimaging techniques have uncovered both common and distinct neural correlates of re-experiencing past events or pre-experiencing future events. A gap in the mental time travel literature exists, as paradigms have not explored the affective component of re-experiencing past episodic events; this study explored this sparsely researched area. The present study employed standardized low resolution electromagnetic tomography (sLORETA) to identify electrophysiological correlates of re-experience affect-laden and non-affective past events, as well as pre-experiencing a future anticipated event. Our results confirm previous research and are also novel in that we illustrate common and distinct electrophysiological correlates of re-experiencing affective episodic events. Furthermore, research from this experiment yields results outlining a pattern of activation in the frontal and temporal regions is correlated with the time frame of past or future events subjects imagined.

1. Introduction

Previous research on mental time travel into the past and imagining the future has yielded very interesting results; however, an exploration of ecphory of affect-laden past events is not well covered in the mental time travel literature. Few studies explicitly focus on positive and negative affective past events. Furthermore, although some studies provide a specific temporal focus for subjects to mentally time travel to, few studies have attempted to allow subjects to mentally time travel to an event without temporal restrictions. We were also interested in determining quantitative electroencephalographic (EEG) spectral power that is associated with a temporal frame of remembering the past and imagining the future to provide insight into how the brain processes events within a temporal sequence. Thus, the rationale for this study was to determine intracerebral source generators for when an affect-laden past event (either positive or negative) is remembered and when a future event is imagined, as well to explore associations between spectral power and the time frame in which events were imagined.

It has been debated that the ability to mentally represent oneself throughout space and time is an attribute or characteristic unique to humans (Suddendorf & Corballis, 1997). This ability has been coined "mental time travel" and reflects the humans' capacity to re-experience or relive previous events or situations in their personal past, as well as pre-experience future anticipated events through imagination (Wheeler, Stuss, & Tulving, 1997). The ability to pre-experience events has

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been termed "episodic future thinking" and reflects the ability to project one's self forward in time (Atance & O'Neill, 2001). It has been proposed that the ability to mentally time travel is a function of the episodic memory system of the brain, where episodic memory represents the individuals' personal experiences and is linked to particular autobiographical events in one's personal past, which are spatially and temporally located (Tulving, 1972, 1983).

Although autobiographical memory, by definition, contains episodic memories relevant to ones' past, the constructive episodic simulation hypothesis argues that a critical function of autobiographical memory includes the ability to imagine possible future events (Addis, Wong, & Schacter, 2007; Schacter & Addis, 2007). The ability to generate elaborations on future plans may be an adaptive function, as suggested by Suddendorf & Busby (2005), in that the ability to remember events evolved from the need to generate actions for the future.

Recent research from developmental fields has demonstrated a link between episodic memory (i.e. autobiographical past) and episodic future thinking. Research from developmental studies has identified that episodic memory formation and episodic future thinking (i.e. mental time travel abilities) emerges at approximately 3–4 years of age (Suddendorf & Busby, 2005), although the causal factors are not well known, parental talk and the role of language may play an important factor in the emergence of these abilities (Atance & O'Neill, 2005). These studies demonstrate that there is some fundamental link between episodic memory and imagining future events.

Qualitatively different memory subsystems may differ in the type of conscious awareness that is necessary for its operation, because according to Tulving (1985), different types of memory systems are linked to different levels of knowing or awareness and their associated representation of the "self". For example, non-declarative memory is anoetic (i.e. non-knowing), semantic memory is noetic, where "knowing" or awareness is a requirement; however, autonoetic (self-knowing) consciousness is necessary for episodic memory. Autonoetic consciousness is the capacity that provides adults the ability to mentally represent and become aware of their existence across time (Tulving, 1985; Wheeler et al., 1997). This provides humans the possibility to apprehend subjective experiences throughout time and to perceive the present moment as both a continuation of the past and prelude to one's future.

Tulving used the term "ecphory" to describe the automatic retrieval process when a specific cue interacts with information previously stored in memory, whereby the retrieval cue reactivates and recovers the stored information (1983). Previous studies have identified both common and distinct neural correlates of remembering or ecphorizing the past and pre-experiencing the future with various neuroimaging techniques (Addis et al., 2007; Botzung, Denkova, & Manning, 2008). It has been speculated that these abilities, which share common neural associations, rely on a common set of processes whereby past experiences are utilized adaptively to envision future events or perspectives (Buckner & Carroll, 2007; Quoidbach, Hansenne, & Mottet, 2008).

The purpose of the present study was to demonstrate the electrophysiological correlates of ecphory of autobiographical material. To evaluate the episodic system, subjects were to think back to a specific moment in their personal subjective past to consciously recollect a personally experienced episode or event (Wheeler et al., 1997). In addition to this, we were also interested in the electrophysiological activation associated with mentally projecting oneself into the future via "mental time travel." Since there is a gap in the literature on studies researching affect-laden past events, this study will also cover positive and negative affective past experiences. Furthermore, since cognitive processes such as emotional processing serve to maintain accurate information about ones' environment by highlighting events of significance (Pollak, Cicchetti, Klorman, & Brumaghim, 1997), it would be prudent to identify the cortical structures that are involved in the recreation or imagination of these emotional events. This study is novel in that it combines imagination of future events and ecphory of past events (affective and non-affective), where affect-laden past events have not been well-researched in the mental time travel literature. Furthermore, to the authors' knowledge, the literature does not outline quantitative EEG correlates between regional (lobe/hemisphere) electrical activity and the time frame in which both past and future events are imagined.

2. Materials and methods

2.1. Participants

Ten volunteers were recruited for participation in the study; however, only nine subjects' records were utilized for analysis as one EEG record had to be discarded due to artifact. Nine subjects were utilized for analysis (six males, mean age = 23.7 range 22–31; three females, mean age = 21.3, range 20–22). Subjects were undergraduate students in psychology at Laurentian University. All subjects were right handed and subjects had no known illnesses/diseases that would affect their EEG record or ability to imagine future events or recall past events. Subjects were informed about the nature of the procedure as they had to prepare (prior to the EEG session) a brief write-up of the events they would think about during the experimental procedure. Written informed consent was obtained from all subjects and the ethics protocol for the experiment was approved through Laurentian University's Research Ethics Board.

2.2. Tasks and experimental design

Participants were instructed to write a paragraph on each of the following events: a future upcoming event that they had planned, a non-affect laden event in their personal past, the happiest moment in their past, as well as the saddest moment