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Frontotemporal function]al connectivity and executive functions contribute to episodic memory performance

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ABSTRACT

The contributions of hemispheric-specific electrophysiology (electroencephalogram or EEG) and independent executive functions (inhibitory control, working memory, cognitive flexibility) to episodic memory performance were examined using abstract paintings. Right hemisphere frontotemporal functional connectivity during encoding and retrieval, measured via EEG alpha coherence, statistically predicted performance on recency but not recognition judgments for the abstract paintings. Theta coherence, however, did not predict performance. Likewise, cognitive flexibility statistically predicted performance on recency judgments, but not recognition. These findings suggest that recognition and recency operate via separate electrophysiological and executive mechanisms.

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1. Introduction

Explicit memory requires conscious awareness of information processing (Schacter, 1987; Schacter and Graf, 1986) and interacts with many other cognitive processes, such as executive functions, to facilitate encoding and retrieval (Mazoyer et al., 2001). Explicit memory is typically associated with activation within the medial temporal lobe and the prefrontal cortex (Dolan and Flectcher, 1997; Lepage et al., 2000; Shallice et al., 1994). A general understanding of how these brain regions contribute to explicit memory performance is known. However, it is important to examine the functional connectivity (e.g., coherence) of frontal and temporal regions during various explicit memory tasks (e.g. episodic memory) in order to better understand the neural networks involved in explicit memory. Additionally, examining cognitive processes related to explicit memory may allow for a more comprehensive picture of how explicit memory operates. Research does not exist exploring both the electrophysiological and individual executive function contributors to explicit memory.

In the current study, we recorded electroencephalogram (EEG) measures of frontotemporal coherence during an episodic memory task, broken into the components of recency and recognition. We also collected measures of individual EF processes. In the following sections we describe what is known about episodic memory processes, the neural mechanisms of episodic memory, and the relations between EFs and episodic memory.

1.1. Recency and recognition

Episodic memory is a form of explicit memory and allows for the conscious recollection of past events (Moscovitch et al., 2006; Tulving, 2002). Episodic memory operates via encoding and retrieval processes, and can be measured using recognition tasks (Diana et al., 2007; Haist et al., 1992; Yotsumoto et al., 2008). Recognition is the ability to determine if a currently presented item had been encountered previously (Yonelinas, 2002). Two processes can drive recognition: familiarity and recollection. The type of information that is retrieved to support recognition differentiates these processes. Familiarity relies exclusively on the strength of the item being recognized without awareness of additional information. Recollection indicates retrieval of contextual information that was associated with an item during encoding (Yonelinas, 2002). Recognition tasks are more difficult when context information must be retrieved in addition to item information (Brown et al., 2009; Milner et al., 1991). Relative recency judgments are a form of recognition task in which retrieval of temporal order information, a context detail (Riggins et al., 2008) may drive performance. Therefore we might

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expect that recency judgments rely more heavily on the recollection process than do recognition judgments.

1.2. Brain processes

Prefrontal and temporal interactions have been supported by empirical evidence (Simon and Spiers, 2003). Specifically, studies have found co-activation of these brain areas during memory tasks (e.g. McIntosh et al., 1997). Furthermore, activation of prefrontal and temporal regions during encoding statistically predicts success during retrieval (e.g., Menon et al., 2005). EEG can be used to quantify coupled neural activity and, thus, provide a measure of functional connectivity between prefrontal and temporal areas during cognition. The particular measure that can be used for this purpose is EEG coherence, which is the frequency-dependent squared cross-correlation of electrical signals between two scalp electrode sites (Nunez, 1981; Thatcher et al., 1986). If the EEG activity at two electrodes is synchronized, then coherence values approach 1; and if there is no synchronization, then coherence values approach 0. Theoretically, lower and higher levels of coherence reflect differentiation and integration of function between two brain areas, respectively (Thatcher et al., 2008). Unlike EEG power values, EEG coherence is not affected by arousal, opening or closing of eyes, or changes in state (Thatcher, 1994).

Frontotemporal hemispheric differences have been found in relation to memory encoding and retrieval. The left hemisphere is usually biased toward local features of stimuli, while the right hemisphere is biased toward more global features (Mevorach et al., 2005). Abstract images require global processing because local (smaller) forms are not obvious, suggesting that abstract images would elicit more activation from right when compared to the left hemisphere. Visuo-spatial memory is predominantly active within the right hemisphere of the medial temporal lobe, providing further support that the right hemisphere would be active during encoding and retrieval of abstract images (Smith and Milner, 1981). The difficulty of forming verbal labels to abstract images would also support this claim, given research supporting left hemisphere's role in language (Vigneau et al., 2006; Smith et al., 1996).

Although correlated with memory recognition, we propose that the measure of recency is separate. Recency requires retrieval of contextual information making it more reliant on recollection processes rather than familiarity (Yonelinas, 2002). Brain activity may distinguish the processes such that recency involves higher activation in the PFC than recognition, which may be indicative of higher cognitive processing demands (Tendolkar and Rugg, 1998). Furthermore, during fMRI studies, activation necessary for difficult temporal order decisions involve the bilateral middle lateral prefrontal areas, left inferior lateral prefrontal area and left anterior prefrontal area, as well as bilateral medial temporal areas (Konishi et al., 2002). This activation was above that of less taxing recognition judgments. We expected frontotemporal coherence differences between recollection and familiarity task performance.

1.3. Executive functions

EFs are a set of higher order cognitive control processes typically divided into three components: updating (working memory), inhibitory control, and cognitive flexibility (attention shifting; Miyake and Friedman, 2013). Working memory is often defined as the active process of updating and manipulating information (Miyake and Shah, 1999); inhibitory control is the suppression of a prepotent response in favor of another less dominant response; and cognitive flexibility is the ability to switch attention between tasks or mental sets (Miyake and Friedman, 2013). The literature focusing on EFs has suggested that, although interactions occur between the processes, they are separate mechanisms (Miyake et al., 2000). Rehearsal within working memory is crucial for the encoding and later retrieval process (Gallo and Wheeler, 2013), whereas the ability to suppress interference during retrieval is often associated with inhibitory control processes (Levy and Anderson, 2002). Considering that performance on the Wisconsin Card Sort Task has been related to episodic memory in adults, one would deduce that cognitive flexibility (an EF typified by the card sort task) is also a contributor to memory flexibility and thus encoding and retrieval (McCabe et al., 2010).

Recollection performance appears to be more reliant on EFs than familiarity-based processes (Bugaiska et al., 2007). Bugaiska and colleagues found that aging populations displayed deficits in recollection, but not familiarity, performance. Furthermore, the recollection deficits were predicted by EF ability. This suggests that recollection performance is reliant on EF ability, whereas familiarity is not. These findings led us to conclude that pure recognition performance would be less reliant on EFs than recency, since recency should elicit recollection whereas recognition, without reliance on contextual binding, should elicit familiarity (Yonelinas, 2002). This conclusion was drawn because recency tends to be more reliant on recollection processes while pure recognition tends to be more reliant on familiarity.

1.4. Overview of current study

The association between episodic memory and EF has typically been examined with composite measures of EF. We examined the individual components of EF, in an attempt to tease apart specific EF contributions to recency and recognition performance. We also investigated electrophysiological contributions to recency and recognition memory, with particular focus on frontotemporal coherence. We used abstract paintings as stimuli and examined EEG coherence during encoding and retrieval. Coherence was examined within both theta (4–7) and alpha (8–13) bands, based on research implementing these bands in memory processes (Nyhus and Curran, 2010; Klimesch, 1999). Finally, we included the EF and EEG coherence contributors in the same regression analyses in order to examine the unique contributions of EFs and frontotemporal coherence to recency and recognition performance. Our study focused on three questions: (a) Will electrophysiological differences exist when comparing recency and recognition performance? We hypothesized that frontotemporal coherence within both theta and alpha bands would be greater during recency than recognition performance. (b) Will individual executive functions display different prediction patterns for recency and recognition performance? We hypothesized that EFs would be associated with recency but not recognition performance. (c) Will electrophysiological and executive functions display unique contributions to recency and recognition performance? We hypothesized that both EFs and electrophysiology would contribute unique variance to recency performance. The inclusion of EFs and electrophysiology (frontotemporal EEG coherence) is a unique approach that will allow for a more holistic understanding of the processes associated with recency and recognition. Answering these questions will broaden our understanding of the differences between recognition and recency aspects of episodic memory.

2. Method

2.1. Participants

Our sample included 108 women ranging in age from 18 to 49 years ($M = 32.4$, $SD = 6.1$). Two-thirds of the women participated in our laboratory in a small urban area, after being recruited through community agencies and advertisements (e.g., flyers distributed in schools and common areas in the community, university website and email announcements) for a study focused on mothers' parenting of young children. The other third of the sample was from a cohort of families from an ongoing longitudinal community study, who participated in a visit to our rural university laboratory.

The sample was representative of our Appalachian region, according to US Census data. The participants were predominantly Caucasian

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