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Lateralized differences in tympanic membrane temperature, but not induced mood, are related to episodic memory

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ABSTRACT

The present research examined the effects of pre-encoding and pre-recall induced mood on episodic memory. It was hypothesized that happy and/or angry mood prior to encoding (increasing left hemisphere activity), in tandem with fearful mood prior to recall (increasing right hemisphere activity) would be associated with superior episodic memory. It was also hypothesized that tympanic membrane measures (TMT), indicative of hemispheric activity, would change as a function of induced mood. Although subjectively-experienced mood induction was successful, pre-encoding and pre-recall mood did not alter memory, and only altered TMT in the pre-encoding fear and pre-recall angry mood induction conditions. Interestingly, baseline absolute difference between left and right TMT, a measure of differential hemispheric activity, regardless of the direction of that activity, was significantly positively related to number of total words written, number of correctly recalled words, and corrected recall score. This same TMT measure pre-encoding, regardless of specific mood, was significantly negatively related to false recall. Results are discussed in terms the HERA model of episodic memory, and in the nature of inter-hemispheric interaction involved in episodic recall.

1. Introduction

The left and right frontal lobes are differentially involved in the experiencing of emotional/motivational state, with increased left hemisphere activity associated with positive/approach emotion/motivation, such as happiness, and increased right hemisphere activity associated with negative/withdrawal emotion/motivation, such as fear (e.g.; Davidson, 2002, 2004; Tomarken, Davidson, Wheeler, & Doss, 1992). Although there are other theoretical accounts of hemispheric lateralization of emotion/motivational state [see Shobe, 2014, for example and for review], examination and detailed discussion of these other accounts is beyond the scope of this manuscript. Instead, the current research assumes left hemisphere-happiness and right-hemisphere anxiety cortical lateralization, a conception that is well supported by other work (see Davidson, 2004; Urry et al., 2004). There is controversy regarding lateralization of anger, with some suggestion that anger is a left hemisphere approach emotion (Carver & Harmon-Jones, 2009) while other work indicating it is a right hemisphere, withdrawal state (Zinner, Brodish, Devine, & Harmon-Jones, 2008). Given this controversy, anger is also investigated here, and it is hoped that the current work could help to illuminate the lateralization of anger.

Interestingly, increased neuronal activity within one versus the other hemisphere results in a biasing of information processing, such that the more active hemisphere's mode of 'experiencing' dominates the processing of incoming information (e.g.: Goldstein, Revivo, Kreitler, & Metuki, 2010; Harmon-Jones, 2006; Propper, Christman, Brunyé, & Januszewski, 2013; Propper, McGraw, Brunyé, & Weiss, 2013; Propper, Brunyé, Christman, & Januszewski, 2012; Spielberg et al., 2011; Seta, McCormick, Gallagher, McElroy, & Seta, 2010). For example, increased performance on the Remote Associates Test (RAT) was found after left hand contractions, presumed to have activated global processing mechanisms in the right hemisphere, compared to following right hand contractions (Goldstein et al., 2010). Specifically, the RAT, considered a measure of convergent creativity, requires participants to find the commonality between three word roots. For example, individuals may be presented with the word trio of 'falling', 'actor' and 'dust', with the correct response being 'star'. Superior performance following left, but not right, hand contractions was suggested to be the result of an increased right hemisphere

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neural activation, resulting in an increased spread of activation and superior creativity (Goldstein et al., 2010).

Similarly, other research has also demonstrated that sustained unilateral motor activity increases hemispheric activation in the contralateral hemisphere, and that this increased activation is associated with increases in lateralized cognitive processes. For example, Schiffer et al. (2004), using fMRI, reported increased activity in the dorsolateral prefrontal cortex contralaterally to side of sustained unilateral gaze. In support of the notion that such sustained unilateral movements alter not only brain activity, but cognition as well, Propper et al. (2012), using methodologies for gaze identical to that of Schiffer et al. (2004), reported changes in semantic memory abilities as a function of sustained unilateral gaze. Presumably these changes in semantic memory were the result of alteration in hemispheric activity in (at least) dorsolateral prefrontal cortex, as a function of side of gaze.

Work has also demonstrated that activity designed to increase lateralized hemispheric activation is associated with changes in affective state. For example, right hand clenching (left hemisphere activation) versus left hand clenching (right hemisphere activation) resulted in increased approach (e.g.: happiness, anger) versus withdrawal (e.g.: sadness, anxiety) emotional states, respectively (e.g.: Harmon-Jones, 2006; Peterson, Shackman, & Harmon-Jones, 2008; Schiff & Lamon, 1989). Additionally, the pattern of results in the unilateral hand clenching literature also supports models (e.g.; Davidson, 2002, 2004; Tomarken et al., 1992) of left hemisphere anger lateralization. Thus, induced unilateral hemispheric activity of one versus the other hemisphere is associated with the experiencing of a particular emotional/motivational orientation.

Given that positive/approach and negative/withdrawal affects/motivations may be left versus right hemisphere (respectively) oriented (e.g.; Davidson, 2002, 2004; Tomarken et al., 1992).), it may be possible to alter lateralized hemispheric activity via changes in mood. Mood induction itself may therefore alter hemispheric activity (Flores-Gutiérrez et al., 2009; Schmidt & Trainor, 2001; Tsang, Trainor, Santesso, Tasker, & Schmidt, 2001). Supporting this notion, Schmidt and Trainor (2001) reported changes in mood-congruent affect, as well as decreased alpha power (increased hemispheric activity) in left frontal areas in response to joyful and happy music, and decreased alpha power (increased hemispheric activity) in right frontal areas in response to sad and anxiety producing music. These results indicate that mood induction alters hemispheric activity and, furthermore, alters such activity in a manner consistent with theories of left lateralization of positive/approach and right hemisphere negative/withdrawal states (e.g.; Davidson, 2002, 2004; Tomarken et al., 1992).

Given that music-induced mood induction alters hemispheric activity (e.g.; Schmidt & Trainor, 2001), and given that hemispheric activity is reflected in cognition, it is proposed that music-induced mood, thereby changing hemispheric activity, will be associated with changes in performance on tasks thought to be lateralized to the cerebral hemispheres. In support of this notion, mood induced changes in cognition may be associated with lateralized processes involving attention (e.g.; Ford et al., 2010). For example, Ford et al. (2010) reported that anger increased visual attending to rewarding information, an orientation that may support anger as an approach, left hemisphere motivational state in some contexts.

The Hemispheric Encoding/Retrieval Asymmetry (HERA) model of memory proposes that left prefrontal regions are associated with encoding, and right prefrontal regions with retrieval, of episodic memories (Habib, Nyberg, & Tulving, 2003; Tulving, Kapur, Craik, Moscovitch, & Houle, 1994). Although this model has its detractors (e.g.; Lee, Robbins, Pickard, & Owen, 2000; Owen, 2003), as countered by Habib et al. (2003) the criticisms themselves do not necessarily invalidate the HERA model, which in itself also has heuristic value (e.g.; Tulving et al., 1994). Additionally, more recent work has provided results that have been interpreted as supportive of the HERA model (Babiloni et al., 2004; Griessenberger et al., 2012; Okamoto et al., 2011). For example, Babiloni et al. (2004), in a re-analysis of data from a 2004 EEG study, found results supportive of the HERA model using nonverbal stimuli. Okamoto et al. (2011), using functional near-infrared spectroscopy, reported increased right hemisphere activity during recall for a taste, a result they interpreted as supportive of HERA. As suggested by others (e.g.; Cabeza, 2002; Habib et al., 2003; Propper et al., 2012), the left hemisphere encoding/right hemisphere retrieval of episodic memory proposed by HERA may be influenced by a variety of factors, including stimuli material (i.e.; language or spatial-based; e.g.; Propper et al., 2012) and age (e.g.; Cabeza, 2002). The materials in the present study were language-based, and the participants were young adults; both factors which are associated with the patterns of brain activity predicted by HERA.

Because increased activity of a given hemisphere is associated with domination of information processing by that hemisphere, increasing one versus the other hemisphere's neuronal activity immediately prior to encoding, and immediately prior to recalling information, may influence recall ability. Specifically, increased left hemisphere activity during/prior to encoding, and increased right hemisphere activity during/prior to retrieval would be predicted by the HERA model to result in superior recall for episodic information. Previous work has supported this notion. Propper, Christman, et al. (2013) and Propper, McGraw, et al. (2013) reported that presumed increased left hemisphere activity in response to right hand clenching prior to the encoding of list words, and presumed increased right hemisphere activity in response to left hand clenching prior to recall, resulted in superior memory for list words relative to other hand clench conditions. These results suggest (a) differential hemispheric activity in frontal areas may bias cognitive processing and (b) episodic memory may be benefitted by increased left hemisphere activity during encoding and increased right hemisphere activity during retrieval.

One purpose of the present research was to examine the effects of mood induction on hemispheric activity and on episodic memory. Happy and fearful mood induction were chosen as differential activators of the left versus right hemisphere, respectively. It was hypothesized that induced moods of happiness prior to encoding, and induced fearfulness prior to recall, would result in superior episodic memory, relative to other mood-induction encoding and retrieval combinations. An anger mood induction was also examined. As mentioned earlier, controversy in the literature regarding anger makes predictions regarding this emotion difficult (e.g.; Carver & Harmon-Jones, 2009; Zinner et al., 2008), and another purpose here was to investigate anger lateralization. If induced anger in the present research causes a pattern of results similar to that found for induced happiness, anger may be similar to left hemisphere lateralized/approach motivational states. Conversely, if anger causes a pattern of results similar to that found for induced fear, then anger might be more similar to right hemisphere lateralized/withdrawal motivational states.

Hemispheric activity was assessed via lateralized differences in tympanic membrane temperature (TMT). TMT is a relatively novel measure of lateralized hemispheric activation, and may be a simple, fast way of measuring general cortical activation non-invasively and without the expenses of imaging (e.g.; Helton, 2010; Helton & Carter, 2011; Helton, Harynen, & Schaeffer, 2009; Helton, Kern, & Walker, 2009; Propper & Brunyé, 2013; Propper, Brunyé, Christman, & Bologna, 2010; Propper, Christman, et al., 2013; Propper, Januszewski, Christman, & Brunyé, 2011; Propper, McGraw, et al., 2013). TMT reflects hemispheric activity in frontal and temporal areas, and may be indicative of performance on