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Abnormal frontal and parietal activity during working memory updating in post-traumatic stress disorder

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Abstract

This study used event-related potentials (ERPs) to investigate the timing and scalp topography of working memory in post-traumatic stress disorder (PTSD). This study was designed to investigate ERPs associated with a specific working memory updating process. ERPs were recorded from 10 patients and 10 controls during two visual tasks where (a) targets were a specific word or (b) targets were consecutive matching words. In the first task, nontarget words are not retained in working memory. In the second task, as in delay-match-to-sample tasks, a non-target word defines a new target identity, so these words are retained in working memory. This working memory updating process was related to large positive ERPs over frontal and parietal areas at 400–800 ms, which were smaller in PTSD. Estimation of cortical source activity indicated abnormal patterns of frontal and parietal activity in PTSD, which were also observed in regional cerebral blood flow [Clark, C.R., McFarlane, A.C., Morris, P., Weber, D.L., Sonkkilla, C., Shaw, M., Marcina, J., Tochon-Danguy, H., Egan, G., 2003. Cerebral function in posttraumatic stress disorder during verbal working memory updating: a positron emission tomography study. Biological Psychiatry 53, 474–481]. Frontal and parietal cortex are known to be involved in distributed networks for working memory processes, interacting with medial temporal areas during episodic memory processes. Abnormal function in these brain networks helps to explain everyday concentration and memory difficulties in PTSD.

Keywords: Anxiety; Cognition; Electrophysiology; Topographic brain mapping; P300; Vision

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1. Introduction

The symptoms of post-traumatic stress disorder (PTSD) comprise traumatic intrusions, with associated avoidance, withdrawal and emotional numbing (Horowitz, 1986; American Psychiatric Association, 1994). Conceptually, PTSD requires understanding the interaction of the brain and events that challenge the capacity to survive horror and threat. Information-processing concepts are central to understanding the way that people adapt to and integrate the memory of a traumatic stressor (McFarlane et al., 2002). Equally, the symptoms of PTSD such as disordered concentration and memory, exaggerated startle response and numbing indicate that the capacity to focus on and modulate neutral information is impaired. Consistent intrusive interference with cognition can lead to chronic failure to maintain the integrity of everyday cognitive schemata (Chemtob et al., 1988; Foa et al., 1989).

Over the last 15 years, many studies have demonstrated various deficits in processing neutral information in PTSD, even in the absence of emotional distress (Buckley et al., 2000). Behavioral evidence obtained from neuropsychological studies indicates general impairment of executive functions in PTSD (e.g., Everly and Horton, 1989; Gil et al., 1990; Uddo et al., 1993; Bremner et al., 1993; Yehuda et al., 1995; Anagnostaras et al., 1999). In addition, event-related potentials (ERPs) demonstrate abnormal cognition for traumatic and neutral information in PTSD. There are several ERP studies that suggest abnormal increases in activity for traumatic information in PTSD, such as enhanced N1 and P3 components of the ERP for traumatic images (Attias et al., 1996a,b). There are also several ERP studies, including our previous work, that demonstrate abnormal responses to neutral stimuli, in the absence of traumatic stimuli. These studies indicate abnormal activity in early thalamocortical components of the auditory evoked potential (e.g., Paige et al., 1990; Gillette et al., 1997; Neylan et al., 1999), suggesting some difficulty with early selective attention processes. More particularly, there have been several reports of abnormal endogenous ERPs, such as the N2 and P3 components, which have been shown to be delayed and attenuated, respectively (cf. McFarlane et al., 1993; Charles et al., 1995; Boudarene and Timsit-Berthier, 1997; Metzger et al., 1997; Galletly et al., 2001; Kimble et al., 2000; Neylan et al., 2003; Metzger et al., 2004). These components are usually associated with the evaluation of significant attended stimuli within the context of working memory goals and plans (Kutas and Hillyard, 1984; Donchin and Coles, 1988; Näätänen, 1992).

These studies have provided important biological evidence of abnormality in the processing of non-traumatic stimuli in PTSD. In particular, they suggest attenuation and delay in the brain processes required for the controlled processing of nontraumatic stimuli. However, it is not clear whether the difficulty relates to stimulus evaluation itself, or to the ongoing maintenance of the working memory context essential for effective stimulus evaluation. The ERP paradigms used to identify the N2 and P3 abnormalities referred to above fail to differentiate between these two possibilities. To help resolve this issue, the present study focuses on whether the difficulty in PTSD relates to the updating of working memory with relevant change in the sensory field.

For the purposes of this article, working memory is defined as the short-term storage and manipulation of sensory information to facilitate adaptive action (see Baddeley, 1992; Moscovitch, 1992). Neuroimaging studies of primate and human performance during working memory tasks indicate that association cortex, including frontal, temporal and parietal regions, is involved in the retention of stimulus information for short periods (see Goldman-Rakic, 1990; Fuster, 1991; McCarthy, 1995; Miller and Cohen, 2001). ERP studies of working memory are often associated with frontal and parietal electrical potentials, such as the P3 component of ERP mentioned earlier (see Magliero et al., 1984; Rösler et al., 1985; Donchin and Coles, 1988; Johnson, 1988; Leuthold and Sommer, 1998; Pritchard et al., 1999). The study of Rösler et al. (1985) is particularly interesting, as it demonstrated that updating sensory representations in working memory is related to greater parietal P3 and positive slow wave amplitude. Also, Gevins et al. (1996) reported working memory activity in a series of positive ERPs over frontal and parietal regions between 300 and 900 ms (cf. Begleiter et al., 1993; Martin-Loeches et al., 1994; Gevins et al., 1995; Rämä et al., 1995). Similarly, delayed match-to-sample studies show that P3 is related to acquisition of information, while later slow waves are