2 RESEARCH AIMS

The previous chapter illustrates that PTSD comprises both trauma sensitivity and deficits in neutral information processing. Given that the latter is important for recovery, possibly prevention, it is essential to understand the cognitive neuroscience of attention and working memory processes in PTSD, especially for neutral information. In the past 10-15 years, many studies have investigated ERP measures of cortical responses to neutral tones and these studies have indicated abnormal responses in PTSD. These range from early gating deficits, apparent in P50 ERPs, and early attention differences, apparent in augmenting/reducing patterns of N1/P2 responses, to later abnormalities of stimulus discrimination and novel stimulus evaluation, apparent in abnormal N2 and P3 potentials. While the refined evaluation of these different stages of information processing are important, it is also essential to evaluate the visual modality of stimulus processing. All of the neutral information processing investigated with ERP studies, to date, has been done in the auditory modality. This study sought to investigate the visual modality. Furthermore, given neuropsychological evidence of deficits in linguistic processing in PTSD, we have employed visual word stimuli to not only investigate the visual modality, but also engage linguistic encoding processes. Given the evidence for deficits in neutral information processing, plus indications of abnormal linguistic processes in PTSD, we hypothesized that the present study would identify deficits in the visual modality for linguistic stimuli.

Previous ERP studies of cognition in PTSD have applied low-resolution scalp recording techniques and simple target detection tasks. This study employed a dense scalp electrode array for ERP recording and analysis, which involves greater regional topographic estimation of cognitive ERP components than many previous studies that simply evaluate midline electrode sites. More importantly, this study comprises a sophisticated cognitive task paradigm to provide better dissection of the component structure of attention and working memory deficits of PTSD. In particular, it was of interest to delineate aspects of information processing that contains sensory responses, modulated by selective attention, further stimulus evaluation and working memory manipulation of attended events, and finally target detection and response activity. The aim was to identify failures in PTSD at a specific stage or stages in the information-processing stream. The design of this study provided specific cognitive contrasts for selective attention, working memory updating and target detection.

The tasks of this study employed a relatively simple stimulus presentation sequence and two simple task instruction sets, yet it provides for sophisticated cognitive contrasts (the method section will provide more detail). To investigate visual linguistic stimulus processing, subjects were presented with a series of red and blue words. Selective attention was invoked by attending to words of one color or another, which was counterbalanced across color. The red and blue colors are primary colors, so we expected to examine early aspects of visual selective attention. For two task instruction sets, exactly the same stimulus sequence was designed and presented to each subject, providing for within-subject contrasts. The stimulus sequence and response requirements of the tasks were constant across the two task instructions. As mentioned, both tasks required target detection for words in the attended color. An additional working memory manipulation was invoked by two target detection criteria.

In one task, a fixed target criterion required detection of a specific word in the attended color. This task required a comparison of each new attended stimulus with a fixed representation of the target attributes. In terms of cognitive modeling, the comparison process requires integrated processing of both the new stimulus information and the target attributes held in working memory. In many respects, this task is very similar to a conventional oddball task, which requires rehearsal of a working memory trace for target stimulus attributes and a comparison of each new attended stimulus with this memory trace.

In the other task, a variable target criterion required detection of repeated words in the attended color. This task requires continual updating of the working memory trace of target attributes, as every attended stimulus that is not a target needs to be evaluated against the following attended stimulus. This invokes greater working memory demands because it requires regular updating of a working memory model of target attributes.

A persuasive model of P3 ERP activity proposes that it comprises updating of a contextual model of current experiences (see Donchin & Coles, 1988). This formed the basis for design of the two tasks, which provide a contrast to elicit precisely this updating process. The key to extracting this working memory updating process from these two tasks is to compare the ERP activity from the attended common events from each task. In the fixed target task, the attended common stimuli are evaluated against a target representation, which they do not match, so they are no longer required for effective task performance. On the other hand, the attended common events of the variable target task are first compared with the current target representation, which they do not match, but they must then replace the current target representation, otherwise the task cannot be performed accurately. This is the contextual updating process, which appears to comprise at least one component process similar to the P3 ERP (see Clark, Orr, Wright & Weber, 1998).

Lastly, this study investigates the targets of the fixed target task for ERP activity related to target recognition and response execution, which is comparable to the simple oddball target response. In the fixed target task, the attended common and target events involve less complex processing than for the variable target task. It may be possible to elicit interesting cognitive contrasts between the target events of the fixed and variable target tasks, primarily related to the duration over which a target representation is maintained, but this was beyond the scope of the present study.

Thus, this study was designed to investigate visual, verbal stimulus processing in PTSD, with careful manipulation of task parameters to provide several conditions that reflect various degrees of attention, working memory processing and target detection. The following chapters describe the components of this investigation and the results observed. Each chapter provides relevant reviews of the cognitive components investigated, including visual attention, working memory and target detection processes. These chapters are arranged to delineate the progression of stimulus information processing from early visual encoding to later evaluation and response activity. The millisecond temporal resolution of ERPs provides one of the best techniques available to measure variations in stimulus information processing generated by careful task designs that manipulate attention and working memory processes (MEG also provides high temporal resolution measures of event-related fields [ERFs]). Tomographic neuroimaging techniques, such as PET and fMRI, are limited by the poor temporal resolution of blood flow dynamics. The ERP literature and associated neuroimaging findings are reviewed in the following chapters, with a view to conceptual integration and cautious inferences from ERP activity to cognitive neurophysiology. In this regard, the greater spatial resolution of dense array ERP recordings provides more information relevant to the localization of cognitive activity (although important caveats must be placed on any inferences from scalp topography to brain sources, e.g., see Clark et al., 2001). Although many ERP studies of PTSD simply report midline electrode sites, recent studies of PTSD have employed as many as 32 or 64 scalp electrodes (e.g., Galletly et al., 2001; Neylan et al., 1999); this study samples the electroencephalograph (EEG) from 124 scalp electrodes, to provide better spatio-temporal resolution to the measurement of ERP components related to cognitive processes. Also, this study was conducted as a multimodal investigation that measured both PET and ERP activity. The focus of the present work is on scalp topographic analysis of ERPs, with associated neuroimaging results given elsewhere (see Shaw et al., 2002; Clark et al., 2003; see also Clark et al., 2000). A very important reason for this is that ERP data analysis provides the capability to extract relevant activity for individual stimulus types in any given task, whereas PET activity can only reflect the overall summation of responses to all stimulus types in a given task block (i.e., PET has very poor temporal resolution). Hence, the two measurement systems are not commensurate for the present purposes. Thus, ERP activity provides not only fine temporal resolution, but also extraction of stimulus specific activity rather than overall task activity (recent developments in event-related fMRI can provide greater correspondence between ERP and fMRI activity for stimulus specific responses, with the best correspondence to be expected from simultaneous recordings of EEG and fMRI). The focus on event specific responses, rather than overall task activity, is critical for the cognitive comparisons reported here.

The method chapter to follow will explain the task design in more detail, with clear explanation of the cognitive task comparisons. A brief chapter on the behavioral response findings is followed by three chapters that examine (a) selective attention, (b) working memory, and (c) target detection.