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Psychiatry Research 136 (2005) 201–209

PSYCHIATRY RESEARCH

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Effects of cold stress on early and late stimulus gating

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Received 22 January 2002; received in revised form 30 December 2002; accepted 5 March 2003

Abstract

The P50 component of the event-related potential (ERP) mainly reflects early pre-attentional processing. Along with P50, the N100 component and mismatch negativity (MMN) were postulated to represent a complex multistage and multi-component gating system. If some variable threshold or gating is exceeded by the MMN signal, the MMN is often followed by a relatively sharp fronto-central positive wave, the P3a component, which reflects an attentional switch to an environmental change. The P50 was shown to be affected by mental and cold stress, and the P3a amplitude was shown to be increased by the anticipation of threat. The aim of this study is to examine concurrently the early and late ERP indices of gating during acute stress. The ERPs to auditory stimuli in a passive oddball paradigm were recorded in 15 normal subjects during the cold pressor test and a control condition. The cold pressor test diminished P50 gating, increased N100 amplitude, elicited P3a responses and had no significant effect on MMN. Transient stress could impair early sensory gating and the ability to ignore irrelevant information that can cause passive attention switches indexed by the P3a component.

Keywords: Event-related potential; Mismatch negativity; Evoked potentials; Electrophysiology; Oddball paradigm; Stress

1. Introduction

Sensory gating is broadly defined as the ability of the brain to modulate its sensitivity to incoming sensory stimuli (Braff and Geyer, 1990). It reflects a complex multistage, multi-component process (Boutros and Belger, 1999). Sensory gating is commonly studied in paired click, oddball, and trains paradigms (Boutros et al., 1999). In the paired click paradigm, the effects of repetition on the amplitude of the P50 component of the event-related potential (ERP) is believed to reflect an automatic pre-attentive inhibitory capacity. In the oddball paradigm, on the other hand, increased amplitude of the P50 component to infrequent auditory stimuli has been shown to reflect pre-attentive recognition of novel stimuli or "gating in" of stimuli while decreased amplitude to frequent auditory stimuli reflects "gating out" of stimuli (Boutros et al., 1995).

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0165-1781/$ - see front matter © 2005 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.psychres.2003.03.002

In the oddball paradigm, the subject is presented a sequence of repetitive "standard" (frequent) stimuli that are randomly, and with a low probability, replaced by a different deviant (infrequent) stimulus. In the passive (ignore) paradigm, attention is directed away from the acoustic stimuli to a concurrent (primary) task, usually involving another sensory modality, such as reading an interesting book or performing a challenging visual discrimination task. The passive oddball paradigm is used to study brain responses to ignored stimuli and to underlying involuntary discrimination of, and attention switches to, deviant stimuli (Näätänen, 1990). On the other hand, in the active oddball condition, the subject has to attend to all the stimuli to discriminate the deviant stimuli among them. Thus, the main interest is in the brain responses associated with attention.

Infrequent auditory stimuli deviating from a repetitive standard sound in some physical features, such as frequency, elicit the mismatch negativity (MMN) component of the ERP. MMN can be derived from a difference wave obtained by subtracting the standard stimulus ERP from the deviant stimulus ERP (Sams et al., 1985). MMN is thought to reflect the outcome of a mismatch process automatically registering the deviation of the current input from the neuronal representation of a repetitive stimulus in sensory memory (Näätänen, 1990).

MMN is often followed by a relatively sharp fronto-central positive wave that peaks at about 250 ms and is caused by the P3a component (Squires et al., 1975). The P3a component seems to be more easily elicited by the deviant stimulus when the magnitude of stimulus deviation is great, the interstimulus interval is short, and the primary task is not very demanding. The P3a component might reflect an attentional switch to an environmental change encoded by the cerebral process generating the MMN if some variable threshold is exceeded by this signal. Then a subsequent stage may be activated, resulting in the conscious detection of the deviant event. The P3a component might be the most sensitive cerebral indicator of an attentional switch (Schröger, 1997). However, in "attend" conditions when infrequent nontarget stimuli are inserted into the sequence of target and standard stimuli (three-stimuli oddball), the N2b–P3a complex is elicited in fronto-central and central scalp distributions to the infrequent nontarget stimuli (Courchesne et al., 1975; Squires et al., 1975).

The data suggest a specific role for noradrenaline in the modulation of sensory processing in humans and rats (Adler et al., 1988; Stevens et al., 1991; Miyazoto et al., 2000) and in the modulation of automatic attentional processing (Missonnier et al., 1999). Increased noradrenergic neuronal transmission in the central nervous system (CNS) induced by the alpha-2 noradrenergic antagonist yohimbine in normal controls can cause a transient impairment in auditory sensory gating (Adler et al., 1988; Stevens et al., 1993). Combat veterans with posttraumatic stress disorder (PTSD) exhibited decreased habituation of the P1 (P50) mid-latency auditory evoked potential (Neylan et al., 1999; Skinner et al., 1999).

Cerebral events underlying the P3a component probably participate in the sequence of processes leading to the release of an autonomic nervous system (ANS) response pattern typical of the orienting response (Näätänen and Gaillard, 1983). The integrity of the locus ceruleus (LC) and its ascending fibers was shown to be important in the generation and modulation of surface-recorded P300-like activity (Swick et al., 1994).

The prefrontal cortex seems to be a common generator site of P50 and P3a components of the ERP. Both components have been shown to be affected by prefrontal lesions (Knight, 1984; Knight et al., 1989).

In this study, we examined the effects of sympathetic nervous system processes induced by a cold pressor test on sensory gating, pre-attentive deviance detection, and attentional shifts. A modified passive oddball paradigm was used to assure that the interstimulus interval (ISI) between the deviant stimuli would be long enough to allow recovery from the effects of the preceding deviant stimulus and to delineate the effects of stress on sensory gating, pre-attentive deviance detection and attentional switch.

2. Methods

2.1. Subjects

Fifteen healthy volunteers (8 men and 7 women), who ranged in age from 19 to 46 years (mean = 26.3, S.D. = 8) and who were without hypertension, were