



# Modulation of spatial attention by fear-conditioned stimuli: an event-related fMRI study

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## Abstract

Stimuli that signal threat can capture subjects' attention, leading to more efficient detection of, and faster responses to, events occurring in that part of the environment. In the present study we explored the behavioural and anatomical correlates of the modulation of spatial attention by emotion using a fear conditioning paradigm, combined with a covert spatial orienting task. Reaction times for the detection of a peripheral target, which was preceded by brief (50 ms) presentations of the visual conditioned stimulus (CS+) in either the same or opposite visual field, showed an interaction between stimulus emotionality and attention shifts. We used event-related functional magnetic resonance imaging (fMRI) to characterise the associated neural responses. Consistent with previous studies, conditioning-induced enhanced responses were observed in the amygdala and extrastriate visual cortex. The modulation of spatial attention by a conditioned stimulus was associated with enhanced activity in regions of frontal and parietal cortices previously implicated in spatial attention, as well as in the lateral orbitofrontal cortex (IOFC). © 2002 Elsevier Science Ltd. All rights reserved.

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## 1. Introduction

Detection of danger and rapid elicitation of appropriate defence reactions are crucial for survival. The fear system, highly conserved throughout evolution, operates in a rapid and efficient fashion, in some cases even without conscious awareness of an eliciting stimulus [21]. In many instances, however, once danger is detected and the initial automatic fear responses elicited, further action is necessary, requiring the redirection of attentional resources, with the engagement of flexible response repertoires, towards the threatening stimulus. This influence of emotionality on spatial attention in humans has been investigated using a variety of behavioural tasks (e.g. [3,28,38,39,54]). However, although much progress has been made in characterising neural circuits underlying fear processing (for reviews see [4,23,34]) and spatial attention (e.g. [13,14,27,37,52]), little is known about how these two systems interact in humans.

Attention and emotion can interact either by attention influencing emotional processing, or emotion modulating attentional processing. In the present study we used event-related functional magnetic resonance imaging (fMRI) to address the question of how emotion, specifically fear, influences attention, by employing a paradigm that combined discriminatory fear conditioning with a covert spatial orienting task. During scanning, subjects viewed pictures of two angry faces, one of which was paired (conditioned stimulus (CS+)), and the other not paired (CS-), with a loud burst of white noise, the unconditioned stimulus (US). We hypothesised that the CS+, having acquired aversive emotional value through conditioning, would automatically capture subjects' attention. We tested this hypothesis with a modified version of the well-known dot-probe covert attention task [47]. Subjects were instructed to detect the location of a target, appearing on either side of the central fixation location. In the critical experimental condition, the dot target was preceded by a brief presentation of a CS+ and CS- side by side, but in opposite visual fields. If attention was captured by the CS+, detection of targets on the opposite side (incongruent trials) should be slower than those on the same side (congruent trials). That is, a difference in reaction times between congruent

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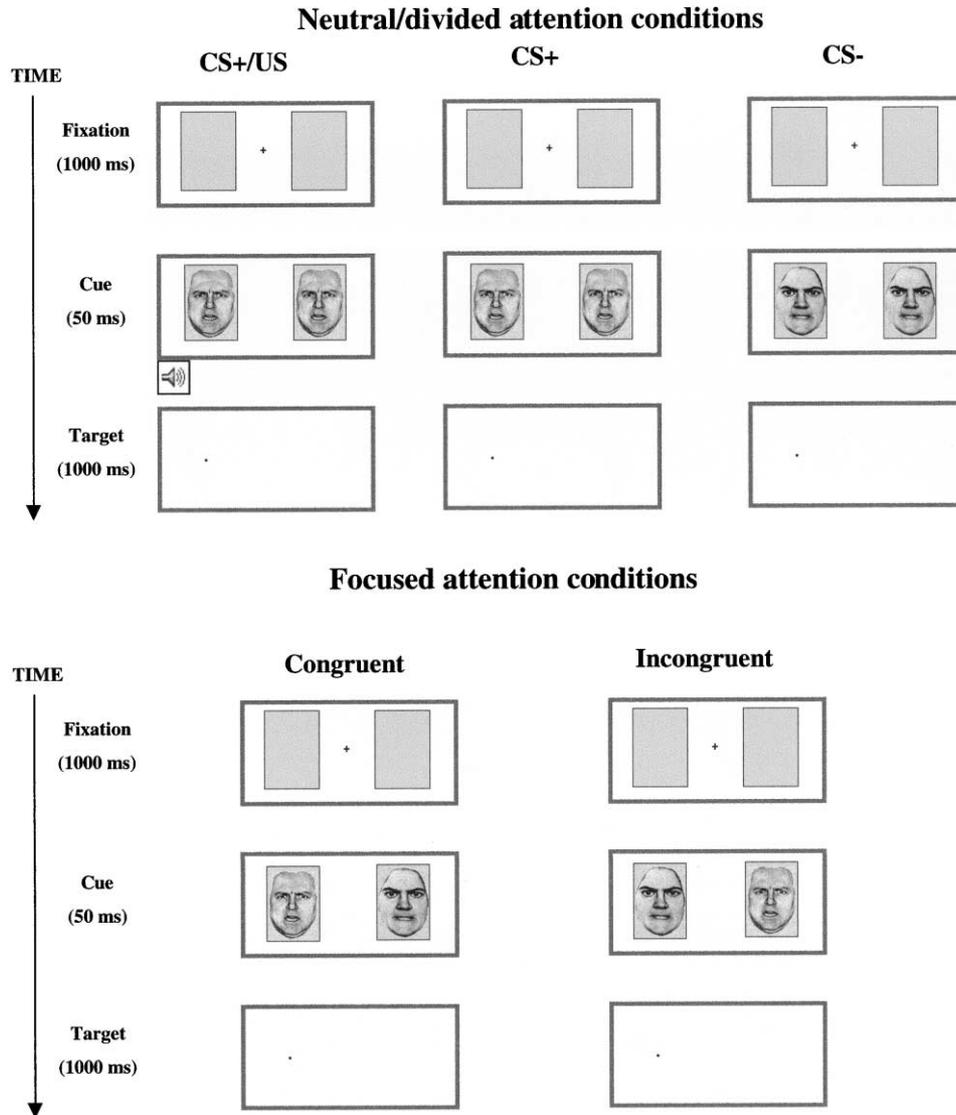


Fig. 1. Schematic illustration of the five trial types used in the study (see Section 2 for details). The fixation cross was present for 1 s, and the face stimuli (cue) appeared for 50 ms, immediately followed by the target. In the neutral/divided attention conditions, the same stimulus (either CS+ or CS–) was presented on both sides, whereas in the focused-attention conditions the CS+ and CS– were presented together, side by side; in congruent trials the location of target was the same as that of the CS+, and opposite in the incongruent trials. In the CS+/US condition, a loud burst of white noise (200 ms) was presented in conjunction with the face stimuli.

and incongruent trials would suggest that indeed spatial attention was modulated by the affective value of the stimuli. Furthermore, by comparing neural responses between these trials where, according to our hypothesis, attention would be captured by the CS+ (henceforth, referred as *focused-attention* conditions) with trials in which the same face stimulus, either the CS+ or the CS–, was presented on both sides—therefore, attention being equally allocated to both hemifields (the *neutral/divided attention* conditions; see Fig. 1), we were able to determine which brain regions were involved in this modulation of attention by emotion.

## 2. Materials and methods

### 2.1. Subjects

Ten healthy volunteers, without a history of neurological or psychiatric impairments, participated in this study. All subjects provided written informed consent before the experiment. Data from four subjects were excluded from the analysis due to technical problems with the scanner and/or the stimulus delivery system. The results presented here correspond to data obtained from the remaining six subjects (three male, three female). All procedures were approved by

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