International Journal of Psychophysiology 70 (2008) 127–136

Contents lists available at ScienceDirect

International Journal of Psychophysiology

journal homepage: www.elsevier.com/locate/ijpsycho

# Electrophysiological evidence for early non-conscious processing of fearful facial expressions

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ARTICLE INFO

*Article history:*
Received 21 March 2008
Received in revised form 28 June 2008
Accepted 19 August 2008
Available online 6 September 2008

*Keywords:*
Subliminal
Awareness
ERP
Face
Source localisation

ABSTRACT

Non-conscious processing of emotionally expressive faces has been found in patients with damage to visual brain areas and has been demonstrated experimentally in healthy controls using visual masking procedures. The time at which this subliminal processing occurs is not known.

To address this question, a group of healthy participants performed a fearful face detection task in which backward masked fearful and non-fearful faces were presented at durations ranging from 16 to 266 ms. On the basis of the group's behavioural results, high-density event-related potentials were analysed for subliminal, intermediate and supraliminal presentations. Subliminally presented fearful faces were found to produce a stronger posterior negativity at 170 ms (N170) than non-fearful faces. This increase was also observed for intermediate and supraliminal conditions. A later component, the N2 occurring between 260 and 300 ms, was the earliest component related to stimulus detectability, increasing with target duration and differentiating fearful from non-fearful faces at longer durations of presentation. Source localisation performed on the N170 component showed that fear produced a greater activation of extrastriate visual areas, particularly on the right.

Whether they are presented subliminally or supraliminally, fearful faces are processed at an early stage in the stream of visual processing, giving rise to enhanced activation of right extrastriate temporal cortex as early as 170 ms post-stimulus onset.



## 1. Introduction

An ongoing debate in the field of emotional face processing and awareness concerns the extent to which facial expressions, in particular fear, may be processed automatically without necessarily reaching conscious awareness.

In patients lacking visual cortex, de Gelder et al. (1999) first observed affective blindsight, in which a patient with right hemianopia was capable of guessing the emotional expression on a face at a level above chance, even though the stimuli did not reach consciousness due to damage to the left primary visual cortex. Later, similar results were found in a patient with complete cortical blindness (Pegna et al., 2005). When emotional and neutral expressions were contrasted in an fMRI paradigm in this patient, the former were found to activate the right amygdala despite the bilateral destruction of the primary visual cortex.

Similar findings were observed in healthy controls, in whom awareness of emotional faces was eliminated by using backward masking paradigms. Indeed, emotional faces that were masked, and thus not accessible on a conscious level, nevertheless produced patterns of activation that differed from neutral faces, showing that the stimuli were processed despite the fact that masking had disrupted awareness (Morris et al., 1998b; Whalen et al., 1998; Morris et al., 1999; Liddell et al., 2004).

However, the view that emotional faces could be processed without awareness has been called into question. For example, Pessoa et al. (2006) presented masked fearful faces at 33 or 67 ms durations and assessed detection using an objective measure taken from signal detection theory, in addition to a confidence rating. The authors observed that, independently of presentation times, when fearful faces were not detected, no activation was found in the amygdala or in the fusiform gyrus. By contrast, when subjects reported seeing a fearful face (whether or not one had actually appeared), an increase in activation was observed in both the amygdala and fusiform gyrus. Thus, fearful faces may not actually be processed automatically and non-consciously. The authors argue that the divergence with previous results stems in part from the fact that the degree of awareness might not be sufficiently controlled. Indeed, in a separate behavioural study, the authors (Pessoa et al., 2005) found a variable threshold for conscious perception of a masked stimulus across subjects. These findings demonstrate the importance of using objective measures of detection when studying subliminal processing.

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doi:10.1016/j.ijpsycho.2008.08.007

The extent to which fearful faces might be processed non-consciously remains therefore to be established. Moreover, special care must be taken in ensuring that the stimuli are consciously undetectable. In addition, studies using event-related potential (ERP) measures, which possess a high temporal resolution, are necessary to investigate whether the processing of emotional expressions occurs early or late in time.

Until now, most ERP studies of emotional face processing have used tasks in which the stimuli are largely visible on a conscious level. Faces are generally claimed to give rise to a specific response, the N170 (e.g., see Bentin et al., 1996; Itier and Taylor, 2004) but it was previously thought that this response was insensitive to emotional expressions (Munte et al., 1998; Bobes et al., 2000; Krolak-Salmon et al., 2001; Eimer and Holmes, 2002; Herrmann et al., 2002; see also Eimer and Holmes, 2007; Vuilleumier and Pourtois, 2007 for recent reviews). Recently however, evidence has begun emerging that the N170 might nevertheless be modulated by emotional expression (Batty and Taylor, 2003; Miyoshi et al., 2004; Stekelenburg and de Gelder, 2004; Blau et al., 2007; Hendriks et al., 2007), although it is not known whether this modulation can be extended to non-conscious processing. Indeed, little has been done in the way of ERPs and subliminal processing. Liddell et al. (2004) investigated the ERP responses to subliminal and supraliminal presentations of fearful and neutral faces and found that fear enhanced an N2 component on fronto-central sites, while supraliminal presentations affected later (N4 and late P3) components. This result therefore upheld the view that the earliest difference for non-conscious processing of fear occurred after 200 ms. However very recently, Kiss and Eimer (2008) and Eimer et al. (2008) reported earlier effects of subliminally-presented fearful faces, occurring between 140 and 180 ms over anterior sites. In these studies, no effect was seen over posterior electrodes that could suggest an N170 modulation.

We therefore investigated the processing of masked fearful faces using an ERP paradigm, in which stimulus duration was varied parametrically and awareness established using the behavioural $d'$ measure from signal detection theory (Green and Swets, 1966, Macmillan and Creelman, 1991). The aim of the experiment was to determine whether electrical brain responses, in particular the N170, N4 and the late positive component or late P3, varied for fearful faces at stimulus durations that were below the threshold of conscious awareness.

## 2. Materials and methods

### 2.1. Subjects

Eighteen students and medical staff from Geneva University Hospital (9 females) were recruited through local advertisements for this experiment. Average age was 27.4 (standard deviation: 3.9). The study was approved by the local Ethics Committee. Subjects gave their informed consent and were paid for their participation. All those retained for the experiment had normal or corrected-to-normal vision, were medication-free and had no history of psychiatric disorder. All subjects were right-handed (mean laterality index: 87.7; range: 40–100) as measured on the Oldfield–Edinburgh scale (Oldfield, 1971).

### 2.2. Procedure

Backward masked neutral, happy or fearful faces – the stimuli – were presented to subjects who were asked to detect the presence of a fearful face (target). Non-fearful faces were composed of both happy and neutral expressions in order to avoid any detection based solely on lower-level features, in line with previous investigations (Pessoa et al., 2006). Stimuli were presented at different durations and were always followed by a novel, neutral face (i.e., which did not appear as a target) that served as a mask. The stimuli appeared for durations of 16 ms, 33 ms, 66 ms, 133 ms or 266 ms. The duration of the mask was set such that the total stimulus duration (target + mask) was of 300 ms. Masks thus lasted respectively 284 ms, 267 ms, 234 ms, 167 ms and 34 ms.

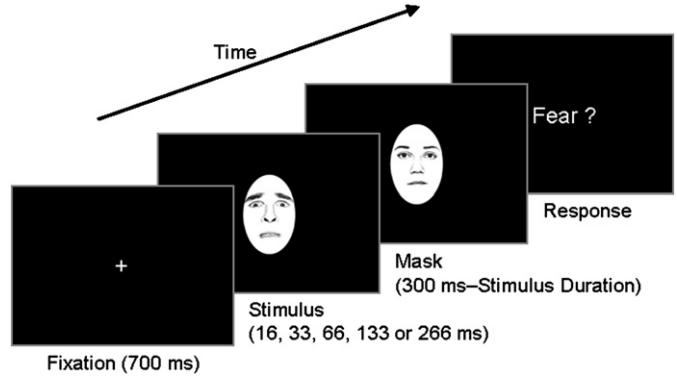


**Fig. 1.** Experimental procedure. After an initial 700 ms fixation point, a target was presented for one of 5 durations between 16 and 266 ms, followed immediately by the mask. The total duration (stimulus + mask) lasted 300 ms. A delayed response prompt then allowed the subject to answer using a key press.

The sequence of events for each trial began by a fixation cross that lasted 700 ms, followed by the target and mask pair, followed by a 1000 ms blank screen (see Fig. 1). A response prompt then appeared on the screen asking for the subjects' response. The delay between the mask and the response prompt was set so as to avoid a contamination of the ERP by the faster reaction times that occurred for longer durations of presentation (observed during previous pre-tests). However as a result, reaction times could not be analysed.

After the response, there was a 500 ms pause and the following trial was initiated with the fixation cross. The participants responded whether they saw a fearful face or not by pressing on a keypad with the index or middle finger of their right hand after the response prompt. Half the subjects responded "yes" by pressing their index finger and "no" with the middle finger, while this order was reversed for the other half of the subjects. The proportion of targets was also counterbalanced with half of the targets composed of fearful expressions and the remaining half of an equal number of neutral and happy facial expressions. Thus, 50% of the targets were composed of fearful faces ("yes" responses), while 25% were happy and 25% neutral faces ("no" responses).

The stimuli were presented in a random order, totalling 640 trials (64 trials × 2 stimuli × 5 durations). A break was observed halfway through the experiment.

The experiment proper was preceded by a habituation session of approximately 10 min during which the participants were given the instructions and were familiarised with the task and the stimuli.

### 2.3. Stimuli

Faces were black and white photographs taken from the Ekman–Friesen series (Ekman and Friesen, 1975). In order to limit the contribution of low-level effects of the photographs, the stimuli were modified using Adobe Photoshop, so that only the eyes, eyebrows, nose and mouth were visible features, while other characteristics such as the skin texture, wrinkles, etc. were not seen. An oval area centred on the face was then extracted in order to remove the hairline and create identical facial contours (see Fig. 1 for an example). The final stimuli subtended a visual angle of 3° on the horizontal axis by 4.4 on the vertical axis when presented at the centre of the CRT monitor (situated 120 cm from the subject).

The experimental procedure was controlled by a software dedicated to psychological testing (E-prime, v.1.1; www.pstnet.com/eprime). Subjects were comfortably seated in an electrically shielded room with minimal lighting and noise, and used a chin rest to control the distance from the screen.