Journal of Affective Disorders 197 (2016) 159–166

Contents lists available at ScienceDirect

Journal of Affective Disorders

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

Research paper

Influence of spatial frequency and emotion expression on face processing in patients with panic disorder

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ARTICLE INFO

Article history:
Received 11 November 2015
Received in revised form
11 February 2016
Accepted 26 February 2016
Available online 3 March 2016

Keywords:
Panic disorder
Spatial frequency
Event-related potential
ERP
Fear

ABSTRACT

Background: Deficits in facial emotion processing is a major characteristic of patients with panic disorder. It is known that visual stimuli with different spatial frequencies take distinct neural pathways. This study investigated facial emotion processing involving stimuli presented at broad, high, and low spatial frequencies in patients with panic disorder.
Methods: Eighteen patients with panic disorder and 19 healthy controls were recruited. Seven event-related potential (ERP) components: (P100, N170, early posterior negativity (EPN); vertex positive potential (VPP), N250, P300; and late positive potential (LPP)) were evaluated while the participants looked at fearful and neutral facial stimuli presented at three spatial frequencies.
Results: When a fearful face was presented, panic disorder patients showed a significantly increased P100 amplitude in response to low spatial frequency compared to high spatial frequency; whereas healthy controls demonstrated significant broad spatial frequency dependent processing in P100 amplitude. Vertex positive potential amplitude was significantly increased in high and broad spatial frequency, compared to low spatial frequency in panic disorder. Early posterior negativity amplitude was significantly different between HSF and BSF, and between LSF and BSF processing in both groups, regardless of facial expression.
Limitation: The possibly confounding effects of medication could not be controlled.
Conclusions: During early visual processing, patients with panic disorder prefer global to detailed information. However, in later processing, panic disorder patients overuse detailed information for the perception of facial expressions. These findings suggest that unique spatial frequency-dependent facial processing could shed light on the neural pathology associated with panic disorder.

1. Introduction

Researchers argue that deficits in emotional processing—particularly fear-related stimuli—and cognitive bias are associated with dysfunction of brain activity in PD (Lueken et al., 2014; McNally, 1990; Windmann, 1998). Altered emotion recognition is a one of the most distinctive characteristics of patients with panic disorder (PD) (Bouton et al., 2001; Lissek et al., 2010); in particular, they tend to show excessive responses to fear stimuli compared to healthy controls (HCs). Patients with PD unconsciously misinterpret fear-related stimuli or situations as a threatening signal to them; thus, compared to HCs, they show dysfunctional inhibitory modulation at the prefrontal sites of affective information processing (Windmann et al., 2002). Dysfunctional cognitive processes of emotional stimuli characterise PD.

Patients with PD showed different visual perception and recognition of facial expressions of emotions compared to HCs (Benecke and Krause, 2005; Cai et al., 2012); they were more sensitive to and eventually caused aberrant responses to fearful face stimuli (Benecke and Krause, 2005; Cai et al., 2012). In addition, the role of visual contents in facial emotion recognition has been well explained by different spatial frequency (SF) information (Holmes et al., 2005; Pourtois et al., 2005; Vuilleumier et al., 2003).

Abbreviations: ERP, event-related potential; VPP, vertex positive potential; EPN, the early posterior negativity; LPP, the late positive potential

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http://dx.doi.org/10.1016/j.jad.2016.02.063
0165-0327/

Visual images are composed of various SF ranges that are processed by different visual neural systems. Spatial frequency refers to the energy distribution in a scale specified as the number of cycles per degree of visual angle and/or the number of cycles per image (Morrison and Schyns, 2001; Park et al., 2012). Broad spatial frequency (BSF) images, which contain all SF ranges, can be filtered to contain either high spatial frequency (HSF) or low spatial frequency (LSF) (Vuilleumier et al., 2003). Vuilleumier et al. (2003) found that the LSF contains coarse information that is transmitted to the subcortical regions (e.g. the amygdala) via the magnocellular pathway at a rapid speed, whereas the HSF contains detailed information, such as shape and colour, and is transferred via the parvocellular pathway to the ventral visual cortex at a relatively slow speed (Vuilleumier et al., 2003). However, it remains unclear which SF information is more important for the emotional processing of fearful faces in patients with anxiety disorder.

Several researchers have suggested that detailed LSF information plays an important role in recognizing fearful facial expressions (Alorda et al., 2007; Holmes et al., 2005), while others argue that the HSF information is detrimental to perceiving fearful expression (Halit et al., 2006). According to a previous fMRI study, there was no significant difference in brain activity between patients with PD and HCs when processing facial expressions (fear and neutral) with different SFs (LSF and BSF) (Ottaviani et al., 2012). The authors also mentioned that LSF information was “not so crucial” for subcortical area responses during the processing of fearful faces. However, SF information was processed at high speeds in the brain via visual systems; thus, fMRI has a very low temporal resolution and may not be a suitable tool to capture the processing of SF stimuli. An event-related potential (ERP) study using electroencephalogram (EEG) could be an appropriate way to investigate information processing with SF because EEG has high temporal resolution. Furthermore, the authors focused only on the processing of LSF information and did not include the processing of HSF. Thus, it is still unknown if PD patients demonstrate different facial processing presented at HSF.

The purpose of this study is to use ERP techniques to investigate the visual processing of patients with PD in response to facial stimuli at different spatial frequency ranges. We used facial pictures of two emotions (fear and neutral) that were filtered to contain three types of SF (BSF, HSF, and LSF). We hypothesised that patients with PD would show disrupted processing of LSF information in an early stage of neural processing, whereas HSF deficit may occur in the later stages of neural processing. To the best of our knowledge, this is the first attempt to investigate rapid neural processes occurring in the visual system by studying the ERPs with SFs stimuli occurring in patients with PD.

2. Methods

2.1. Participants

Eighteen patients with PD (13 males and 5 females) and 19 HC (8 males and 11 females) were recruited for this study from the Psychiatry Department of Inje University Ilsan Paik Hospital. The patients' diagnoses were based on the Structured Clinical Interview for Diagnostic and Statistical Manual of Mental Disorders, 4th edition (DSM-IV) Axis I Psychiatric Disorders (Sheehan et al., 1998). Patients were excluded if they had diseases of the central nervous system, medical histories of alcohol or drug abuse, experience with electrical therapy, mental retardation, or a history of head injuries with loss of consciousness. Healthy controls were recruited from the local community through local newspapers and posters. After initial screening using the same criteria, control subjects were interviewed using the Structured Clinical Interview for DSM-IV Axis II Disorders. All subjects provided written informed consent, and the study protocol was approved by the Institutional Review Board of Inje University Ilsan Paik Hospital. Table 1 presents the demographic data of patients and healthy controls.

Table 1
Demographic data of patients with panic disorder and healthy controls.

	Panic disorder	Healthy controls	*p*
Cases (*N*)	18	19	
Gender (male/female)	13/5	8/11	0.099
Age (years)	42.89 ± 10.12	40.316 ± 8.73	0.431
Education	13.88 ± 2.85	14.60 ± 737	0.303
HAMA	20.59 ± 7.11	2.53 ± 3.20	0.000
HAMD	18.00 ± 8.86	2.82 ± 2.98	0.000
BDI	12.41 ± 7.53	6.16 ± 6.48	0.011
BAI	19.21 ± 10.95	6.11 ± 4.95	0.001
STAI_trait	43.20 ± 13.33	36.61 ± 6.55	0.074

HAMA: the Hamilton Rating Scale for Anxiety, HAMD: the Hamilton Rating Scale for Depression, BAI: Beck Anxiety Inventory, BDI: Beck Depression Inventory, STAI: Trait Subscale of Stated and Trait Anxiety Inventory.

2.2. Psychological evaluation and medication

To investigate symptoms of anxiety, the Hamilton Rating Scale for Anxiety (HAMA) (Hamilton, 1959) and the Beck Anxiety Inventory (BAI) (Beck and Steer, 1990) were used. Depression symptoms were evaluated by the Hamilton Rating Scale for Depression (HAMD) (Hamilton, 1986) and Beck Depression Inventory (BDI) (Beck et al., 1988). The participants' trait anxiety was assessed by the Trait Subscale of the Stated and Trait Anxiety Inventory (STAI) (Spielberger, 2010). Seventeen patients of PD take drugs such as escitalopram(n=8), venlafaxine(n=2), Paxil CR (n=5) and sertraline(n=1), and one patient does not take medication. Also, patients under medication take benzodiazepine medicines such as lorazepam(Ativan) and alprazolam.

2.3. Procedure

A total of 104 pictures of faces (52 fearful and 52 neutral facial expressions) were selected from the Korea University Facial Expression Collection (KUFEC) (Lee et al., 2006). The pictures were converted into grayscale. High SF and LSF pictures were obtained by applying high-pass (< 24 cycles/image) and low-pass (< 8 cycles/image) filters, respectively. The filtering procedures were carried out using MATLAB software, version 7.9 (The MathWorks, Natick, MA, USA). A statistical test using repeated measures ANOVA was used to ensure that the average intensity of each gray scale image did not differ between the SF and emotion (SF: F[1.730,88.210]=3.149, p=0.055; emotion: F[1,51]=1.959, p=0.168)).

The participants were seated in a comfortable chair facing a 17-inch CRT monitor in a sound-attenuated room. The experiment consisted of three sessions. In each session, the participant was presented with two facial stimuli, a fearful and a neutral face, and an irrelevant stimulus (a picture of a chair). The SF of the facial stimuli in a session was set to be either BSF, HSF, or LSF, which was maintained during each session. The participants were instructed to focus on the stimulus appearing on the screen. To ensure that the participants were concentrating on the stimulus, they were instructed to press a button whenever a chair was shown. Each session was composed of 100 facial (50 fearful and 50 neutral faces) and 20 chair stimuli appearing in a random order. Each trial began with a fixation cross for 200 ms, followed by a blank screen for 500 ms. The face or chair stimuli were presented for 500 ms