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Electrophysiological correlates of local–global visual processing in college students with schizotypal traits: An event-related potential study☆

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ABSTRACT

We examined local–global visual processing in college students with schizotypal traits using event-related potentials (ERPs). Local–global processing was assessed using a divided-attention task, in which large numbers (global level) composed of small numbers (local level) were presented. The control group had faster response time (RT) and more accurate responses to global-level than to local-level stimuli, whereas RT and accuracy did not differ between levels in the schizotypal-trait group. N150 amplitudes for local stimuli were larger than those for global stimuli in the schizotypal-trait group, whereas N150 amplitudes did not differ between levels in the control group. P300 amplitudes for local stimuli were larger relative to global stimuli in the control group, whereas P300 amplitudes did not differ between levels in the schizotypal-trait group. These results indicate that the global precedence effect was reduced in the schizotypal-trait group, possibly because of local-biased visual processing or difficulty in global processing.

1. Introduction

Visual processing abnormalities are associated with impairments in cognitive function including memory and attention (Brenner, Lysaker, Wilt, & O'Donnell, 2002; Haenschel et al., 2007; Lee & Cheung, 2005), increases in psychotic symptoms (Silverstein, Kovacs, Corry, & Valone, 2000; Uhlhaas, Phillips, Mitchell, & Silverstein, 2006), illness severity or chronicity (Silverstein et al., 2006), and impaired social functioning (Butler et al., 2005; Kim, Doop, Blake, & Park, 2005) in patient with schizophrenia. Moreover, visual processing abnormalities are thought to be a biological marker of schizophrenia, because they are present in patients with schizotypal personality disorder (Granholm, Cadenhead, Shafer, & Filoteo, 2002; Kent, Weinstein, Passrelli, Chen, & Siever, 2011), in nonclinical individuals with schizotypal traits (Goodarzi, Wykes, & Hemsley, 2000; Koychev, EL-Deredy, Haenschel, & Daekin, 2010; Tsakanikos & Reed, 2003), and in healthy first-degree biological relatives of patients with schizophrenia (Green, Nuechterlein, & Breitmeyer, 1997; Ross, Hommer, Radant, Roath, & Freedman, 1996).

Several studies have shown a deficit in global visual processing or a bias toward local visual processing in patients with schizophrenia; that is, patients tend to over-focus on local or irrelevant details at the expense of global or relevant information (Butler et al., 2005; Coleman et al., 2009; Landgraf et al., 2011; Poirel et al., 2010). Navon (1977) developed a local–global paradigm, in which hierarchically organized stimuli, such as large letters or numbers (global level) composed of small letters or numbers (local level), are presented, and participants are required to respond to either the global- or local-level stimuli. Based on the results of studies using this paradigm, Navon (1977) proposed the global precedence effect, which is characterized by a global advantage effect (perception of the global level occurs prior to perception of the local level, as indicated by faster and more accurate responses to global-level than to local-level stimuli) and a global interference effect (a conflicting global-level stimulus interferes with processing the local-level stimulus, but not *vice versa*). Most studies of local–global processing have observed the global precedence effect in healthy individuals (Navon & Norman, 1983; Peressotti, Rumiati, Nicoletti, & Job, 1991; Poirel, Pineau, & Mellet, 2008; Roux & Ceccaldi, 2001; Shedden & Reid, 2001).

Patients with schizophrenia have deficits in global-level processing of visual information and have a tendency for local-biased visual processing (Ferman, Primeau, Delis, & Jampala, 1999; Johnson, Lowery, Kohler, & Turetsky, 2005; Poirel et al., 2010;

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Silverstein et al., 1996). For example, Poirel et al. (2010) detected no significant differences in response time (RT) and accuracy between patients with schizophrenia and controls in response to local-level stimuli, whereas patients with schizophrenia had significantly slower RT and more errors than did controls in response to global-level stimuli.

Local–global visual processing can be assessed by directed-attention or divided-attention tasks, which produce different performance patterns in patients with schizophrenia. The directed-attention task consists of global and local conditions. For the global condition, participants are required to detect a target stimulus that occurs at the global level, whereas for the local condition, participants are required to respond to a target stimulus that occurs at the local level. Congruent (same features at both global and local levels) and incongruent (different features at global and local levels) stimuli are presented in the directed-attention task. However, in the divided-attention task, participants are required to detect a target stimulus whether it is presented at the global or local level, and only incongruent stimuli are presented. Previous studies have shown that performance on the divided-attention, but not on the directed-attention, task is impaired in patients with schizophrenia compared with control subjects because it requires greater cognitive effort, such as attentional shift, than the directed-attention task (Bellgrove, Vance, & Bradshaw, 2003; Coleman et al., 2009).

Psychophysiological and neuroimaging studies have identified neuroanatomical substrates underlying the global visual processing deficit observed in patients with schizophrenia (Butler et al., 2001, 2005; Inami & Kirino, 2004; Martinez et al., 2008, 2012). For example, using steady-state visual evoked potentials (ssVEP), Butler et al. (2001, 2005) found selective deficits in the magnocellular pathway, which is involved in processing gestalt or global features, in patients with schizophrenia. Compared with control subjects, the signal-to-noise ratio was reduced in patients in response to stimuli with low luminance contrast and low spatial frequency (LSF) but not in response to stimuli with high luminance contrast and high spatial frequency (HSF). Calderone, Martinez, et al. (2013) also observed that patients with schizophrenia showed selective deficit under LSF ssVEP condition, and reduced occipital activation volume for LSF, but not HSF, condition. Martinez et al. (2008) observed reduced activation in the magnocelluar visual pathway, including the striate and extrastriate visual areas, while processing stimuli with LSF in patients with schizophrenia compared with controls. In addition, Inami and Kirino (2004) found that local-level stimuli elicited greater activity in the left precuneus and global-level stimuli elicited less activity in the right middle/inferior occipital gyrus in patients compared with control subjects. Recently, Calderone, Hoptman, et al. (2013) investigated the cortical activations during an object recognition task, where objects containing either LSF or HSF were presented. Control subjects showed increased activation for LSF over HSF information in precuneus, superior temporal, and medial/dorsolateral prefrontal areas, whereas schizophrenia patients showed increased activation for HSF over LSF information in these areas. The authors suggested that these results demonstrate impaired processing of LSF information or a preference for local over global visual processing in patients with schizophrenia.

Event-related potentials (ERPs) arise from neural populations involved in information processing and, thus, may provide valuable information on the stages underlying local–global processing (Osman et al., 1992). Previous investigations of ERPs revealed that different neurophysiological mechanisms are involved in processing local and global aspects of stimuli (Beaucousin et al., 2011; Proverbio et al., 1998). For example, Johannes et al. (1996) reported that the posterior negative component occurring between 250 and 500 ms post-stimulus differed between local and global stimuli, and Proverbio et al. (1998) observed that N180 and P300 amplitudes were larger when attention was focused on global-level rather than local-level stimuli. Furthermore, Han et al. (2001) found that posterior P1 and N2 amplitudes were enhanced under the local stimuli relative to the global stimuli, and Jiang and Han (2005) reported that P1 amplitudes were larger under the local than the global condition; however, P2 amplitudes were larger under the global condition.

Few studies have used ERPs to investigate local–global processing in patients with schizophrenia. Johnson et al. (2005) found no differences in RT and accuracy between patients and healthy control subjects in response to local-level stimuli; however, responses to global stimuli were significantly slower and less accurate in the schizophrenia group. The N150 ERP amplitude, which was correlated with the speed of the response to global stimuli, was significantly reduced in the patients. Furthermore, the control group, but not patients, showed enhanced P300 amplitudes under the local relative to the global condition. The authors concluded that their findings supported a deficit in global visual processing in patients with schizophrenia.

Given that schizophrenia is highly heterogeneous and that several factors including antipsychotic drugs and length of illness or hospitalization can affect performance, investigating endophenotypes associated with schizotypal personality disorder (SPD) and non-clinical schizotypal traits have been viewed as a promising approach to understand schizophrenia (Siever & Davis, 2004). Indeed, SPD and schizophrenia share common genetic (Lin et al., 2005), neuroimaging (Dickey et al., 2002; Moorhead et al., 2009), and neuropsychological (Noguchi et al., 2008) abnormalities. Furthermore, visual processing abnormalities in figure/ground discrimination (Tsakanikos & Reed, 2003) and global–local processing (Goodarzi et al., 2000) have been detected in non-clinical individuals with schizotypal traits.

We used ERPs to investigate local–global processing in non-clinical college students with psychometrically defined schizotypal traits. The present study investigated whether individuals with schizotypal traits showed local-biased visual processing or deficits in processing of global-level stimuli as well as whether ERPs reflected these deficits. Based on previous findings in patients with schizophrenia, we hypothesized that behavioral and electrophysiological measures would reveal impaired processing of global information or a bias toward processing local information in individuals with schizotypal traits. To our knowledge, ours is the first reported study to use ERPs to investigate local–global processing in non-clinical individuals with schizotypal traits.

2. Method

2.1. Participants

We recruited 38 female college students from a pool of 564 students based on the Korean version of the Schizotypal Personality Questionnaire (SPQ; Moon et al., 1997; Raine, 1991) scores. The SPQ is a 74-item self-administered questionnaire with a “yes/no” response format. All “yes” responses receive a score of one, and higher scores indicate more schizotypal features. Students scoring in the top 5% of the SPQ were included in the schizotypal-trait group ($n = 19$), and the control group ($n = 19$) comprised students with average scores (± 1 standard deviation [SD]) on this instrument. The Structured Clinical Interview for DSM IV, non-patient version (First et al., 1996) was administered to ensure that participants did not have a history of psychiatric, medical, or neurological disorders or drug/alcohol abuse. The Korean version of the Wechsler Adult Intelligence Scale (K-WAIS; Yum et al., 1992) was administered to determine the IQ. All participants were right handed, and none was taking medication at the time of testing. The participants were paid