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Altered automatic face processing in individuals with high-functioning autism spectrum disorders: Evidence from visual evoked potentials

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ABSTRACT

Individuals with autism spectrum disorders (ASDs) have different automatic responses to faces than typically developing (TD) individuals. We recorded visual evoked potentials (VEPs) in 10 individuals with high-functioning ASD (HFASD) and 10 TD individuals. Visual stimuli consisted of upright and inverted faces (fearful and neutral) and objects presented subliminally in a backward-masking paradigm. In all participants, the occipital N1 (about 100 ms) and P1 (about 120 ms) peaks were major components of the evoked response. We calculated "subliminal face effect (SFE)" scores by subtracting the N1/P1 amplitudes and latencies of the object stimuli from those of the face stimuli. In the TD group, the SFE score for the N1 amplitude was significantly higher for upright fearful faces but not neutral faces, and this score was insignificant when the stimuli were inverted. In contrast, the N1 amplitude of the HFASD subjects did not show this SFE in the upright orientation. There were no significant group differences in SFE scores for P1 amplitude, latency, or N1 latency. Our findings suggest that individuals with HFASD have altered automatic visual processing for emotional faces within the lower level of the visual cortex. This impairment could be a neural component of the disrupted social cognition observed in individuals with HFASD.

Social dysfunction is a fundamental problem in autism spectrum disorders (ASDs). Consequently, face processing in individuals with ASD has been intensively studied on both the behavioral and neurological level. A range of face processing abnormalities has been described in individuals with ASD (Behrmann et al., 2006; Berger, 2006; Dawson, Webb, & McPartland, 2005; Grelotti, Gauthier, & Schultz, 2002; Sasson, 2006; Schultz, 2005), and their relatives (Baron-Cohen & Hammer, 1997; Bölte & Poustka, 2003; Wallace, Sebastian, Pellicano, Parr, & Bailey, 2010). Some researchers have proposed face processing as a candidate for a cognitive ASD endophenotype (Dawson et al., 2002; Wallace et al., 2010; Wilson, Brock, & Palermo, 2010).

Face processing relies on a distributed, patchy network of cortical regions and subcortical structures (Atkinson & Adolphs, 2011). The core cortical regions include the inferior occipital gyri (early perception of facial features), the lateral fusiform

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gyrus (perception of unique identity) and the superior temporal sulcus (perception of eye gaze, expression, and lip movement; Calder & Young, 2005). The non-conscious perception of emotional stimuli appears to involve several subcortical structures, which comprise two subsystems (Tamietto & de Gelder, 2010). One is the visually related emotion-encoding subsystem, which includes the amygdala, and the other is the non-visual emotion-encoding subsystem. These subcortical structures modulate cortical face processing (Tamietto & de Gelder, 2010). Further, these subcortical structures have been reported to be sensitive to low spatial frequency (SF) information about the emotional content of faces (Nakashima et al., 2008; Vlamings, Goffaux, & Kemner, 2009; Vuilleumier, Armony, Driver, & Dolan, 2003).

Emotionally significant stimuli, such as threat-related or social information, are first automatically processed outside of conscious awareness before being integrated with slower and more elaborative processing (Johnson, 2005). Abnormalities in automatic emotional processing are thought to be a key source of disrupted social cognition in individuals with ASD (Bailey, Braeutigam, Jousmäki, & Swithenby, 2005; Critchley et al., 2000). In accordance with this concept, our earlier behavioral study found that individuals with ASD responded to emotional faces differently than typically developing (TD) individuals, at an automatic level (Kamio, Wolf, & Fein, 2006). In contrast, ASD participants had normal performance for face tasks at a conscious level (Kamio et al., 2006a). Despite these findings, the neural basis of abnormal automatic processing of emotional faces in individuals with ASD remains uncertain.

The measurement of visual evoked potentials (VEPs) is an objective tool that has been useful in studies investigating the physiology and pathophysiology of the human visual system, including visual pathways and the visual cortex (Tobimatsu & Celesia, 2006). In particular, VEPs have high temporal resolution and are therefore suitable for the investigation of early automatic face processing. The major components evoked by conscious face stimuli are the occipital N1 (around 100 ms) and P1 (around 120 ms) peaks, and the occipito-temporal N170 (around 170 ms) peak (Bötzel, Schulze, & Stodieck, 1995; George, Evans, Fiori, Davido, & Renault, 1996). Both the N1 and P1 reflect the coarse processing of faces within the primary visual cortex (V1; Goto, Kinoe, Nakashima, & Tobimatsu, 2005; Mitsudo, Kamio, Goto, Nakashima, & Tobimatsu, 2011; Nakashima et al., 2008), whereas the N170 plays a role in processing features of faces or facial identification within the fusiform face area (FFA; Bentin, Allison, Puce, Perez, & McCarthy, 1996). When a supra-threshold face is inverted (the so-called "face inversion effect"), the N170 shows increased amplitude and delayed latency (Jacques, d'Arripe, & Rossion, 2007). This effect results from impaired integration of the features into a gestalt or holistic face representation (Young, Hellawell, & Hay, 1987). We recently reported that in healthy participants, occipital P1 amplitudes for unrecognizable (subliminal) faces are significantly larger than those for objects in the upright position (Mitsudo et al., 2011). However, P1 amplitudes for inverted faces are significantly smaller than those for upright faces. This is opposite to the face inversion effect for supra-threshold stimuli. Here, we call this phenomenon the "subliminal face effect (SFE)". Therefore, we consider that faces and objects are processed differently at the V1 level, even when the subjects are unaware of the stimuli before the face-specific processing occurs within the FFA. Taken together, changes in N1 or P1 in response to subliminal upright and inverted faces could provide an insight into the neural basis of automatic face processing in high-functioning ASD (HFASD).

In the present study, we hypothesized that individuals with HFASD have abnormal automatic processing at the V1 level (SFE in the upright or inverted orientation). To test this hypothesis, we used a 128-channel EEG system to record VEPs elicited by subliminally presented faces (fearful and neutral) and objects in the upright and inverted position. We measured the amplitudes and latencies of N1 and P1 peaks in response to these visual stimuli in HFASD and TD adults and calculated the SFE to quantify automatic face processing. We predicted that individuals with HFASD would exhibit a different pattern of V1 responses to masked subliminal faces in different orientations than TD individuals.

1. Methods

1.1. Participants

Ten individuals with HFASD (7 males and 3 females, aged 23–39 years, mean age 31.5) and 10 healthy TD control individuals (8 males and 2 females, aged 19–39 years, mean age 26.8) participated in this study. HFASD participants included four individuals with Asperger syndrome, one individual with high-functioning autism, and five individuals with pervasive developmental disorder not otherwise specified. The HFASD participants were recruited from the local Autism Society and local specialized psychiatric clinic. Diagnoses of ASD were confirmed, according to the DSM-IV-TR criteria (American Psychiatric Association, 2000), by a clinical research team that included an experienced child psychiatrist (Y.K.). ASD diagnoses were corroborated by a parental semi-structured interview that was developed and validated for Japanese populations with ASD, with a sensitivity of 0.943–0.975 and specificity of 0.929–0.956 (the PDD-Autism Society Japan Rating Scale [PARS]; Ito et al., 2012; Kamio et al., 2006b). Diagnostic agreement among the team was obtained for all participants. Although two of the 10 HFASD participants were being treated with small doses of antidepressants (1 with serotonin and noradrenalin reuptake inhibitors, 1 with quadricyclic antidepressants and selective serotonin reuptake inhibitors) at the time of participation, their symptoms were in remission and these individuals were psychologically stable. We evaluated intellectual function of the HFASD participants using the Japanese version of the Wechsler Adult Intelligence Scale-Revised. Individuals with ASD who had a full-scale IQ score lower than 85 were not included in the study.

TD control subjects were local college students and members of our faculty, who were interviewed to confirm the absence of any developmental or neuropsychiatric history, and/or medical conditions. None of the control participants were currently taking medication. TD control participants were confirmed to have normal intellectual functioning via interviews,