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Altered right frontal cortical connectivity during facial emotion recognition in children with autism spectrum disorders

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ABSTRACT

A growing body of evidence suggests that autism spectrum disorders (ASD) is associated with altered functional connectivity of the brain and with impairment in recognizing others' emotions. To better understand the relationships among these neural and behavioral abnormalities, we examined cortical connectivity which was indicated by theta coherence during tasks of facial emotion recognition in 18 children with ASD and 18 typically developing (TD) children who were between 6 and 18 years of age. We found that the children with ASD had general impairment in recognizing facial emotions, after controlling for response bias. Additionally, we found that the TD children demonstrated significant modulation of right frontal theta coherence in response to emotional faces compared to neutral faces, whereas children with ASD did not exhibit any modulation of theta coherence. The extent of modulation of theta coherence to emotions was further found to be related to the severity of social impairments in ASD. Our findings of a general impairment in facial emotion recognition and the involvement of disordered cortical connectivity in social deficits in children with ASD have shed light for future exploration of interventions regarding emotional processing and social functioning in ASD.

1. Introduction

Facial expressions convey important, specific social information, such as internal emotional states, to the observer (Blair, 2003). The interpretation and understanding of facial expressions of other people could guide appropriate actions, which are necessary for reciprocal social interaction (Baron-Cohen, Wheelwright, & Jolliffe, 1997). Thus, confusion of emotions and especially the misinterpretation of thinking that negative emotions are actually other kinds of emotions, for instance, positive emotions such as surprise (Kuusikko et al., 2009), might lead to inappropriate behavior and undesirable social outcomes. In school-aged children, the ability to recognize facial expressions of emotions was found to contribute to social competence (Goodfellow & Nowicki, 2009; Izard et al., 2001; Mostow, Izard, Fine, & Trentacosta, 2002). A longitudinal study

Abbreviations: ASD, autism spectrum disorders; CVT, Chinese vocabulary test; EEG, electroencephalography; TD, typically developing.

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by Izard et al. (2001) reported that the ability to recognize facial emotions at age 5 is a significant predictor of better social skills and fewer behavior problems at age 9, suggesting that the emotion recognition ability might have long-term effects on social competence.

Although the exact neural basis of emotion processing is not known, recent meta-analytic studies have suggested that it involves the functional coupling of various brain regions, including the amygdala, insula, visual cortex, temporal lobe and various sectors of the prefrontal cortex (Fusar-Poli et al., 2009; Kober et al., 2008; Lindquist, Wager, Kober, Bliss-Moreau, & Barrett, 2012). Kober et al. (2008) identified six functional groups of co-activated brain regions that make up the large-scale neural network in emotion processing. These regions include two frontal cortical groups that are responsible for executive function and the conceptualization of emotion, two posterior cortical groups that are responsible for visual processing and two sub-cortical groups that are responsible for the regulation of autonomic physiological activities. These functional groups also interact with each other during emotion processing. For example, the lateral prefrontal cortex might be co-activated with the medial prefrontal cortex and sub-cortical groups during the appraisal of emotions.

Autism spectrum disorders (ASD) is a group of lifelong neurodevelopmental disorders that are characterized by core impairments in reciprocal social interaction (American Psychiatric Association, 2000). Individuals with ASD tend to display inappropriate facial expressions and behavior in social situations (Lord, Rutter, & Le Couteur, 1994). One reason for such aberrant behavior might be their deficient skills in understanding others' emotions. However, despite decades of research, controversy remains regarding whether the ability to recognize facial emotions is impaired in individuals with ASD (See Harms, Martin, & Wallace, 2010; Uljarevic & Hamilton, 2013, for review). Some studies found that these individuals have general deficits in recognizing facial emotions (e.g., Kuusikko et al., 2009; Sucksmith, Allison, Baron-Cohen, Chakrabarti, & Hoekstra, 2013), while other studies showed that these deficits were limited to recognize negative emotions (e.g., Ashwin, Chapman, Colle, & Baron-Cohen, 2006; Philip et al., 2010) or complex emotions, such as surprise (Baron-Cohen, Spitz, & Cross, 1993). In contrast, some studies did not find any deficits (e.g., Castelli, 2005; Tracy, Robins, Schriber, & Solomon, 2011). Although these inconsistent findings might be due to the differences in methodology across these studies, a recent meta-analytic study (Uljarevic & Hamilton, 2013) reported that there is a general emotion recognition difficulty in autism, which had a large mean effect size (Cohen's $d = 0.80$). The mean effect is reduced to a medium ($d = 0.41$) effect that is still significant after correcting for publication bias.

A growing body of evidence suggests that individuals with ASD are characterized by disordered functional connectivity of the brain (see Kana, Libero, & Moore, 2011, for review). In the resting state of the brain in these individuals, abnormal short-range connectivity and abnormal long-range connectivity have been frequently reported (Cherkassky, Kana, Keller, & Just, 2006; Murias, Webb, Greenson, & Dawson, 2007; Weng et al., 2010). Murias et al. (2007) observed patterns of over- and under-connectivity at distinct temporal and spatial scales. Cherkassky et al. (2006) observed reduced frontal-posterior functional connectivity within the autistic brain. Additionally, disordered connectivity of the autistic brain was also extensively found in task-related states, such as during tasks of executive functioning (Just, Cherkassky, Keller, Kana, & Minshew, 2007), language processing (Just, Cherkassky, Keller, & Minshew, 2004), mental state attribution (Kana, Keller, Cherkassky, Minshew, & Just, 2009) and interpretations of the affective meaning of actions (Grèzes, Wicker, Berthoz, & de Gelder, 2009). Because emotion processing involves short-range and long-range functional coupling of brain regions that have been consistently reported to be disordered in ASD, it is conceivable that individuals with ASD would exhibit abnormal functional connectivity of these brain regions during tasks of facial emotion recognition. Additionally, this altered connectivity might be related to emotion recognition performance and the severity of the social impairments that are observed in ASD.

Electroencephalography (EEG) coherence measures have been used to study cognitive and affective processes. EEG coherence measures the level of synchronization between two cortical areas in terms of the EEG signals that are recorded at different channel sites of the scalp (Nunez & Srinivasan, 2006; Srinivasan, Nunez, & Silberstein, 1998) and could be influenced by the sub-cortical regions that mediate the two cortical regions (Locatelli, Cursi, Liberati, Franceschi, & Comi, 1998; Petsche, Kaplan, Von Stein, & Filz, 1997). High coherence indicates a high level of synchronization between the two brain areas, whereas low coherence indicates a low level of synchronization (Murias et al., 2007). It is believed that different EEG frequency bands correlate with different cognitive and emotional processes. The theta band (4–7.5 Hz) has been shown to be associated with affective processes (Aftanas, Varlamov, Pavlov, Makhnev, & Reva, 2001; Knyazev, Slobodskoj-Plusnin, & Bocharov, 2009). Previous studies that used typically developing (TD) individuals reported a robust increase of theta coherence that was mostly evident in the right frontal region in the initial stage of viewing affective pictures (Balconi, Brambilla, & Falbo, 2009) and static facial expressions of emotion (Balconi & Pozzoli, 2009). These studies found significant differences in theta coherence between viewing emotional and neutral pictures, regardless of valence. In the present study, we hypothesized that TD individuals would show modulation of theta coherence while viewing emotional faces, whereas individuals with ASD would exhibit an abnormal theta coherence pattern.

The objective of the present study was to understand the relationships between cortical connectivity, facial emotion recognition ability and social impairment in children with ASD. We anticipated that these children would have a general impairment in recognizing facial emotions. Additionally, we anticipated that these children would show an abnormal theta coherence pattern in short-range and long-range connectivity during facial emotion recognition and that this pattern would differ from the pattern that is observed in TD children. Lastly, we hypothesized that the abnormality in the theta coherence pattern in children with ASD would be associated with their facial emotion recognition ability and the severity of their social deficits.