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Recognizing syntactic errors in Chinese and English sentences: Brain electrical activity in Asperger's syndrome

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ABSTRACT

This study investigates electroencephalographic (EEG) oscillatory activity in the brain for bilingual participants with Asperger's syndrome (AS) and bilingual healthy control participants during visual recognition of syntactic errors in traditional Mandarin Chinese (native) and English (foreign) sentences. Reading performance is similar for the two groups in both languages. While reading Mandarin Chinese, the control group showed a left-hemispheric specialization within the 400–600 ms interval in delta synchronization. However, delta synchronizations were widely distributed in all scalp regions and lasted longer than 600 ms in the AS group. One possible interpretation of our data is the hypothesis that the AS group has more difficulty in brain organization of semantic and syntactic processes than the control group when reading their native language, because Chinese syntactic structure requires more work to be done by the perceiver. Nevertheless, other brain mechanisms (e.g., top-down regulation), can partially compensate for this difficulty, allowing AS subjects to attain the same level of response activity as the controls.

1. Introduction

Asperger's Syndrome (AS) was initially defined by Austrian psychiatrist Hans Asperger (cf. Asperger, 1994) to be an autism spectrum disorder in both behavioral and mental levels, with major difficulty in social communication. Examining the medical literature, there are numerous research paradigms focusing on the AS disorder, including physiological factors and possible treatments (American Psychiatric Association, 2000; Attwood, 2008; Fombonne, 2003; Klin, Volkmar, & Sparrow, 2000; Matson, Kozlowski, Hattier, Horovitz, & Sipes, 2012; Saracino, Noseworthy, Steiman, Reisinger, & Fombonne, 2010). The disorder appears in the first three years of life, and is more frequently observed in males than in females (Baron-Cohen et al., 2011). In clinical assessment, AS subjects demonstrate functional disorders in visual and phonological related perceptions (Jansson-Verkasalo et al., 2003; Saalasti, Tiippana, Katsyri, & Sams, 2011), and have problems of movement coordination and body position maintenance. When communicating verbally with others, they have essential difficulties in recognition of others' intentions and in expression of their own emotional states. According to Duverger, Da Fonseca, Bailly, and Deruelle (2007), AS children often experience failure to recognize emotional situations portrayed in pictures. On the

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other hand, their cognitive profiles show high verbal intelligence and normal linguistic ability with regard to syntax and semantics in speech recognition (Attwood, 2008; Klin et al., 2000). According to the ICD-10 criteria Asperger's syndrome differs from the non-specified autism spectrum disorder primarily in the fact that there is no general delay or retardation in language or in cognitive development.

It is possible to note that AS individuals can be worse in some mental abilities but better in others as compared with healthy controls (O'Connor & Kirk, 2008). Many AS adults are very successful in professional skills requiring a high intellectual ability, but involving relatively less inter-personal communication (Church, Alisanski, & Amanullah, 2000; Griswold, Barnhill, Myles, Hagiwara, & Simpson, 2002; Howlin & Yates, 1999). AS individuals who keep a normal level of cognitive development can partially compensate for syndrome-related behavioral disturbances through attention regulation. While AS children and adolescents occasionally exhibit aggressive behavior against peers and parents, for example, AS adults can use a mindfulness-based procedure to effectively control their aggressive tendencies to achieve a considerable amount of social success regardless of their perceptive and communicative deficits (Singh et al., 2011).

Neurophysiological studies on the disorder have primarily focused on its biological causes in the nervous system using modern neuroimaging techniques. For instance, structural and functional magnetic resonance imaging (fMRI) studies have shown that the disorder is accompanied by a decrease in volume size and hemodynamic responses in the amygdala, hippocampus (Dziobek, Fleck, Rogers, Wolf, & Convit, 2006; Murphy et al., 2012; Nacewicz et al., 2006; Schumann et al., 2004; Via, Radua, Cardoner, Happé, & Mataix-Cols, 2011; Williams et al., 2006) and thalamus (Baron-Cohen et al., 2006; Egawa et al., 2011; Hardan et al., 2006, 2008), and by a connectivity failure in the cortical-subcortical networks (Di Martino et al., 2011; Ecker et al., 2012; Langen et al., 2012; Williams, 2008). It is well known that AS children have difficulty recognizing vocal intonation, resulting in social communication problems (Kujala, Lepisto, Nieminen-von Wendt, Naatanen, & Naatanen, 2005). Functional MRI research indicates that AS deficits in perception in general and in identification of emotional faces in particular can be attributed to structural abnormality in the subcortical structure such as the amygdala and thalamus, which further deteriorate cortical-subcortical interactions (Aylward et al., 1999; Kleinhans et al., 2011; McAlonan et al., 2008; Pierce, Müller, Ambrose, Allen, & Courchesne, 2001; Salmond, de Haan, Friston, Gadian, & Vargha-Khadem, 2003).

While fMRI offers excellent spatial resolution for localizing brain regions activated during experiments, execution of tasks may engage real-time functional processes, which cannot be easily identified without tools of sufficient temporal resolution. Recently, there has emerged a research interest in neural correlates of AS using electro/magneto-encephalography (EEG or MEG) techniques, which assist the investigation of temporary dynamics of cognitive processes with reasonable accuracy (Lewine et al., 1999; Yang, Savostyanov, Tsai, & Liou, 2011; Yasuhara, 2010). These studies have used various experimental paradigms, namely resting-state (Barttfeld et al., 2011; Murias, Webb, Greenson, & Dawson, 2007), visual stimulus recognition (Milne, Scope, Pascalis, Buckley, & Makeig, 2009), speech recognition (Pijnacker, Geurts, van Lambalgen, Buitelaar, & Hagoort, 2010), face recognition (O'Connor & Kirk, 2008; Yang et al., 2011) and different sleep states (Lazar et al., 2010). AS subjects in general show atypical EEG reactions in visual perception (Milne et al., 2009), and tend to engage greater amplitudes in event-related potentials (ERPs) than healthy controls under stressful situations (Tiinanen et al., 2011). Although AS has been well studied by use of EEG paradigms, the isolated research findings do not serve an integrated support for interpreting behavioral disorders in terms of atypical brain oscillations. There is also a lack of knowledge on the compensatory mechanisms that assist AS adults in achieving a high level of success in cognitive performance.

High-level cognitive control is a self-regulation ability modulated by attention to important details in the environment. Cognitive controls are typically associated with top-down activity from the prefrontal cortex to other cortical and subcortical regions (Forstmann, van den Wildenberg, & Ridderinkhof, 2008; Koechlin, Ody, & Kouneiher, 2003; Ridderinkhof, Ullsperger, Crone, & Nieuwenhuis, 2004). In EEG studies, electrographic responses in the frontal and anterior temporal cortical regions reflect top-down brain activity associated with high-level cognitive controls, whereas responses in occipital-parietal regions are more related to sensory bottom-up processes (Näätänen, 1992). Top-down cognitive controls are also included in stimulus recognition during language processing (Yvert, Perrone-Bertolotti, Baciu, & David, 2012). The recognition of written speech includes both top-down and bottom-up processes, as indicated by different ERP peaks or fMRI blood oxygen level-dependent (BOLD) responses. It was shown that the left inferior prefrontal cortex (LIPC) is involved in top-down control in language comprehension, and its activation level is correlated with task difficulty in word and sentence recognition (Mishra, 2009; Hirschfeld & Zwitserlood, 2011; Whitney, Grossman, & Kircher, 2009). A fMRI study on brain transfer effects also suggested that language training may modulate brain activity in the fronto-parietal regions involved in the top-down regulation of auditory functions (Elmer, Meyer, Marrama, & Jäncke, 2011). Clinical studies have suggested that some neurological and psychiatric disorders in stimulus recognition can be compensated for by strengthening top-down controls (Clement & Belleville, 2010; Rabinovich, Afraimovich, Bick, & Varona, 2012; Woodard et al., 2009); that is, patients suffering disorders in bottom-up processes can demonstrate almost normal behaviors by strengthening top-down cognitive controls. For example, an age-related decline in sensory functions in elderly people can be compensated for by strengthening top-down activity in language comprehension (Wingfield & Grossman, 2006). It seems that the language organization in the AS brain differs in some aspects from that in the brains of healthy controls. As mentioned, AS children have gross violations in diction and phonological perception (Jansson-Verkasalo et al., 2003; Saalasti et al., 2011), but AS adults are able to improve their linguistic skills, using speech communication effectively. We hypothesize that AS adults with the compensated disorder (e.g., high response accuracy in language tasks) will demonstrate an increase in the brain electrical activity that reflects top-down control in language comprehension tasks.