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Differential electrophysiological responses to biological motion in children and adults with and without autism spectrum disorders

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A B S T R A C T

Although atypical processing of biological motion (BM) in individuals with autism spectrum disorder (ASD) has been reported, the temporal profile of the neural response to BM is not well explored. In the current study, event-related potentials (ERPs) were measured in 12 individuals with ASD, aged 8–22 years, and 12 age- and gender-matched normal controls, to investigate the electrophysiological response to BM and a control visual stimulus. By introducing a novel experimental paradigm that can dissociate the electrophysiological responses to motion processing and the global shape processing of BM, we found that: (1) the timing of the response was preserved in ASD groups, whereas (2) the ERP response to BM was significantly enhanced compared with scrambled point-light motion (SM) in normal controls; the responses to both BM and SM were not significantly different in subjects with ASD. Because we did not find a significant group effect on the peak and mean amplitude induced by BM, it is presumed that this atypical response in individuals with ASD was due to over-sensitivity to the local motion signals. This experimental paradigm showed atypical local motion processing of BM in individuals with ASD.

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1. Introduction

Our visual system can retrieve socially relevant information from human body movements. One of the well-known visual phenomena is biological motion (BM), whereby one can perceive vivid actions from only a dozen points of light attached to the joints (Johansson, 1973). Recently, much attention has been drawn to this visual phenomenon in the context of social perception (Allison, Puce, & McCarthy, 2000; Pavlova, 2011) because it has been found that individuals with autism spectrum disorder (ASD) have difficulty in detecting or identifying a human action from point-lights movement (Blake, Turner, Smoski, Pozdol, & Stone, 2003; see for the review, Dakin & Frith, 2005; Kaiser, Delmolino, Tanaka, & Shiffrar, 2010; Koldewyn, Whitney, & Rivera, 2010). Early pioneering work suggests that individuals with ASD perform poorly in identifying an action from point-lights, but the performance is not significantly worse compared with that of normal control individuals (Moore, Hobson, & Lee, 1997). A subsequent behavioral study by Blake et al. (2003) found that children with ASD have difficulty in identifying a human action from point-lights, however, the ability to detect a coherent figure from static lines was comparable to normally developed children. Compatible with this view, a recent eye-tracking study revealed that even 2-year-old children with ASD showed an atypical preference for BM stimulus (Klin, Lin, Gorrindo, Ramsay, & Jones, 2009). In common with the study, several researchers have reported a similar tendency in children with ASD, indicating that they are not good at detecting a human figure from moving dots using behavioral measures (Annaz, Campbell, Coleman, Milne, & Swettenham, 2012; Annaz et al., 2011; Kaiser, Delmolino, et al., 2010; Klin et al., 2009; Koldewyn et al., 2010). However, for adults with ASD, the results still seem to be controversial whether the processing of BM is typical (Murphy, Brady, Fitzgerald, & Troje, 2009; Saygin, Cook, & Blakemore, 2010) or atypical (Cook, Saygin, Swain, & Blakemore, 2009; Kaiser, Delmolino, et al., 2010).

Studies have shown that BM perception is a part of 'social perception' (Allison et al., 2000), and the core brain regions of social brain network are involved in the processing of BM, such as the posterior part of the superior temporal sulcus (pSTS) (Bonda, Petrides, Ostry, & Evans, 1996; Grossman & Blake, 2001; Grossman et al., 2000; Michels, Kleiser, de Lussanet, Seitz, & Lappe, 2009; Pelphrey et al., 2003; Peuskens, Vanrie, Verfaillie, & Orban, 2005; Vaina, Solomon, Chowdhury, Sinha, & Belliveau, 2001), fusiform gyrus (Grossman & Blake, 2002; Grossman, Blake, & Kim, 2004; Santi, Servos, Vatikiotis-Bateson, Kuratate, & Munhall, 2003), amygdala (Bonda et al., 1996), and the frontal region (Saygin, 2007; Saygin, Wilson, Hagler, Bates, & Sereno, 2004). In addition to these brain regions, the middle temporal/V5 complex (hMT/V5+) (Grezes et al., 2001; Howard et al., 1996), kinetic-occipital (Servos, Osu, Santi, & Kawato, 2002; Vaina et al., 2001), and cerebellum (Grossman et al., 2000; Jokisch, Troje, Koch, Schwarz, & Daum, 2005) are also involved. A recent fMRI study demonstrated that the fusiform body area and the extrastriate body area are the two main regions involved in the processing of the point-light walker stimulus (Jastorff & Orban, 2009). Furthermore, transcranial magnetic stimulation (TMS) and neuropsychological studies have shown that the pSTS region (Grossman, Battelli, & Pascual-Leone, 2005) and premotor region (Saygin, 2007) are also vital for detecting a human figure from point-lights motion.

Along with the behavioral findings, atypical neural activities underlying the perception of BM in individuals with ASD (Freitag et al., 2008; Kaiser, Hudac, et al., 2010; Koldewyn, Whitney, & Rivera, 2011) or Asperger syndrome (Herrington et al., 2007) have also been reported (Kaiser & Pelphrey, 2012). Freitag et al. also found less activation in the middle temporal gyrus close to the STS, as well as in the postcentral gyrus and inferior parietal lobe in individuals with ASD when the activation during perception of BM was contrasted with activation during perception of control visual stimulus, such as spatially scrambled point-light motion (SM; the same number of point-lights with the same velocity vectors, but their initial starting positions are randomized) (Freitag et al., 2008). Kaiser, Hudac, et al. (2010) found reduced activities in the right pSTS region contrasting BM minus SM stimulus in subjects with ASD compared with unaffected siblings and normally developing children. These findings imply that the dysfunction in a part of the social brain network, such as the pSTS region, might lead to impairment in the ability to detect BM in individuals with ASD (Zilbovicius et al., 2006).

Despite the fact that our visual system can process BM rapidly (Puce & Perrett, 2003), the temporal aspect of the neural activities underlying BM perception in individuals with ASD has not been well explored except for a recent event-related potential (ERP) study (Kroger et al., 2013). Using electroencephalography (EEG) and magnetoencephalography (MEG) techniques, the temporal aspect of the neural activities underlying the perception of BM in normal adults and children was explored. Several ERP (Hirai, Fukushima, & Hiraki, 2003; Hirai, Senju, Fukushima, & Hiraki, 2005; Jokisch, Daum, Suchan, & Troje, 2005; Krakowski et al., 2011; Hirai, Watanabe, Honda, & Kakigi, 2009) and magnetoencephalography (MEG) (Hirai, Kaneoke, Nakata, & Kakigi, 2008; Pavlova et al., 2006; Virji-Babul, Cheung, Weeks, Kerns, & Shiffrar, 2007) studies have also shown the neural dynamics of BM processing. ERP studies (Hirai et al., 2003; Hirai et al., 2005; Jokisch, Daum, et al., 2005; Krakowski et al., 2011) have demonstrated that two negative components are specified at around 200 ms and 240–500 ms after stimulus onset in the bilateral occipitotemporal region. These results suggest that the first component, which was estimated in the vicinity of the kinetic occipital and hMT region (Krakowski et al., 2011), reflects the processing of motion (Hirai & Kakigi, 2008) or a pattern of moving dots that represent a familiar human form, such as body-sensitive neural responses that are observed at 190 ms (Peelen & Downing, 2007; Stekelenburg & de Gelder, 2004; Thierry et al., 2006). The second component ($\sim$500 ms), which was estimated in the vicinity of the pSTS region (Hirai et al., 2008; Krakowski et al., 2011) or the superior temporal gyrus and fusiform gyrus regions (Jokisch, Daum, et al., 2005), might be sensitive to coherent human forms, rather than object forms as mediated by global motion information (Safford, Hussey, Parasuraman, & Thompson, 2010; Virji-Babul et al., 2007). This concept of a two-stage processing model in BM seems to be compatible with the framework regarding a hierarchical model of BM processing (Troje, 2008).