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Individual differences in high-level biological motion tasks correlate with autistic traits

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ABSTRACT

Human actions are rich in social cues and play an essential role in interacting with the social environment. Hence, the perception of biological motion (i.e., movement elicited by humans and other animals) is considered to be an important gauge of a person's social cognition capacities. It has been well-documented that Autism Spectrum Disorder (ASD) is associated with difficulties in social interactions. In the present study, we examined whether individual differences in biological motion perception relate to the degree of autistic traits among people in the typically-developing population. We employed three tasks that require different degrees of involvement of global action processing: action discrimination in noise, action inversion effect in binocular rivalry, and inter-personal interaction recognition. We found that individuals with higher numbers of autistic traits showed similar action discrimination performance as individuals with fewer autistic traits but exhibited a reduced inversion effect in binocular rivalry, and a decreased ability to recognize meaningful human interactions. These findings provide converging evidence that global processing of biological motion is affected in people with a high degree of autistic traits.

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1. Introduction

In our very social world, a person who is not able to interact properly with other people, or correctly interprets their intentions, is confronted with a social disadvantage. Autism Spectrum Disorder (ASD) is a range of developmental conditions in which a person has difficulties with social interaction and social communication, and exhibits a restricted range of behaviors and interests (Frith, 1989). Because of the difficulties in these important social tasks, ASD has been the topic of many investigations.

Biological motion stimuli are very rich in social cues. Even very impoverished visual stimuli, consisting only of around a dozen points depicting joint movements of human body motion (point-light displays, PLD; (Johansson, 1973)) carry information about action types, emotions, gender, sign-language, and interactions (Chouhrouelou, Matsuka, Harber, & Shiffrar, 2006; Dittrich, 1993; Dittrich, Troscianko, Lea, & Morgan, 1996; Manera, Del Giudice, Bara, Verfaillie, & Becchio, 2011; O'Toole et al., 2011; Poizner, Bellugi, & Lutes-Driscoll, 1981; Roether, Omlor, Christensen, & Giese, 2009; Thurman & Lu, 2014; van Boxtel &

Lu, 2011, 2012). Because of the importance of biological motion perception in facilitating social communications, it has often been investigated in the clinical ASD population, as well as in the broader spectrum.

Early investigations showed that biological motion perception was impaired in the ASD population (Blake, Turner, Smoski, Pozdol, & Stone, 2003; Moore, Hobson, & Lee, 1997). Subsequent work has yielded mixed evidence regarding the impact of autism on biological motion perception (Kaiser & Pelphrey, 2012; Kaiser & Shiffrar, 2009). Some studies showed impairments in biological motion perception in ASD (Annaz et al., 2010; Klin, Lin, Gorrindo, Ramsay, & Jones, 2009; Koldewyn, Whitney, & Rivera, 2010; Nackaerts et al., 2012; van Boxtel, Dapretto, & Lu, 2016), but others found an absence of behavioral impairments (Cleary, Looney, Brady, & Fitzgerald, 2014; Cusack, Williams, & Neri, 2015; Herrington et al., 2007; Jones et al., 2011; Kaiser et al., 2010; McKay et al., 2012; Murphy, Brady, Fitzgerald, & Troje, 2009; Saygin, Cook, & Blakemore, 2010). Furthermore, some recent studies found that even in the absence of behavioral impairments, brain activity can still differ between the people with ASD and a control group (Freitag et al., 2008; Herrington et al., 2007; Kaiser et al., 2010; McKay et al., 2012), suggesting that more subtle differences in the neural mechanisms involved in biological motion processing

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may be present, even when not directly reflected in behavioral differences.

A possible contributor to the equivocal nature of the findings regarding biological motion perception in ASD is that many of the previously employed tasks can be solved using different processing levels. Biological motion perception is supported by both local processes that analyze motion trajectories of individual joints (e.g., foot movements in a walking action), and global processes that are sensitive to the combined movements of the joints resulting in posture changes over time (Chang & Troje, 2009a, 2009b; Hirai, Chang, Saunders, & Troje, 2011; Saunders, Suchan, & Troje, 2009; Thurman & Lu, 2013; Troje & Westhoff, 2006; van Boxtel & Lu, 2015). Many tasks, such as a discrimination task in which participants were asked to categorize a point-light walker embedded in a noise background (e.g., Jones et al., 2011; Koldewyn, Whitney, & Rivera, 2011; Koldewyn et al., 2010), could potentially be performed using either local movements of individual joints or global cues of body movements. Thus, if people in the general population process biological motions automatically at the global level, while people with ASD employ a more local process, a group difference would not be observed in behavioral measures. It follows that finding an impairment in the ASD group will depend not only on the type of stimulus (e.g., biological motion), but also on specific stimulus differences (e.g., type of noise, or type of action), or task differences (e.g., action detection/discrimination versus emotion detection/discrimination). Hence, to understand the impact of autism on biological motion perception, a range of experimental paradigms should be tested and compared.

In order to examine whether the perceptual difficulties in ASD extend into the general population, the present paper focuses on the relationship between individual differences in biological motion perception and variations in the degree of autistic traits among participants drawn from the typically-developing population. The systematic study of individual differences is a powerful paradigm that may reveal important findings that would otherwise be lost through averaging over individual results (Wilmer, 2008; Peterzell, 2016). Previous research has shown that people who are not clinically diagnosed with ASD also differ in their ability to interpret social actions and interactions, with some individuals being better than others. This variability in non-clinical samples has spurred interest in the “broader phenotype” of autism (Bailey et al., 1995). For example, researchers have tested family members of those diagnosed with ASD (e.g., Ahmed & Vander Wyk, 2013; Kaiser et al., 2010; Scheeren & Stauder, 2008), or looked at variation within the general population as a whole (see below).

The desire to investigate individual differences in ASD-related difficulties within the general population has inspired the development of a self-administered questionnaire that measures the number of “autistic traits” in adults (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) and children (Auyeung, Baron-Cohen, Wheelwright, & Allison, 2008). This questionnaire aims to measure “where any given individual lies on the continuum” in a quick and easy manner. The questionnaire yields a score of 0–50, which is termed the Autism-Spectrum Quotient (AQ), with higher scores meaning more autistic traits. The AQ score has been widely used in research settings to investigate individual differences, addressing a wide range of research questions, spanning from magnocellular visual responses (Sutherland & Crewther, 2010) to social understanding (Yang & Baillargeon, 2013). One of the main aims has been to investigate the relation between social perception tasks and the AQ. In the present paper, we will focus on the task of biological motion perception, which is considered to be an important gauge of a person’s social cognition capacities (Pavlova, 2012).

The relation between individual differences in biological motion perception and the degree of autistic traits has recently received

attention in several studies. Miller and Saygin (2013) found that an individual’s ability to perform tasks that involve form cues in biological motion correlated with measures of social perception, including Empathy Quotient (EQ), AQ and Reading the Mind in the Eyes Test (RMET). Our recent study also showed that individuals with a high number of autistic traits display reduced adaptation to biological motion at the global processing level (van Boxtel & Lu, 2013b) (as was subsequently confirmed in an ASD sample; van Boxtel et al., 2016). Individuals with high AQ scores are distracted to a lesser extent by task-irrelevant biological motion (van Boxtel & Lu, 2013b). People with a high level of autistic traits have also been found to have an elevated detection threshold for biological motion stimuli, and this effect was especially strong for threatening actions (Kaiser & Shiffrar, 2012). This latter finding is consistent with a reduced recognition of fear in biological motion displays by people with high levels of autistic traits (Actis-Grosso, Bossi, & Ricciardelli, 2015).

To examine the relation between biological motion perception and autistic traits more systematically, we gathered data on three biological motion tasks, aiming to vary the degree to which global processing is needed to perform the tasks in the different experiments. We focused on action discrimination in noise in Experiment 1, inversion effects during binocular rivalry in Experiment 2, and recognition of inter-personal interactivity in Experiment 3. We aimed to investigate tasks that could potentially be solved based on local processing alone (discrimination in noise), tasks that require automatic holistic processing, and tasks that heavily rely on global processing (such as recognition of meaningful interactivity between two actors). This range of tasks allowed us to examine the dependence of AQ on different levels of action processing.

2. Experiment 1: Biological motion discrimination in noise does not correlate with AQ

Previous research found that individuals with autism showed reduced discrimination to biological motion in noise relative to a control group (Annaz et al., 2010; Koldewyn et al., 2010, 2011). In Experiment 1, we employed the classic paradigm of dynamic random dot kinematograms to mask action dynamics, and to measure action discriminability. We measured the discrimination of facing directions of walking actors, and investigated the relationship between discrimination performance and the AQ measure in the typically-developing population.

2.1. Participants

Seventy-two undergraduate students at the University of California, Los Angeles (UCLA) (mean age = 20.6 years; 46 female) participated in the experiment for course credit. All participants involved in the three studies reported in the present paper had normal or corrected-to-normal vision. Throughout the paper we excluded potential outliers based on Z-scores of both the dependent measure and the AQ score, excluding participants that were more extreme than 99% of the population ($abs(Z) > 2.5758$). We excluded one participant based on this exclusion criterion in the analysis of Experiment 1.

2.2. Stimuli

All action stimuli in the present paper were selected from the CMU motion-capture database (<http://mocap.cs.cmu.edu>) and processed by the Biological Motion Toolbox (van Boxtel & Lu, 2013a). In Experiment 1, we selected one walker from the dataset and presented the walking action with the point-light display (Johansson, 1973) in the profile view, as shown in Fig. 1 (left). The point-light

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