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In sync or not in sync? Illusory body ownership in autism spectrum disorder

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ABSTRACT

Background: A fundamental aspect of self-consciousness is body ownership, which refers to the experience that our body and its parts belong to us and it is distinct from those of other persons. Body ownership depends on the integration of different sensory stimulations and it is crucial for the development of functional motor and social abilities, which are compromised in individuals with autism spectrum disorder (ASD). Here we examined the multisensory nature of body ownership in individuals with ASD by using a procedure based on tactile conflicts, namely the numbness illusion (NI).

Method: We induced an illusory feeling of numbness and ownership for another person's finger by asking participants to hold their palm against another person's palm and to stroke the two joined index fingers with the index and thumb of their other hand.

Results: As expected, when the agent self-strokes their finger, healthy participants do not perceive the NI if the stroking is performed asynchronously. Conversely, in individuals with ASD the illusion occurred with both synchronous and asynchronous self-stroking.

Conclusions: We contend that individuals with ASD are more vulnerable than controls to this illusory tactile experience and we discuss the findings in light of impaired perception of the temporal relationships between tactile and proprioceptive inputs.

1. Introduction

The feeling that our body and its parts belong to us and not to other people is a fundamental aspect of self-consciousness, termed body ownership (Gallagher, 2000). Body ownership changes dynamically depending on the nature of the sensory and motor signals experienced (Tajadura-Jiménez & Tsakiris, 2013), as well as on the agent generating those signals (self vs. other; Dijkerman & de Haan, 2007). It originates from the integration of multisensory signals (Van den Bos & Jeannerod, 2002). Therefore, certain incongruent conditions of visual, tactile and proprioceptive stimulation can induce errors or illusions of body ownership for a fake (i.e., rubber) hand (e.g. Botvinick & Cohen, 1998) or for a virtual body (Ehrsson, 2007; Lenggenhager, Tadi, Metzinger, & Blanke, 2007). The integrity of the perception of body ownership has been investigated by manipulating the usual spatial and temporal correlations among sensory inputs using tasks such as the 'rubber hand illusion' (RHI; Botvinick & Cohen, 1998; Tsakiris & Haggard, 2005). In this task, the sense of body ownership is altered by delivering regular brush strokes to the participant's visually obscured hand while

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simultaneously administering identical strokes to the same somatic location on a visible rubber hand that the participant is instructed to watch. After a short period of synchronous brushing, participants often report that it begins to feel as if the rubber hand is the participant's own hand. These illusory effects are not reported when the tactile (own hand) and visual (rubber hand) brush strokes are delivered asynchronously, suggesting that such temporally incongruent stimuli are not integrated in a unitary percept.

Given that the development of a sense of body ownership is crucial not only for motor skills such as navigating one's environment (Piaget, 1952), but also for the development of social relations (Chaminade, Meltzoff, & Decety, 2005; Gallese, Keysers, & Rizzolatti, 2004), the study of the RHI illusion has been thought to be of value for the characterization of autism spectrum disorder (ASD). Results from the relatively few studies investigating this issue indicate that children with ASD were initially less susceptible to the illusion than the comparison group, showing a delayed effect of the illusion (Cascio, Foss-Feig, Burnette, Heacock, & Cosby, 2012). Furthermore, they did not show the same overall sensitivity to visuotactile-proprioceptive discrepancy between the rubber hand and the real hand, as for the control group (Paton, Hohwy, & Enticott, 2012). Overall, these findings have been explained in terms of an atypical multisensory temporal integration processing in ASD (Foss-Feig et al., 2010; Kwakye, Foss-Feig, Cascio, Stone, & Wallace, 2011). An additional (and non-mutually exclusive) explanation regarding the RHI in ASD considers an increased difficulty in disembodying the bodily self and embodying the bodily other, suggestive of a steeper and less flexible gradient from self-to-other perception (Noel, Cascio, Wallace, & Park, 2017). Altogether these findings have helped disentangling how typical and atypical recruitment of somatosensory resources modulates the embodied experience (Gallese, 2003), opening to a better understanding of how socio-emotional skills such as imitation and empathy may emerge in ASD.

Despite the evidence for atypical body ownership in ASD collected via the RHI (Cascio et al., 2012), empirical evidence on which conditions promote the emergence of abnormal body representations in individuals with ASD is still scarce. To fill this gap, here we empirically explored how tactile and proprioceptive cues modulate the sense of body ownership in ASD, by evaluating the strength of the 'numbness illusion' (NI; Boulware, 1951). The NI arises when one person holds her palm against another person's palm and strokes with the index and thumb of his/her free hand the two joined index fingers. When the stroking occurs synchronously, individuals tend to experience their index finger as bigger or numb and belonging to the confederate (Dieguez, Mercier, Newby, & Blanke, 2009), suggesting an illusory tactile sensation and the disruption of body ownership over one's own finger. In neural terms, the NI has been explained as a result of somatosensory predictions and lack of anticipated somatosensory stimulation (Blakemore, Frith, & Wolpert, 1999). In particular, by inducing the NI while recording somatosensory evoked potentials (SEPs) provoked by median nerve stimulation, Dieguez et al. (2009) showed that illusory finger ownership was associated with a modulation of the earliest cortical component (i.e., the N20 component) of the SEP, which is a marker of the activity in the primary somatosensory cortex (S1). This result has been later confirmed and extended by Martuzzi et al. (2015) in an fMRI study showing that bodily experience modulates the activity within certain subregions of S1, and that the high degree of somatosensory specialization in S1 extends to bodily self-consciousness.

In the present work, we aimed at exploring for the first time the behavioral manifestations of the NI in individuals with ASD, as to assess whether and how their body ownership experience is modulated by synchronous as asynchronous stroking of their fingers as performed by themselves and by another agent. In case of a typical experience of the NI, we would expect individuals with ASD to experience it only when self-synchronous pattern stroking occurs. Variations from this typical pattern would be considered informative in the characterization of body ownership experience in ASD.

2. Methods

2.1. Participants

Eighty-two participants (22 females and 60 males, age range 19–36 years) were included in the study: forty-one individuals with autism spectrum disorder (ASD; 11 females and 30 males, age range 19–31 years, mean age ± 24.78) and forty-one individuals with typical development (11 females and 30 males, age range 19–36 years, mean age ± 24.56). Sample size was estimated by means of the G*Power 3.1 software (Faul, Erdfelder, Buchner, & Lang, 2009) in order to have a high statistical power ($> .95$) even in the case of a medium-small effect size (.22). Individuals with ASD were recruited via the local Pediatric and Developmental Neuropsychiatric Clinics. Diagnosis of ASD was confirmed with the evaluation of a licensed clinical psychologist based on the Diagnostic and Statistical Manual of Mental Disorder – 5 (DSM-5) and supported with standardized measures as the Autism Diagnosis Observation Schedule (ADOS; Lord, Risi, Lambrecht, Leventhal, & DiLavore, 2000) and the Autism Diagnostic Interview – Revised (ADI-R; Lord, Rutter, & Le Couteur, 1994).

A comparison group of healthy participants was recruited on campus at the University of Padova. Volunteers were included in the control group if they indicated that they did not have a diagnosis of ASD, nor suspect they have ASD, nor have a family member with a diagnosis of ASD. The general cognitive functioning of participants was measured by means of the Wechsler Adults Intelligence Scale – Fourth Edition (WAIS-IV; Wechsler, 2008; Italian language adaptation: Orsini & Pezzuti, 2013) or by Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999). Both groups did not differ for age, gender and full-scale IQ. All information about the sample description is provided in Table 1.

The experimental procedures were approved by the local ethical committee and the study was carried out in line with the ethical standards of the Declaration of Helsinki (Sixth Revision, 2008). All participants provided written informed consent.