Original Articles

Reduced sensitivity to social priors during action prediction in adults with autism spectrum disorders

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ABSTRACT

An extensive amount of evidence has documented a diminished ability to predict and understand other people's action in individuals with autism spectrum disorders (ASD). Recently, two theoretical accounts, the "Hypo-priors" and the "Aberrant precision" hypotheses, have suggested that attenuated Bayesian priors or an imbalance of the precision ascribed to sensory evidence relative to prior expectations may be responsible for the atypical perceptual experience and difficulties with action understanding in ASD. In the present study, we aimed to directly investigate whether difficulties in the appreciation of others' intentions can be accounted for by abnormal interaction between these two types of information: (i) the sensory evidence conveyed by movement kinematics, and (ii) the observer's expectations, acquired from past experience or derived from prior knowledge. To test this hypothesis, we contrasted the ability to infer Non-Social and Social intentions in adults with and without ASD, using a series of tasks in which both sensory evidence and prior expectations were manipulated. The results showed that attenuated effect of prior expectations in ASD individuals does not result from a generalized impairment in mentalizing, but one confined to social intentions. Attenuated priors in the social domain predicted the severity of clinical symptoms in the area of social interaction. Importantly, however, we found that reduced priors in the social domain could be compensated by ASD through observational learning, i.e. through deriving statistical regularities from observed behaviours. This capacity to balance reduced social expectations by learning inversely correlated with the severity of repetitive and stereotyped behaviours. Collectively, these findings suggest that adults with ASD exhibit a disturbance in the inferential mechanism that integrates sensory evidence into prior beliefs to produce accurate inferences about other people's intentions.

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1. Introduction

Diminished social functioning constitutes one of the core features of ASD. In the last decades, an extensive literature has focused on disturbances of mentalizing or Theory of Mind (ToM), i.e. the ability to attribute beliefs and other mental states to oneself and to others, in individuals with ASD (e.g. Baron-Cohen, 1995; Baron-Cohen, Leslie, & Frith, 1985, 1986; Frith, 1989; Happé & Frith, 1996). However, the nature of the impairment affecting action and intention understanding in ASD is still a matter of debate (Hamilton, 2009). While children with autism have impaired or delayed maturation of ToM, adults with high-functioning ASD continue to experience difficulties with understanding others' intentions in real-life situations, even when they succeed on standard tests for ToM. Questions have also been raised as to whether difficulties reflect selective impairments in mentalizing or disturbances of low-level mechanisms of action perception or of the resonance mechanism supported by the neuron mirror system (Smith & Bryson, 1994; Hughes, 1996; Russell & Jarrold, 1998, 1999; Zalla, Bouchilloux et al., 2006; Zalla, Labruyere, & Georgieff, 2006; Cattaneo et al., 2007; Fabbri-Destro, Cattaneo, Boria, & Rizzolatti, 2009; Vanvuchelen, Roeyers, & De Weerdt,

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2007; von Hofsten & Rosander, 2012; Zalla, Labruyère, & Georgieff, 2013).

Using different experimental paradigms, current studies support the notion of preserved goal and action understanding in individuals with ASD (Hamilton, 2009) while difficulties arise when goals and actions are not visible outcomes, and have to be inferred on the basis of the available visual and contextual information (Cattaneo et al., 2007; Gomot & Wicker, 2012; Zalla, Labruyere, Clément, & Georgieff, 2010). These results suggest that difficulties with action understanding in individuals with ASD might arise from impairments in complementing (i.e. contextualizing) the available sensory evidence with other information. Recently, it has been suggested that sensory atypicalities in ASD – such as enhanced sensations, experience of sensory overload, or hypersensitivity – can be explained by a diminished influence of top-down prior expectations on perceptual experience ("hypo-priors") associated with increased reliance on sensory evidence, possibly as a consequence of enhanced "bottom-up" functioning (Lawson, Rees, & Friston, 2014; Van de Cruys et al., 2014; see also Pellicano & Burr, 2012). Such abnormal interplay between top-down priors and bottom-up sensory evidence may provide a simple explanation for ASD difficulties in inferring other people's intentions, by yielding significant deviations from normative Bayesian inference (McKay, 2012).

Bayesian models of intention understanding posit that our brain is constantly engaged in the process of drawing inference on the basis of two distinctive types of information: the sensory evidence conveyed by movement kinematics and the observer's prior expectations about which intention is the most likely cause of what is observed, given past experience (Baker, Saxe, & Tennenbaum, 2009; Baker, Tenenbaum, & Saxe, 2006; Chambon, Domenech et al., 2011; Kilner, 2011). Intention inference is contingent upon an adaptive interplay between these two sources of information, with observers tending to rely progressively more on their prior expectations as the reliability of sensory evidence decreases, and vice versa. Crucially, this interaction has also been found to vary according to the 'type' of intention to be inferred, with participant's prior experience gaining weight over sensory evidence when inferring motor intentions directed at a third party (Social intentions) rather than motor intentions directed at objects in isolation (Non-Social intentions) (Chambon, Domenech et al., 2011; Chambon, Pacherie et al., 2011).

Here, in accordance with theoretical models (Lawson et al., 2014; Pellicano & Burr, 2012), we hypothesized that diminished mentalizing abilities in individuals with ASD could be accounted for by an abnormal weighting of these two types of information (prior expectations and sensory evidence), in turn depending on the type of intention to be inferred (Social vs. Non-Social intentions). Specifically, attenuated "top-down" priors might be responsible for difficulties encountered by ASD in inferring *social* intentions. Indeed, social intentions often show a complex relationship with the behaviour they cause, i.e., in social situations many competing intentions are potentially consistent with what is observed. As such, social intentions cannot be unambiguously inferred from mere observation, and prior knowledge is required to constrain the space of candidate intentions (Chambon, Domenech et al., 2011; Kilner, Friston, & Frith, 2007a, 2007b). If individuals with ASD do show attenuated priors, one would expect deficits to be more severe in social situations where priors are massively required (Lawson et al., 2014). Thus, particularly relevant to the autistic symptomatology is the hypothesis that poor "social-specific" priors may result in an incapability to reduce the intrinsic uncertainty of social behaviours, in turn compromising one's ability to effectively interact with others (Chambon, Pacherie et al., 2011; Sinha et al., 2014; see also Fletcher & Frith, 2009). Although not yet supported by direct empirical evidence, this hypothesis is otherwise consistent with observations made in individuals with schizophrenia suffering from negative ("autistic-like") symptoms. While these patients exhibit poor prior expectations in the social domain, they also rely more strongly on sensory evidence to infer intentions when those are directed at a third party rather than at a non-meaningful object (Chambon, Pacherie et al., 2011). Interestingly, it has been suggested that, in these patients, social situations may not prompt the same expectations as those typically observed in comparison participants, leading to the formation of abnormal (unreliable) predictions about others' social intentions (Zalla, Verlut, Franck, Puzenat, & Sirigu, 2004; Zalla, Bouchilloux et al., 2006; Zalla, Labruyere et al., 2006; Barbalat, Chambon, Franck, Koechlin, & Farrer, 2009; Barbalat et al., 2011; Chambon, Pacherie et al., 2011; Chambon et al., 2012).

In the present study, we aimed to test this hypothesis by contrasting the ability to infer non-social and social intentions in a group of adults with ASD, as compared to a control group of typically developed adults. Participants were presented with a series of video clips showing an actor manipulating (either transporting or rotating) a non-meaningful object and asked to infer intentions directed at an object or intentions directed at a third party, respectively. In both the "Social" and the "Non-Social" intention tasks, the specific contributions of sensory evidence and prior expectations to the intentional inference were systematically manipulated by varying the amount of visuo-motor evidence conveyed by the action scene (i.e. the completeness of action sequences) and the probability of occurrence associated with each different intention. We then looked at (i) whether participants' performance on each condition could be accounted for by an abnormal dependence on visuo-motor evidence and/or prior expectations, depending on the type (Social vs. Non-Social) of the intention being manipulated, and (ii) whether this abnormal dependence – if observed – correlated with the severity of autistic symptoms, as measured by the Autism Diagnostic Interview–Revised (ADI-R) (Lord, Rutter, & Le Couteur, 1994).

2. Methods and materials

2.1. Participants

Eighteen adult participants with ASD and twenty comparison participants (CP) were recruited to participate in the study from Albert Chenevier Hospital in Créteil. The groups were matched for age, education, gender and full-scale IQ, as measured by the Wechsler Adult Intelligence Scale (Wechsler, 1999) (see Table 1). All participants were screened for exclusion criteria (dyslexia, epilepsy, and any other neurological or psychiatric conditions) prior to taking part to the study. Participants in the ASD group had a clinical diagnosis of Asperger Syndrome or High Functioning Autism

Table 1
Means (and standard deviations) of demographic and clinical data for participants with ASD and the comparison volunteers.

	ASD	Comparison	*p* value
N (male:female ratio)	15:3	16:4	0.9
Age in years (mean, SD, range)	35.7 (7.7)	34.8 (6.4)	0.7
Education in years (mean, SD)	14.3 ± 3.3	14.5 ± 3.4	0.28
ADI [B,C,D][*]	14.6 (5.7); 9.2 (5.2); 6.9 (3.2)	–	
Full-scale IQ	104.9 (18.6)	107.7 (7.9)	0.55
Verbal IQ	108.6 (15.6)	109.7 (7.8)	0.78
Performance IQ	98.7 (20.8)	103.7 (8.1)	0.35

[*] [B] = reciprocal social interaction, [C] = communication, [D] = stereotyped behaviours.