1 **Seeing Minds: A Signal Detection Study of Agency Attribution in Autism and Psychosis**

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Abstract

The phenotypic behaviour associated with psychosis and autism spectrum disorder (ASD) have been theorised to stem from diametrically opposite tendencies in mental state attribution. We investigated whether tendencies towards psychosis and ASD relate to opposite tendencies in agency attribution. Participants from the general population ($N=165$) completed a visual search task, where the goal was to identify (intentional) chasing motion. In line with predictions, psychotic traits were associated with a bias to see chasing. In contrast, we found no support that autistic traits reduced agency detection. There was also an oddity in the relationship between bias and ability to detect chasing. We discuss the implication of our findings in light of social brain theories and methodological issues of signal detection theory.

Keywords: intentionality, Asperger, Schizophrenia, anthropomorphism, animacy, Theory of Mind

17 Seeing Minds: A Signal Detection Study of Agency Attribution
18 in Autism and Psychosis

19 When the first edition of the Diagnostic and Statistical Manual for Mental Disorders
20 was published in 1952, autism was described as the psychotic manifestation of childhood
21 schizophrenia (American Psychiatric Association, 1952). Kanner (1943) described the
22 behaviour of an autistic girl using phrases like “ignored persons completely” and “expression
23 of ideas completely lacking” (p. 232). While such descriptions are today associated with
24 autism spectrum disorder (ASD), this girl is one of the many autistic children who prior to the
25 1980s were diagnosed with schizophrenia. ASD and psychotic disorders have since then been
26 classified into separate diagnoses. However, this earlier tendency to merge psychotic and
27 autistic behaviour may not have been entirely unfounded. Although the behavioural
28 expressions of ASD and psychosis are quite distinct, individual accounts have identified the
29 same mechanism as the potential cause of autistic and psychotic symptoms.

30 **Empirical Evidence for a Connection Between ASD and Psychosis**

31 ASD and psychosis have been linked to, for example, deficits in social cognition
32 (Solomon et al., 2011), impaired recollection (Greenland-White, Ragland, Niendam, Ferrer, &
33 Carter, 2017; Solomon, McCauley, Iosif, Carter, & Ragland, 2016), and language difficulties
34 (Nunn & Peters, 2001; Solomon et al., 2011).

35 ASD and psychotic disorders co-occur at higher rates than what would be expected in
36 the general population. Kincaid, Doris, Shannon, and Mulholland (2017) recently reviewed
37 seven studies in which participants diagnosed with psychotic disorders were screened for
38 ASD or autistic traits. They found that the prevalence of ASD and autistic traits was higher in
39 the clinical sample than expected in the general population. Solomon et al. (2011) reported
40 that approximately 20% of patients with first episode psychosis (FEP) or clinical-high-risk for
41 psychosis (CHR) met the criteria for Pervasive Developmental Disorder Not Otherwise

Specified. When measuring for social responsiveness, 31% of the FEP group and 40% of the CHR group scored within the severe range, which indicates a strong likelihood of ASD.

Barneveld et al. (2011) reported a higher rate of psychotic traits in ASD samples compared to community samples. Hallucinations and perceptual experiences have specifically been found to occur at higher rates in ASD samples compared to the general population (Milne, Dickinson, & Smith, 2017). Other studies have linked paranoid thoughts to ASD (Blackshaw, Kinderman, Hare, & Hatton, 2001; Jansch & Hare, 2014). Craig, Hatton, Craig, and Bentall (2004) found that people with Asperger's syndrome reported higher rates of paranoia than typically developed adults, but less so than people with a delusional disorder.

Ford, Apputhurai, Meyer, and Crewther (2017) examined two separate scales, one measuring autistic traits and the other psychotic trait, and found several items from both scales which measured the same phenotypic traits in a non-clinical sample. These shared items connect to the psychosocial symptoms that are the core features in both ASD and schizophrenia. In sum, ASD and psychosis also overlap at trait level in the general population (Blain, Peterman, & Park, 2017; Gong, Wang, Lui, Cheung, & Chan, 2017; Sierro, Rossier, & Mohr, 2016).

Theoretical Basis for a Connection Between ASD and Psychosis

Excessive surprise caused by overestimation of prediction error has been proposed to be a causative factor in both ASD and psychosis (Fletcher & Frith, 2009; Frith, 2005; Van de Cruys et al., 2014). Prediction is one of the fundamental functions of brains. Prediction allows organisms to prepare for events, to ignore what is unimportant, to focus on what is known to be important, and to focus on what might be important, because it is unexpected, surprising, and unknown. An event can only be identified as unexpected if there is an expectation or prediction in the first place, and if there is a large enough deviation from that prediction. That is the prediction error. Because there is random variation in events themselves, in the

perception of events, and in their prediction, “large enough” can only be a statistical judgement. If the estimate of prediction error is systematically wrong, then the balance between type I and type II errors shifts. If prediction error is underestimated, people are too laid back and fail to notice when things change, or they keep being surprised by mere random fluctuations. If prediction error is overestimated, normal variation leads to false alarms.

Theories of ASD and psychosis differ in what they expect the consequences of excessive surprise and prediction error to be. Van de Cruys et al. (2014) proposed that subjectively large prediction errors demand attention, as they signify that something important must be learned. To individuals with ASD, the world may appear as if continuously changing in important ways, resulting in sensory overload. Social interactions (which are complex and noisy) are avoided, and repetitive behaviour and specialised interests are used to create predictable environments as a countermeasure to sensory overload.

Theories of prediction error in psychosis differ in which second explanatory factor besides overestimation of prediction error they invoke. Fletcher and Frith (2009) proposed that prediction errors feed into a hierarchical inference system. Low-level prediction errors lead to adjustments at higher levels, but because the low-level errors persist, adjustments are made at ever more abstract levels, until all bizarre perceptions can be explained away by an abstract and general enough belief, such as “aliens are controlling my thoughts”. The difference between psychosis and ASD is then either explained by the earlier onset of ASD leading to unspecified adaptations that alter the symptoms in unspecified ways, or else to processing abnormalities occurring at different levels of the inference hierarchy (van Schalkwyk, Volkmar, & Corlett, 2017).

Frith (2005) proposed that prediction errors are overestimated specifically when predicting movement trajectories and how it feels to move. For example, people can’t tickle themselves. They predict the sensory consequences of their own movements, even if

transmitted through a robot arm, and their brains dismiss the sensation as self-caused. Introduce a short delay into the actions of the robot arm, or change the direction of movement, and the touch feels ticklish (Blakemore, Wolpert, & Frith, 2000). Chronic problems arise when normal statistical fluctuations in perception and/or predictions are consistently overinterpreted as indicating such external causes. The resulting hallucination is that one's own actions feel like they are not under one's own control.

To explain delusions, Frith (2005) invoked a second factor, an increased tendency to attribute events to *someone*. Then delusions of being controlled by someone else may result. The existence of that second factor is supported by Blakemore, Sarfati, Bazin and Decety's (2003) finding of excessive attribution of intention to geometrical shapes in delusional patients. Thus, one difference between ASD and psychosis may lie in social cognition; too much attribution of intention, hypermentalising, in psychosis, and too little attribution, hypomentalising, in ASD. That would be consistent with Abu-Akel, Wood, Hansen and Apperly's (2015) finding that people with tendencies towards both ASD and psychosis, in whom hypo- and hypermentalising may cancel each other, make as few errors in a perspective taking task as people with little tendency towards either ASD or psychosis. Shi et al. (2017) found that the interaction between autistic traits and psychosis proneness was negatively correlated with cognitive disability, while either autistic traits or psychosis proneness alone was positively correlated with cognitive disability. When considering total schizotypy scores, the interaction between autistic traits and schizotypy correlated positively with social functioning. Both psychosis and ASD have been linked to problems with mentalising (see, e.g., Kimhi, 2014; Pickup, 2006).

Several studies on social functioning and mentalising in ASD and psychosis indicate the existence of the hypo- and hypermentalising dimension. Although there are studies that demonstrate the link between impaired mentalising and psychotic traits (e.g., Pickup, 2006) as

well as autistic traits (e.g., Mintah & Parlow, 2018), only reports of directional errors (rather than errors in accuracy) can inform on the legitimacy of the hypo- versus hypermentalising dimension. That is, one must look at research that measure the extent to which someone attributes mental states. van Boxtel, Peng, Su, and Lu (2017) showed a negative correlation between autistic traits and the participants' ratings of the level of interactions of two stick figures. An increase of autistic traits was related to a greater tendency to label meaningful interaction as less interactive, as well as a reduced ability to distinguish between true social interactions and non-interactive motion. Psychotic patients, specifically patients with delusions, demonstrated a tendency to interpret random or incidental movements as intentional gestures (Bucci, Startup, Wynn, Baker, & Lewin, 2008).

Ciaramidaro et al. (2015) found that hypomentalising in ASD was related to less activation for processing information concerning mental states, while hypermentalising in psychosis was related to increased activation for processing information concerning physical causality.

Agency Attribution

Attributional styles in delusions and Asperger's syndrome are distinct (Craig et al., 2004). Delusional patients made more external-personal attributions directed at outside agents (e.g., "He did not call because he does not like me"), while patients with Asperger's syndrome made more situational attribution (e.g., "He did not call me because his phone had no reception"). Delusional patients seem to have a greater tendency to attribute agency, and thereby responsibility, to outside agents. Patients with Asperger's syndrome demonstrate the opposite pattern. These different attributional styles occurred despite both patient groups scoring similarly on a mentalising task.

Gray, Jenkins, Heberlein, and Wegner (2011) examined the attribution of agency by distinguishing between agency (capacity for memory, self-control and acting morally) and

experience (capacity for experiencing fear, pleasure and hunger). People with more autistic traits tended to attribute less agency to adult humans, whereas people with high schizotypy scores tended to attribute more agency and/or experience to trees, deceased people, robots, animals and God. Thus, psychosis is linked to attributing mental capacities where there should be none, while autistic traits are related to attributing reduced mental capacities where there should be more. Furthermore, in a perceptual causality study, patients with paranoid delusions were more likely than the control group to detect contingency between action and outcome, despite the outcome preceding the action (Maeda et al., 2012). Perceptual causality is similar to animacy, in the sense that knowing that something is not animate or causal does not hinder the automatic perception of causality and animacy (Scholl & Tremoulet, 2000).

Stimuli material building on Heider and Simmel's (1944) animations have been used in several research studies, replicating the phenomena in which the triangles are perceived as interacting agents (for review, see, Scholl & Tremoulet, 2000). Some of these studies appear highly relevant for the current topic, especially those studies which also include triangles with less "social" movements for comparison. One example is the study by Russell, Reynaud, Herba, Morris, and Corcoran (2006) where patients with paranoid delusion and patients with passivity experiences described randomly moving triangles as interacting or even referring to mental states, in line with hypermentalising proposition (Abu-Akel et al., 2015).

While agency attribution has been investigated in the context of psychotic or autistic tendencies (reviewed by Bliksted, Ubukata, & Koelkebeck, 2016), they have not examined whether performance differences are caused by distinct biases where the aforementioned theories predict opposite biases in agency attribution (Frith 2005, Fletcher and Frith, 2009, Van de Cruys et al., 2014). Furthermore, there is a lack of conclusive evidence that describes how agency attribution relates to the tendencies towards ASD and psychosis. The present study aims to investigate the hypo-and hypermentalising dimension by examining how the

167 traits relate to agency attribution in a detection task designed to evoke the perception of
168 animacy. No other study has previously examined both autistic and psychotic traits within the
169 same agency detection paradigm.

170 We use animations based on the wolf and sheep task of Gao, Newman, and Scholl
171 (2009), which was designed to elicit the perception of chasing. Perception of chasing is a
172 salient and robust form of animacy, perhaps carrying evolutionary advantages (Gao & Scholl,
173 2011). We also included a measure of anthropomorphism as it reflects a behavioural trait
174 (Waytz, Cacioppo, & Epley, 2010) and has previously been used as a proxy for measuring
175 agency attribution (Imhoff & Bruder, 2014). Our first objective is therefore to investigate
176 whether the individual's tendency to anthropomorphize predict bias to see agency in the wolf
177 and sheep task. Our second objective is to investigate how bias to see agency relates to the
178 tendencies towards autism and psychosis. Not performance but bias is the crucial measure
179 from the wolf and sheep task, that is, the individual's tendency to detect chasing as measured
180 by response bias c .

181 Hypothesis one: Anthropomorphism and bias to see a wolf measure the same construct
182 and correlate positively. If not, both become separate predictors in all the following
183 hypotheses.

184 Hypothesis two: Anthropomorphism and bias to see a wolf correlate positively with the
185 positive symptoms of psychosis.

186 Hypothesis three: Anthropomorphism and bias to see a wolf do not correlate with the
187 ability to distinguish trials with a wolf from trials without, (i.e., the ability to detect signal, as
188 measured by d').

189 Hypothesis four: Tendencies towards autism do not correlate with tendencies towards
190 psychosis.

Hypothesis five: Tendencies towards autism do not correlate with ability to distinguish trials with a wolf from trials without a wolf.

Hypothesis six: We expect that ability to distinguish trials with and without wolf correlates positively with the proportion of correct identifications of the wolf, and that the two variables have the same relationships to other variables. We therefore expect to replicate the relationships in hypotheses three and five if we substitute the ability to distinguish trials with a wolf from trials without by proportion correct identifications of the wolf.

The following relationships will be explored using exploratory analysis. If anthropomorphism and bias correspond to the hypo- and hypermentalising dimension, then anthropomorphism and bias to see wolf should correlate negatively with the Autism Spectrum Quotient (AQ). If instead the attribution of intention we hope to measure with anthropomorphism and bias corresponds to detection of goal-directed action, as opposed to identification of intention, then anthropomorphism and bias should be uncorrelated with the AQ. Several studies show elevated incidence of paranoid ideation associated with ASD (see above), which would suggest that anthropomorphism and bias to see a wolf correlate positively with AQ.

Positive symptoms should not affect the ability to detect wolf, which implies no correlation between the ability and the Community Assessment of Psychic Experiences Positive Subscale (CAPEpos). Roux, Passerieux, and Ramus (2015) found a decreased ability in a clinical sample with schizophrenic patients, which suggests that ability would be negatively correlated with the CAPEpos. However, this study did not control for positive and negative symptoms. We therefore expect either a zero or negative correlation.

Method

The study was preregistered and approved November 11th, 2017. Material and data are available at <https://osf.io/n3rbp/>.

Participants

The participants were recruited by direct recruitments, by the distribution of an URL link on social media and at the Aspie Quiz website (<http://rdos.net/eng/>). Direct recruitment happened primarily at University A and University B. Participation was voluntary, and no incentives were given. However, to ensure that most participants completed the study, they were told that their scores would be available to them upon completion. Participation was anonymous, which means that no identifiable (e.g., names) nor personal information (e.g., IP addresses) was collected. As a result, the study was not subject to notification according to the procedures of National Ethics Committee X.

932 participants consented to participate. 553 (~59%) participants responded to less than 2/3 and were excluded. Another 214 participants were excluded due to either being under the age of 18 years old, scoring an average of ≥ 2 on the CAPE 42 Positive Subscale control questions or indicating that they watched videos (see Material and Procedures) twice on more than 1/3 of the trials. Spending more than 12.0 seconds on the webpages that contain each video was interpreted as seeing the videos twice. The analysed sample included 165 adults (94 females, four participants identifying as “other”, and two participants did not disclose gender). The age of the participants ranged from 18 to 69, with a mean age of 31 years ($SD = 10.8$).

Measures and Procedure

The participants completed an online survey (Qualtrics.com) composed of self-report measures for autistic traits, psychotic traits and anthropomorphism, as well as a visual search task assessing the perception of chasing. The survey consisted of a total of 66 questionnaire items and 50 trials from the visual search task. To avoid fatigue, questionnaire items and

visual search task trials were intermixed. Both an English and a Norwegian version of the survey were published online.

Demographic measures. Age and gender were the only demographic variables collected, with the intention of preserving the participants' anonymity.

The individual differences in anthropomorphising questionnaire. Participants completed the 15-item version of the Individual Differences in Anthropomorphising Questionnaire (IDAQ; Waytz et al., 2010), and rated on an 11-point scale (0 = not at all to 10 = very much) the extent to which they believed the nonhuman entities possessed human characteristics, such as free will or emotions. The total scores range from 0 to 150 points, with higher number indicating greater tendency to anthropomorphise. The 15 non-anthropomorphic items were not included as they do not measure anthropomorphising. The IDAQ demonstrates good internal consistency (Letheren, Martin, & Jin, 2017) and moderately high reliability (Waytz et al., 2010). Cronbach's alpha was .824, indicating a high level of internal consistency for the current sample.

The autism spectrum quotient – short form. The participants completed the abridged version of the Autism Spectrum Quotient (AQ; Hoekstra et al., 2011). This is a shorter version of the Autism Spectrum Quotient by Baron-Cohen, Wheelwright, Skinner, Martin, and Clubley (2001). The short AQ has shown to be highly correlated with the original 50-item questionnaire (Hoekstra et al., 2011). This questionnaire consists of 28 items assessing autistic traits along a continuum in the general population. The items were rated on a four-point scale (1 = definitely agree to 4 = definitely disagree). Traits are assessed along the five dimensions of social skills, routine, imagination, switching and numbers/patterns. The scoring procedures followed the four-response scoring format of Hoekstra et al. (2011), based on the recommendation by Kuenssberg, Murray, Booth, and McKenzie (2014). The total scores

range from 28 to 112, where the maximum score represents full endorsement of all autistic traits.

The internal consistency and reliability of the AQ-S has been validated using several independent samples (Hoekstra et al., 2011). The study by Kuenssberg et al. (2014) suggests that the proposed structure of the short AQ include structural and scale properties that can be extended to samples of individuals with the clinical diagnosis of Autism Spectrum Disorder. Cronbach's alpha was .926, indicating a very high level of internal consistency for the current sample.

The positive subscale of the community assessment of psychic experiences.

Participants completed the positive subscale of the Community Assessment of Psychic Experiences scale (CAPEpos; Stefanis et al., 2002). The self-report questionnaire consists of 20 items measuring the presences of positive symptoms, such as paranormal beliefs and bizarre perceptual experiences. The distress items were not included in the current study. Three control questions reflecting common misconceptions about psychosis were added (Moritz et al., 2013). The items were rated on a four-point scale (0 = never to 3 = always) for frequency. The scores were recoded from 0-3 to 1-4. Thus, total scores range from 20 to 60 points, with the maximum score representing full endorsement of all symptoms of psychosis.

Konings, Bak, Hanssen, van Os, and Krabbendam (2006) demonstrated good reliability and validity of the questionnaire, and the positive subscale of the CAPE 42 has previously been used to measure psychotic traits in general population samples (Booij, Snippe, Jeronimus, Wichers, & Wigman, 2018), clinical samples (Krkovic, Moritz, & Lincoln, 2017) and student samples (Capra, Kavanagh, Hides, & Scott, 2013). Cronbach's alpha was .915, indicating a very high level of internal consistency for the current sample.

Visual search task. We modified the wolf and sheep task by Gao et al. (2009), which assesses perception of chasing. We created new videos using the 16.0.0 version of LabVIEW

(2016) to avoid both ceiling effects and floor effects, encouraging participants making enough errors to calculate a bias c score. We modified the parameters (video length, speed, number of distractors and chase/escape angle) during pilot testing to produce a d' as close to 1.0 as possible. The participants were presented with a total of 50 videos. The parameters described in the following sections were chosen based on their contribution to the optimal difficulty level.

We used 16 red distractor discs and one yellow discs, all moving in random directions, as if moving of their own accords. In half of the 50 videos, one of the 16 red discs would chase the yellow disc (see figure 1). The cover story was that this red disc was a wolf that was trying to catch the sheep (yellow disc). The yellow disc is hereafter referred to as the sheep, while the chasing disc is referred to as the wolf. All red discs were marked with a different letter. The length of each video was reduced to 5 seconds. The participants were instructed to watch the videos once, and after each video they were asked, “was the yellow sheep being hunted?”. In trials were the participants answered yes, they were asked to identify the wolf by clicking on a letter.

Figure 1. A screenshot from a video from the wolf and sheep task.

There were two warm-up trials with decreased difficulty level, achieved by reducing the number of distractors. This method for decreasing the difficulty level was used to ensure that participants could clearly distinguish between warm-up trials and main trials, and adjust their strategies accordingly.

Stimuli. The discs, measuring at 34 pixels wide and 33 pixels long, moved across a black, 726x554 background. The discs appeared in random location at the beginning of each video and moved in random directions, with each disc moving 12 steps of 5 pixels length in one direction before choosing a new direction randomly from $\pm 90^\circ$ of the previous direction. This speed was constant for all discs. Each step was calculated every 20ms, so that a change in direction could be made if the discs encountered the edge of the frame before completing the 12 steps. The discs instantly chose a new direction when reaching the edge of the frame, by choosing a random direction from the 180° range leading away from the edge.

In trials without chasing, the sheep moved the same way as the other discs. In chasing-present trials, the sheep would choose a direction from the $\pm 90^\circ$ range that was leading away from the wolf (fig. 1a). The wolf's direction would be chosen from the $\pm 90^\circ$ range leading towards the sheep (fig. 1b).

Figure 2. An illustration of the chase angle and escape angle in chasing present trials. The grey areas show the angular zones from which new directions are chosen. The grey area, the lines and the arrows were not part of the actual display. (a) The sheep (yellow disc) chooses a direction from the $\pm 90^\circ$ range (total grey area) leading away from the wolf (red

disc). (b) The wolf chooses a direction from the $\pm 90^\circ$ range (total grey area) leading towards the sheep.

Statistical Analysis and Preliminary Analysis

Analysis uses signal detection theory. Bias c and d' were calculated according to Macmillan and Creelman (1991) (see Appendix A). The d' was within an acceptable range of our goal of $d'=1.0$ (see table 1), thereby ensuring that the wolf and sheep task yielded enough errors to calculate a meaningful bias c . Larger d' means better ability to detect when the wolf was present. Response bias c reflects the participants' propensity to perceive the wolf as present or absent. A negative bias c score represents a bias to see wolf, while a positive score represents a bias not to see the wolf. The proportion of trials in which the wolf was correctly identified (ID) was transformed using arcsine square root.

We calculated a proportional score to avoid biasing the AQ score of those with missing values. The range of possible values for the proportional AQ score range from a minimum of 1.0 to a maximum of 4.0, with higher values reflecting more autistic traits.

The hypotheses were examined by using Bayesian correlations. The Bayes factor was interpreted according to Wetzels and Wagenmakers (2012) descriptions. The threshold for evidence in favour of a hypothesis was $BF \geq 3.0$.

The normality test was calculated using IBM SPSS Statistics version 25, while correlations were performed using JASP version 0.8.6 (JASP Team, 2018). Normality was tested using Shapiro-Wilk test, in which all variables violated the assumption of normality ($p < .05$), except the d' , $p = .059$. Bayesian Kendall's tau-b was therefore chosen as the non-parametric correlation test.

Results

Means, standard deviations, skewness and all correlations are presented in table 1.

Anthropomorphism and Response Bias c

Contrary to predictions, IDAQ was unrelated to bias c, $r_{tb} = .040$, $BF_{0-} = 16.4$. This Bayes factor implies strong evidence for an absence of a relationship between tendency to anthropomorphise and a bias to see wolf. IDAQ and bias c were therefore examined independently in relation to the remaining indices. As a result, the number of tests for some hypotheses increased, and interpretation about relationships were therefore based on joint evidence from both IDAQ and bias c.

Traits and Bias to See Agency

As predicted, the CAPEpos correlated negatively with bias c, $r_{tb} = -.13$, $BF_{-0} = 4.06$, and positively with the IDAQ, $r_{tb} = .14$, $BF_{+0} = 5.43$. An increase in psychotic traits was related to an increased tendency to detect chasing in the wolf and sheep task, as well as an increased tendency to anthropomorphise. There was no relationship between AQ and the IDAQ, $r_{tb} = .063$, $BF_{01} = 4.77$. The relationship between AQ and bias c was not meaningful, $r_{tb} = -.089$, $BF_{01} = 2.38$. Only psychotic traits were related to anthropomorphising and bias to see wolf, while autistic traits were unrelated to the tendency to anthropomorphise. Nevertheless, AQ was found to correlate positively with the CAPEpos, $r_{tb} = .46$, $BF_{10} > 100.0$, with an increase in autistic traits associated with an increase in psychotic traits.

Ability to Detect and Identify Chasing

The relationship between traits and d' was examined to determine whether there was a relationship between traits and performance on the wolf and sheep task. We found no support for a relationship or absence of relationship between d' and autistic traits, $r_{tb} = -.11$, $BF_{01} = 1.03$, and between d' and psychotic traits, $r_{tb} = -.099$, $BF_{01} = 1.69$. Thus, there were no meaningful relationships between the ability to detect chasing and the autistic and psychotic traits.

Contrary to prediction, decisive evidence was found for a relationship between bias c and d' , $r_{tb} = 0.24$, $BF_{10} > 100$. An increase in ability to detect chasing was related to a stronger bias to not see the wolf (see figure 2). In contrast, there was substantial evidence for an absence of relationship between d' and IDAQ, $r_{tb} = -.078$, $BF_{01} = 3.29$. As predicted, the ability to detect chasing was unrelated to the tendency to anthropomorphise.

The relationship between d' and the proportion of correctly identified wolf (ID) was examined. As predicted, d' correlated positively with ID, $r_{tb} = .36$, $BF_{10} > 100$, yielding decisive evidence for the hypothesis that an increase in ability to detect wolf was related to an increase in ability to identify the wolf. Accordingly, there was also decisive evidence for a positive correlation between bias c and ID $r_{tb} = .21$, $BF_{10} > 100$, thereby replicating the relationships between bias c and d' .

ID was found to be unrelated to AQ, $r_{tb} = -.044$, $BF_{01} = 6.92$, while neither a relationship nor absence of relationship was found between ID and CAPEpos, $r_{tb} = -.091$, $BF_{01} = 2.25$. The absence of relationship between d' and IDAQ was not replicated by ID and IDAQ, $r_{tb} = -.093$, $BF_{01} = 2.11$. Thus, only the relationship between the ability to detect chasing and psychotic traits was replicated when substituting ability to detect chasing for proportion of correctly identified wolf.

Table 1.

Means, standard deviations and Bayesian Kendall's tau-b correlation coefficients with Bayes factors.

	1	2	3	4	5	6
Mean	33.2	36.5	2.70	1.45	.37	1.32
(SD)	(18.7)	(8.91)	(.58)	(.64)	(.50)	(.30)
1. IDAQ	-					
2. CAPEpos	.14 BF ₊₀ = 5.43	-				
3. AQ	.063 BF ₀₁ = 4.78	.460 BF ₁₀ > 100	-			
4. d'	-.078 BF ₀₁ = 3.29	-.099 BF ₀₁ = 1.69	-.11 BF ₀₁ = 1.03	-		
5. Bias c	.040 BF ₀₋ = 16.4	-.13 BF ₀₋ = 4.06	-.089 BF ₀₁ = 2.38	.24 BF ₁₀ > 100	-	
6. ID	-.093 BF ₀₁ = 2.11	-.091 BF ₀₁ = 2.25	-.044 BF ₀₁ = 6.92	.36 BF ₁₀ > 100	.21 BF ₁₀ > 100	-

Note. IDAQ=Individual differences in anthropomorphism questionnaire, CAPEpos= the positive subscale of the Community Assessment of Psychic Experiences scale, AQ=Autism Spectrum Quotient (Short form) proportional score, ID=Proportion of trials in which the wolf was correctly identified, transformed using arcsine square root.
N = 165.

Figure 3. The relationship between bias c and d' scores from the present study. The dashed line marks the separation between a decision environment that induces as bias to see the wolf (underneath the line) and a decision environment that induces a bias to not see the wolf (above the line).

Discussion

Our first aim of the present study was to investigate whether the individuals' tendency to anthropomorphize could predict bias to see wolf in the detection task. Contrary to prediction, the tendency to anthropomorphise did not predict bias to see wolf. This suggests that the bias *c* and the IDAQ do not measure the same construct. One possible interpretation is that the IDAQ taps into social judgement, whereas bias to see agency only involves social perception. Waytz et al. (2010) argued that anthropomorphising extends beyond perceiving an agent as animate, because the agent is also attributed characteristics that are only associated with being human. The IDAQ required the participants to rate animals and objects on characteristics that are, perhaps, uniquely human. As we make top-down judgements or inferences about other humans' mental states, the participants' rating might therefore reflect top-down judgements that are not necessary for the detection of animacy cues. Comparing self-report measures to a behavioural task might also cause disparity. Evidence of an absence of a relationship might be better explained by anthropomorphising extending beyond the detection of agency.

Although anthropomorphising might extend beyond agency attribution, it would not be appropriate to treat the IDAQ as proxy for mentalising. Research on anthropomorphising has generally been focused on accuracy and functioning (Epley, Waytz, & Cacioppo, 2007), rather than investigating the relationship between anthropomorphising and mentalising. It is therefore not clear how these two processes are related.

The second aim of this study was to investigate whether tendencies towards ASD and psychosis relates to bias to see agency in a chasing detection task. As predicted, psychotic traits were related to an increased tendency to see agency in the wolf and sheep task, as well as an increased tendency to anthropomorphise. These results correspond with Frith's (2005) idea concerning excessive agency attribution in psychosis and support that psychosis is

associated with hypermentalising tendencies. They also correspond to as research that link psychosis or psychotic traits to excessive agency attribution (e.g., Blakemore et al., 2003; Elk, 2013; Gray et al., 2011). These relationship sizes correspond to the correlations between psychotic traits and self-reported agency in Gray et al (2011), which could be an indicator of small effect sizes in future studies.

Bias to see agency and IDAQ correlated positively with psychotic traits suggests that the IDAQ measures some form of mental states attribution. This might be different from agency attribution, as IDAQ and bias c were unrelated. If anthropomorphising is equivalent to neither mentalising nor agency attribution, this could imply that there are at least three dimensions to mental state attribution. If mentalising does not extend to agency attribution, then the analogous relationship between psychotic traits and bias c indicate that there might be two dimensions to agency attribution.

Exploratory analysis revealed no clear association between autistic traits and bias to see agency. Autistic traits were not related to anthropomorphising, while the relationship between traits and bias to see wolf was inconclusive. Recall that conflicting findings indicated that autistic traits should either be a) negatively related, b) unrelated or c) positively related to anthropomorphising and bias to see the wolf. As the IDAQ's and bias's relationships to autistic traits do not correspond, neither of these explanations are likely.

Our findings can be used to explain the findings of Castelli, Frith, Happe, and Frith (2002). People with ASD did not differ from typically developed people when attributing levels of intentionality to a group of animations that consisted of triangles that were dancing, leading, imitating and chasing. The lack of these features in the wolf and sheep task could imply that the discs were not anthropomorphised to the same extent as the goal-directed triangles.

The results from AQ and bias c suggests that the wolf and sheep task was low in power. Low power is seen by the mean d' , which indicates that the overall performance level was high and that the wolf and sheep task was too easy. In addition, Kuzmanovic et al. (2014) demonstrated that such behavioural task might generally have low power. Kuzmanovic et al. (2014) asked typically developed people and patients diagnosed with high functioning autism to rate the extent to which they perceived the motion of two dots to be “person-like”. While the scores did not differ significantly between groups, higher animacy ratings in the control group resulted in more neural activation in networks associated with social processing compared to the patient group. The authors reasoned that the dissociation between task performance and neural activation was caused by patients relying on physical properties to rate the stimuli, whilst failing to spontaneously interpret the dots’ movements as social cues.

Autistic and psychotic traits were positively associated, which means that those with more autistic traits also tend to have more psychotic traits. The relationship was not hypothesised, but nevertheless, not unexpected. In the general population, correlations between autistic and psychotic traits range from 0.31 to 0.48 (Abu-Akel et al., 2015; Blain et al., 2017; Dinsdale, Hurd, Wakabayashi, Elliot, & Crespi, 2013; Gong et al., 2017; Shi et al., 2017; Sierro et al., 2016; Wakabayashi, Baron-Cohen, & Ashwin, 2012).

Both d' and the proportion of trials in which the wolf was correctly identified measured the ability to detect wolf. That is, those with a higher ability to detect the wolf were also better at identifying the wolf.

It should be mentioned that misidentifications were not treated as false alarms, because a misidentification does not necessarily imply that no signal was detected. Recall that the perception of animacy is an automatic process. This means that the speed of which we detect cues of animacy is likely to be quicker than the process of becoming consciously aware of these cues. However, those with better ability to detect the signal are more able to

successfully discriminate between noise and signal, thereby increasing their likelihood of identifying the wolf.

Autistic traits were hypothesised to be unrelated to the ability to detect chasing. However, there was no evidence that supported either a relationship or absence of relationship between autistic traits and d' . Similarly, exploratory analysis revealed that there was no evidence to support either a relationship or an absence of relationship between psychotic traits and ability to detect chasing. The investigation of ID and psychotic traits yielded the same results, while ID was unrelated to autistic traits. Thus, these results are inconclusive, and this study does not provide clear evidence for how performance relates to autistic and psychotic traits in the wolf and sheep task.

Contrary to prediction, we found a positive relationship between d' and bias c , indicating that a better ability was related to a greater tendency not to see the wolf. There was also substantial evidence for an absence of relationship between d' and IDAQ, but no evidence for either a relationship or absence of relationship between ID and IDAQ. Thus, it is not evident how the ability to detect wolf is related to the tendency to anthropomorphise. Lynn and Barrett (2014) offered a utility-based explanation or optimization of decision-making for the unexpected relationship between ability to detect wolf and bias. They demonstrated that an extreme bias compensates for a low ability to detect the signal. Those with extreme biases do not show impairment in both ability and bias, but rather a single impairment (low ability) that causes extreme biases. Accordingly, those with a low d' and lack of bias are impaired both in their ability to detect the signal and in their ability to adjust their bias to compensate for the low d' .

Although Lynn and Barrett (2014) demonstrate why we should expect bias c and d' to be related, their utility-based account conflict with the direction of the relationship between bias c and d' in the present study. This relationship is an oddity, and we therefore recommend

that one should investigate whether this finding can be replicated, to help determine whether this atypical relationship reflects something meaningful.

Limitations and Strengths

An important limitation is the large d' despite pilot testing. As the large d' might have created ceiling effects, the lack of variation in the scores may have resulted in a detection task with lower power. As indicated by Lynn and Barrett's (2014) study, the lack of low d' means that few participants would have to compensate for their low ability by more extreme scores. A larger sample might partly compensate the low power of the wolf and sheep task.

Participants could play the videos more than once. Our screening criterion using time spent on the webpage, excluded many participants.

Due to time concerns, we did not include a measurement of mentalising, thus limiting our ability to provide conclusive evidence that validates the relationship between hypo- and hypermentalising and agency attribution. While several meaningful patterns have been found, the fact that no evidence was found for either a relationship or an absence of relationship in several instances weakens one's ability to make statements about the implication of these relationships. This also applies to those relationships that were not confirmed by the analogous relationship.

This study also has several strengths. Examining relationships rather than group differences corresponds to the fact that autistic and psychotic traits are distributed continuously in the population (Hoekstra et al., 2011; Stefanis et al., 2002). Investigating both autistic and psychotic traits within the same detection paradigm offers more validity to any speculations regarding the hypo- and hypermentalising dimension. Sampling from a general population rather than a clinical one also means that general impairment and medication would not bias any results. Lastly, by preregistrating the study, the procedure and analysis have been performed in a transparent way.

Conclusion

This is the first study that compares individual differences in anthropomorphism to agency detection using an animacy task. We found that this anthropomorphising did not predict agency detection. Furthermore, we identified a meaningful pattern suggesting psychotic traits can be linked to excessive agency attribution. This study could not provide support for opposite tendencies in agency attribution associated with autistic and psychotic traits.

References

- Abu-Akel, A. M., Wood, S. J., Hansen, P. C., & Apperly, I. A. (2015). Perspective-taking abilities in the balance between autism tendencies and psychosis proneness. *Proc Biol Sci*, 282(1808), 20150563. doi:10.1098/rspb.2015.0563
- American Psychiatric Association. (1952). *Diagnostic and Statistical Manual of Mental Disorders* (1st ed.). Washington, D. C.: American Psychiatric Association.
- Barneveld, P. S., Pieterse, J., de Sonnevile, L., van Rijn, S., Lahuis, B., van Engeland, H., & Swaab, H. (2011). Overlap of autistic and schizotypal traits in adolescents with Autism Spectrum Disorders. *Schizophr Res*, 126(1), 231-236. doi:<https://doi.org/10.1016/j.schres.2010.09.004>
- Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism-spectrum quotient (AQ): evidence from Asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. *J Autism Dev Disord*, 31(1), 5-17.
- Blackshaw, A. J., Kinderman, P., Hare, D. J., & Hatton, C. (2001). Theory of mind, causal attribution and paranoia in Asperger syndrome. *Autism*, 5(2), 147-163. doi:10.1177/1362361301005002005
- Blain, S. D., Peterman, J. S., & Park, S. (2017). Subtle cues missed: Impaired perception of emotion from gait in relation to schizotypy and autism spectrum traits. *Schizophr Res*, 183, 157-160. doi:<https://doi.org/10.1016/j.schres.2016.11.003>
- Blakemore, S. J., Sarfati, Y., Bazin, N., & Decety, J. (2003). The detection of intentional contingencies in simple animations in patients with delusions of persecution. *Psychol Med*, 33(8), 1433-1441.
- Blakemore, S. J., Wolpert, D., & Frith, C. (2000). Why can't you tickle yourself? *Neuroreport*, 11(11), R11-16.
- Bliksted, V., Ubukata, S., & Koelkebeck, K. (2016). Discriminating autism spectrum disorders from schizophrenia by investigation of mental state attribution on an on-line

- 564 mentalizing task: A review and meta-analysis. *Schizophr Res*, 171(1-3), 16-26.
565 doi:10.1016/j.schres.2016.01.037
- 566 Booij, S. H., Snippe, E., Jeronimus, B. F., Wichers, M., & Wigman, J. T. W. (2018).
567 Affective reactivity to daily life stress: Relationship to positive psychotic and
568 depressive symptoms in a general population sample. *Journal of Affective Disorders*,
569 225, 474-481. doi:https://doi.org/10.1016/j.jad.2017.08.051
- 570 Bucci, S., Startup, M., Wynn, P., Baker, A., & Lewin, T. J. (2008). Referential delusions of
571 communication and interpretations of gestures. *Psychiatry Res*, 158(1), 27-34.
572 doi:https://doi.org/10.1016/j.psychres.2007.07.004
- 573 Capra, C., Kavanagh, D. J., Hides, L., & Scott, J. (2013). Brief screening for psychosis-like
574 experiences. *Schizophr Res*, 149(1), 104-107.
575 doi:https://doi.org/10.1016/j.schres.2013.05.020
- 576 Castelli, F., Frith, C., Happe, F., & Frith, U. (2002). Autism, Asperger syndrome and brain
577 mechanisms for the attribution of mental states to animated shapes. *Brain*, 125(8),
578 1839-1849.
- 579 Ciaramidaro, A., Bölte, S., Schlitt, S., Hainz, D., Poustka, F., Weber, B., . . . Walter, H.
580 (2015). Schizophrenia and Autism as Contrasting Minds: Neural Evidence for the
581 Hypo-Hyper-Intentionality Hypothesis. *Schizophr Bull*, 41(1), 171-179.
582 doi:10.1093/schbul/sbu124
- 583 Craig, J. S., Hatton, C., Craig, F. B., & Bentall, R. P. (2004). Persecutory beliefs, attributions
584 and theory of mind: comparison of patients with paranoid delusions, Asperger's
585 syndrome and healthy controls. *Schizophr Res*, 69(1), 29-33. doi:10.1016/s0920-
586 9964(03)00154-3

- 587 Dinsdale, N. L., Hurd, P. L., Wakabayashi, A., Elliot, M., & Crespi, B. J. (2013). How are
588 autism and schizotypy related? Evidence from a non-clinical population. *PLoS One*,
589 8(5), e63316. doi:10.1371/journal.pone.0063316
- 590 Elk, M. v. (2013). Paranormal believers are more prone to illusory agency detection than
591 skeptics. *Conscious Cogn*, 22(3), 1041-1046.
592 doi:<https://doi.org/10.1016/j.concog.2013.07.004>
- 593 Epley, N., Waytz, A., & Cacioppo, J. T. (2007). On seeing human: a three-factor theory of
594 anthropomorphism. *Psychol Rev*, 114(4), 864-886. doi:10.1037/0033-295x.114.4.864
- 595 Fletcher, P. C., & Frith, C. D. (2009). Perceiving is believing: a Bayesian approach to
596 explaining the positive symptoms of schizophrenia. *Nat Rev Neurosci*, 10(1), 48-58.
597 doi:10.1038/nrn2536
- 598 Ford, T. C., Apputhurai, P., Meyer, D., & Crewther, D. P. (2017). Confirmatory factor
599 analysis of autism and schizophrenia spectrum traits. *Personality and Individual*
600 *Differences*, 110, 80-84. doi:<https://doi.org/10.1016/j.paid.2017.01.033>
- 601 Frith, C. (2005). The neural basis of hallucinations and delusions. *C R Biol*, 328(2), 169-175.
602 doi:10.1016/j.crvl.2004.10.012
- 603 Gao, T., Newman, G. E., & Scholl, B. J. (2009). The psychophysics of chasing: A case study
604 in the perception of animacy. *Cogn Psychol*, 59(2), 154-179.
605 doi:10.1016/j.cogpsych.2009.03.001
- 606 Gao, T., & Scholl, B. J. (2011). Chasing vs. stalking: interrupting the perception of animacy. *J*
607 *Exp Psychol Hum Percept Perform*, 37(3), 669-684. doi:10.1037/a0020735
- 608 Gong, J.-b., Wang, Y., Lui, S. S. Y., Cheung, E. F. C., & Chan, R. C. K. (2017). Childhood
609 trauma is not a confounder of the overlap between autistic and schizotypal traits: A
610 study in a non-clinical adult sample. *Psychiatry Res*, 257, 111-117.
611 doi:<https://doi.org/10.1016/j.psychres.2017.07.035>

- 612 Gray, K., Jenkins, A. C., Heberlein, A. S., & Wegner, D. M. (2011). Distortions of mind
613 perception in psychopathology. *Proc Natl Acad Sci U S A*, 108(2), 477-479.
614 doi:10.1073/pnas.1015493108
- 615 Greenland-White, S. E., Ragland, J. D., Niendam, T. A., Ferrer, E., & Carter, C. S. (2017).
616 Episodic memory functions in first episode psychosis and clinical high risk
617 individuals. *Schizophr Res*, 188, 151-157.
618 doi:<https://doi.org/10.1016/j.schres.2017.01.035>
- 619 Heider, F., & Simmel, M. (1944). An Experimental Study of Apparent Behavior. *The*
620 *American Journal of Psychology*, 57(2), 243-259. doi:10.2307/1416950
- 621 Hoekstra, R. A., Vinkhuyzen, A. A., Wheelwright, S., Bartels, M., Boomsma, D. I., Baron-
622 Cohen, S., . . . van der Sluis, S. (2011). The construction and validation of an abridged
623 version of the autism-spectrum quotient (AQ-Short). *J Autism Dev Disord*, 41(5), 589-
624 596. doi:10.1007/s10803-010-1073-0
- 625 Imhoff, R., & Bruder, M. (2014). Speaking (Un-)Truth to Power: Conspiracy Mentality as a
626 Generalised Political Attitude. *European Journal of Personality*, 28(1), 25-43.
627 doi:10.1002/per.1930
- 628 Jansch, C., & Hare, D. J. (2014). An investigation of the "jumping to conclusions" data-
629 gathering bias and paranoid thoughts in Asperger syndrome. *J Autism Dev Disord*,
630 44(1), 111-119. doi:10.1007/s10803-013-1855-2
- 631 JASP Team. (2018). JASP (Version 0.8.6) [Computer software]. The Netherlands. Retrieved
632 from <http://jasp-stats.org/download/>
- 633 Kanner, L. (1943). Autistic disturbances of affective contact. *Nervous Child*, 2, 217-250.
- 634 Kimhi, Y. (2014). Theory of Mind Abilities and Deficits in Autism Spectrum Disorders,
635 *Topics in Language Disorders*, 34(4), 329-343.

- 636 Kincaid, D. L., Doris, M., Shannon, C., & Mulholland, C. (2017). What is the prevalence of
637 autism spectrum disorder and ASD traits in psychosis? A systematic review.
638 *Psychiatry Res*, 250, 99-105. doi:<https://doi.org/10.1016/j.psychres.2017.01.017>
- 639 Konings, M., Bak, M., Hanssen, M., van Os, J., & Krabbendam, L. (2006). Validity and
640 reliability of the CAPE: a self-report instrument for the measurement of psychotic
641 experiences in the general population. *Acta Psychiatr Scand*, 114(1), 55-61.
642 doi:10.1111/j.1600-0447.2005.00741.x
- 643 Krkovic, K., Moritz, S., & Lincoln, T. M. (2017). Neurocognitive deficits or stress overload:
644 Why do individuals with schizophrenia show poor performance in neurocognitive
645 tests? *Schizophr Res*, 183, 151-156. doi:<https://doi.org/10.1016/j.schres.2016.11.002>
- 646 Kuenssberg, R., Murray, A. L., Booth, T., & McKenzie, K. (2014). Structural validation of
647 the abridged autism spectrum quotient-short form in a clinical sample of people with
648 autism spectrum disorders. *Autism*, 18(2), 69-75. doi:10.1177/1362361312467708
- 649 Kuzmanovic, B., Schilbach, L., Georgescu, A. L., Kockler, H., Santos, N. S., Shah, N. J., . . .
650 Vogeley, K. (2014). Dissociating animacy processing in high-functioning autism:
651 neural correlates of stimulus properties and subjective ratings. *Soc Neurosci*, 9(3),
652 309-325. doi:10.1080/17470919.2014.886618
- 653 LabVIEW (Version. 16.0.0) [computer software]. (2016): National Instruments.
- 654 Letheren, K., Martin, B. A. S., & Jin, H. S. (2017). Effects of personification and
655 anthropomorphic tendency on destination attitude and travel intentions. *Tourism*
656 *Management*, 62, 65-75. doi:<https://doi.org/10.1016/j.tourman.2017.03.020>
- 657 Lynn, S. K., & Barrett, L. F. (2014). "Utilizing" signal detection theory. *Psychol Sci*, 25(9),
658 1663-1673. doi:10.1177/0956797614541991
- 659 Macmillan, N. A., Creelman, C. D. (1991). *Detection Theory: A User's Guide*. New Work:
660 Cambridge University Press.

- 661 Maeda, T., Kato, M., Muramatsu, T., Iwashita, S., Mimura, M., & Kashima, H. (2012).
662 Aberrant sense of agency in patients with schizophrenia: Forward and backward over-
663 attribution of temporal causality during intentional action. *Psychiatry Res*, 198(1), 1-6.
664 doi:<https://doi.org/10.1016/j.psychres.2011.10.021>
- 665 Milne, E., Dickinson, A., & Smith, R. (2017). Adults with autism spectrum conditions
666 experience increased levels of anomalous perception. *PLoS One*, 12(5), e0177804.
667 doi:[10.1371/journal.pone.0177804](https://doi.org/10.1371/journal.pone.0177804)
- 668 Mintah, K., & Parlow, S. E. (2018). Are you flirting with me? Autistic traits, theory of mind,
669 and inappropriate courtship. *Personality and Individual Differences*, 128, 100-106.
670 doi:<https://doi.org/10.1016/j.paid.2018.02.028>
- 671 Moritz, S., Favrod, J., Andreou, C., Morrison, A. P., Bohn, F., Veckenstedt, R., . . . Karow, A.
672 (2013). Beyond the Usual Suspects: Positive Attitudes Towards Positive Symptoms Is
673 Associated With Medication Noncompliance in Psychosis. *Schizophr Bull*, 39(4), 917-
674 922. doi:[10.1093/schbul/sbs005](https://doi.org/10.1093/schbul/sbs005)
- 675 Nunn, J., & Peters, E. (2001). Schizotypy and patterns of lateral asymmetry on hemisphere-
676 specific language tasks. *Psychiatry Res*, 103(2-3), 179-192.
- 677 Pickup, G. J. (2006). Theory of mind and its relation to schizotypy. *Cogn Neuropsychiatry*,
678 11(2), 177-192. doi:[10.1080/13546800444000236](https://doi.org/10.1080/13546800444000236)
- 679 Roux, P., Passerieux, C., & Ramus, F. (2015). An eye-tracking investigation of intentional
680 motion perception in patients with schizophrenia. *J Psychiatry Neurosci*, 40(2), 118-
681 125.
- 682 Russell, T. A., Reynaud, E., Herba, C., Morris, R., & Corcoran, R. (2006). Do you see what I
683 see? Interpretations of intentional movement in schizophrenia. *Schizophr Res*, 81(1),
684 101-111. doi:[10.1016/j.schres.2005.10.002](https://doi.org/10.1016/j.schres.2005.10.002)

- 685 Scholl, B. J., & Tremoulet, P. D. (2000). Perceptual causality and animacy. *Trends Cogn Sci*,
686 4(8), 299-309.
- 687 Shi, L.-j., Liu, W.-h., Shi, H.-s., Yan, C., Wang, Y., Wang, Y., . . . Chan, R. C. K. (2017). Co-
688 occurrence of autistic and schizotypal traits and its association with emotional and
689 psychosocial function in Chinese college students. *Psychiatry Res*, 248, 64-70.
690 doi:<https://doi.org/10.1016/j.psychres.2016.12.021>
- 691 Sierro, G., Rossier, J., & Mohr, C. (2016). Validation of the French Autism Spectrum
692 Quotient scale and its relationships with schizotypy and Eysenckian personality traits.
693 *Comprehensive Psychiatry*, 68, 147-155.
694 doi:<https://doi.org/10.1016/j.comppsy.2016.03.011>
- 695 Solomon, M., McCauley, J. B., Iosif, A.-M., Carter, C. S., & Ragland, J. D. (2016). Cognitive
696 control and episodic memory in adolescents with autism spectrum disorders.
697 *Neuropsychologia*, 89, 31-41.
698 doi:<https://doi.org/10.1016/j.neuropsychologia.2016.05.013>
- 699 Solomon, M., Olsen, E., Niendam, T., Ragland, J. D., Yoon, J., Minzenberg, M., & Carter, C.
700 S. (2011). From lumping to splitting and back again: Atypical social and language
701 development in individuals with clinical-high-risk for psychosis, first episode
702 schizophrenia, and autism spectrum disorders. *Schizophr Res*, 131(1), 146-151.
703 doi:<https://doi.org/10.1016/j.schres.2011.03.005>
- 704 Stefanis, N. C., Hanssen, M., Smirnis, N. K., Avramopoulos, D. A., Evdokimidis, I. K.,
705 Stefanis, C. N., . . . Van Os, J. (2002). Evidence that three dimensions of psychosis
706 have a distribution in the general population. *Psychol Med*, 32(2), 347-358.
- 707 van Boxtel, J. J. A., Peng, Y., Su, J., & Lu, H. (2017). Individual differences in high-level
708 biological motion tasks correlate with autistic traits. *Vision Research*, 141, 136-144.
709 doi:<https://doi.org/10.1016/j.visres.2016.11.005>

- 710 Van de Cruys, S., Evers, K., Van der Hallen, R., Van Eylen, L., Boets, B., de-Wit, L., &
711 Wagemans, J. (2014). Precise minds in uncertain worlds: predictive coding in autism.
712 *Psychol Rev*, 121(4), 649-675. doi:10.1037/a0037665
- 713 van Schalkwyk, G. I., Volkmar, F. R., & Corlett, P. R. (2017). A Predictive Coding Account
714 of Psychotic Symptoms in Autism Spectrum Disorder. *J Autism Dev Disord*, 47(5),
715 1323-1340. doi:10.1007/s10803-017-3065-9
- 716 Wakabayashi, A., Baron-Cohen, S., & Ashwin, C. (2012). Do the traits of autism-spectrum
717 overlap with those of schizophrenia or obsessive-compulsive disorder in the general
718 population? *Research in Autism Spectrum Disorders*, 6(2), 717-725.
719 doi:<https://doi.org/10.1016/j.rasd.2011.09.008>
- 720 Waytz, A., Cacioppo, J., & Epley, N. (2010). Who Sees Human? The Stability and
721 Importance of Individual Differences in Anthropomorphism. *Perspect Psychol Sci*,
722 5(3), 219-232. doi:10.1177/1745691610369336
- 723 Wetzels, R., & Wagenmakers, E.-J. (2012). A default Bayesian hypothesis test for
724 correlations and partial correlations. *Psychon Bull Rev*, 19(6), 1057-1064.
725 doi:10.3758/s13423-012-0295-x

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Appendices

Appendix A

Calculation of Bias c and d'

Bias c and d' were calculated according to Macmillan and Creelman (1991):

$$\text{bias c} = -0,5(z(\text{hit rate}) + z(\text{false alarm rate}))$$

$$d' = z(\text{hit rate}) - z(\text{false alarm rate})$$

Following the recommendations of Macmillan and Creelman (1991), extremes scores were corrected by converting 0 to $1/(2N)$, and 1 to $1-1/(2N)$, where N is number of trials with wolf.