

Decreased reward value of biological motion among individuals with autistic traits Cognition

Williams, Elin H.; Cross, Emily

Cognition

DOI:
[10.1016/j.cognition.2017.10.017](https://doi.org/10.1016/j.cognition.2017.10.017)

Published: 01/02/2018

Publisher's PDF, also known as Version of record

[Cyswllt i'r cyhoeddiad / Link to publication](#)

Dyfyniad o'r fersiwn a gyhoeddwyd / Citation for published version (APA):
Williams, E. H., & Cross, E. (2018). Decreased reward value of biological motion among individuals with autistic traits Cognition. *Cognition*, 171, 1-9.
<https://doi.org/10.1016/j.cognition.2017.10.017>

Hawliau Cyffredinol / General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal ?

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.



Original Articles

Decreased reward value of biological motion among individuals with autistic traits



Elin H. Williams^a, Emily S. Cross^{a,b,c,*}

^a *Social Brain in Action Laboratory, Wales Institute for Cognitive Neuroscience, School of Psychology, Bangor University, Wales, United Kingdom*

^b *Institute of Neuroscience and Psychology, University of Glasgow, Scotland, United Kingdom*

^c *School of Psychology, University of Glasgow, Scotland, United Kingdom*

ARTICLE INFO

Keywords:

Biological motion
Human motion
Autism spectrum disorders
Autistic traits
Reward value
Social motivation

ABSTRACT

The Social Motivation Theory posits that a reduced sensitivity to the value of social stimuli, specifically faces, can account for social impairments in Autism Spectrum Disorders (ASD). Research has demonstrated that typically developing (TD) individuals preferentially orient towards another type of salient social stimulus, namely biological motion. Individuals with ASD, however, do not show this preference. While the reward value of faces to both TD and ASD individuals has been well-established, the extent to which individuals from these populations also find human motion to be rewarding remains poorly understood. The present study investigated the value assigned to biological motion by TD participants in an effort task, and further examined whether these values differed among individuals with more autistic traits. The results suggest that TD participants value natural human motion more than rigid, machine-like motion or non-human control motion, but this preference is attenuated among individuals reporting more autistic traits. This study provides the first evidence to suggest that individuals with more autistic traits find a broader conceptualisation of social stimuli less rewarding compared to individuals with fewer autistic traits. By quantifying the social reward value of human motion, the present findings contribute an important piece to our understanding of social motivation in individuals with and without social impairments.

1. Introduction

Humans naturally find certain types of stimuli more rewarding than others. A well-established literature documents the high reward value of food and money (Berridge, 1996; Breiter, Aharon, Kahneman, Dale, & Shizgal, 2001), as well as social stimuli, such as human faces (Aharon et al., 2001; Kampe, Frith, Dolan, & Frith, 2001). When we view such stimuli, whether material or social in nature, brain regions associated with reward processing, including the ventromedial prefrontal cortex, the striatum, and the orbitofrontal cortex, are reliably engaged (Lin, Adolphs, & Rangel, 2012; Sescousse, Redouté, & Dreher, 2010; Spreckelmeyer et al., 2009).

Stimuli such as faces are suggested to be rewarding because they provide an abundance of information about another individual's mood, feelings and intentions, thus providing rich social cues (Kampe et al., 2001). Further, faces may predict social outcomes. For example, smiles may lead one to anticipate positive social outcomes, while frowns may predict negative social outcomes (Kringelbach & Rolls, 2003). Research into the reward value of faces demonstrates that faces with genuine smiles are valued more than faces with polite smiles, as demonstrated

by participants' willingness to forgo higher monetary rewards to view faces with genuine compared to polite smiles (Shore & Heerey, 2011). Male heterosexual participants also work harder, or exert more effort, to view images of attractive, rather than average, female faces (Hayden, Parikh, Deaner, & Platt, 2007).

However, it has become apparent that the value assigned to social stimuli is subject to individual differences. For example, research has demonstrated that individuals with an autism diagnosis, or individuals without a clinical diagnosis of autism, but who report more autistic traits, show a reduced response to social, but not non-social, rewards (Carter Leno, Naples, Cox, Rutherford, & McPartland, 2016; Cox et al., 2015; Gossen et al., 2014; Zeeland et al., 2010). This reduced sensitivity to social rewards has been observed in a number of different tasks, including incentive delay (Cox et al., 2015; Gossen et al., 2014), reward learning (Zeeland et al., 2010), and effort tasks (Dubey, Ropar, & Hamilton, 2015). Furthermore, modulating the reward value of social stimuli, such as faces (Sims, VanReekum, Johnstone, & Chakrabarti, 2012) and hands (Haffey, Press, O'Connell, & Chakrabarti, 2013) in conditioning paradigms increases spontaneous mimicry and prosocial behaviour (Panastis,

* Corresponding author at: School of Psychology, Bangor University, Bangor, Gwynedd, LL57 2AS Wales, United Kingdom.
E-mail address: e.cross@bangor.ac.uk (E.S. Cross).

Puzzo, & Chakrabarti, 2016) in individuals with fewer autistic traits, but not in those with more autistic traits. Together, these findings provide support for the idea that a deficit in sensitivity to social rewards exists in individuals with autism as well as in those reporting high numbers of autistic traits.

The Social Motivation Theory of Autism (Chevallier, Kohls, Troiani, Brodtkin, & Schultz, 2012) suggests that individuals with autism spectrum disorders (ASD) fail to form a representation of the reward value of social stimuli, and therefore place less value on these types of stimuli. It is thought that the reduced reward value associated with social stimuli consequently leads individuals with ASD to differ in their motivation to engage socially (Dawson et al., 2004). In a recent attempt to test this theory, Dubey et al. (2015) conducted an elegant behavioural experiment to measure the reward value of social stimuli based on the number of autistic-like traits participants reported, and whether or not they had a clinical diagnosis of ASD. Specifically, the authors investigated the value of dynamic smiling faces with direct and averted gaze via an innovative task that used participant effort to gauge the reward value of each stimulus type. The results demonstrated that participants exerted more effort to watch videos of smiling faces with direct gaze, compared to videos of smiling faces with averted gaze or videos of moving objects (a non-social control condition). However, this preference for social stimuli was reduced in participants who reported more autistic traits or had a clinical ASD diagnosis. These results support the notion that individuals with ASD, as well as individuals without a clinical ASD diagnosis who report more autistic traits, assign a reduced reward value to social stimuli relative to typically developing individuals.

Although many studies have suggested that individuals assign a high value to faces as they may predict social outcomes (Fridlund, 1991; Hooker, Germine, Knight, & D’Esposito, 2006) and provide a wealth of other social cues (Kampe et al., 2001), faces are rarely encountered independently from other types of social information, such as bodies. Moreover, in a social world, faces and bodies move together. Biological motion, defined as motion produced by an animate agent, is another type of social stimulus that provides rich social information about others we encounter in our environment (Grossman et al., 2000). During social interactions, we receive valuable information from bodies as they gesture and signal emotions, ideas and intentions (Atkinson, Dittrich, Gemmell, & Young, 2004; Johansson, 1973; Pollick, Kay, Heim, & Stringer, 2005).

Biological motion is suggested to be of great value for adaptive social behaviour, and sensitivity to this type of motion is thought to be a precursor to social development (Klin, Lin, Gorrindo, Ramsay, & Jones, 2009). Seminal research documents how the human visual system is sensitively tuned to recognise biological motion even in minimal circumstances, such as point-light displays (Johansson, 1973). Preferentially orienting to biological motion is suggested to be an evolutionarily important behaviour – protecting us from predators and ensuring filial attachment (Atkinson et al., 2004). This natural orientation towards other animate agents is manifest in a range of species, from humans to birds (Simion, Regolin, & Bulf, 2008; Vallortigara, Regolin, & Marconato, 2005), and is demonstrated in human infants as young as two days old (Simion et al., 2008). However, these aforementioned behaviours seem to be impaired in infants with ASD, and these individuals appear to, instead, preferentially orient to non-biological, or non-social motion (Klin et al., 2009). Research has suggested that these behaviours point to a disruption in an innate predisposition to attend to biological motion, which may have negative downstream consequences for the processing of social cues (Blake, Turner, Smoski, Pozdol, & Stone, 2003; Clarke, Bradshaw, Field, Hampson, & Rose, 2005; Grossmann & Johnson, 2007; Toth, Munson, Meltzoff, & Dawson, 2006).

To summarise, copious research has demonstrated that typically developing individuals assign high reward value to social stimuli, such as human faces, and that the value of social stimuli may differ in

individuals who report more autistic traits or who have an ASD diagnosis (Chevallier et al., 2012; Dubey et al., 2015; Sepeta et al., 2012; Zeeland et al., 2010). Research has also demonstrated that typically developing individuals preferentially orient to biological motion compared to other types of motion, but this same preference is not shown among individuals with ASD. However, it remains unknown whether individuals from these two populations assign different *reward value* to biological, or human-like, motion compared to less or non-biological motion, in a manner similar to what has been demonstrated for faces. Therefore, it is important to determine the extent to which familiar, human-like motion is perceived as a rewarding social stimulus among individuals with and without ASD, as well as among those reporting greater or fewer autistic-like traits, in order to advance our understanding of social motivation in typically developing individuals and those with social impairments.

The aim of the present study is to investigate the value individuals assign to biological, natural human motion, and how these assigned values differ depending on the number of autistic traits reported by each individual. In this study, we operationalise reward value by measuring the amount of effort participants are willing to exert in order to view a particular stimulus (Aharon et al., 2001), as we predict that certain stimuli should lead to higher positive affect in the viewer than others. A modified version of the Choose-a-Movie paradigm (CAM), originally developed by Dubey et al. (2015), enables us to measure the effort participants are willing to exert to watch different types of videos. On each trial of the CAM task, participants choose to open one of two boxes, based on their knowledge of the videos that are associated with those boxes (e.g., a green box is always associated with human motion), and the number of locks on each box (a box with 3 locks requires more key presses, and therefore more effort to open, compared to a box with 1 lock). Participants must choose between opening boxes containing videos of natural human motion, machine-like motion or non-human control motion. We hypothesised that participants with fewer autistic traits should find natural human motion most rewarding, and will thus choose to open more of these boxes and exert more effort to watch them relative to the other two video categories. However, if participants with more autistic traits value social stimuli less, we predict that these individuals should open fewer boxes containing human motion, and exert less effort to view these types of videos. This would manifest as an interaction between autistic traits and stimulus category, or a three-way interaction between autistic traits, effort and stimulus category.

2. Materials and methods

2.1. Participants

Participants were 105 Bangor University students and individuals from the local community, who received either course credits or £7 per hour for their participation. Five participants were excluded from the sample due to not following task instructions, leaving a final sample for data analysis of 100 participants (77 females; $M_{age} = 21.45$ years, $SD = 3.46$). Due to the complexity of conducting power analyses for experiments employing mixed effects models (Kain, Bolker, & McCoy, 2015), the sample size for the present study was chosen based on a sample size used in a similar experiment by Dubey et al. (2015). All participants provided written informed consent, and the Research Ethics Committee of the School of Psychology at Bangor University, provided ethical approval for all aspects of this study (Ethical Approval Code: 2015-15400).

2.2. Stimuli

Stimuli included three kinds of videos. The first category of videos featured a human actor performing simple, natural, human-like motion (such as moving his arms or legs from side to side smoothly; see [Supplementary Video 1](#)). This motion was used as a proxy for biological

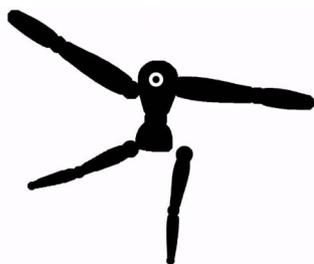
motion, and is henceforth referred to as ‘Natural Human Motion’. The second category of videos featured rigid, jerky, robotic-like motion, such as the actor moving his arms or legs up and down or from side to side rigidly. These videos were created as a proxy for non-biological motion, and are henceforth referred to as ‘Machine-Like Motion’ (Supplementary Video 2). From these original video recordings, an additional set of CGI videos featuring a non-human control figure “performing” both types of motion were developed (Supplementary Video 3).



Supplementary Video 1.



Supplementary Video 2.



Supplementary Video 3.

To create the original videos, a male actor was instructed to move in front of a green screen in a fluid, human-like manner for natural human motion videos, and to move in a rigid, robotic manner for machine-like motion videos (Fig. 1). Videos were recorded on a SONY HD Handycam video recorder and were edited in MATLAB (R2015b, The MathWorks Inc. 2000). The model’s figure was extracted from the green screen and placed onto a white background, and all facial information was removed. These steps were undertaken in order to minimise the effects of any other information on task performance other than the effects of body motion. The control videos were created by mapping the motion created by the model, using MOCAP (Reallusion Inc, 2015), a motion capture software for Windows Kinect (Microsoft, 2015), onto a non-human figure via iClone 6 (Reallusion Inc, 2015). Thus, our control stimuli, although a non-human figure, performed the exact same

motions as our human figure. The control figure was further manipulated to minimise human-likeness by rotating limbs at different angles, and moving the arms to the location of the legs and the legs to the location of the arms (Fig. 1).

Experimental stimuli were piloted in an online experiment prior to the main study in order to ascertain whether the two motion categories, human and machine-like, were rated by naïve observers as human-like and machine-like, respectively. Thirty-two independent participants were asked to rate each of the 30 videos on a scale from 0 to 100, with 0 corresponding to ‘not human like at all’ and 100 being ‘very human like’. Participants rated the videos in the human motion category ($M = 69.00$, $SE = 2.51$) as being significantly more human-like than the motion in the machine-like motion category ($M = 40.40$, $SE = 3.20$) ($t(31) = 8.63$, $p < .001$). This confirmed that the agent’s motion in the human category was perceived as more human-like, and that the agent’s motion in the machine-like category was perceived as less human-like. Ten videos from each video category were included in this experiment; human-motion videos that were rated as the most human-like, and machine-like motion videos that were rated as least human-like in the pilot study, were chosen. Each video lasted 3 seconds. Additionally, three coloured squares were used as prompts for each movie category (Fig. 2a).

2.3. Procedure

The Choose-a-Movie (CAM) task, developed by Dubey et al. (2015), was presented using Psychopy software (Peirce, 2007; Peirce, 2009). In this task, participants were required to open one of two coloured boxes; a coloured box was always associated with a particular video category. In order to learn how the task worked and to generate associations between what types of videos were associated with the coloured boxes, participants firstly completed 21 familiarisation trials. For each of the first 15 trials, one box with one lock was presented, and for the remaining six trials, participants were presented with a box on the left and a box on the right with one lock on each box. From these familiarisation trials, participants learnt that unlocking all locks from a box would reveal a video. Opening a lock required one key press, resulting in a one-second delay before the participant would be able to unlock another lock. Multiple locks could not be removed at once due to the one-second delay between key presses. During the main task, participants saw a coloured box on the left, and a coloured box on the right side of the screen with between one and three locks on each (Fig. 2b). Participants chose to open either the coloured box on the left or the differently coloured box on the right, and would subsequently see the video associated with the chosen coloured box. There were 3 coloured boxes: a blue box, a red box, and a green box. The associations between colour and video category remained consistent within participants, and were counterbalanced across participants (Fig. 2a).

In accordance with Dubey et al. (2015), participants completed 180 experimental trials. These 180 trials included 60 trials with a choice between human motion and control videos, 60 trials with a choice between human motion and machine-like motion videos, and 60 trials with a choice between machine-like motion and control videos. In each set of 60 trials, 32 trials had 3 locks on one box and 1 on the other, 8 had 2 locks on one box and 1 on the other, 8 had 3 locks on one box and 2 on the other, and 12 had an equal number of locks on each box. The box with the greater number of locks was randomly assigned to either the left or the right side of the screen. Participants were required to select a box to open from the choice of two – they could choose to open the box with fewer locks (requiring fewer key presses, less effort and less time) or to open the box with more locks (requiring more key presses, effort and time). The number of locks on the boxes, and the videos associated with the colour of the boxes, would influence the choices participants made.

After providing written informed consent, participants completed a demographic questionnaire assessing their age, gender, and education,

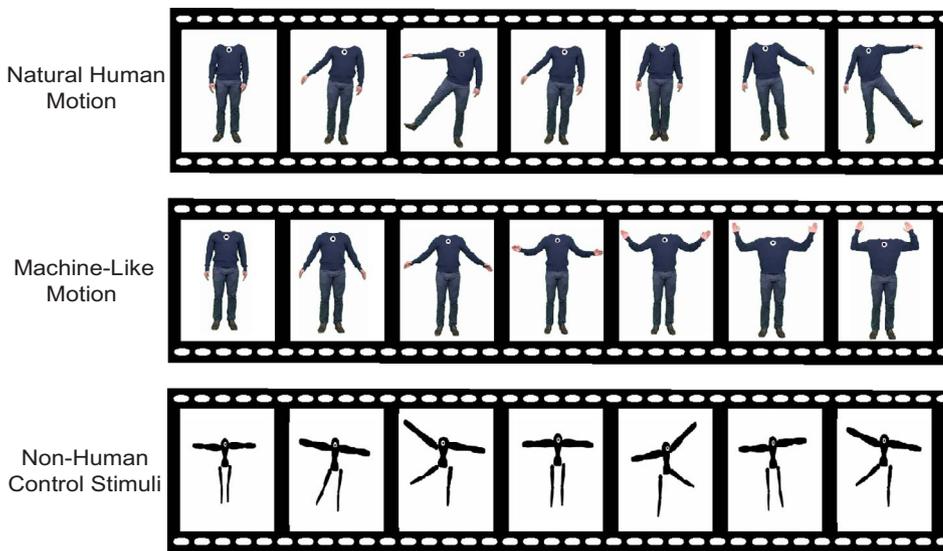


Fig. 1. Video stills from the three stimulus categories.

and then completed the Edinburgh Handedness Inventory (EHI) (Oldfield, 1971). Next, the CAM task was presented using Psychopy software (Peirce, 2007; Peirce, 2009); participants were instructed to open one box on each trial. Lastly, participants completed the Adult Autism Spectrum Quotient (AQ) questionnaire (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) and the Social Responsiveness Scale (SRS; Constantino & Gruber, 2007). The AQ is a brief, self-administered questionnaire developed to measure autistic traits in individuals with normal IQ for scientific (e.g. to establish the caseness of an individual) and applied reasons (e.g. to screen individuals to refer for diagnostic assessment; Baron-Cohen et al., 2001). A recent meta-analysis suggests that the mean AQ score of participants in the typical population is 16.94, while the mean AQ score of those on the Autism Spectrum is 35.19 (Ruzich et al., 2015). However, as the mean AQ score of our sample of TD participants ($M = 19.25$, $SD = 9.92$) is higher than the mean score of the typical population and our participants reported a broad range of autistic traits (scores ranged from 1 to 49), we note that the results from our study are not necessarily representative of the typical population. To address these possible issues with atypicalities in our study sample, we evaluate and report additional analyses focusing on subsamples of our participant

group in supplementary materials (see Section 2.6 Supplementary Data Analyses, below).

The SRS is another widely-used measure of autistic traits that can be used among the general population (Bölte, Poustka, & Constantino, 2008). SRS scores of 59 or below are considered to indicate that an individual has few autistic traits, while scores of 76 or higher indicate that an individual has many autistic traits (Constantino & Gruber, 2012). As with the AQ, we note that our sample of participants show a broad range of SRS scores, ranging from 34 to 90 ($M = 65.71$, $SD = 14.96$).

2.4. Data analyses

The data were analysed following the approach outlined by Dubey et al. (2015). The data from the experiment comprising of 180 trials was split into three sets of 60 trials – one data set for trials which consisted of a choice between opening human motion and control videos, one set for machine-like motion and control videos, and one set for human and machine-like motion videos. Data were split into three sets of trials as we were interested in investigating the factors contributing to the choice participants make when choosing to open one of two boxes.

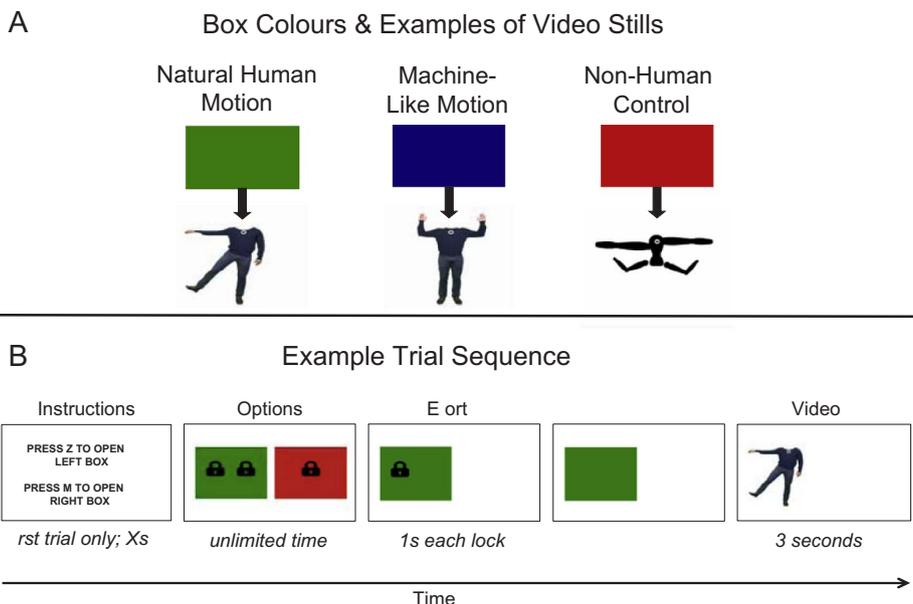


Fig. 2. (A) Association between coloured boxes and videos. Three different coloured boxes were associated with three different video categories. The associations between colour and video type were counterbalanced across participants. (B) Trial sequence. Participants saw two coloured boxes with differing numbers of locks, and were required to choose to open one box. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Three separate logistic mixed effects models were fit for each of the three sets of choice data, using the lme4 package (version 1.1-13) (Bates, Maechler, Bolker, & Walker, 2015) in R (Version 3.3.3, R Core Team, 2016). Models were fit via a maximum likelihood procedure.

The three mixed effects models aimed to predict the probability of choosing to open the box on the left, based on the difference in utility between the box on the left and the box on the right. The subjective value, or desirability, of a stimulus in economics is referred to as *utility*. Utility, in this study, is modelled as a function of 1) the *Effort* required to open the box on the left (locks on the left box minus locks on the right, thus varied from -2 to $+2$), and 2) the *Stimulus Category* of the left box. Therefore, Effort and Stimulus Category were included in each model as fixed factors. Further, Autistic Traits was included as a grand mean-centred, participant-level factor, as well as gender, age, handedness, and the colour of the box on the left. We also modelled the interaction between Autistic Traits, Stimulus Category, and Effort. A random by-participant intercept was included with random slopes for Effort and Stimulus Category (Barr, Levy, Scheepers, & Tily, 2013). Models were probed for over parameterisation using the RePsychLing package in R (Bates, Kliegl, Vasishth, & Baayen, 2015); this analysis did not reveal any rank deficiency in our models. Plotting and inspecting the residuals for all models detected no violations of linearity, homoscedasticity, or normality.

For each model, we made a prediction as to whether the participant would choose to open the box on the left based on the effort the participant would have to exert to open it, the stimulus category (e.g. natural human motion vs. control stimuli; machine-like motion vs. control stimuli; natural human motion vs. machine-like motion) and their autistic traits.

2.5. Supplementary data analyses

In addition to evaluating our main models of interest, we conducted several additional analyses to further explore our data. First, when initially setting up our models, we found that including both measures of autistic traits (the AQ and SRS) as factors led to non-convergence of the mixed effects models. This is likely due to their strong correlation ($r = 0.63$), which resulted in issues with multicollinearity. In the present study, our primary focus is on results from models that included the AQ instead of the SRS as the measure of autistic traits (see above), in order to draw the clearest comparisons to the results from a similar study by Dubey et al. (2015). However, it should be noted that both questionnaire measures of autistic traits yielded similar results, and for transparency, we report full results from the models that used the SRS instead of the AQ as the measure of autistic traits in [Supplementary](#)

[Results 1 and Supplementary Table 1](#). We also evaluated our three main models of interest with only those participants with AQ scores of 20 or below, given that a recent meta-analysis identified the 95% CI for neurotypical adults as 11.6–20 (Ruzich et al., 2015). These findings are reported in [Supplementary Results 2 and Supplementary Table 2](#). Furthermore, we evaluated our three main models after excluding participants whose AQ scores were > 2 standard deviations from the group mean ([Supplementary Results 3 and Supplementary Table 3](#)). Due to the uneven representation of male and female participants in our sample, we also evaluate our models with female participants only, and these results are reported in [Supplementary Results 4 and Supplementary Table 4](#). In addition, we ran correlational analyses to evaluate how autistic traits influence stimulus preferences, collapsed across effort levels, and to illustrate the relationship between autistic traits and stimulus preference in a different way to our main analyses. These results are presented as [Supplementary Results 5 and Supplementary Fig. 2](#). We also plotted the coefficient estimates for each fixed effect of interest for each of the three models to visualise how each fixed effect influences the data within each model ([Supplementary Results 6 and Fig. 3](#)). Further, we ran exploratory multiple regression analyses to investigate the relationships between autistic traits, gender, age, and handedness ([Supplementary Results 7 & 8](#)).

3. Results

3.1. Natural human motion vs. control stimuli

A fixed effect of Effort showed that choosing the left box was significantly influenced by the effort participants needed to exert to open that box; the likelihood of choosing to open the box on the left decreased when the effort required increased. A fixed effect of the factor Stimulus Category revealed that participants were more likely to open the box on the left when it contained a video of Natural Human Motion, compared to when it contained control stimuli. Unexpectedly, a fixed effect of Autistic Traits also significantly predicted the choice participants made, revealing that those with more autistic traits were more likely to open the box on the left regardless of any other factors. As predicted, a significant interaction emerged between Autistic Traits and Stimulus Category, such that participants with more autistic traits were less likely to open the box containing natural human motion compared to individuals with fewer autistic traits. The colour of the box, and handedness, were also found to be significant predictors of the choice participants made. Participants who were more left-handed were more likely to open the box on the left. For all study results, the main findings of participant preference for stimuli featuring different kinds of motion,

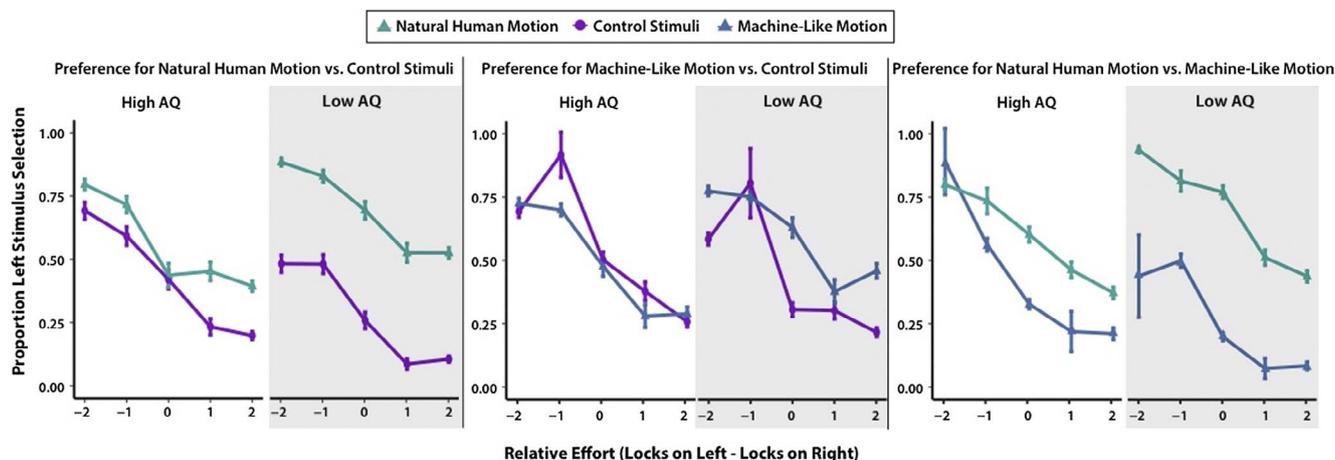


Fig. 3. To highlight differences in participant performance based on AQ scores, participants with AQ scores above the mean-centred AQ score were put in a 'High AQ' group, and participants with AQ scores below the mean-centred AQ score were put in a 'Low AQ' group. The plots show how Effort, the Stimulus Category of the left box, and Autistic Traits contribute to opening the box on the left.

Preference for Stimuli Featuring Different Kinds of Motion, as a Function of Effort and AQ Score

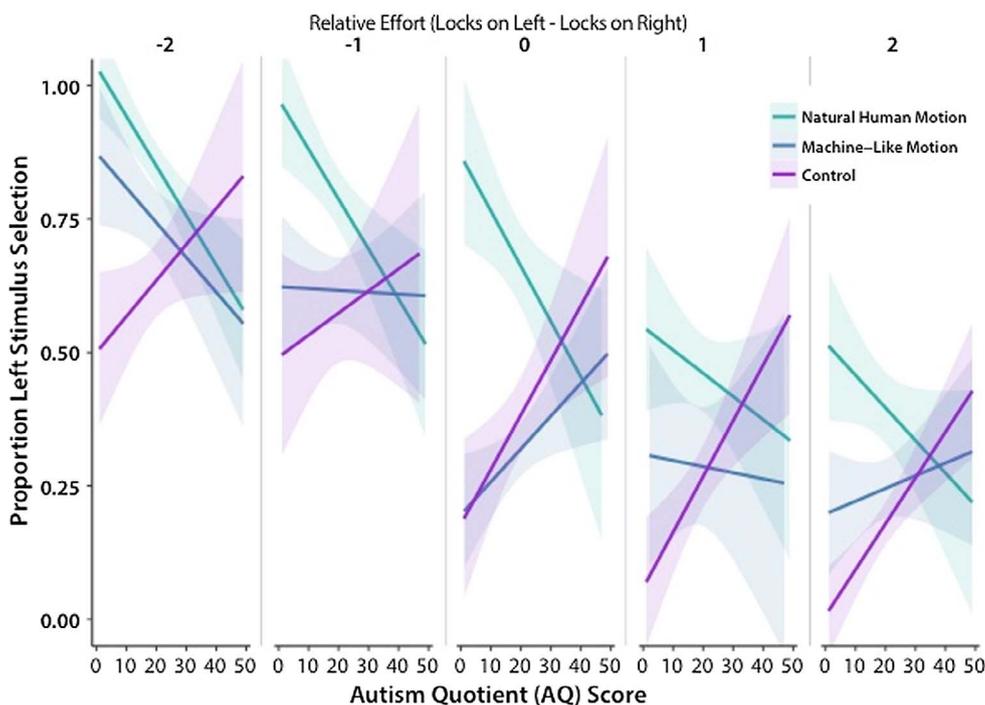


Fig. 4. Preferences for stimuli featuring different kinds of motion, as a function of Effort and Autistic Traits (plotted here as a continuous variable).

as a function of effort and AQ score are illustrated in two different ways for ease of interpretation: as a function of high versus low AQ scores (Fig. 3), and with AQ scores as a continuous variable (Fig. 4). Table 1 details the findings from each of the three mixed effects logistic regression models.

3.2. Machine-like motion vs. control stimuli

A fixed effect of Effort revealed that choosing to open the box on the left was significantly influenced by the effort participants needed to exert to open it; participants were less likely to open the box on the left if it required more effort to open than the box on the right. A fixed effect of Stimulus Category showed that participants were more likely to open the box on the left when it contained a video of machine-like motion compared to when it contained control stimuli. A fixed effect of Autistic Traits was also significant. As hypothesised, a significant interaction emerged between Autistic Traits and the Stimulus Category, suggesting that participants with more autistic traits were more likely than those with fewer autistic traits to open the box containing control stimuli compared to machine-like motion (Figs. 3 and 4). A significant effect of age also emerged, such that older participants were more likely to choose to open the left box (Table 1).

3.3. Natural human motion vs. machine-like motion

A fixed effect of Stimulus Category showed that participants were more likely to open the box on the left when it contained a video of natural human motion, compared to when it contained a video of machine-like motion, and a fixed effect of Effort showed that the number of locks on the left box significantly influenced the choice participants made, such that participants were less likely to open the left box when the effort required to open it was greater. Autistic Traits was a significant predictor of choice. Further, gender was also a significant predictor, which showed that females were more likely to open the box on the right. As predicted, a significant interaction emerged between Autistic Traits and Stimulus Category, such that participants reporting more autistic traits were less likely to open the box containing natural human motion compared to individuals reporting fewer autistic traits.

Finally, a significant interaction also emerged between Autistic Traits and Effort. This demonstrated that although all participants were influenced by effort, and were more likely to choose to open the box with fewer locks, participants with fewer autistic traits appeared to be more strongly influenced by effort compared to participants with more autistic traits (Figs. 3 and 4; Table 1; Supplementary Results 9 and Supplementary Fig. 4).

4. Discussion

The results from our Choose-a-Movie task suggest that most participants prefer social videos (natural human motion or machine-like motion) compared to non-social videos (control stimuli), and that the strength of this preference is linked to the number of autistic traits they report. Overall, participants preferred to watch the most social stimulus out of each pair of stimuli. However, participants who reported fewer autistic traits displayed a stronger preference for more social videos, while those reporting more autistic traits displayed a weaker preference for more social videos. This finding suggests that participants reporting more autistic traits valued these types of stimuli less, as they opened fewer of these boxes and exerted less effort to watch them. These results are consistent with our hypothesis that participants with fewer autistic traits assign a higher value to biological, or natural human motion, compared to the motion of the other two video categories.

Unexpectedly, we found that autistic traits significantly predicted box choice in all three of our models, regardless of any other factors. To investigate this, we assigned participants with AQ scores below the mean AQ into a 'Low AQ' group, and assigned participants with scores above the mean AQ into a 'High AQ' group. This revealed that individuals within the Low AQ group ($M_{EHI} = 79.46$, $SE = 4.08$) appeared to be more strongly right handed than those within the High AQ group ($M_{EHI} = 63.07$, $SE = 7.66$). As participants were asked to press the 'Z' key to unlock the left box, and the 'M' key to unlock the right box, individuals within the High AQ group may have been more likely to open the left box as the 'Z' key is easier to press with the dominant left hand. However, this explanation requires further investigation in order to say with certainty that the effect of box choice we see here is explained by participant handedness.

Table 1
Mixed effects logistic regression models investigating variables contributing to opening the box on the left, in the three types of choice trials.

	B	SE	Z	p-value
<i>Natural Human Motion vs. Control</i>				
Fixed Parts				
Intercept	−1.71	0.31	−5.60	< 0.001
Stimulus Category	2.61	0.50	5.22	< 0.001
Effort	−1.12	0.11	−10.26	< 0.001
Autistic Traits	0.09	0.03	3.43	< 0.001
Handedness	−0.14	0.05	−2.54	0.011
Age	0.08	0.06	1.29	0.198
Gender	0.07	0.13	0.57	0.571
Box Colour	0.18	0.07	2.66	0.008
Stimulus Category * Effort	0.06	0.07	0.94	0.350
Stimulus Category * Autistic Traits	−0.20	0.05	−3.88	< 0.001
Effort * Autistic Traits	0.02	0.01	1.66	0.097
Stimulus Category * Effort * Autistic Traits	−0.01	0.01	−1.82	0.068
Random Parts				
N _{PID}	100			
Tjur's D	0.61			
AIC	4255.89			
<i>Machine-Like Motion vs. Control</i>				
Fixed Parts				
Intercept	−0.53	0.28	−1.89	0.059
Stimulus Category	0.98	0.50	1.98	0.048
Effort	−0.95	0.09	−10.14	< 0.001
Autistic Traits	0.07	0.02	3.05	0.002
Handedness	−0.03	0.05	−0.64	0.522
Age	0.10	0.05	2.11	0.035
Gender	0.01	0.11	0.06	0.951
Box Colour	−0.02	0.06	−0.35	0.726
Stimulus Category * Effort	−0.08	0.06	−1.45	0.148
Stimulus Category * Autistic Traits	−0.14	0.05	−2.90	0.004
Effort * Autistic Traits	0.01	0.01	1.24	0.216
Stimulus Category * Effort * Autistic Traits	0.00	0.01	−0.20	0.842
Random Parts				
N _{PID}	100			
Tjur's D	0.57			
AIC	4665.89			
<i>Natural Human Motion vs. Machine-Like Motion</i>				
Fixed Parts				
Intercept	−1.42	0.28	−5.05	< 0.001
Stimulus Category	3.18	0.48	6.65	< 0.001
Effort	−1.52	0.15	−10.16	< 0.001
Autistic Traits	0.08	0.02	3.31	0.001
Handedness	−0.06	0.06	−1.08	0.282
Age	0.05	0.06	0.89	0.374
Gender	−0.26	0.13	−1.99	0.047
Box Colour	0.01	0.07	0.10	0.919
Stimulus Category * Effort	0.16	0.08	1.93	0.053
Stimulus Category * Autistic Traits	−0.17	0.05	−3.51	< 0.001
Effort * Autistic Traits	0.03	0.01	2.33	0.020
Stimulus Category * Effort * Autistic Traits	−0.01	0.01	−1.04	0.298
Random Parts				
N _{PID}	100			
Tjur's D	0.58			
AIC	4579.43			

Bolded font indicates all p values less than 0.05.

Using a similar CAM paradigm, [Dubey et al. \(2015\)](#) suggested that participants showed a preference for social videos (faces with direct gaze) compared to less social videos (faces with averted gaze, or objects), however, this preference was reduced in participants with more autistic traits or with a diagnosis of ASD. The findings from the present study indicate that participants show a similar pattern of preference when asked to open boxes associated with more or less social human body motion. On the whole, participants preferred to open the more social video (natural human motion) over the less social video (machine-like motion, or non-human control), but this preference was reduced in individuals with more autistic traits.

Our findings are consistent with other studies that have investigated the reward value of social stimuli, and how this value is modulated by

either autistic traits or a clinical diagnosis of autism. For example, [Cox et al. \(2015\)](#) demonstrated that individuals reporting more autistic traits showed decreased sensitivity to social compared to non-social rewards in an incentive delay task. Reduced spontaneous mimicry and prosocial behaviour to rewarding faces and hands has also been observed in individuals with more autistic traits ([Haffey, Press, O'Connell, & Chakrabarti, 2013](#); [Panasiti et al., 2016](#); [Sims et al., 2012](#)). Our findings add support to the growing literature that examines how autistic traits modulate the reward value of social stimuli, and document how human bodies in motion are also appraised as rewarding social stimuli.

The Social Motivation Theory of Autism ([Chevallier et al., 2012](#)) posits that atypical social behaviour observed in individuals on the autism spectrum could be due to their failure to assign high reward values to social stimuli. Previous studies that have investigated the value of social stimuli have used stimuli that signal engagement (e.g. a smiling face with direct gaze, which is an important platform for social interaction and communication; [Dubey et al., 2015](#); [Spreckelmeyer et al., 2009](#)). However, the reward value of another type of social stimulus that we encounter in abundance in our daily lives, namely, that of others' bodies moving around us in a social world, has been overlooked. Therefore, it is difficult to disentangle whether TD participants value the types of stimuli presented in previous studies because they indicate that social interaction will follow as they include faces with direct gaze, or simply because they feature other people, and are thus more generically social. The findings from the present study lend support to the notion that TD participants value different types of social stimuli, not only those that signal imminent social engagement, and that individuals with more autistic traits might show a reduced preference across a range of social stimuli (again, not only those signalling social engagement). As such, these findings contribute significant new insights to our understanding of social motivation and the value of bodies in motion, and how autistic traits can influence this value.

Previous research has shown that TD participants preferentially orient their attention towards biological motion ([Simion et al., 2008](#)). It is of note that this preference for biological motion is present across a number of non-human species as well, such as birds ([Vallortigara et al., 2005](#)) and monkeys ([Oram & Perrett, 1996](#)), thus demonstrating the adaptive value of attending to biological motion across phylogeny. In humans, this adaptive value is arguably even greater, as the motion of others can help us determine whether to engage in or avoid social interaction, and allows us to develop complex skills for understanding facial expressions and gaze direction. In the present study, typically developing participants preferred to watch videos of natural human motion, and exerted more effort to view this type of motion; this preference is in accordance with participants' preferential looking towards biological motion, compared to other types of motion, demonstrated in other studies ([Fox & McDaniel, 1982](#); [Simion et al., 2008](#)). Thus, the data show that not only do participants implicitly guide their attention towards human motion as shown in previous studies, but also, explicitly behave in ways that results in their viewing the more social motion when given a choice of two to choose between.

However, the behaviour of preferentially orienting towards biological motion appears impaired in infants with ASD, who preferentially attend to non-biological motion instead ([Annaz, Campbell, Coleman, Milne, & Swettenham, 2012](#); [Klin et al., 2009](#)). In the present study, we show that the preference for biological motion is reduced in typical adults with more autistic traits. These results are consistent with the finding that individuals with ASD fail to preferentially orient their attention towards biological motion ([Annaz et al., 2012](#); [Klin et al., 2009](#)).

5. Limitations and future directions

Given that males are more likely to receive a clinical diagnosis of ASD compared to females ([Baio, 2012](#)), it might seem counterintuitive

that we find a robust relationship between autistic traits and the reward value assigned to body motion when our study sample was predominantly female (77%). One concern that could arise from having a majority female sample is that higher scores on the AQ would not be observed, as males report higher AQ scores on average (Ruzich et al., 2015). However, we observed a broad range of AQ scores (1–49) within our sample. Results from models analysing data from female participants only are presented in supplementary materials (Supplementary Results 4 and Supplementary Table 4). These findings confirm that males are not driving the results obtained in the present study, as the same pattern of findings emerges even when we consider an all-female sample. Furthermore, the focus of the study was to investigate the influence of autistic traits on the reward value of social stimuli within an opportunity sample, and not the influence of an ASD diagnosis *per se* (although it would absolutely be valuable for future studies to examine similar questions among a clinical sample).

Another aspect of the present study that warrants consideration is our use of full-body stimuli to examine the reward value of human/biological motion. Many previous studies that have investigated the perception of biological and non-biological motion in ASD (Atkinson et al., 2004; Blake et al., 2003; Klin et al., 2009) presented point-light displays of motion to participants. In these experiments, participants must infer the shape and size of the human body, as no form cues are present. Thus, the inclusion of a fuller depiction of the human body in the present study could maximise reward differences for those with few or many autistic traits. It was our intention to create stimuli that included information about body form, however, as the social agents we encounter in the real world feature biologically salient form and motion cues. It could nonetheless be of interest to dissect the independent contributions made by form and motion cues to the reward value of human bodies in future studies.

6. Conclusions

It is well established that typically developing individuals assign a higher value to social stimuli, such as faces, compared to non-social stimuli (Chevallier et al., 2012; Dubey, Ropar, & Hamilton, 2017; Dubey et al., 2015), but the extent to which we find other types of highly familiar social stimuli rewarding has remained poorly understood. The findings from the present study offer valuable insights about reward value of human bodies in motion, and thus significantly advance our knowledge pertaining to social motivation among individuals for whom social engagement is pleasurable or painful. The increased value assigned to human motion in this study by individuals who report few autistic traits could relate to our innate preference to orient our attention towards biological motion. However, as with all lab-based experiments, it will be vital to confirm that the preferences demonstrated by participants in our task are reflected in the real social world. Future studies can thus help to establish the generalisability of the present findings, as well as the extent to which the present pattern holds when individuals with a clinical diagnosis of ASD are tested. Nonetheless, the finding that participants with few autistic traits exert more effort to view videos of neutral human motion suggests that the human body in motion which conveys a wealth of social information, can be a powerful and rewarding stimulus.

Acknowledgements

The authors would like to thank Manon Jones, Kami Koldewyn and Rob Ward for constructive feedback on earlier versions of this manuscript, Indu Dubey and Josh Payne for assistance with data analyses, Filipe Cristino for assistance with stimuli creation, and the Bangor Social Neuroscience Group for fruitful discussions on this work from start to finish. This work is supported by a PhD studentship from Coleg Cymraeg Cenedlaethol, a Future Research Leaders Award funded by the Economic and Social Research Council and Medical Research Council

(ES/K001892/1); a Marie Curie Career Integration award (CIG11-2012-322256); and a European Research Council starting grant (ERC-2015-STG-677270). All stimuli and analysis scripts are available upon request from the authors.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.cognition.2017.10.017>.

References

- Aharon, I., Etcoff, N., Ariely, D., Chabris, C. F., O'Connor, E., & Breiter, H. C. (2001). Beautiful faces have variable reward value: fMRI and behavioral evidence. *Neuron*, 32(3), 537–551. [http://dx.doi.org/10.1016/S0896-6273\(01\)00491-3](http://dx.doi.org/10.1016/S0896-6273(01)00491-3).
- Annaz, D., Campbell, R., Coleman, M., Milne, E., & Swettenham, J. (2012). Young children with autism spectrum disorder do not preferentially attend to biological motion. *Journal of Autism and Developmental Disorders*, 42(3), 401–408.
- Atkinson, A. P., Dittrich, W. H., Gemmell, A. J., & Young, A. W. (2004). Emotion perception from dynamic and static body expressions in point-light and full-light displays. *Perception*, 33(6), 717–746.
- Baio, J. (2012). Prevalence of Autism Spectrum Disorders: Autism and Developmental Disabilities Monitoring Network, 14 Sites, United States, 2008. Morbidity and Mortality Weekly Report. Surveillance Summaries. Volume 61, Number 3. *Centers for Disease Control and Prevention*.
- 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. *Journal of Autism and Developmental Disorders*, 31(1), 5–17.
- Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, 68, 255–278. <http://dx.doi.org/10.1016/j.jml.2012.11.001>.
- Bates, D., Kliegl, R., Vasishth, S., & Baayen, R. H. (2015). Parsimonious mixed models. Available from arXiv:1506.04967.
- Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, 67(1), 1–48. <http://dx.doi.org/10.18637/jss.v067.i01>.
- Berridge, K. C. (1996). Food reward: Brain substrates of wanting and liking. *Neuroscience & Biobehavioral Reviews*, 20(1), 1–25. [http://dx.doi.org/10.1016/0149-7634\(95\)00033-B](http://dx.doi.org/10.1016/0149-7634(95)00033-B).
- Blake, R., Turner, L. M., Smoski, M. J., Pozdol, S. L., & Stone, W. L. (2003). Visual recognition of biological motion is impaired in children with autism. *Psychological Science*, 14(2), 151–157.
- Bölte, S., Poustka, F., & Constantino, J. N. (2008). Assessing autistic traits: Cross-cultural validation of the social responsiveness scale (SRS). *Autism Research*, 1(6), 354–363. <http://dx.doi.org/10.1002/aur.49>.
- Breiter, H. C., Aharon, I., Kahneman, D., Dale, A., & Shizgal, P. (2001). Functional imaging of neural responses to expectancy and experience of monetary gains and losses. *Neuron*, 30(2), 619–639. [http://dx.doi.org/10.1016/S0896-6273\(01\)00303-8](http://dx.doi.org/10.1016/S0896-6273(01)00303-8).
- Carter Leno, V., Naples, A., Cox, A., Rutherford, H., & McPartland, J. C. (2016). Common and distinct modulation of electrophysiological indices of feedback processing by autistic and psychopathic traits. *Social Neuroscience*, 11(4), 455–466. <http://dx.doi.org/10.1080/17470919.2015.1108223>.
- Chevallier, C., Kohls, G., Troiani, V., Brodtkin, E. S., & Schultz, R. T. (2012). The social motivation theory of autism. *Trends in Cognitive Sciences*, 16(4), 231–239. <http://dx.doi.org/10.1016/j.tics.2012.02.007>.
- Clarke, T. J., Bradshaw, M. F., Field, D. T., Hampson, S. E., & Rose, D. (2005). The perception of emotion from body movement in point-light displays of interpersonal dialogue. *Perception*, 34(10), 1171–1180.
- Constantino, J. N., & Gruber, C. P. (2007). *Social responsiveness scale (SRS)*. Los Angeles, CA: Western Psychological Services.
- Constantino, J. N., & Gruber, C. P. (2012). *Social responsiveness scale (SRS)*. Torrance, CA: Western Psychological Services.
- Cox, A., Kohls, G., Naples, A. J., Mukerji, C. E., Coffman, M. C., Rutherford, H. J., ... McPartland, J. C. (2015). Diminished social reward anticipation in the broad autism phenotype as revealed by event-related brain potentials. *Social Cognitive and Affective Neuroscience*, 10(10), 1357–1364. <http://dx.doi.org/10.1093/scan/nsv024>.
- Dawson, G., Toth, K., Abbott, R., Osterling, J., Munson, J., Estes, A., & Liaw, J. (2004). Early social attention impairments in autism: Social orienting, joint attention, and attention to distress. *Developmental Psychology*, 40(2), 271.
- Dubey, I., Ropar, D., & Hamilton, A. F. de C. (2015). Measuring the value of social engagement in adults with and without autism. *Molecular Autism*, 6(1), 1. <http://dx.doi.org/10.1186/s13229-015-0031-2>.
- Dubey, I., Ropar, D., & Hamilton, A. F. de C. (2017). A comparison of the preference for viewing social and non-social movies in typical and autistic adolescents. *Journal of Autism and Developmental Disorders*, 47, 514–519.
- Fox, R., & McDaniel, C. (1982). The perception of biological motion by human infants. *Science*, 218(4571), 486–487. <http://dx.doi.org/10.1126/science.7123249>.
- Fridlund, A. J. (1991). The sociality of solitary smiles: Effects of an implicit audience. *Journal of Personality and Social Psychology*, 60, 229–240.
- Gossen, A., Groppe, S. E., Winkler, L., Kohls, G., Herrington, J., Schultz, R. T., ... Sprekkelmeyer, K. N. (2014). Neural evidence for an association between social

- proficiency and sensitivity to social reward. *Social Cognitive and Affective Neuroscience*, 9(5), 661–670. <http://dx.doi.org/10.1093/scan/nst033>.
- Grossman, E., Donnelly, M., Price, R., Pickens, D., Morgan, V., Neighbor, G., & Blake, R. (2000). Brain areas involved in perception of biological motion. *Journal of Cognitive Neuroscience*, 12(5), 711–720. <http://dx.doi.org/10.1162/0898929000562417>.
- Grossmann, T., & Johnson, M. H. (2007). The development of the social brain in human infancy. *European Journal of Neuroscience*, 25(4), 909–919. <http://dx.doi.org/10.1111/j.1460-9568.2007.05379.x>.
- Haffey, A., Press, C., O'Connell, G., & Chakrabarti, B. (2013). Autistic traits modulate mimicry of social but not nonsocial rewards. *Autism Research*, 6(6), 614–620. <http://dx.doi.org/10.1002/aur.1323>.
- Hayden, B. Y., Parikh, P. C., Deaner, R. O., & Platt, M. L. (2007). Economic principles motivating social attention in humans. *Proceedings of the Royal Society of London B: Biological Sciences*, 274(1619), 1751–1756. <http://dx.doi.org/10.1098/rspb.2007.0368>.
- Hooker, C. I., Germine, L. T., Knight, R. T., & D'Esposito, M. (2006). Amygdala response to facial expressions reflects emotional learning. *Journal of Neuroscience*, 26(35), 8915–8922. <http://dx.doi.org/10.1523/JNEUROSCI.3048-05.2006>.
- Johansson, G. (1973). Visual perception of biological motion and a model for its analysis. *Perception and Psychophysics*, 14(2), 201–211.
- Kain, M. P., Bolker, B. M., & McCoy, M. W. (2015). A practical guide and power analysis for GLMMs: Detecting among treatment variation in random effects. *PeerJ*, 3, e1226. <http://dx.doi.org/10.7717/peerj.1226>.
- Kampe, K. K., Frith, C. D., Dolan, R. J., & Frith, U. (2001). Psychology: Reward value of attractiveness and gaze. *Nature*, 413(6856), 589–589.
- Klin, A., Lin, D. J., Gorrindo, P., Ramsay, G., & Jones, W. (2009). Two-year-olds with autism orient to non-social contingencies rather than biological motion. *Nature*, 459(7244), 257–261. <http://dx.doi.org/10.1038/nature07868>.
- Kringelbach, M. L., & Rolls, E. T. (2003). Neural correlates of rapid reversal learning in a simple model of human social interaction. *Neuroimage*, 20(2), 1371–1383. [http://dx.doi.org/10.1016/S1053-8119\(03\)00393-8](http://dx.doi.org/10.1016/S1053-8119(03)00393-8).
- Lin, A., Adolphs, R., & Rangel, A. (2012). Social and monetary reward learning engage overlapping neural substrates. *Social Cognitive and Affective Neuroscience*, 7(3), 274–281. <http://dx.doi.org/10.1093/scan/nsr006>.
- Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh Inventory. *Neuropsychologia*, 9, 97–113. [http://dx.doi.org/10.1016/0028-3932\(71\)90067-4](http://dx.doi.org/10.1016/0028-3932(71)90067-4).
- Oram, M. W., & Perrett, D. I. (1996). Integration of form and motion in the anterior superior temporal polysensory area (STPa) of the macaque monkey. *Journal of Neurophysiology*, 76(1), 109–129.
- Panasiti, M. S., Puzzo, I., & Chakrabarti, B. (2016). Autistic traits moderate the impact of reward learning on social behaviour. *Autism Research*, 9(4), 471–479. <http://dx.doi.org/10.1002/aur.1523>.
- Peirce, J. W. (2007). PsychoPy - Psychophysics software in Python. *Journal of Neuroscience Methods*, 162(1–2), 8–13. <http://dx.doi.org/10.1016/j.jneumeth.2006.11.017>.
- Peirce, J. W. (2009). Generating stimuli for neuroscience using PsychoPy. *Frontiers in Neuroinformatics*, 2, 10. <http://dx.doi.org/10.3389/neuro.11.010.2008>.
- Pollick, F. E., Kay, J. W., Heim, K., & Stringer, R. (2005). Gender recognition from point-light walkers. *Journal of Experimental Psychology: Human Perception and Performance*, 31(6), 1247–1265.
- R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: < <https://www.R-project.org/> > .
- Ruzich, E., Allison, C., Smith, P., Watson, P., Auyeung, B., Ring, H., & Baron-Cohen, S. (2015). Measuring autistic traits in the general population: A systematic review of the Autism-Spectrum Quotient (AQ) in a nonclinical population sample of 6900 typical adult males and females. *Molecular Autism*, 6(1), 2.
- Sepeta, L., Tsuchiya, N., Davies, M. S., Sigman, M., Bookheimer, S. Y., & Dapretto, M. (2012). Abnormal social reward processing in autism as indexed by pupillary responses to happy faces. *Journal of Neurodevelopmental Disorders*, 4(1), 1. <http://dx.doi.org/10.1186/1866-1955-4-17>.
- Sescousse, G., Redouté, J., & Dreher, J. C. (2010). The architecture of reward value coding in the human orbitofrontal cortex. *The Journal of Neuroscience*, 30(39), 13095–13104. <http://dx.doi.org/10.1523/JNEUROSCI.3501-10.2010>.
- Shore, D. M., & Heerey, E. A. (2011). The value of genuine and polite smiles. *Emotion*, 11(1), 169.
- Simion, F., Regolin, L., & Bulf, H. (2008). A predisposition for biological motion in the newborn baby. *Proceedings of the National Academy of Sciences*, 105(2), 809–813.
- Sims, T. B., VanReekum, C. M., Johnstone, T., & Chakrabarti, B. (2012). How reward modulates mimicry: EMG evidence of greater facial mimicry of more rewarding happy faces. *Psychophysiology*, 49(7), 998–1004. <http://dx.doi.org/10.1111/j.1469-8986.2012.01377.x>.
- Spreckelmeyer, K. N., Krach, S., Kohls, G., Rademacher, L., Irmak, A., Konrad, K., ... Gründer, G. (2009). Anticipation of monetary and social reward differently activates mesolimbic brain structures in men and women. *Social Cognitive and Affective Neuroscience*, 4(2), 158–165. <http://dx.doi.org/10.1093/scan/nsn051>.
- Toth, K., Munson, J., Meltzoff, A. N., & Dawson, G. (2006). Early predictors of communication development in young children with autism spectrum disorder: Joint attention, imitation, and toy play. *Journal of Autism and Developmental Disorders*, 36(8), 993–1005.
- Vallortigara, G., Regolin, L., & Marconato, F. (2005). Visually inexperienced chicks exhibit spontaneous preference for biological motion patterns. *PLoS Biology*, 3(7), e208. <http://dx.doi.org/10.1371/journal.pbio.0030208>.
- Zeeland, S. V., Ashley, A., Dapretto, M., Ghahremani, D. G., Poldrack, R. A., & Bookheimer, S. Y. (2010). Reward processing in autism. *Autism Research*, 3(2), 53–67. <http://dx.doi.org/10.1002/aur.122>.