CANADIAN JOURNAL
of UNDERGRADUATE
RESEARCH

RESEARCH
AUTISM
MAY 2026 | VOL 10(2)

Action prediction in autistic and non-autistic observers with perceptual and cognitive load

Kiara Sun[1]

[1] Undergraduate Program in Neuroscience, The University of British Columbia, Vancouver, British Columbia, Canada

Received: June 19, 2025
Published: May 25, 2026

Keywords
imitation, prediction, movement, autism, load

Citation
Sun, K. (2026). Action prediction in autistic and non-autistic observers with perceptual and cognitive load. *Canadian Journal of Undergraduate Research*, *10*(2), 7–11. https://doi.org/10.14288/cjur.v10i2.200923

ABSTRACT

According to the broken mirror neuron theory of autism, autistic individuals are less efficient at mapping the behaviors of others onto their own bodily representations, which leads to difficulties in imitating and understanding others' actions. However, limited research has explored the broken mirror neuron theory within the context of action prediction, the application of action understanding. In a pilot study, I employed a modified version of the pointing task where autistic and non-autistic participants predicted whether a target actor would point to the right or left without knowing that the actors were either instructed or allowed to choose freely where to point. I expanded on the original study by incorporating trials with perceptual or cognitive load. For the former, three actors were shown instead of just one, requiring the observer to respond to the actions of one target actor. For the latter, the observer was required to guess the target actor's actions by pressing a key that is in the opposite (anti) direction as the target actor's predicted pointing direction, as opposed to the same (pro) direction. All observers responded faster in the trials where the target actor chose freely where to point, called the choice advantage. However, an analysis of the autistic and non-autistic groups separately indicated that the choice advantage was observed in all experimental conditions in the non-autistic cohort but was reduced to the 1-actor, anti-pointing trials in the autistic group. These results indicate that autistic individuals may not be using body-language cues to predict the actions of others as effectively as non-autistic individuals, while offering a more nuanced perspective on autistic peoples' understanding of others' actions than the broken mirror neuron theory.

INTRODUCTION

In 1996, Gallese et al. discovered a novel class of neurons in the premotor cortex of macaque monkeys: Neurons that selectively fire both when a monkey performs a meaningful action, such as grasping an object, and when it observes an experimenter mirror the same action. Since then, a distributed collection of neurons in humans that display mirror neuron-like firing properties have been identified (Rizzolatti & Craighero, 2004). Subsequent experiments showing increased activity in brain regions that are thought to constitute the human mirror neuron system (MNS) during imitation (Iacoboni et al., 1999) and are responsive to the inferred intentions of an observed action (Iacoboni et al., 2005) suggest a functional role of mirror neurons in facilitating imitation and action understanding. Given the importance of imitation in facilitating social connectedness and in understanding others' intentions (Vivanti & Hamilton, 2014), differences in the MNS were thought to underly Autism Spectrum Disorder (ASD), a neurodevelopmental condition characterized by atypical social behavior (Smith & Bryson, 1994; Williams et al., 2001).

The potential role of mirror neurons in contributing to social cognition, as well as their functional differences in autism, is outlined in the direct matching hypothesis (Iacoboni et al., 1999). According to the hypothesis, our understanding of the intentions of others stems from an embodied simulation of their actions where observing an action recruits an internal representation of the same action in the form of a collection of mirror neurons such that it is as if the observer is performing the action themselves (Gallese, 2006; Iacoboni et al., 1999). Under the assumption that we understand the goals of our own actions, the observer may then use their internal representation, including its associated goals, to derive an experiential-based inference of others' actions.

While the broken mirror neuron theory of autism has been used to explain social differences of autistic people such as absent spontaneous imitation (McIntosh et al., 2006) and challenges in the use of motor information to understand the intentions of others (Boria et al., 2009), these findings are inconsistent (Sowden et al., 2016) and require further characterization (Chetcuti et al., 2019). Additionally, few experiments have examined the behavioural prediction component of social interactions directly, that is, the application of action understanding, or the nuances of autistic individuals' abilities in contexts of cognitive or perceptual load. To further contribute to our understanding of action understanding in autism and address these limitations in the literature, I asked the following question: How do autistic individuals use body-language cues differently than non-autistic individuals to predict the actions of others?

Correspondence: Address correspondence to Kiara Sun at ksun11@student.ubc.ca.

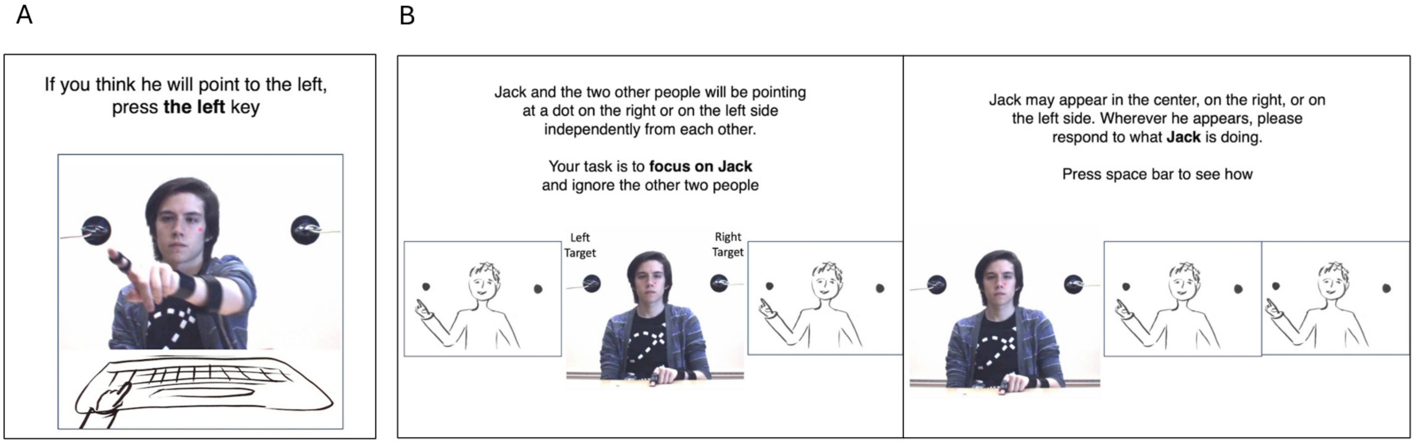
According to the broken mirror neuron theory of autism, functional differences in the MNS of autistic individuals result in their ineffective use of internal representations to understand and predict the intentions of observed actions (Gallese, 2006). Given that predictive processing is practically useful in that it allows the observer to orient their actions at a future state of the target, it is possible to infer the efficiency of predictive processing and by extension, the functioning of participants' MNS by examining the speed at which observers make predictions. One experimental paradigm that assesses predictive processing in response to socially relevant body cues in others is the pointing task, where participants view actors pointing to a button on either the right or left side of the screen and are asked to predict in which direction they will point as fast as possible (Pesquita et al., 2016). Unknown to the participant, in half of the trials, the actors are instructed where to point while in the other half of the trials, the actors choose themselves where to point (Pesquita et al., 2016). The original paper reported that the observers' reaction times were significantly faster on the choice-trials compared to the directed-trials, showing a 19-ms choice advantage on average, independent of accuracy (Pesquita et al., 2016). Thus, the presence of the choice advantage indicates the capacity for observers to use internal representations of the actors' movements that are specific to the actors' choice of where to point to enhance the speed of their predictions, a process that is mediated by the MNS. To further explore subliminal body-language processing in autistic participants compared to non-autistic controls, I conducted a modified version of the pointing task by incorporating cognitive and perceptual types of load.

METHODS

I used a variation of the pointing task developed by Pesquita et al. (2016). The task was administered on MATLAB on a computer and the participants sat approximately 60 cm from the screen. Each participant completed four blocks with each block consisting of 100 trials. On each trial, a video was played that showed one of four possible actors pointing to one of two targets (black buttons) located on the right and left sides of the screen. In each trial, the participant was instructed to guess as quickly as possible where the actor would point—either to the left or to the right—by pressing one of two spatially-mapped keys on a keyboard. The video stimuli were identical to those used by Pesquita et al. (2016). Each trial began with a black screen followed by a fixation cross shown for 100–150 ms (varied randomly). Then the video played until a response was made by the participant, or for 1000 ms (1 s) and was followed by a blank screen if no response was recorded. The inter-trial interval, or the time between the participant's response input and the reappearance of the fixation cross, was 1 s. While the participant was instructed to "try to beat the person" to their point and to "guess as quickly as possible", there was no time limit set for each trial. If the participant failed to respond prior to the end of each video, a black screen would appear, and they would be required to input a response to begin the next trial. The blocks were separated by self-paced breaks. The videos were centered in the middle of the screen but did not take up the full screen.

Each of the four blocks differed in two ways: the number of actors that were shown, and the participant's response type. Either one or three actors could be shown in each trial. Additionally, the participant could be asked to respond by pressing a key that is in the same (pro) or opposite (anti) direction as the target. Thus, each of the four blocks represented a unique combination of these two factors (Figure 1). The participant was given 6–12 practice trials prior to the start of each block. Practice trials differed from test trials in that when participants answered incorrectly, a feedback message was shown saying, "Oops!" and reinstated the task. The order of the four blocks were counterbalanced across the participants such that each participant could start with any of the four blocks. The three actors remained the same within each three-person block but differed both across participants and between the "triple-pro" and "triple-anti" blocks. Additionally, a different target actor was chosen for each of the four blocks such that all four actors were the target actor in one of the blocks. The target actor for each block was randomly selected for each participant.

I recruited 40 participants via the Human Subject Pool (HSP) that constitutes the UBC Psychology Research Participation Program. The HSP consists of undergraduate students enrolled in at least one psychology course at the time of their participation, and was chosen as a convenient, efficient, and cost-effective method to recruit participants. Consent to participate in the study was obtained prior to their participation, and they received 1.0 course credit for 30 minutes of their participation. The only exclusion criterion was failing to consent to participate in the study. The participants completed the pointing task followed by a Qualtrics



If you think he will point to the left, press **the left** key

Jack and the two other people will be pointing at a dot on the right or on the left side independently from each other.

Your task is to **focus on Jack** and ignore the other two people

Jack may appear in the center, on the right, or on the left side. Wherever he appears, please respond to what **Jack** is doing.

Press space bar to see how

Figure 1. The pointing task instructions. **(A)** A screenshot of the instructions presented to participants at the start of a single-actor, pro-pointing block. The participant is instructed to press the key that is in the same direction as the target actor's predicted pointing direction. **(B)** Two screenshots of the successive instructions presented to participants at the start of a three-actor block. The participant is instructed to focus on the target actor who may appear on the left, middle, or right of the screen along with two distractor actors.

survey. The survey included questions about the participant's gender and age, as well as the 65-item Social Responsiveness Scale (SRS 2) (Constantino & Gruber, 2012). Additionally, since the study was not advertised to autistic individuals due to limited time and resources, 10 autistic participants were recruited from a separate lab at the university that actively seeks participants with a clinical diagnosis of ASD. There was no requirement that these participants were students enrolled at the university. Consent was obtained prior to their participation, and they received $5 CAD for their participation. The participants completed the pointing task, and their demographic information was obtained, with the participant's consent, from the first lab.

The study contained limited psychological or physical risks; no adverse events or side effects resulted from participation in the study. The study took place in-person at a lab located on the university campus by three undergraduate students who were trained in administering the experiment by a postdoctoral researcher at the lab. Data was also collected by the postdoctoral researcher themself. An a priori power analysis to determine the number of participants needed was not performed given that time was the limiting factor of the sample size. Instead, as many autistic and non-autistic participants were recruited as was possible within the available time to complete the study, which resulted in 50 participants (40 non-autistic, 10 autistic) who were initially recruited.

There were no statistically significant differences in the gender compositions of "female", "male", or "other" ($\chi^2(2, N = 50) = 4.33$, $p = .115$) between the non-autistic (30; 10; 0) and autistic (6; 3; 1) groups. An independent samples *t*-test revealed a statistically significant difference in age ($t(13) = -3.06$, $p = .009$, 95% CI [–6.23, –1.07]) between the two groups, with the non-autistic group ($M = 22.05$, $SD = 3.40$, range: 19–36 years) being younger than the autistic group ($M = 25.70$, $SD = 3.37$, range: 21–29 years). Additionally, there was a statistically significant difference in the SRS scores ($t(17) = -8.48$, $p < .001$, 95% CI [–64.05, –42.25]) between the two groups, with the non-autistic group ($M = 57.15$, $SD = 21.22$) scoring lower than the autistic group ($M = 110.30$, $SD = 16.73$).

RESULTS

Excel version 2502 was used for data preprocessing and Jamovi version 2.4.11 for statistical analysis. Outliers in the data based on reaction time and accuracy were removed to account for potential lapses in attention or effort by participants, which helped to ensure that the data used for the final analyses represented typical task performance. The data was preprocessed by first removing the reaction times for any trials where the participant's response was incorrect since these reaction times may not accurately represent participants' typical processing speed. Reaction times that were less than 200 ms, which would be too fast to be based on information from the video, or greater than 3 s, which would be significantly after the video had ended and the actor's movement had been completed, were also removed. Among those that remained, reaction times that were 3 SD above the average reaction time across all conditions and within each participant's data were removed to exclude data that may indicate lapses in effort or attention relative to each participant's typical reaction time. One individual in the non-autistic and another in the autistic group had incomplete and therefore unusable data, so their data were removed. Similarly, participants were excluded from the analysis if their average reaction time or accuracy across all conditions was less than or greater than 3 SD from the mean. Using this method, one outlier was identified in the non-autistic group, resulting in a final sample of 38 non-autistic participants and 9 autistic participants.

In addition to reducing the final sample size of the study, which decreased participant representation and slightly lowered the power to detect effects, removing these results improved the validity of the analyses with respect to two primary assumptions of ANOVA: normally distributed data and homogeneity of variance. Removing extreme reaction times between and within participants reduced skewness in the data and produced more comparable variances. To verify that the assumptions were met, a Q-Q plot was produced and indicated that standardized residuals across all conditions were approximately normally distributed. Additionally, a Levene's test for homogeneity of variance between autistic and non-autistic participants for all conditions were all non-significant ($p > 0.05$), suggesting that the variances were comparable. Thus, the assumptions of normality and homogeneity of variance were satisfied in our sample.

Statistical analyses used a four-way mixed ANOVA with point type (choice vs. directed), number of actors (1 vs. 3), and response type (pro vs. anti) as within-participant variables and group (non-autistic vs. autistic) as the between-participant variable, yielding three significant effects. There was a main effect of point type [$F(1, 45) = 48.989$, $p < 0.001$, $\eta^2 = 0.521$] where participants responded faster in the choice trials ($M = 0.747$ s, 95% CI [0.731, 0.763]) than in the directed trials ($M = 0.760$ s, 95% CI [0.744, 0.776]). Additionally, there was a main effect of the number of actors [$F(1, 45) = 124.960$, $p < .001$, $\eta^2 = 0.735$] where participants responded faster in the 1-actor trials ($M = 0.707$ s, 95% CI [0.691, 0.724]) than in the 3-actor trials ($M = 0.800$ s, 95% CI [0.780, 0.819]). Finally, there was a main of response type [$F(1, 45) = 33.399$, $p < .001$, $\eta^2 = 0.426$] where participants responded faster in the pro trials ($M = 0.726$ s, 95% CI [0.709, 0.742]) than in the anti trials ($M = 0.781$ s, 95% CI [0.761, 0.802]). Notably, the between-participant factor of group was not statistically significant [$F(1, 45) = 1.790$, $p = .187$, $\eta^2 = 0.038$]; the non-autistic participants did not respond faster ($M = 0.743$ s, 95% CI [0.729, 0.757]) compared to the autistic participants ($M = 0.764$ s, 95% CI [0.735, 0.793]). There were also no statistically significant interactions between any of the factors.

To further clarify any potential trends in the effects of point type, number of actors, and response type on reaction time between the autistic and non-autistic groups, I conducted paired samples t-tests to examine the presence of the choice advantage across the experimental conditions separately in autistic and control participants. The non-autistic group responded faster in the choice trials compared to the directed trials for all conditions, including in the 1-actor pro-pointing trials ($t(37) = 5.59$, $p < .001$, $MD = 0.020$ s, 95% CI [0.013, 0.027], $d = 0.907$, 95% CI [0.524, 1.281]), 1-actor anti-pointing trials ($t(37) = 2.71$, $p = .010$, $MD = 0.010$ s, 95% CI [0.003, 0.018], $d = 0.439$, 95% CI [0.103, 0.769]), 3-actor pro-pointing trials ($t(37) = 5.61$, $p < .001$, $MD = 0.019$ s, 95% CI [0.012, 0.026], $d = 0.910$, 95% CI [0.527, 1.285]), and 3-actor anti-pointing trials ($t(37) = 3.75$, $p < .001$, $MD = 0.015$ s, 95% CI [0.007, 0.023], $d = 0.608$, 95% CI [0.258, 0.951]). In contrast, the autistic participants only responded faster in the choice trials compared to the directed trials in the 1-actor anti-pointing trials ($t(8) = 2.73$, $p = .026$, $MD = 0.022$ s, 95% CI [0.003, 0.041], $d = 0.911$, 95% CI [0.105, 1.680]).

DISCUSSION

The present study sought to investigate how autistic people may differ from non-autistic people in interpreting the body-language cues of others and responding appropriately to motor predictions derived from them. I employed a pointing task that assesses participants' sensitivity to actors' movements to facilitate their prediction speed, an assessment of participants' action understanding mediated by the MNS. For all participants, the 3-actor and anti-pointing trials were overall slower to respond to compared to the 1-actor and pro-pointing trials respectively, indicating that the perceptual and cognitive load manipulations were effective. However, they did not impair the magnitude of the choice advantage due to the presence of a main effect of point type across all conditions. While there were no overall differences between the autistic and non-autistic groups in the presence of the choice advantage, contrasts comparing choice and directed trials in each condition separately between autistic and non-autistic participants revealed some interesting trends. For the non-autistic group, the choice advantage, although present in all conditions, was less robust for the 1-actor anti-pointing condition, which suggests that cognitive load was more effective at influencing the magnitude of the choice advantage compared to the 3-actor cognitive load. In the autistic group, the choice advantage was only present in the 1-actor, anti-pointing condition, suggesting that the autistic participants were not using the body cues of the actors as efficiently or consistently as the non-autistic participants to enhance their predictions.

Despite the small sample size of the study, the findings fail to provide support for the broken mirror neuron theory of autism, indicated by the presence of the choice advantage in the 1-actor anti-pointing trials in the autistic group, and across all conditions and independent of group membership more generally based on the ANOVA results. The presence of the choice advantage in the autistic group suggests that body cues that were present in the actors and that were specific to the actor's own choice of where to point were accurately detected by the autistic observers and used to enhance the speed of their predictions on at least some trials. Interpreted through the direct-matching hypothesis, the autistic participants displayed a similar capacity to map the bodily representations of the freely-choosing actors onto their own motor systems to obtain an understanding of the actors' intentions as the non-autistic participants, which were then used to more efficiently predict the actors' future decisions.

Instead, the results are more in line with the social top-down response modulation (STORM) framework, which posits that autism is characterized not by impairments in imitation or action understanding, but by differences in regulating when and how imitation and action understanding takes place (Southgate & Hamilton, 2008). In our study, the autistic participants were able to interpret the body cues of the actors that were specific to chosen (as opposed to directed) points and use the information to predict their actions in a task where they were explicitly told to do so, as predicted by the STORM model. However, further research is needed to directly address the STORM model. For example, it would be interesting to investigate whether autistic people would still predict the actions of the actors as effectively without top-down control signals, explicit instruction, or social motivational signals. Moreover, exploring whether the absence of the choice advantage in certain trials in the present study was due to challenges in regulating top-down control of action representation in autistic participants could more directly address the STORM model and provide new interpretations to the present study. For example, previous research has shown reduced automatic facial imitation in autistic adults but accurate facial imitation when they were explicitly instructed to imitate (McIntosh et al., 2006), demonstrating the role of social motivation in mediating imitation and potentially action prediction as well.

Beyond the small sample size, there were several limitations of the study that impact the generalizability of the results. I did not verify that the students that constituted the control group were not autistic or were diagnosed with any other neurological condition. While they scored lower on the SRS 2 compared to the autistic group, a measure of social difficulties that might indicate the presence of autism, it cannot be used in isolation to draw conclusions about a diagnosis of ASD. Additionally, there was a statistically significant difference in the mean ages of the autistic and non-autistic participants with the autistic participants approximately three years older on average. Age may have acted as a confounding factor, which was not accounted for in the statistical analyses. Moreover, there was a lack of representation of both the autistic and non-autistic participants in the study. All non-autistic individuals were undergraduate students enrolled in a psychology course at the University of British Columbia, and thus do not represent a random sample of the general population. Similarly, the autistic participants were all verbal and capable of reading and speaking, a sample that excludes a great portion of non-verbal, minimally-verbal, or intellectually impaired autistic individuals (Russell et al., 2019).

CONCLUSION

In the present study, I confirmed the presence of the choice advantage in non-autistic and autistic observers when completing a modified version of the pointing task. All participants responded faster in the 1-actor tasks compared to the 3-actor tasks, and to the pro-pointing tasks compared to the anti-pointing tasks. The choice advantage was present for all conditions in the non-autistic participants but was reduced to the 1-actor, anti-pointing condition in the autistic participants. While our results do not provide support for the broken mirror neuron theory of autism, further work is needed to verify our results given the small sample size of the present study. Additionally, it would be interesting to examine the potential role of motivation in mediating social differences in autistic people, which may provide support for the social top-down response modulation (STORM) framework of autism (Southgate & Hamilton, 2008).

ACKNOWLEDGEMENTS

The present paper was based on research and written work that was completed for a Directed Studies course at the University of British Columbia. The author would like to express gratitude to Dr. James Enns for providing the lab space and equipment to conduct the research, as well as for evaluating the author's coursework. The author would also like to thank Dr. Veronica Dudarev for directly supervising the project and providing support, guidance, and feedback on the research and original manuscript.

CONFLICTS OF INTEREST

The author declares no conflicts of interest.

REFERENCES

[1] Boria, S., Fabbri-Destro, M., Cattaneo, L., Sparaci, L., Sinigaglia, C., Santelli, E., Cossu, G., & Rizzolatti, G. (2009). Intention understanding in autism. *PLoS ONE*, *4*(5), e5596. https://doi.org/10.1371/journal.pone.0005596

[2] Chetcuti, L., Hudry, K., Grant, M., & Vivanti, G. (2019). Object-directed imitation in autism spectrum disorder is differentially influenced by motoric task complexity, but not social contextual cues. *Autism*, *23*(1), 199–211. https://doi.org/10.1177/1362361317734063

[3] Constantino, J. N., & Gruber, C. P. (2012). *Social responsiveness scale–second edition (SRS-2)*. Torrance, CA: Western Psychological Services.

[4] Gallese, V., Fadiga, L., Fogassi, L., & Rizzolatti, G. (1996). Action recognition in the premotor cortex. *Brain*, *119*(2), 593–609. https://doi.org/10.1093/brain/119.2.593

[5] Gallese, V. (2006). Intentional attunement: A neurophysiological perspective on social cognition and its disruption in autism. *Brain Research*, *1079*(1), 15–24. https://doi.org/10.1016/j.brainres.2006.01.054

[6] Iacoboni, M., & Dapretto, M. (2006). The mirror neuron system and the consequences of its dysfunction. *Nature Reviews Neuroscience*, *7*(12), 942–951. https://doi.org/10.1038/nrn2024

[7] Iacoboni, M., Molnar-Szakacs, I., Gallese, V., Buccino, G., Mazziotta, J. C., & Rizzolatti, G. (2005). Grasping the intentions of others with one's own mirror neuron system. *PLoS Biology*, *3*(3), e79. https://doi.org/10.1371/journal.pbio.0030079

[8] Iacoboni, M., Woods, R. P., Brass, M., Bekkering, H., Mazziotta, J. C., & Rizzolatti, G. (1999). Cortical mechanisms of human imitation. *Science*, *286*, 2526–2528. https://doi.org/10.1126/science.286.5449.2526

[9] McIntosh, D. N., Reichmann-Decker, A., Winkielman, P., & Wilbarger, J. L. (2006). When the social mirror breaks: Deficits in automatic, but not voluntary, mimicry of emotional facial expressions in autism. *Developmental Science*, *9*(3), 295–302. https://doi.org/10.1111/j.1467-7687.2006.00492.x

[10] Pesquita, A., Chapman, C. S., & Enns, J. T. (2016). Humans are sensitive to attention control when predicting others' actions. *Proceedings of the National Academy of Sciences of the United States of America*, *113*(31), 8669–8674. https://doi.org/10.1073/pnas.1601872113

[11] Rizzolatti, G., & Craighero, L. (2004). The mirror-neuron system. *Annual Review of Neuroscience*, *27*, 169–192. https://doi.org/10.1146/annurev.neuro.27.070203.144230

[12] Russell, G., Mandy, W., Elliott, D., White, R., Pittwood, T., & Ford, T. (2019). Selection bias on intellectual ability in autism research: A cross-sectional review and meta-analysis. *Molecular Autism*, *10*, 9. https://doi.org/10.1186/s13229-019-0260-x

[13] Smith, I. M., & Bryson, S. E. (1994). Imitation and action in autism: A critical review. *Psychological Bulletin*, *116*(2), 259–273. https://doi.org/10.1037/0033-2909.116.2.259

[14] Southgate, V., & Hamilton, A. F. de C. (2008). Unbroken mirrors: Challenging a theory of autism. *Trends in Cognitive Sciences*, *12*(6), 225–229. https://doi.org/10.1016/j.tics.2008.03.005

[15] Sowden, S., Koehne, S., Catmur, C., Dziobek, I., & Bird, G. (2016). Intact automatic imitation and typical spatial compatibility in Autism Spectrum Disorder: Challenging the broken mirror theory. *Autism Research*, *9*(2), 292–300. https://doi.org/10.1002/aur.1511

[16] Vivanti, G., & Hamilton, A. (2014). Imitation in autism spectrum disorders. In Volkmar, F. R., Rogers, S. J., Paul, R., & Pelphrey, K. A. (Eds.), *Handbook of autism and pervasive developmental disorders, fourth edition*. John Wiley & Sons, Ltd. https://doi.org/10.1002/9781118911389.hautc12

[17] Williams, J. H., Whiten, A., Suddendorf, T., & Perrett, D. I. (2001). Imitation, mirror neurons and autism. *Neuroscience and Biobehavioral Reviews*, *25*(4), 287–295. https://doi.org/10.1016/s0149-7634(01)00014-8