Using a Gaze-Cueing Paradigm to Examine Social Cognitive Mechanisms of Individuals with Autism Observing Robot and Human Faces

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Abstract. This paper reports a study in which we investigated whether individuals with autism spectrum disorder (ASD) are more likely to follow gaze of a robot than of a human. By gaze following, we refer to one of the most fundamental mechanisms of social cognition, i.e., orienting attention to where others look. Individuals with ASD sometimes display reduced ability to follow gaze [1] or read out intentions from gaze direction [2]. However, as they are in general well responding to robots [3], we reasoned that they might be more likely to follow gaze of robots, relative to humans. We used a version of a gaze cueing paradigm [4, 5] and recruited 18 participants diagnosed with ASD. Participants were observing a human or a robot face and their task was to discriminate a target presented either at the side validly cued by the gaze of the human or robot; or at the opposite side. We observed typical validity effects: faster reaction times (RTs) to validly cued targets, relative to invalidly cued targets. However, and most importantly, the validity effect was larger and significant for the robot faces, as compared to the human faces, where the validity effect did not reach significance. This shows that individuals with ASD are more likely to follow gaze of robots, relative to humans, suggesting that the success of robots in involving individuals with ASD in interactions might be due to a very fundamental mechanism of social cognition. Our present results can also provide avenues for future training programs for individuals with ASD.

Keywords: Autism Spectrum Disorder, Human-Robot Interaction, Social Cognition, Social Interactions.

1 Introduction

Research in the area of social robotics and autism has greatly expanded in recent years. Robots have been shown to be effective in evoking social behavior in individuals with ASD (for review, see [3]). This has led many researchers to design social robots that could ultimately be used for training social skills in those who are impaired in this domain.

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Robots that are designed for training social skills in individuals with ASD are typically tailored to match the needs of these particular populations. That is, they are designed to have simplified, not too overwhelming features; they are usually sufficiently human-like to be able to train *social* skills, but not too human-like to be intimidating for individuals with ASD; they offer sensory rewards for achievements (attractive sensory feedback related to behaviors that are being trained); they are designed to be safe in interaction (e.g., no sharp edges or jerky movements) and to offer control options to the interacting individual, which should enhance the ability to initiate an interaction (for list of design characteristics of robots for autism, see [3]).

Several case studies in which children with ASD responded well to an interaction with a humanoid robot have been described in the literature. For example, the robot Kaspar – designed at the University of Hertfordshire – has been shown to train children with ASD in emotion recognition, imitation games, turn-taking, and triadic interactions involving other humans [6]. Another robot, NAO (Aldebaran Robotics), was able to elicit eye contact in a child with ASD, and has also been reported to help in improving social interaction and communication skills [7]. Also Keepon – a robot simple in form and appearance developed by Hideki Kozima at the National Institute of Information and Communications Technology, Japan – has proved to evoke in children with autism social behaviors, interest, interpersonal communication [8-12] and even joint attention [13, 14].

These documented examples show that creating social robots for the purpose of training social skills in individuals with ASD is a promising avenue. To date, however, researchers have not unequivocally answered the question why robots are well accepted as social companions by individuals with ASD. The reported cases of social interactions between individuals with ASD and robots are, in most parts, qualitative data (video recordings, caregivers' reports or observation of an unconstrained interaction) and only a few studies have quantitatively investigated social interaction patterns [14-17]. Stanton and colleagues [15], for instance, found that children with ASD spoke more words with and were more engaged in interactions with social robots compared to simple toys that did not react to the children's behavior. As another example, Robins and colleagues [16] investigated whether the robot's appearance affects the patients' willingness to interact with them. It was found that children with ASD prefer robots with reduced physical features over very human-like robots. The studies provide evidence that children with ASD benefit from interacting with social robots resulting in improved social skills. However, the studies do not inform about the basic cognitive mechanisms that are triggered during interactions with social robots.

In order to answer the question of what cognitive mechanisms are actually at stake during interactions with robots – and what is the reason why the interactions with robots are more successful than those with other humans, one needs to conduct well-controlled experimental studies that are designed to examine selected cognitive mechanisms.

For example, the gaze-cueing paradigm [4, 5] is a well-established protocol to examine one of the most fundamental mechanisms of social cognition – gaze following. Gaze following occurs when one agent directs their gaze to a location; and another agent attends to that location (being *spatially* cued by the gaze direction of the first agent). Gaze following has been postulated to underlie important social cognitive processes such as mentalizing and joint attention [2]. Gaze following is an evolutionary adaptive mechanism [18], as attending to where others attend (as signaled by their gaze direction) informs about potentially relevant events in the environment (such as the appearance of a predator or prey). It also serves the purpose of establishing a common social context for joint action [19], among other types of interactions.

Individuals with ASD sometimes do not exhibit the typical pattern of results when reading out mental states from gaze behavior or in gaze cueing studies [1, 2]. A gaze cueing paradigm typically consists of a trial sequence in which first a face is presented centrally on a computer screen with gaze straight-ahead (in the direction of the observer). Subsequently, the gaze is shifted to a location and, then, a stimulus is presented either at a location in the direction to which the gaze is pointing (validly cued trials) or at a different location (invalidly cued trials). Participants are typically asked to detect, discriminate or localize the target stimulus. The logic behind this paradigm is that if participants follow the gaze of the observed agent on the screen, their focus of attention should be allocated to where the gazer gazes. Therefore, when the target stimulus appears at the attended location, its processing should be prioritized (due to attention having been already focused there), relative to when the target stimulus appears elsewhere. This has indeed been demonstrated by observing shorter reaction times [4, 5, 20-22] or lower error rates [22] to the target stimulus at the validly cued location, relative to invalidly cued locations. Moreover, brain responses (as measured by target-locked event-related potentials of the EEG signals) have been shown to be more enhanced for validly cued targets, relatively to invalidly cued targets [22, 23].

Interestingly, in our previous studies [20, 22], we have shown that gaze cueing effects were larger for human faces, as compared to robot faces when healthy adult participants were tested. We attributed this effect to humans adopting the so-called Intentional Stance [24] towards the observed human agent, but not towards the robot. Adopting the Intentional Stance is understood as "treating the object whose behavior you want to predict as a rational agent with beliefs and desires and other mental states exhibiting (…) intentionality" [24, p. 372]. In other words, adopting the Intentional Stance is simply attributing 'a mind' to the observed agent. In case of healthy adult participants, gaze following might make more sense when mind is attributed to the observed agent, relative to when the agent is treated only as a mechanistic device – because the gaze behavior of an agent with a mind might carry socially relevant content [18], while the gaze of a mechanistic device is devoid of such content. Accordingly, healthy adult participants follow the gaze of humans to a larger extent than that of mechanistic agents.

Aim of the Present Study

In the present study, we adopted a controlled paradigm targeted at a particular cognitive mechanism that can play a role in social interactions between individuals with ASD and robots. The aim was to test – using the gaze cueing paradigm involving human and robot agents – whether individuals with ASD would follow the gaze of a robot, even if they are reluctant to follow the gaze of humans [2]. The logic behind this was that since gaze following is one of the most fundamental mechanisms of social cognition, it might be affected by the general aptitude of individuals with ASD to interact with robots. If that were to be the case, this would cast light on the question of why robots are effective in eliciting social interactions in individuals with ASD.

2 Methods

2.1 Participants

18 patients (Mean age = 19.67, SD = 1.5, 3 women) diagnosed with ASD took part in this experiment as volunteers for monetary compensation. Participants were recruited at the St. Franziskus Berufsbildungswerk in Abensberg, where individuals with ASD are trained on a job to be integrated in a normal working environment. Participants received 8 Euros per hour as honorarium for participation. We decided to test social skills in adult participants diagnosed with autism, so that we would be able to conduct the study with the same paradigm (i.e., not modified for purposes of conducting the study with children) that has been designed earlier [20, 22] to test social attention in healthy adult participants.

2.2 Stimuli and Apparatus

Stimuli were photos 5.7° × 5.7° of visual angle in size. We decided to use static photographs in a very structured experimental setup in order to have properly controlled experimental conditions to examine the fundamental mechanisms of cognition. This is typically a first step to subsequent more realistic protocols, where experimental paradigms are introduced into real-life environments. First, however, it is necessary to answer the question of what are the exact cognitive mechanisms that are at stake and that are pinpointed by the controlled experimental setup.

In the human condition, the face of the same female individual was presented (source: Karolinska Directed Emotional Faces database [25]). In the robot condition, photos of an anthropomorphic robot (EDDIE, LSR, TU München) were presented, see Figure 1. EDDIE is a robot face developed to express emotions and thus has salient colourful facial features relevant for emotional expressiveness (big eyes, eyebrows, prominent lips) with additional animal-like characteristics (folding and extending cockatoo-like comb on top of its head as well as lizard-like ears on the sides) [26]. For our purposes, these features were not used: the robot had an invariable happy expression, with the comb and ears folded (almost not visible). The only "dynamic" part of the robot was the eyes that could move leftward or rightward. In fact, these were all static images, but the sequence of the images was rapidly presented producing an impression of a dynamic movement of the eyes.

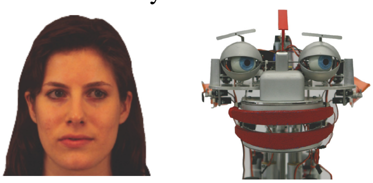

Fig. 1. The human face (left) and the robot face (right) used in the present paradigm

Leftward or rightward gaze direction deviated by 0.2° from straight-ahead, in both the human and the robot condition. Stimuli were presented centrally on a white background, with eyes positioned on the central horizontal axis of the screen. Peripheral target letters were always presented at the same level as the eyes of the human or robot face. The target stimulus was a black capital letter (F or T), 0.2° × 0.2° in size, which was presented at an eccentricity of 5.7° relative to the screen center (Fig. 2). Target positions (left or right) were determined pseudo-randomly.

Gaze direction was not predictive of the target position: gaze was directed either to the side on which the target appeared (valid trials, 50% trials) or to the other side (invalid trials, 50% of trials).

2.3 Procedure

Each experimental trial began with presentation of a fixation point (2 pixels) for 850 ms. The fixation display was followed a display with a face gazing straight-ahead (in the direction of the observer, 850 ms). The fixation dot remained visible (in-between the eyebrows of the face). The next event in the trial sequence consisted of a directional gaze shift to the left or the right. Subsequently, after 500 ms, the target letter was presented on either the left or the right side of the screen, with the face remaining present in the centre. Upon target presentation, participants responded as quickly and as accurately as possible to the identity of the target letter (F or T) using the 'd' or 'k' key on a standard keyboard, with response assignment counterbalanced across participants (d=F/k=T vs. d=T/k=F; the d/k letters were covered with F and T stickers). The target letter remained visible on the screen until a response was given or a time-out criterion (1200 ms) was reached. Figure 2 depicts an example trial sequence. The experiment consisted of 596 experimental trials preceded by 20 practice trials. All conditions were pseudo-randomly mixed.

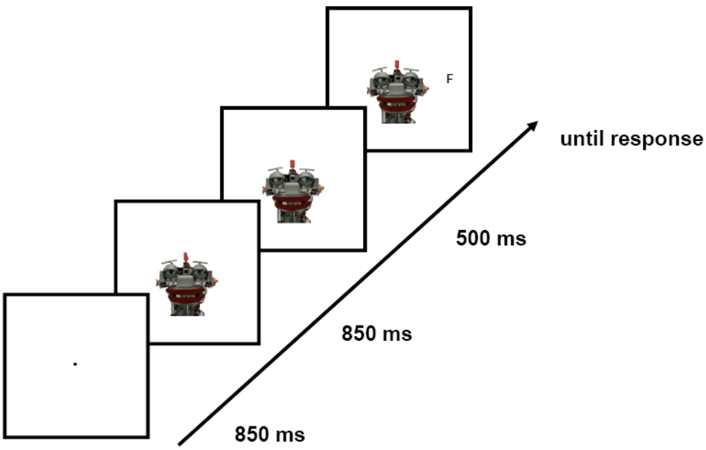

Fig. 2. An example trial sequence with validly cued condition. Proportions of stimuli relative to the screen are represented as they were in the experiment.

3 Results

Median reaction times (RTs) were computed for each participant. Individual median RTs were submitted to a 2×2 repeated-measures analysis of variance (ANOVA) with the factors *cue type* (human vs. robot face) and *validity* (valid vs. invalid). This ANOVA revealed a significant main effect of validity, $F(1, 17) = 10.848$, $p = .004$, $\eta_p^2 = .390$, with validly cued trials eliciting faster RTs (M = 541 ms, SEM = 24) than invalidly cued trials (M = 551 ms, SEM = 26). Importantly, however, this effect interacted significantly with the type of cue (human vs. robot face), $F(1, 17) = 5.104$, $p = .037$, $\eta_p^2 = .231$: while the human face did not elicit a gaze cueing effect ($M_{valid} = 543$ ms, SEM = 24 vs. $M_{invalid} = 547$ ms, SEM = 25, $t(17) = 1.203$, $p = .246$), the robot face did ($M_{valid} = 538$ ms, SEM = 23 vs. $M_{invalid} = 555$ ms, SEM = 27, $t(17) = 3.331$, $p = .004$), see Figure 3. The main effect of cue type was not significant, $F < .5$, $p > .55$.

An analogous analysis of error rates revealed no significant effects or interactions, all Fs < 2, all ps > .22. The mean error rate was 2%, with a standard deviation of .15.

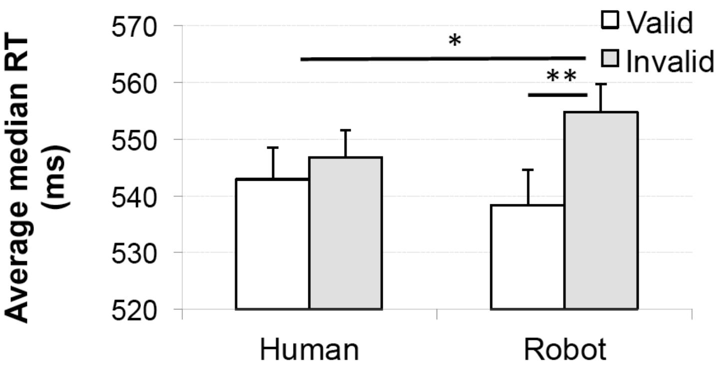

Fig. 3. Average median reaction times (RTs) required to discriminate the target (F vs. T) as a function of the validity of the gaze cue (valid vs. invalid) and the cue type (human vs. robot). Error bars represent standard errors of the mean adjusted to within-participants designs, according to [27]. *p < .05, **p < .005.

4 Discussion

The present findings reveal that individuals diagnosed with ASD are more likely to follow the eye movements of a robot face than those of a human face. Interestingly, this is in contrast with results obtained with healthy individuals [20], who – with the same paradigm – were more likely to attend to the direction of human gaze, relative to a robot gaze. This shows that while healthy participants are more ready to follow attention of human agents than of mechanistic devices, individuals with autism are more inclined to follow "eyes" of a non-human entity. This finding is of particular importance for social robotics, for several reasons. It demonstrates empirically that people with ASD can indeed process the eye movements displayed by a robot and shift their attentional focus to the gazed-at location. In doing so, individuals with ASD appear to react to robots in a similar way as healthy participants do to human partners: they share attention with them and attend to where others are attending. Thus, our data provide empirical evidence that robots have the capability of inducing attentional shifts in people with ASD and can thus be used to train people with ASD in the more general ability of gaze following. Sharing attention with others is also an important prerequisite for mentalizing and understanding others' actions – two social skills that are known to be impaired in ASD [2]. Since eye gaze directly informs about internal states, such as preferences or interests, and helps predicting what other people are going to do next [28], it seems that robots can be used to train individuals with ASD to understand others' intentions and predict others' actions – through gaze following.

While many robot systems have proved to be very successful in engaging individuals with ASD into an interaction [3], it is as yet little understood what the underlying cognitive mechanisms are. Our study reveals that it might be fundamental mechanisms (such as shared attention/gaze following) that are the basis for other higher-order social cognitive processes that are elicited in interactions with robots, but are not activated during interactions with humans. Therefore, the phenomenal experience of pleasantness and fun [3] that individuals with ASD seem to have when interacting with robots might be a consequence of more basic (and perhaps even implicit) cognitive mechanisms that come into play in human-robot interaction.

This raises the question of why individuals with ASD activate those fundamental mechanisms of social cognition when interacting with robots, but not to the same extent when interacting with humans. That is, why are they less likely to follow the eyes of humans, but more likely to follow the eyes of robots? This question is particularly interesting in the light of previous findings of Wiese, Wykowska and colleagues [20], where the same stimuli were used with healthy participants, but the opposite effect was found: stronger gaze following for the human than for the robot face. A possible explanation for this comes from Baron-Cohen [29, 30], who proposed that individuals with ASD have reduced mentalizing but increased systemizing skills, which makes them more interested in understanding the behavior of machines rather than of minds. Thus, it appears that the degree to which eye gaze is followed depends on how meaningful it is to the observer: Healthy controls make more sense of human-like eye movements and show stronger gaze following for human-like agents (presumably due to the behavior of human agents carrying socially informative content, [18]), while individuals with ASD make more sense of robot-like eye movements and show stronger gaze following for robot-like agents, presumably due to their aptitude for mechanistic systems and systemizing in general.

It might also be the case that both patterns of results are attributable to the same mechanism. That is, the differential cueing effects for human vs. robot faces (in both healthy participants and individuals with ASD) might be related to pre-activating certain representations of the observed stimulus: when a human face is observed, a whole representation of a human being might be activated; while a representation of a robot is activated when a robot face is seen. These representations include various characteristics. One of the characteristics of a human is that humans possess minds and their behavior is driven by mental states. In the case of healthy, typically developed people, this might produce a higher incentive to follow human gaze (relative to following gaze of a robot), because mental states and intentions carry socially informative meaning [18]. However, for individuals with ASD, the representation of a human might be associated with complex and probabilistic (hard to determine) behavior [31, 32]. A mechanistic device, by contrast, might be associated with a deterministic (and thus more predictable) behavior [30, 31]. Hence individuals with ASD may be more comfortable in the presence of systems with more predictable behavior, and thus be more ready to engage fundamental mechanisms of social cognition in interactions with them.

5 Concluding Remarks and Future Directions

There are two main conclusions that can be drawn from this research: First, social robots can be used to train people with ASD to follow eye gaze and understand that objects of interest are usually looked at before an action is performed with/on them. In doing so, one would hope that gaze following behavior shown with robots would generalize to human-human interactions and help people with ASD to develop basic mentalizing skills. Second, the present study casts light on the mechanisms that might be the reason for the success of robots in involving individuals with ASD into interactions with them [3]. We show that it might be the most fundamental mechanisms of social cognition that are elicited by robots, but that are not activated when individuals with ASD interact with other humans. As a consequence, interactions with robots are more efficient and smooth, and hence robots are successful in engaging individuals with ASD.

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References

1. Ristic, J., et al.: Eyes are special but not for everyone: The case of autism. Cognit. Brain Res. 24, 715–718 (2005)
2. Baron-Cohen, S.: Mindblindness: an essay on autism and theory of mind. MIT Press/ Bradford Books, Boston (1995)
3. Cabibihan, J.J., Javed, H., Ang Jr., M., Aljunied, S.M.: Why Robots? A Survey on the Roles and Benefits of Social Robots for the Therapy of Children with Autism. Intl. J. of Social Robotics 5, 593–618 (2013)
4. Friesen, C.K., Kingstone, A.: The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. Psychon. B. Rev. 5, 490–495 (1998)

5. Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., et al.: Gaze perception triggers reflexive visuospatial orienting. Vis. Cogn. 6, 509–540 (1999)
6. Robins, B., Dautenhahn, K., Dickerson, P.: From isolation to communication: a case study evaluation of robot assisted play for children with autism with a minimally expressive humanoid robot. In: Proc. 2nd Intern. Conf. Adv. Comp.–Human Inter., pp. 205–211. IEEE Press, New York (2009)
7. Shamsuddin, S., Yussof, H., Ismail, L.I., Mohamed, S., Hanapiah, F.A., Zahari, N.I.: Initial response in HRI-a case study on evaluation of child with autism spectrum disorders interacting with a humanoid robot Nao. Proc. Eng. 41, 1448–1455 (2012)
8. Kozima, H., Nakagawa, C., Yasuda, Y.: Interactive robots for communication-care: A case-study in autism therapy. In: IEEE International Workshop on Robot and Human Interactive Communication (ROMAN 2005), Nashville, TN, USA, pp. 341–346 (2005)
9. Kozima, H., Michalowski, M.P.: Keepon: A socially interactive robot for children. In: IEEE International Conference on Robotics and Automation (ICRA 2008),), The ICRA Robot Challenge Workshop, Pasadena, CA, USA (2008)
10. Kozima, H., Yasuda, Y., Nakagawa, C.: Social interaction facilitated by a minimally-designed robot: Findings from longitudinal therapeutic practices for autistic children. In: IEEE International Workshop on Robot and Human Interactive Communication, ROMAN 2007, Jeju, Korea (2007)
11. Kozima, H., Yasuda, Y., Nakagawa, C.: Robot in the loop of therapeutic care for children with autism. In: IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2007), Workshop on Assistive Technologies: Rehabilitation and Assistive Robotics, San Diego, CA, USA (2007)
12. Kozima, H.: Robot-mediated communication for autism therapy. In: International Conference on Infant Studies, ICIS 2008, Vancouver, Canada (2008)
13. Kozima, H., Nakagawa, C., Yasuda, Y.: Children–robot interaction a pilot study in autism therapy. Prog. Brain Res. 164–385 (2007)
14. Zheng, Z., Bekele, E., Swanson, A., Crittendon, J.A., Warren, Z., Sarkar, N.: Impact of Robot-mediated Interaction System on Joint Attention Skills for Children with Autism. In: IEEE International Conference on Rehabilitation Robotics (2013)
15. Stanton, C.M., Kahn, P.H., Severson, R.L., Ruckert, J.H., Gill, B.T.: Robotic animals might aid in the social development of children with autism. In: Proc. HRI 2008, pp. 271–278. ACM Press (2008)
16. Robins, B., Dautenhahn, K., Dubowski, J.: Does appearance matter in the interaction of children with autism with a humanoid robot? Interaction Studies 7(3), 479–512 (2006)
17. Kim, E.S., Berkovits, L.D., Bernier, E.P., Leyzberg, D., Shic, F., Paul, R., Scassellati, B.: Social robots as embedded reinforcers of social behavior in children with autism. J. Autism Dev. Disord. 43, 1038–1049 (2013)
18. Tomasello, M.: Origins of Human Communication. MIT Press, Cambridge (2010)
19. Sebanz, N., Knoblich, G.: Prediction in joint action: what, when, and where. Topics in Cognitive Science 1, 353–367 (2009)
20. Wiese, E., Wykowska, A., Zwickel, J., Müller, H.I.: see what you mean: how attentional selection is shaped by ascribing intentions to others. PLoS ONE 7(9), e45391 (2012)
21. Wiese, E., Wykowska, A., Müller, H.: What we observe is biased by what other people tell us: Beliefs about the reliability of gaze behavior modulate attentional orienting to gaze cues. PLoS ONE 9(4), e94529 (2014)
22. Wykowska, A., Wiese, E., Prosser, A., Müller, H.: Beliefs about the minds of others influence how we process sensory information. PLoS ONE 9(4), e94339 (2014)

23. Schuller, A.M., Rossion, B.: Spatial attention triggered by eye gaze increases and speeds up early visual activity. Neuroreport 12, 2381–2386 (2001)
24. Dennett, D.C.: True believers: the intentional strategy and why it works. In: O'Connor, T., Robb, D. (eds.) Philosophy of Mind: Contemporary Readings, pp. 370–390. Routledge, London (2003)
25. Lundqvist, D., Flykt, A., Öhman, A.: The Karolinska Directed Emotional Faces (KDEF). Department of Neurosciences Karolinska Hospital, Stockholm (1998)
26. Kühnlenz, K., Sosnowski, S., Buss, M.: The Impact of Animal-like Features on Emotion Expression of Robot Head EDDIE. Advanced Robotics 24 (2010)
27. Cousineau, D.: Confidence intervals in within-subjects designs: A simpler solution to Loftus and Masson's method. Tutorial in Quantitative Methods for Psychology 1, 42–45 (2005)
28. Frith, C.D., Frith, U.: How we predict what other people are going to do. Brain Res. 1079, 36–46 (2006)
29. Baron-Cohen, S.: The extreme male brain theory of autism. Trends Cogn. Sci. 6, 248–254 (2002)
30. Baron-Cohen, S.: Autism occurs more often in families of physicists, engineers, and mathematicians. Autism 2, 296–301 (1998)
31. Watson, J.S.: Detection of self: The perfect algorithm. In: Parker, S.T., Mitchell, R.W., Boccia, M.L. (eds.) Self-awareness in Animals and Humans. Developmental Perspectives, pp. 131–148. Cambridge University Press, Cambridge (1994)
32. Schilbach, L., Timmermans, B., Reddy, V., Costall, A., Bente, G., et al.: Toward a second-person neuroscience. Behav. Brain Sci. 36, 393–462 (2013)