INDIVIDUALS WITH HIGH AUTISTIC TRAITS FOCUS EXPLICITLY ON BODY PARTS WHEN TRANSFORMING VISUAL PERSPECTIVES

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Individuals with autism spectrum disorders are known to have difficulties with visual perspective taking. This study used a left–right discrimination task to examine whether autistic traits in typically developing individuals influence visual perspective taking. In each trial, an avatar displaying one of three postures (front, back, and front with arms crossed) was displayed on a PC monitor. For each trial, the direction (left or right) and reference (subjective, objective, or others’ hand) were instructed and participants had to identify the correct side on the display. In trials with an objective reference, individuals with lower levels of autistic traits could easily project themselves onto the back view of the avatar. Individuals with higher levels of several autistic traits (e.g., attention to local detail, imagination difficulty) did not use this advantage, tending to focus body parts of the avatar as cues to discriminate directions.

Key words: visual perspective taking, left–right discrimination, autistic trait, embodiment

INTRODUCTION

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by deficits in social communication and sensorimotor processing difficulties, such as repeated actions and hypersensitivity (Wing & Gould, 1979). Previous studies have suggested that individuals with ASD also find it difficult to understand others’ mental states (Baron-Cohen, Leslie, & Frith, 1985; Frith, 2012; Frith & Frith, 2007; Senju, 2012). Furthermore, younger children with ASD find it difficult to take another’s visual perspective (Hamilton, Brindley, & Frith, 2009), which may underlie impairments in understanding others’ mental states (Conson et al., 2015).

In neurotypical individuals, spatial transformation in the brain is achieved by aligning one’s body and the target perspective according to different three-dimensional references. Such transformations from one’s own to others’ reference might be a basis

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for social recognition because they help in imagining the mental states of others by providing viewpoints of another person’s body (Michelon & Zacks, 2006). Transforming one’s body references to a different spatial position can allow judgment of what is on another person’s left or right, or predictions on how things may appear from a different viewpoint.

There are two types of spatial transformation: egocentric transformation and mental rotation. Egocentric (or ‘self-based’) transformations involve transforming one’s own body as a whole in alignment with a new position in space (Zacks, Rypma, Gabrieli, Tversky, & Glover, 1999). These transformations support visual perspective taking, allowing a person to arrange themselves in another’s location and then suppose what another person can see from that different viewpoint (Steggemann, Engbert, & Weigelt, 2011; Surtees, Apperly, & Samson, 2013; Yu & Zacks, 2010). In contrast, mental rotation (or ‘object-based’ transformation) is used when we manipulate the orientation of objects in our minds (Shepard & Metzler, 1971; Wraga, Thompson, Alpert, & Kosslyn, 2003). Mental rotation could also be utilized to take another person’s perspective by rotating the entire visual scene. However, it is a much less efficient way of taking another’s perspective compared with egocentric transformation because object-based transformations require alignment and configuration of different reference frames for objects, namely, the entire visual scene for visual perspective (Zacks & Tversky, 2005).

A previous study has examined the performance of egocentric transformation and mental rotation in adults with ASD (Pearson, Marsh, Hamilton, & Ropar, 2014). Their results suggested that individuals with ASD have difficulties with egocentric transformations. Other research has indicated that children with ASD are significantly less accurate in visual perspective transforming tasks compared with typical children (Hamilton et al., 2009). However, children with ASD have shown greater accuracy on mental rotation tasks. These results indicate that the ability to conduct specifically egocentric transformations might be essential to taking others’ perspective, because impaired ability to perform egocentric transformations affects performance on the visual perspective transforming task, whereas performance of the mental rotation task is not affected (Pearson, Ropar, & Hamilton, 2013).

Egocentric transformation abilities have been linked to autistic traits within the typical population. Kessler and Wang (2012), using the autism-spectrum quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) as a measure of autistic traits in typically developing participants, reported that participants with higher levels of autistic traits show difficulty with performing egocentric transformations, and tend to use an object-focused rotation strategy. Brunyé et al. (2012) used a similar method and reported that individuals with higher levels of autistic traits have slower reaction times when performing egocentric transformations.

The present study examines the effect of autistic traits on taking another’s perspective in more detail. Our first aim was to examine whether difficulties in taking another’s perspective in individuals with ASD increase with increased levels of autistic traits. We used a left–right discrimination (laterality judgment) task to examine the influence of autistic traits on transforming one’s perspective, and used the AQ to evaluate
autistic traits, similar to previous studies (Brunyé et al., 2012; Kessler & Wang, 2012). We then analysed relations between AQ scores and the behavioural task performance to investigate gradual changes in the influence of autistic traits on taking others’ perspectives.

Our second aim was to examine whether information about others’ body parts could be used as cues in aid of taking another’s perspective in individuals with higher levels of autistic traits. Individuals with ASD tend to use information on internal body references, rather than on external spatial references (Haswell, Izawa, Dowell, Mostofsky, & Shadmehr, 2009; Wada et al., 2014). We tried to examine whether the information related to body part was dominant in the individuals with higher ASD tendency even in the situation observing another person without the person’s proprioceptor information. Therefore, we aimed to investigate the features of laterality judgments in situations where laterality of another’s body parts (e.g., others’ hands) is incongruent with the spatial laterality of another’s body-centred reference (e.g., when the other person holds a pose with crossed hands).

**Methods**

*Participants*

We included 30 participants (14 males; mean age = 21.9 years, SD = 5.0, range = 18–37 years) with normal or corrected-to-normal vision (e.g., glasses or contact lenses) and no history of neurological diseases. All participants completed the Edinburgh Handedness Inventory (Oldfield, 1971), with three participants scoring negatively, showing left-handedness (–30 points, n = 2; –90 points, n = 1). All other participants were right-handed (mean score = 83.9 points, SD = 3.14). The participants also completed the Japanese version of the AQ (Wakabayashi, Tojo, Baron-Cohen, & Wheelwright, 2004).

*Task*

During the task, participants were asked to discriminate between left and right, following instructions given from different perspectives. In each trial, an avatar was presented in one of three postures (front facing, back facing, and front with arms crossed; Fig. 1a). The avatar was displayed on a PC monitor, and a flower was displayed on each side of the avatar. Participants had to touch either the left or right flower as quickly and accurately as possible, according to instructions provided at the beginning of each trial. We used a touch screen display so that participants could answer without having to translate response direction into button placement. The instructions defined both the visual reference and direction (left or right).

There were three references: a subjective view, an objective view, and others’ hand (Fig. 1b). The subjective view refers to each participant’s own perspective; the objective view, to the avatar’s perspective. For the others’ hand reference, the instructions indicated that the participant should touch the flower nearest the avatars’ left or right hand. For example, ‘Touch the flower near the girl’s left hand’ was presented on the instruction screen. Alternatively, if an objective reference was used, the participant was instructed to touch the flower on the left or right side of the avatar’s body. For a subjective reference, participants were instructed to touch the flower on their own left or right side.

Therefore, the target flower was indicated by three factors: the avatar pose, visual reference, and direction given at the start of the trial. All of the participants performed all conditions, and the orders were randomized among participants.

*Stimuli*

The avatars were four characters: two male and two female. The avatars were 28 cm high (visual angle = 33.9 degree) and 11–17 cm wide (visual angle = 13.6–20.9 degree) on the display. The flower targets were 10 cm high (visual angle = 12.4 degree) and 4.5 cm wide (visual angle = 5.6 degree), and were
Fig. 1. Experimental stimuli, setting, and procedure
(a) One of four avatars is shown. Each avatar showed one of three poses in each trial. The left figure is the ‘front-facing pose’, the middle is the ‘back-facing pose’, and the right is the ‘front with arms crossed’. (b) Three reference conditions were used in the experiment: subjective reference, objective reference, and others’ hand reference. (c) Trial sequence. Instructions were shown with a start button in the same display at the beginning of the trial. After the start button was pressed, an avatar and flowers were shown. The participant had to touch a target flower according to the instructions as quickly and accurately as possible.

distanced 10.5 cm horizontally from the centre of the display (visual angle = 13.0 degree).

Apparatus

Visual stimuli were presented on a 19-inch touch screen display (ET1928L-8CJA-1-BG-G, Milpitas CA, USA). Time sequences for the task and data collection were controlled using Matlab (MathWorks Inc.,
MA, USA) with the Psychophysics Toolbox (Brainard, 1997; Pelli, 1997).

Procedures
Fig. 1c illustrates the experimental procedure. Participants stood approximately 50 cm in front of the touch screen display. After the participant pressed the space key on the keyboard, the instructions and a start button were presented on the display. The participants read the instructions and were then required to press the start button to begin each trial. All participants began with the same initial hand position. The centre of the start button was congruent with the location of the avatar’s face. Therefore, the participants naturally looked at the avatar’s face after pressing the start button. Subsequently, one of four avatars was displayed at the centre of the monitor, and a red flower was shown on each side of the avatar. The participants had to touch either of the two flowers as quickly and accurately as possible according to the instructions. Each combination of reference condition (3 conditions), avatar pose condition (3 conditions), and avatar type (4 types) was repeated four times, for a total of 144 trials.

Data Analysis
To investigate the influence of autistic traits, we examined the relation between AQ scores and response time differences between each pose condition in objective and others’ hand reference conditions. We used HAD version 10.42 (Shimizu, Murayama, & Daibo, 2006) and JASP (Version 0.9; JASP Team, 2018) for statistical analysis. To analyse individual differences in response time changes for different AQ scores, we calculated the RT index (1) between different poses for each participant.

\[
RT_{index} = \frac{RT_2 - RT_1}{RT_2 + RT_1} \quad (1)
\]

Results
Fig. 2 shows the average response time of all participants. A two-way analysis of variance (ANOVA; visual reference × avatar pose) on response times of all participants revealed significant main effects of the visual reference \(F(2, 58) = 51.91, p = .000\), avatar pose \(F(2, 58) = 32.79, p = .000\). Shaffer’s posteriori tests indicated that response times in trials of subjective reference were the fastest, followed by those in trials of objective reference and others’ hand reference, respectively \((ps < .001)\). Furthermore, Shaffer’s posteriori tests showed that response times in trials of avatar’s arm-crossing pose were the lowest, followed by those in trials of front view pose and back view pose, respectively \((ps < .001)\). Significant interaction was observed between visual reference and avatar pose conditions \(F(4, 116) = 23.12, p = .000\). In addition, the analysis of the simple effects of avatar pose conditions on the objective reference and others’ hand reference indicated that the response times were different among pose conditions \((ps < .001)\). Shaffer’s posteriori tests further showed that response times in trials of avatar’s arm-crossing pose the lowest, followed by the front view pose and back view pose, respectively, in both conditions of objective reference and others’ hand reference \((ps < .01)\). However, no significant differences were seen between all poses in the condition of subjective reference. Trials using a front pose with crossed arms were the most difficult, whereas a back-view pose was the easiest to discriminate between left and right using the objective and others’ hand references. Nonetheless, there were considerable individual differences.

For further analysis, we used a left–right discrimination (laterality judgment) task
with three references (subjective view, objective view, and others’ hand) to examine the influence of autistic traits in typically developing individuals on visual perspective taking. For this aim, we analysed correlations between task performance and autistic traits. False discovery rate (Benjamini-Hochberg procedure) was recruited to compensate multiple comparisons problem.

To eliminate large individual differences in baseline response times and to analyse the relationships between individual differences in response time changes and AQ scores, we calculated the RT index between trials using different poses for each participant. ‘ERROR index’ was not analysed because much of the error rate data had a value of 0, making it difficult to evaluate individual differences owing to a ceiling effect. There were no significant correlations between any RT index and total AQ score. The AQ score contains five sub-scores, namely, ‘social skills’, ‘attention switching’, ‘local detail’, ‘communication’, and ‘imagination’ (Baron-Cohen et al., 2001). It is possible that these AQ sub-scores may have a different relationship with each RT-index. Therefore, we performed a multiple regression analysis where a stepwise method was recruited. The multiple linear regression was calculated to predict each RT index based on AQ sub-scores. Fig. 3 shows the RT indices plotted as a function of AQ sub-scores; only plots indicating found significant regression equations.

A significant regression equation was found ($F(1,28) = 5.47, p = .03$), with an $R^2$ of
.16. Participants’ predicted RT index (‘front arm-crossing’–‘back’ in objective reference trials) is equal to .30 − .02 (sub-score of ‘local detail’; Table 1). Furthermore, a significant regression equation was found ($F(1,28) = 5.82, p = .02$), with an $R^2$ of .17. Participants’ predicted RT index (‘front’–‘back’ in trials using others’ hand reference) is equal to .21 − .02 (sub-score of ‘local detail’; Table 2). Thus, individuals with higher
scores for ‘local detail’ tended to show not ease discriminating the direction in tasks using a back-facing pose, in which it is usually easy to take the other’s perspective. In addition, a significant regression equation was found ($F(1,28) = 6.77, p = .02$), with an $R^2$ of .20. Participants’ predicted RT index (‘front arm-crossing’– ‘front’ in trials using others’ hand reference) is equal to .25 – .04 (sub-score of ‘imagination’; Table 3). Thus, individuals with higher scores for ‘imagination’ tended to show no more difficulty discriminating the avatar’s hand direction when they were crossed than when the avatars did not cross their hands.

**Table 1. Summary of the multiple linear regression analysis for variable predicting ‘RT index (front arm crossing – back in the objective reference)’**

Regression for Dependent Variable ‘RT index (front arm crossing – back in the objective reference)’

$R = .40, R^2 = .16, F(1,28) = 5.47, p = .03$

<table>
<thead>
<tr>
<th>B</th>
<th>Std.Err.</th>
<th>β</th>
<th>t</th>
<th>p</th>
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<tr>
<td>Intercept</td>
<td>.30</td>
<td>.05</td>
<td>6.00</td>
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<tr>
<td>Local detailed</td>
<td>−.02</td>
<td>.01</td>
<td>−.40</td>
<td>−2.34</td>
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**Table 2. Summary of the multiple linear regression analysis for variable predicting ‘RT index (front – back in the others’ hand reference)’**

Regression for Dependent Variable ‘RT index (front – back in the others’ hand reference)’

$R = .42, R^2 = .17, F(1,28) = 5.82, p = .02$

<table>
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<tbody>
<tr>
<td>Intercept</td>
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<td>.04</td>
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<td>&lt;.001</td>
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<tr>
<td>Local detailed</td>
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<td>.01</td>
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**Table 3. Summary of the multiple linear regression analysis for variable predicting ‘RT index (front arm crossing – front in the others’ hand reference)’**

Regression for Dependent Variable ‘RT index (front arm crossing – front in the others’ hand reference)’

$R = .44, R^2 = .20, F(1,28) = 6.77, p = .02$

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<th>B</th>
<th>Std.Err.</th>
<th>β</th>
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<tbody>
<tr>
<td>Intercept</td>
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<td>.05</td>
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<td>&lt;.001</td>
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<tr>
<td>Imagination</td>
<td>−.04</td>
<td>.01</td>
<td>−.44</td>
<td>−2.60</td>
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DISCUSSION

This study aimed to investigate the influence of autistic traits on transformation of visual perspective. In typically developing individuals, as a whole group, discriminating between left and right using the objective and others’ hand references proved to be the most difficult in trials using a front pose with crossed arms and the easiest in the case of a back-view pose. However, considerable individual differences were observed. We supposed that response times in trials using avatars with front-facing and front with crossed arms poses would increase, specifically in people with lower AQ scores; and that response times in trials using avatars with back-facing pose would increase, specifically in people with higher AQ scores. After eliminating individual differences in baseline response times by calculating RT indices, we did not observe a significant correlation between RT indices and total AQ scores. However, we found that some RT indices were predicted with some AQ sub-scores.

Regarding the multiple linear regressions that predicted response time differences between different avatar poses in different reference conditions based on AQ sub-scores, we observed that two AQ sub-scores (‘local detail’ and ‘imagination’) significantly predicted some response time differences. ‘Local detail’ is a sub-score evaluating the characteristic tendency in ASD for individuals to capture local parts more than global patterns, and obsessiveness with numbers (Baron-Cohen et al., 2001). The ‘imagination’ sub-scale contains a questionnaire investigating whether one can imagine others’ states of mind. Achieving a higher score for ‘imagination’ indicates greater difficulties in imagining others’ intentions.

If someone simulates another’s body images by projecting his/her own body image onto another’s when taking their perspective, a back-facing view of the other’s body is thought to be easy for projecting (Conson et al., 2015). However, projecting one’s own body image onto others from a front-facing view requires one to rotate the self’s body image from a back-facing image (which fits one’s own body reference) to the other’s front-facing image. Therefore, in trials that required participants to discriminate left–right directions using the front face of the avatar, the participants needed to rotate their self’s body image. Such self-based transformation which are used when we transform our own body as a whole into alignment with a new position in space is named as egocentric transformation (Zacks et al., 1999). In the present study, embodiment was determined as associated with such egocentric transformation. We observed that the AQ sub-scores for ‘local detail’ explained some response time differences. Scores for ‘local detail’ increased as the advantage became small in the situation where a participant’s reference was congruent with the avatar, in both objective view and others’ hand reference conditions. Thus, individuals with the lower scores may continue to project themselves onto the back face of the avatar when judging laterality. This strategy allowed them to decrease response time toward the avatar with back poses. However, at the same time rotating their body image may take them more time in front-facing view avatars trials. Therefore, in line with a previous study using children with ASD (Conson et al., 2015), embodiment strongly occurred in those who had lower ‘local detail’ scores.
Individuals with lower particular autistic traits may be induced to simulate implicitly another’s full body image even in situations when they could ignore another’s body parts. Individuals with higher ‘local detail’ autistic traits showed relatively less difference in making laterality judgments between an avatar with a front face with crossed arms and that with a back pose in the objective reference condition. In this reference condition, however, participants could ignore whether an avatar had crossed arms or not. Children with ASD have been shown to have a weak ability in integrating incoming stimuli and more easily attend to parts of stimuli (Plaisted, Swettenham, & Rees, 1999; Pellicano, Gibson, Maybery, Durkin, & Badcock, 2005). This could explain how individuals with higher ‘local detail’ autistic traits were less affected by global information in our task: they could more easily ignore unhelpful information, such as the avatar’s hands in the objective reference condition, and focus on particular information explicitly. In contrast, other previous study reported that individuals with ASD tended to show hyperimitation of actions (Spengler, Bird, & Brass, 2010). Thus, it is noticed that individuals with ASD cannot always ignore needless information selectively and this feature may be dependent on the situation.

Participants with higher ‘local detail’ AQ sub-scores might tend to explicitly use body parts as cues, related to attending to local detail, which is a feature of some individuals with ASD. This may sustain the embodiment difficulties of some individuals with higher ‘local detail’ AQ sub-scores.

Participants with higher ‘imagination’ AQ sub-scores showed little difference in response times between trials in which the avatar had a front-facing pose with crossed arms and a front pose with left–right judgments requiring a reference to another’s hand. Such individuals may have tended to use body parts of the avatar as cues to discriminate directly the directions, given that the avatar’s front-facing pose with crossed arms could interfere with the discrimination of body parts’ directions for the avatar’s left or right. The participants with lower ‘imagination’ AQ sub-scores had a relatively longer response time in the ‘front arm-crossing’ conditions compared with the ‘front’ condition in the reference of others’ hand. They may have simulated the avatar’s pose to discriminate the directions of the avatar’s body parts. Thus, discriminating the direction in the ‘front arm-crossing’ conditions took a relatively longer time.

People with higher ‘imagination’ AQ sub-scores could use the avatar’s hand position as a dominant cue to discriminate hand side when explicitly instructed to detect the hand side. Why do individuals with higher scores for ‘imagination’ not show much more difficulties in discriminating hand side for the avatar with crossed hands than without crossed hands? One possible explanation is that they tended not to project themselves onto the avatar using embodiment, and as such, they did not need to take time to imagine crossing their hands to match the avatar pose.

There were several contradictory reports. Unlike the previous study (Brunyé et al., 2012), our study did not show correlation between the total AQ score and any RT index. In addition, Kessler and Wang (2012) reported the result that the AQ sub-score ‘social skills’ predicted the embodiment index significantly; however, in present research, such relationship was not indicated between any RT index and the AQ sub-score ‘social
skills’. Why these differences were occurred? One possibility is a difference in experimental tasks. There are various different points and the following are specifically the strong difference. In present study, participants had to often switch their perspective because there was the condition of references, which were the subjective reference, the objective reference, and the others’ hand reference. On the other hand, experimental tasks in previous studies (Brunyé et al., 2012; Kessler & Wang, 2012) made participants use only the avatar’s perspective. It is possible that our experimental task design, which made participants always be aware several perspectives, could influence on these differences of results. Another possibility is a difference in numbers of the participants. Both previous studies were attended with more than twice participants of our research. In addition, our study had larger deviation of participants’ age than previous studies.

There is another contradiction between the results of some previous research and the present study. Brunyé and colleagues (2012) calculated a mean angular deviation effect as an index by the differential value between the RT average of conditions with large virtual self-moving angles and with small virtual self-moving angles, similar as in our study. The result that the AQ score increased as angular deviation effect became stronger in previous study (Brunyé et al., 2012) is different from the results of our result. It may be suggested that the decreased response time of the trials with conditions of large virtual self-moving angles (front-facing avatar) by participants with lower AQ was particularly exposed in the previous study (Brunyé et al., 2012); and increased response time of the trials with conditions of small virtual self-moving angles (back-facing avatar) by participants with higher AQ sub-score ‘local detail’ was particularly exposed in the present study. The previous study (Brunyé et al., 2012) can be interpreted that participants with lower AQ score responded faster in the similar condition of the avatar with front-facing pose in our study, compared to participants with higher AQ. Actually, the previous study (Pearson et al., 2014) reported that the typical development participant could judge direction faster from an avatar’s perspective than the participants with ASD in both front-facing avatar (virtual self’s movement angle of 140 degrees) and back-facing conditions (virtual self’s movement angle of 20 degrees). Thus, this previous study (Pearson et al., 2014) showed that these tendencies, which typical developmental participants transferred to quickly the front-facing avatar and the back-facing avatar, were observed at same time, although difference in the response time between in front-facing and back-facing conditions was much larger in the participants with ASD in this study.

On the contrary, another study (Conson et al., 2015) indicated that typical development participants judged left/right discrimination more quickly from the avatar’s perspective than individuals with ASD when the avatar showed its back (back-facing), while they judged slower when the avatar showed its front (front-facing). The tendency does not contradict our present results. Anyway, it is supposed that there is not only one suggestion about the relationship between the response time for left/right judgement from other’s perspective and the autistic tendency when the angle of disparity between the participants and the avatar is large. This issue needs more future researches and discussions.
CONCLUSIONS

Our results indicated that individuals with higher ‘local detail’ AQ sub-scores but without a diagnosis of ASD showed relatively less embodiment strategy. This tendency gradually changed as this autistic trait increased. Thus, ASD features may be related to impairments in visual perspective taking. When participants had to discriminate another’s hand side, individuals with higher particular ASD features not projected own full body image on the avatar but might tend to use partial visual information (specifically avatars’ arms) dominantly as a cue. This tendency to attend to local details may underlie their embodiment difficulties. In addition, ‘imagination’ AQ sub-scores were related to this use of body parts to discriminate another’s hand side. Therefore, this study suggests that embodiment difficulties in individuals with ASD might relate to attending to body parts rather than imagining others’ minds. The findings from this study provide an important implication to examinations of cognitive features relating to degree of autistic traits, with focus on sub-factors underlying bases of ASD symptoms, in research on cognitive features in individuals with ASD.

Conflict of Interest: The authors declare no conflicts of interest.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee, and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The ethics committee of the National Rehabilitation Center for Persons with Disabilities approved the study.

Informed consent: Informed consent was obtained from all participants included in the study.

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