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Memory for Actions and Reality Monitoring in Adults with Autism Spectrum Disorder

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Reality monitoring is the cognitive process of distinguishing between internally and externally generated information sources such as imagined and performed actions. The purpose of this study was to examine self-self-monitoring with action in people with autism, which has not been examined previously, using subject performed tasks along with free recall and recognition. Twenty adults with ASD and 20 adults with typical development (TD) participated in this study. Participants memorized action sentences such as 'write in pencil' and "under imagined, pantomime, or enacted conditions." Free recall, yes/no recognition, and reality monitoring tests were conducted immediately after and one week later. There was no difference in reality monitoring between the ASD and TD groups. The free recall and recognition performance of the ASD group was lower than that of the TD group. The results of the present study support the previously reported finding of unimpaired retrospective mechanisms of sense of agency related to reality monitoring in people with ASD. Moreover, low levels of free recall and recognition were discussed regarding difficulties in memory reconstruction and consolidation.

Keywords: autism spectrum disorder; reality monitoring; subject-performed tasks; action memory

Reality monitoring in ASD

Action memory is an important process for everyday functioning and is the most common form of memory. Failures in action memory can range from forgetting to lock the house to leaving a child in a hot car, but all errors may have serious consequences in our lives (Johnson et al., 1993). One of the causes of action memory failure is a reality monitoring error, such as believing that you actually locked the door even though you only thought (or imagined) locking it (Johnson & Raye, 1981).The definition of reality monitoring by Johnson et al. (1981) is as follows. Reality monitoring is the ability to distinguish internally generated information from externally derived information (Johnson et al., 1981).

There are two types of reality monitoring: self-self monitoring and self-other monitoring. Self-self monitoring is internal source monitoring (Johnson et al., 1993). This is the distinction between one's thoughts and one's experiences, as in the above, whether one only thought of locking the room or whether one actually did so. Self-other monitoring is the distinction between one's own thoughts (imagination) and the actions of others, whether one's own actions or those of others.

Most studies of reality monitoring in people with ASD have examined self-other monitoring. For example, in Hala et al. (2005), participants were required to make a

source judgment whether the presented word was said by themselves or experimenter. The results showed that children with ASD had lower performance than typical development (TD) children. This experiment was a replication of Farrant et al.'s (1998), but Farrant et al. (1998) found no difference between children with ASD and TD children. Hala et al. (2005) pointed out that the reason for this is that verbal ability was not controlled for in Farrant et al.'s (1998) study.

In Cooper et al.'s (2016) self-other monitoring task, adult ASD and TD participants were asked to distinguish whether the word was said by themselves or by the experimenter, and the adult ASD participants reported a decrease in source accuracy. Hala et al. (2005) and Cooper et al. (2016), as well as several other studies, have reported diminished self-other monitoring of people with ASD (Lind & Bowler, 2009; Maras et al., 2013; Russell & Jarrold, 1999; Yamamoto & Masumoto, 2018). On the other hand, some studies, such as Farrant et al. (1998), found no differences between ASD and TD. For example, Williams and Happe (2009) replicated an experiment in conducted by Russell and Jarrold (1999) in which reality monitoring was diminished in people with ASD, but reported no significant differences between children with ASD and TD children. Other studies using tasks in which participants were asked to judge whether they or another person (e.g., experimenter or actor on screen) had performed certain actions reported no differences

between people with ASD and TD (Grainger et al., 2014; Hill & Russell, 2002; Zalla et al., 2010).

As noted above, the results of the self-other monitoring studies of people with ASD are inconsistent. Self-other monitoring is easier than self-self monitoring because the distinction between self and others is clearer and source judgments are easier (Hashtroudi et al., 1990). Therefore, if there is a decrease in reality monitoring with people with ASD, there would be a significant decrease in self-self monitoring.

Two studies have been reported on self-self-monitoring with people with ASD. In Cooper et al.'s (2016) study, participants distinguished whether they remembered the presented words by imagining or perceiving them. The results showed that adults with ASD had lower source accuracy than those with TD. In Hala et al.'s (2005) study, participants were instructed by a male voice on a pre-recorded audiotape to say or imagine aloud the words presented to them, after which they were required to make a source judgment. The results showed that children with ASD had lower source memory performance than TD children. These studies suggest that self-self-monitoring is impaired in people with ASD. However, experimental tasks in previous studies have measured reality monitoring by distinguishing between imagination and perception, whereas self-self monitoring with action has not yet been examined.

The purpose of this study was to examine self-self-monitoring with action in adults with ASD, which has not been examined previously, using subject performed tasks (SPTs) along with free recall and recognition. It also offers the novel contribution of investigating monitoring in adults with ASD. In SPTs, participants are requested to conduct enacted encoding of an action sentence such as 'clapping hands'. When memorizing the action sentence, enacting the movements prescribed in the sentence is known to result in better memory performance than simply memorizing the sentence (verbal encoding) or encoding by observation (observational encoding) (Cohen, 1981; Engelkamp & Krumnacker, 1980; Engelkamp & Zimmer, 1997; Saltz & Donnenwerthnolan, 1981). The enhancement of memory has been termed the enactment effect (Nyberg & Nilsson, 1995). In the present study, we established three conditions for the action sentences: an imagined condition in which the participants memorized the sentences by imagining them, the pantomime condition in which they memorized them by pantomiming them, and the enacted condition in which they memorized them by actually using a tool.

The main purpose of this study, self-self monitoring, requires an element of sense of agency in which one accurately judges that 'I generated my own actions' (Haggard, 2017; Korzyukov et al., 2017). The sense of agency of people with ASD has been found to be impaired in some studies and preserved in others (for review, see Zalla & Sperduti, 2015).

To explain the sense of agency, two mechanisms have been proposed: the prospective mechanism, which occurs before the action is performed, and the retrospective mechanism, which occurs after the action is performed. People with ASD are impaired in prospective mechanisms (Daprati et al., 2013; Rinehart et al., 2006; Rinehart et al., 2001), but not in retrospective mechanisms (David et al., 2008; Hill & Russell, 2002; Williams & Happe, 2009). In this study, the retrospective mechanism is applicable because the memory test is administered after the action is performed. Therefore, it is expected that people with ASD would not be impaired in reality monitoring and would not differ from those with TD.

For the comparison between conditions in the memory test, the presentation of tools in the enacted condition enhances memory performance, as visual stimuli provide rich detail information (Backman et al., 1986; Hutton et al., 1996; Masumoto et al., 2006). People with ASD show the same level of memory performance as TDs when external cues are present (Bowler et al., 2015; Bowler et al., 2004). This effect has been proposed as the *Task Support Hypothesis* (TSH). Previous studies have also reported no problems in processing pantomime of meaningful actions in people with ASD (Gizzonio et al., 2015; Williams et al., 2004). The action sentences used in this study are all meaningful gestures. According to Lind 's (2010) review of theoretical frameworks of self-concept

for people with ASD, people with ASD have diminished psychological aspects of self, while their physical aspects are unimpaired. Encoding in SPT relies on physical rather than psychological aspects. In all memory tests, both the TD and ASD groups are predicted to be highest in the enacted condition using tools rather than imagery or pantomimes.

In addition, previous studies using action sentences found that memory performance differs slightly in children with ASD and TD (Wojcik et al., 2011). Wojcik et al. (2011) identified the effect of SPT on verbal condition and the advantage of observational condition over enacted and verbal conditions in ASD, but memory performance in those with TD showed a usual pattern (i.e., SPT > EPT > VT). This study does not mention whether the Verbal Intelligence Quotient (VIQ) was controlled. The present study goes a step further than previous studies (not only Wojcik et al. (2011) but also Farrant et al. (1998)) and controls for the VIQ to ensure that any possible differences are due to autism characteristics and not language limitations. Cognitive function studies of ASD have indicated that VIQ control is essential (Mervis & Klein-Tasman, 2004).

Another novelty of this study is that the memory test was also conducted one week later. Previous studies have reported that the enactment effect was observed after one week in people with ASD and that their forgetting pattern was similar to that of TD

individuals (Yamamoto & Masumoto, 2018). Therefore, for all of the memory tests in this study, it is predicted that memory performance after one week would be highest in the enacted condition using tools rather than imagery or pantomimes.

However, when focusing on the free recall performance, there are many reports of its impairments (for review see Desaunay et al., 2020). We would expect people with ASD to have lower free recall performance than those with TD. However, no differences between groups are expected under the TSH because the action sentence is presented during the response in recognition.

Materials and methods

Design

A Group (2: ASD, TD) × Condition (3: Imagined, Pantomime, Enacted) × Retention time (2: Immediate, Delayed) design was used, with the group as a between-participants factor and condition and retention time as within-participant factors.

Participants

Adults (n = 20; 18 men and 2 women) with a clinical diagnosis of ASD according to the DSM-IV and ICD-10 criteria were recruited from the Career Transition Support Office in Hyogo Prefecture. A psychiatrist formally diagnosed all the participants with

ASD. People with ASD were all diagnosed before the DSM-5 was published in 2013. The first author visited the Career Transition Support Office and explained the purpose of the study. Those who agreed with the purpose of the study and signed a consent form were included. TD adults (n = 20; 14 men and 6 women) without developmental or mental disorders were recruited from a recruitment company panel.

Table 1 shows the demographic and clinical data for the ASD and TD groups. There was no difference between the two groups in WAIS-III scores. On the Japanese version of the Autism Spectrum Quotient (AQ) (Wakabayashi et al., 2004), all participants with ASD scored above the suggested cut-off score of 26 (Kurita et al., 2005; Woodbury-Smith et al., 2005), whereas all participants with TD scored below the suggested cut-off score.

Reality monitoring task

In this study, 60 action sentences, such as 'write in pencil', were adapted from a previous study (Masumoto et al., 2015). All sentences involved the use of objects. The action sentences were divided into 45 items used as a memory test and 15 items used as distractors in the reality monitoring test. The memory test items were divided into three lists of 15 items each, and one list was assigned to each of the three memory conditions described below. The three lists used for the three encoding conditions and a list used as

a reality monitoring distractor were counterbalanced across participants. The order of the conditions to be conducted was counterbalanced across participants. Experiments were conducted individually with each participant under the imagined, pantomime, and enacted conditions. In all conditions, the experimenter read each sentence aloud but the participants had to do different things in each conditions (listen and imagine, enact with objects, and enact without objects). The following instructions were given to the participants before encoding: 'Now, I will read the action sentences to you. Please remember as many of them as you can. Later, you will recall them'.

In the imagined condition, the participants imagined the action described by the sentences and encoded the sentences read by the experimenter. In the pantomime condition, the experimenter read each sentence aloud and the participants encoded the sentences by performing the action described in the sentences. In the enacted condition, participants performed the action described in the sentences using objects and encoded the sentences after the experimenter read each sentence aloud. Each item was presented at an interval of five seconds. The participants were given two practice trials after the instructions for each condition to ensure that they understood the experimental procedure.

An immediate free recall test was conducted after presentation of the list for each condition. The experimenter required the participants to recall as many action sentences as possible within three minutes. In this study, one block consisted of the time span from the presentation of the list to the end of the free recall test. One block lasted 4 minutes 15 seconds. After the three conditions were tested, a yes/no recognition test and reality monitoring test were conducted. Sentences and distractors were randomly presented on paper in the recognition and reality monitoring tests (see Figure 1). First, participants responded ‘yes’ or ‘no’ to each item (yes/no recognition) and then for the items they recognized, they had to indicate whether the sentence was enacted, pantomimed, or imagined by them. The free recall test, yes/no recognition test, and reality monitoring test were conducted again a week later.

Procedure

On the first day, the participants completed encoding under the three conditions and conducted free recall tests after each condition. Encoding conditions were blocked and order counterbalanced across participants. After all free recall tests were completed, participants conducted a yes/no recognition test and a reality monitoring test. The participants were not informed that a delayed memory test would be conducted. One week later, participants completed a free recall, yes/no recognition test, and reality

monitoring test as a delayed memory test (encoding was not performed). The AQ was administered on the first day after the memory test, and the WAIS-III was administered after the delayed memory test was completed one week later.

Ethical considerations

Ethics approval was obtained from the research ethics committee at Kobe University. All participants were fully informed about the study, and they gave their written informed consent for participation. All study procedures were conducted in accordance with the Helsinki Declaration.

Results

Reality monitoring

Figure 2 shows the reality monitoring rates by group, condition, and retention time. A 'discrimination proportion' score for the source was created following Farrant et al. (1998) and Foley et al. (1983) to analyse the participants' ability to correctly identify the source of the conditions they had experimented with before. For each participant, the number of sentences identified correctly as imagined was divided by the number of all the imagined sentences recognized as old sentences by the participants. For example, if a participant recognized 10 imagined sentences as old sentences during the encoding

and identified 7 of these (correctly) as imagined and 3 (incorrectly) as the other condition, such as pantomime, the proportion of accurately recognized imagined would be 0.7. A higher proportion indicates a higher degree of accuracy. Proportions of identified accuracy in the pantomime and enacted conditions were calculated in the same way. The source scores were analysed using a Group × Condition × Retention time mixed ANOVA.

The results indicated a main effect of condition ($F(2,76) = 14.87$, $p < .001$, $\eta^2_G = .11$) and retention time ($F(1,38) = 90.37$, $p < .001$, $\eta^2_G = .24$), but no main effect of group ($F(1,38) = 2.18$, *n.s.*, $\eta^2_G = .01$). Pairwise comparisons using the Bonferroni correction showed significant differences between imagined and enacted ($p < .05$), pantomime and enacted ($p < .05$), and between imagined and pantomime ($p < .05$) conditions. Moreover, no significant interaction was observed between factors, Group × Condition × Retention time ($F(2,76) = 0.58$, *n.s.*, $\eta^2_G = .01$), Group × Condition ($F(2,76) = 0.69$, *n.s.*, $\eta^2_G = .001$), Group × Retention time ($F(1,38) = 2.13$, *n.s.*, $\eta^2_G = .001$), and Condition × Retention time ($F(2,76) = 2.99$, *n.s.*, $\eta^2_G = .03$). To support the null hypothesis of a main effect of groups, we calculated Bayes factors (BF10). Statistical analyses were performed using JASP (Amsterdam, Netherland) software

Version 0.16.4. The results of the analysis showed that BF10 was 2.7×10^{-12}.

BF10 values < 0.1 provide strong support for a null hypothesis.

These results suggest no significant differences between the two groups, regardless of condition or retention time. The enacted condition resulted in the highest results of all three conditions, regardless of group or retention time. Immediate responses were higher than delayed responses, regardless of group or condition.

Free recall

Figure 3 shows the free recall rate according to group, condition, and retention time. The Free recall performance was calculated and ANOVA was conducted by dividing the number of correct responses by the number of 15 sentences presented in each condition. The results show a main effect for group ($F(1,38) = 22.31$, $p < .001$, $\eta^2_G = .17$), condition ($F(2,76) = 148.48$, $p < .001$, $\eta^2_G = .53$), and retention time ($F(1,38) = 374.56$, $p < .001$, $\eta^2_G = .65$). Pairwise comparisons using the Bonferroni correction showed significant differences between imagined and enacted ($p < .05$), pantomime and enacted ($p < .05$), and between imagined and pantomime ($p < .05$). Moreover, no significant interaction was observed between factors, Group × Condition × Retention time ($F(2,76) = 0.97$, *n.s.*, $\eta^2_G = .001$), Group × Condition ($F(2,76) = 2.66$, *n.s.*, η^2_G

= .02), Group × Retention time ($F(1,38) = 3.05$, *n.s.*, $\eta^2_G = .01$), Condition × Retention time ($F(2,76) = 3.30$, *n.s.*, $\eta^2_G = .02$).

These results indicate that people with ASD had reduced free recall compared to the control group, regardless of retention time. The enacted condition resulted in the highest results of all three conditions, regardless of group or retention time. The results indicated a higher number of correct immediate responses than delayed responses, regardless of group or condition.

Recognition

In this study, a correct response of yes to the presented action sentence was defined as hit, and an erroneous response of yes to the distractor was defined as false alarm. Table 2 shows the mean recognition scores calculated using hits and false alarms. The false alarm rate was analysed using a Group × Retention time mixed ANOVA, which showed a main effect of retention time ($F(1,38) = 25.22$, $p < .001$, $\eta^2_G = .17$). However, there was no main effect of group ($F(1,38) = 1.87$, *n.s.*, $\eta^2_G = .03$). Moreover, no significant interaction was observed between the group and retention time ($F(1,38) = 0.81$, *n.s.*, $\eta^2_G = .01$).

The hit scores were analysed using a Group × Condition × Retention time mixed ANOVA. The results indicated a main effect of group ($F(1,38) = 8.92$, $p < .01$, η^2_G

= .08), condition ($F(2,76) = 75.52$, $p < .001$, $\eta^2_G = .36$), and retention time ($F(1,38) = 49.16$, $p < .001$, $\eta^2_G = .19$). Moreover, a significant interaction was observed between group and retention time ($F(1,38) = 4.73$, $p < .05$, $\eta^2_G = .02$) and between condition and retention time ($F(2,76) = 6.66$, $p < .01$, $\eta^2_G = .02$). However, there was no interaction between group and condition ($F(2,76) = 2.43$, *n.s.*, $\eta^2_G = .02$).

An analysis of the simple main effects for the interaction between groups and retention time revealed a significant effect of retention time in both groups (ASD: $F(1,19) = 30.34$, $p < .001$, $\eta^2_G = .22$, TD: $F(1,19) = 19.21$, $p < .001$, $\eta^2_G = .16$). An analysis of simple main effects on the interaction between group and retention time showed significant differences in delayed recognition ($F(1,38) = 9.77$, $p < .01$, $\eta^2_G = .14$), but no difference in immediate recognition ($F(1,38) = 2.55$, *n.s.*, $\eta^2_G = .03$). These results can also indicate that the ASD group demonstrated greater forgetting (hits drops from about 85% to 64%–21% difference) after a delay than did the TD group (hits drop from about 90% to about 79%–11% difference).

An analysis of simple main effects on the interaction between condition and retention time showed significant differences in retention time among all three conditions (imagined: $F(1,38) = 23.20$, $p < .001$, $\eta^2_G = .14$; pantomime: $F(1,38) = 43.11$, $p < .001$, $\eta^2_G = .30$; enacted: $F(1,38) = 22.38$, $p < .001$, $\eta^2_G = .18$). An analysis of the

simple main effects on the interaction between condition and retention time showed significant differences for both retention times (immediate: $F(2,76) = 40.52$, $p < .001$, $\eta^2_G = .38$, delayed: $F(2,76) = 67.65$, $p < .001$, $\eta^2_G = .39$). Moreover, pairwise comparisons using Bonferroni correction for immediate showed significant differences between imagined and enacted ($p < .05$) and imagined and pantomime ($p < .05$), but no significant differences between pantomime and enacted (*n.s.*). Furthermore, pairwise comparisons using the Bonferroni correction for delay showed significant differences between imagined and enacted ($p < .05$), imagined and pantomime ($p < .05$), and pantomime and enacted ($p < .05$).

In sum, the results of false alarm showed no differences between the groups. Additionally, the delayed score was higher than the immediate score, regardless of the group. The interaction between group and retention time of hit results indicated that the ASD group had lower delayed performance than the TD group, although there was no difference in immediate performance. The results of the interaction between the condition and retention time indicated that there was no difference between the immediate pantomime and enacted conditions. There was a ceiling effect in pantomime and enacted performances in both groups.

Discussion

The purpose of this study was to examine self-self-monitoring with action in people with ASD, which has not been examined previously, using subject performed tasks along with free recall and recognition. Results showed no difference between groups in reality monitoring. In free recall performance, the ASD group had a lower performance than the TD group, although the enactment effect was observed in both groups. For hit in recognition, there was no difference between the ASD and TD groups in the immediate performance, but the ASD group had lower performance than the TD group in the delayed performance. In the following, reality monitoring, free recall, and recognition are discussed in this order.

Reality monitoring

In the present study, people with ASD were impaired in the prospective mechanism (the sense of agency that occurs before an action is performed) but not in the retrospective mechanism (the sense of agency that occurs after an action is performed) (for review, see Zalla & Sperduti, 2015). Moreover, the paradigm used in this study was a retrospective mechanism, so we expected to find no difference between groups. The hypothesis was supported by the results. For example, David et al. (2008) asked participants to operate the mouse on a computer screen and then judge whether the trace of the cursor was

generated by self or others. The results showed that people with ASD were comparable to TD individuals in accuracy of identifying when the cursor was self-generated. In addition, the reality monitoring test at one week did not show a decrease in the ASD group. This suggests that people with ASD maintain their sense of agency regarding their actions over time.

In addition to the sense of agency, another possible reason for no difference being found between the ASD and TD groups was the effect of the tool presentation. In source memory study of ASD, people with ASD show the same level of memory performance as TD individuals when a cue is present. This has been proposed as the TSH (Bowler et al., 2015; Bowler et al., 2004). Although people with ASD showed impairment in executive control (Hill, 2004), such as the need to switch their thinking when identifying the source, the external information in the form of tools supported this difficulty and enabled them to identify the source efficiently.

However, we need to be cautious in interpreting the results of this study as indicating that there is no impairment in the sense of agency of people with ASD. A recent review suggests that people with ASD might have impairments in the predictive aspects of behaviour that are important to sense of agency (Malik et al., 2022). Malik et al. (2022) pointed out that the impairment of sense of agency in people with ASD may be due to

ambiguity in the prior knowledge used for top-down cues, which may poorly predict behavioural outcomes. However, the action sentences used in this study were those familiar in everyday life (e.g., holding a cup). Therefore, there was no impairment in reality monitoring due to the clarity of prior knowledge, which plays an important role in the sense of agency. Further reality monitoring research is needed, focusing on prospective mechanisms that predict behaviour with people with ASD.

Free recall

People with ASD have diminished psychological aspects of self, while their physical aspects are unimpaired (Lind, 2010). Therefore, we expected that the enactment effect would be observed in people with ASD because the encoding process of the subject performed tasks used in this study depends on the physical aspect of the self. The hypothesis was supported by the results. Enacted encoding is conducted effortlessly and automatically (Cohen, 1983; Knopf et al., 2005; Masumoto et al., 2006). Based on the results of this study, people with ASD may have also benefited from enacted encoding; as a result, their memory performance was comparable to that of the TD group.

However, when focusing on free recall performance, we expected that people with ASD would have lower performance than those with TD, because many of their impairments have been reported (Desaunay et al., 2020). This hypothesis was also

supported. In free recall, memory reconstruction is required such that memories of experienced events must be recalled in detail. The decline in performance in ASD shown in free recall reflects a decline in detailed memories for experienced events. Williams et al. (2006) postulates that at the core of memory deficits in people with ASD is a complex information-processing impairment that is affected by the increased demands of information integration. To this end, the free recall test in this study required more complex information processing than the reality monitoring test, resulting in a lower free recall rate.

Recognition

For recognition, the presented action sentence was the cue and the TSH (Bowler et al., 2004; Bowler et al., 2015) predicted that there would be no difference between groups. The hypothesis was thus partially supported. There were no differences in immediate recognition between groups. However, people with ASD performed lower than those with TD on delayed recognition. Previous studies have reported that the amount of information recalled decreases over time for people with ASD (Almeida et al., 2019; Gaigg & Bowler, 2008). This is a possible atypical characteristic of memory consolidation in people with ASD. People with ASD showed similar retention of newly learned items overnight as TDs, but a greater proportion of forgetting compared to TDs in retention one month after

learning (Fletcher et al., 2020). This is an effect of the sleep disorders that most ASD suffer from. Although we were unable to measure the sleep status of the participants in this study, it is possible that several participants in the experiment who had difficulty sleeping had ASD. According to this interpretation, memory performance should be lower for people with ASD for the delay in reality monitoring and free recall performance, but this was not the case in the present study. This discrepancy will need to be examined in the future.

Limitations and future directions

In this study, the effect size of the main effect of the group on the proportion of reality monitoring we are interested in was very small. Therefore, the validity of the result that there was no difference between the ASD and TD groups is uncertain. It is not surprising that effect sizes are small in ASD studies, but future experimental designs should be considered in the power of the test.

Further research is needed to examine in detail the relationship between the core symptoms exhibited by people with ASD and their reality monitoring performance. For example, a study of older adults reported that they would repeat the same mistakes if they could not distinguish whether they had just imagined taking the medication or had actually taken it (McDaniel et al., 2008). People with ASD also have difficulties, such as

repetition errors. Although we should be cautious in treating the repetition errors of TD and ASD equally, future direct examination of repetition errors and reality monitoring will allow us to consider support from aspects other than disability characteristics.

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Data availability statement: The data that support the findings of this study are available from the corresponding author, Kenta Yamamoto, upon reasonable request.

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Table 1. Participants' characteristics.

	ASD n = 20	TD n = 20	t-value	p-value	effect size
Age in years	27.55(4.93)	28.1(9.93)	t = -.22	n.s.	r = .04
Education in years	15.1(1.77)	15.1(1.21)	t = .00	n.s.	r = .00
Full scale IQ	102.3(11.93)	103.85(7.87)	t = -.46	n.s.	r = .07
Verbal IQ	102.05(12.51)	103.3(9.43)	t = -.36	n.s.	r = .06
Performance IQ	100.9(11.76)	103.35(9.61)	t = -.72	n.s.	r = .12
AQ total score	33.8(4.76)	15.5(6.04)	t = 10.64	p < .001	r = .87

Note: ASD = autism spectrum disorder, TD = typical development, IQ = intelligence quotient, AQ = autism-spectrum quotient, ASD and TD values are given as mean (standard deviation).

Table 2. Hit and false alarm scores in the recognition test.

		Hit			False Alarm
		Imagined	Pantomime	Enacted	
ASD	Immediate	.67 (.24)	.93 (.15)	.96 (.09)	.11 (.18)
	Delayed	.42 (.28)	.65 (.25)	.85 (12)	.23 (.23)
TD	Immediate	.75 (.22)	.97 (.05)	.98 (.04)	.02 (.05)
	Delayed	.64 (.16)	.82 (.13)	.91 (.11)	.21 (.16)

Note: ASD = autism spectrum disorder, TD = typical development, ASD and TD values are given as mean (standard deviation).

Figure Captions

Figure 1. Recognition and reality monitoring test.

Figure 2. Mean proportion of reality monitoring in the two groups. *Error bars* represent mean ±SEM.
Note: ASD = autism spectrum disorder, TD = typical development.

Figure 3. Mean proportion of correctly recalled sentences by Free recall in the two groups. *Error bars* represent mean ±SEM.
Note: ASD = autism spectrum disorder, TD = typical development.

Sentence	Yes / No		Condition		
Roll the ball	Yes	No	Imaged	Pantomime	Enacted
Line up playing cards	Yes	No	Imaged	Pantomime	Enacted
Sharpen a pencil	Yes	No	Imaged	Pantomime	Enacted
Wear glasses	Yes	No	Imaged	Pantomime	Enacted
Write with a ballpoint pen	Yes	No	Imaged	Pantomime	Enacted
Put on slippers	Yes	No	Imaged	Pantomime	Enacted
Take a cup	Yes	No	Imaged	Pantomime	Enacted
⋮	⋮	⋮	⋮	⋮	⋮

Figure 1. Recognition and reality monitoring test.

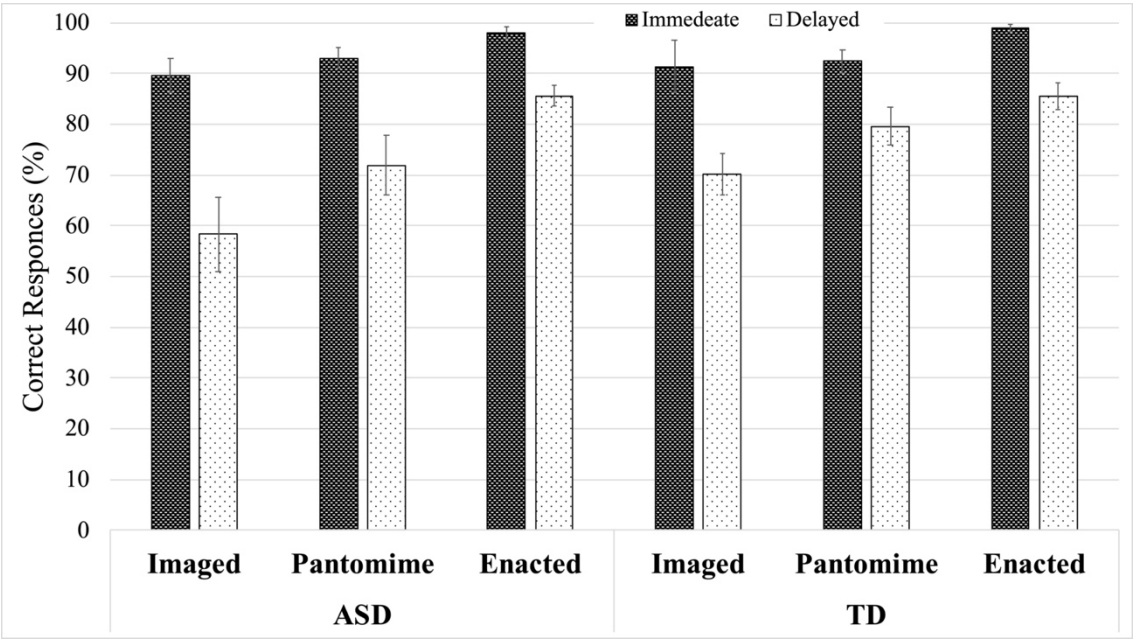

Figure 2. Mean proportion of reality monitoring in the two groups. *Error bars* represent mean ±SEM.

Note: ASD = autism spectrum disorder, TD = typical development.

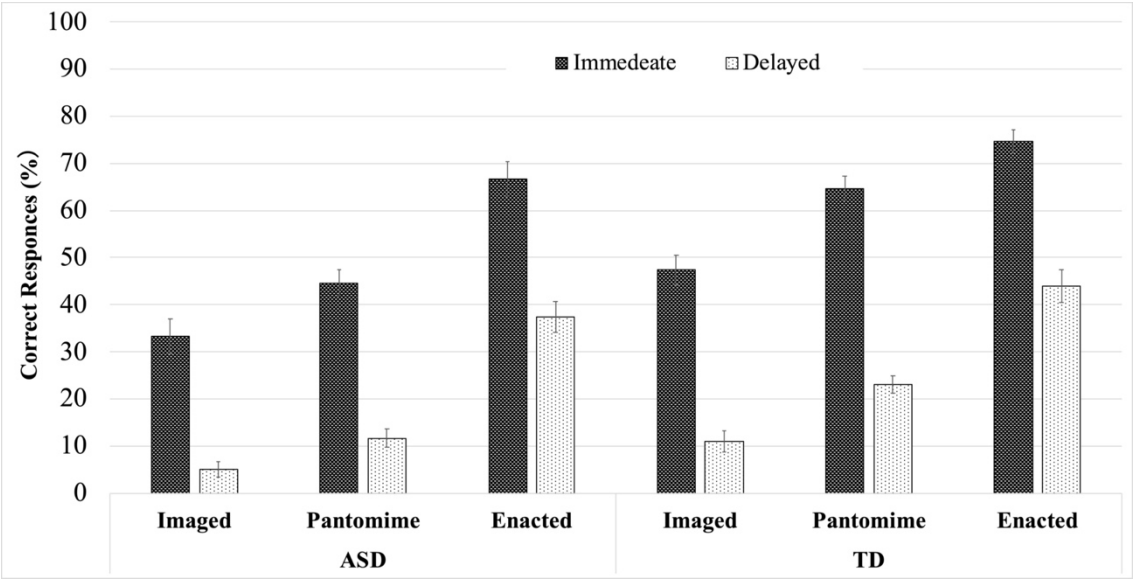

Figure 3. Mean proportion of correctly recalled sentences by Free recall in the two groups. *Error bars* represent mean ±SEM.

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