Memory for Self-Performed Actions in Adults with Autism Spectrum Disorder: Why Does Memory of Self Decline in ASD?

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Conflict of Interest

Author Kenta Yamamoto declares that he has no conflict of interest. Author Kouhei Masumoto declares that he has no conflict of interest.

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Abstract

The decline in self-related memory in ASD was investigated by using encoding, forgetting, and source monitoring. Participants memorized action sentences verbally, observationally, or by enacted encoding. Then, they underwent recall, recognition, and source monitoring memory tests immediately and one week later. If the information were properly encoded, memory performance in the enacted encoding would be the highest (Enactment effect). The result of memory tests in ASD and TD people showed that enacted encoding was superior. However, recall and source monitoring in ASD was significantly lower than in TD, which was not the case for recognition and forgetting. These results suggest that the decline in memory of self in ASD is associated with a deficit in memory reconstruction and source monitoring.

Keywords

Episodic memory, Self-performed tasks, Enactment effect, Encoding, Storage, Source monitoring.

Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder diagnosed through behavioural impairments in social-communication, as well as by fixated interests and repetitive behaviours (American Psychiatric Association, 2013). Recently, episodic memory has been focused in research on the cognitive functions of ASD. Studies have reported that ASD is marked by a decline in self-related memory (Grisdale, Lind, Eacott, & Williams, 2014; Lombardo, Barnes, Wheelwright, & Baron-Cohen, 2007; Toichi et al., 2002). These studies investigated the self-reference effect, which is the phenomenon in which memory performance improves for items remembered in association with the self. For example, Toichi et al. (2002) reported that self-reference effect was not observed in ASD. Also, Lombardo et al. (2007) established three encoding conditions, ‘self’, ‘similar close other’, and ‘dissimilar non-close other’ and presented adjectives describing personality characteristics. Participants then judged how much each adjective was related to each condition. The results of a recognition test conducted after 30 minutes showed that ASD participants had a significantly lower score for ‘self’ and ‘similar close other’ conditions compared to TD participants. However, the reasons for this decline are unclear. Therefore, the current study was designed to clarify the causes of this decline by investigating the following issues.

First, we investigated whether people with ASD could properly encode their experiences by using the Subject-Performed Tasks (SPT). In SPT, 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). To date, the enactment effect has been investigated in elderly adults who show a decline in episodic memory performance (Backman & Nilsson, 1984), Alzheimer’s disease patients (Hutton, Sheppard, Rusted, & Ratner, 1996; Karlsson et al., 1989; Masumoto, Takai, Tsuneto, & Kashiwagi, 2004) and people with Intellectual Disability (Cohen & Bean, 1983). Certain studies have also reported an intact enactment effect in ASD (Summers & Craik, 1994; Wojcik, Allen, Brown, & Souchay, 2011; Grainger, Williams, & Lind, 2014), whereas other studies have reported no such effect (Hare, Mellor, & Azmi, 2007; Zalla et al., 2010). The lack of consistent evidence prompted us to conduct a free recall test and a recognition test to verify whether the enactment effect could be observed in ASD.

Several studies using brain imaging methods such as positron emission tomography (PET), functional magnetic resonance imaging (fMRI), and magnetoencephalography (MEG) have examined the enactment effect. These studies reported that the motor cortex reactivates when remembering action sentences, not only during enactment encoding but also during retrieval (Masumoto et al., 2006; Russ, Mack, Grama, Lanfermann, & Knopf, 2003). A fMRI study reported that activity in the bilateral parietal cortices, especially in the inferior parietal cortex/supramarginal gyrus (SMG), shows a robust increase during recognition performance following enacted encoding compared with verbal encoding (Masumoto et al., 2006; Russ et al., 2003). It has also been reported that the enactment effect is not observed in patients with apraxia, and in parietal lobe deficits. Moreover, the parietal lobes and the motor cortex play an important role in the enactment effect (Masumoto, Shirakawa, Higashiyama, & Yokoyama, 2015). Neuroimaging studies of ASD have suggested abnormalities in the medial temporal lobe (Hippocampus, Amygdala, Striatum), superior temporal gyrus and the prefrontal cortex (Goh & Peterson, 2012; Ben Shalom, 2009). However, ASD shows no abnormality in the motor cortex and parietal lobes, which are considered important for the enactment effect. Therefore, we hypothesized that memory would be enhanced by the enactment in ASD.

Second, we investigated whether individuals with ASD could properly perform source monitoring of their experiences. Source monitoring is the memory for and recognition of information sources about when and where a particular memory was obtained (Johnson, Hashtroudi, & Lindsay, 1993). It is possible that the decline of the memory of self in ASD is caused by the inability to distinguish whether a particular memory is an enactment by the self or another. Previous studies have reported better source memory for "self" items than "other" items in both TD and ASD (e.g., Lind & Bowler, 2009; Zalla et al., 2010). The prefrontal cortex plays an important role in source monitoring (Turner, Simons, Gilbert, Frith, & Burgess, 2008). People with ASD have less prefrontal cortex activity compared to TD people (Ben Shalom, 2009) and functional degradation of source monitoring has been reported as a result of this (Bowler, Gardiner, & Berthollier, 2004; Lind & Bowler, 2009; Maras, Memon, Lambrechts, & Bowler, 2013; Russell & Jarrold, 1999). Therefore, we hypothesized that people with ASD compared to TD might have a deficit in distinguishing information about other's actions from their actions.

Thirdly, we conducted a free recall test, a recognition test, and a source monitoring test after one week to investigate the retention (storage) of episodic memories of the self in people with ASD. Regarding forgetting function in ASD, a study that conducted a free recall tests of words after 30 minutes reported that no significant difference was observed in the performance of ASD and TD (Southwick et al., 2011). On the other hand, a study that conducted a free recall tests of words after 1 hour and 24 hours, indicated no significant difference in the performance between ASD and TD in the test conducted after 1 hour, whereas the test conducted after 24 hours showed that ASD had significantly lower performance than TD (Gaigg & Bowler, 2008). It has been reported that enactment effects could be observed in TD after 2 minutes, 24 hours, and 1 week (Nilsson, Cohen, & Nyberg, 1989), but no studies have conducted delayed memory tests with long-term retention in ASD. The hippocampus plays an important role in establishing episodic memories (Squire, 1992). It has been reported that people with ASD have a morphological abnormality in the hippocampus (Maier et al., 2015). Therefore, we hypothesized that those with ASD compared to TD might display more forgetting over time.

Methods

Design

This experiment had a Group (2: ASD, TD) × Condition (3: Verbal, Observation, Enacted) × Retention time (2: Immediate, Delayed) design. Group was a between-participants factor, whereas Condition and Retention time were within-participants factors.

Participants

Adults (n = 14, 8 men and 6 women) with a clinical diagnosis of Autism Spectrum Disorder (ASD) according to DSM-Ⅳ and ICD-10 criteria were recruited from the Career Transition Support Office in Hyogo Prefecture, and all were formally diagnosed by a psychiatrist. Typical adults (n = 16, 7 men and 9 women) were recruited from a recruitment company. All participants were provided information about the study, and they provided their written consent for participation in the study. The ethics committee of the author's institution approved the study protocol. All procedures were carried out in accordance with the Helsinki Declaration.

Table 1 shows demographic and clinical data of the two groups (ASD and TD). We administered the WAIS-Ⅲ (WAIS-Ⅲ Japanese Version), and the Autism Spectrum Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) to the participants. Results indicated no group differences in age or WAIS-Ⅲ scores. All ASD participants scored above the suggested cut-off score of 26 on the AQ (Kurita, Koyama, & Osada, 2005; Woodbury-Smith, Robinson, Wheelwright, & Baron-Cohen, 2005), whereas all the TD participants scored under the cut-off score.

Materials

This experiment used 60 action sentences. All sentences represented intransitive actions (non-object-directed actions), such as “wave goodbye,” which were developed with reference to Cohen (1981) and by Masumoto et al. (2015). The sentences were divided into 4 lists of 15 sentences, such that the three lists comprised the Verbal, Observation, and Enactment conditions. One list was used as distractors in the recognition and source monitoring tests. Distribution of the list to each condition and distractor was counterbalanced across participants.

Procedure

Experiments were conducted individually with each participant under Verbal, Observational, and Enacted conditions. The experimenter read each sentence aloud. In the verbal condition, participants memorized the sentences that were read by the experimenter. In the observational condition, the experimenter read each sentence aloud and performed in silence, and the participants memorized the sentences by looking at them. Moreover, in the enactment condition, after the experimenter read each sentence aloud, participants performed in silence and memorized the sentences. The order of the conditions to be conducted was counterbalanced across participants. The presentation duration for each sentence was 5 seconds. To confirm whether participants could understand the procedure of the experiment, they were given two practice trials, after giving the instructions for each condition. An immediate free recall test was conducted after the presentation of the list in each condition. The experimenter required the participants to verbally recall as many action sentences as possible within three minutes. In this study, one block consisted of the time span from the presentation of a list to the end of the free recall test. After the three conditions had been tested, a yes/no recognition test and a source monitoring test was also conducted. The sentences and distractors were randomly presented on paper in the recognition and source monitoring tests (See Figure 1). Fig.1 shows the sheet used in recognition and source monitoring tests. First, participants responded yes/no to each item (yes/no recognition), and then they selected one of the three conditions to remember (source monitoring test) for item to which they responded with yes. The free recall test, a yes/no recognition test and a source monitoring test were conducted again a week later. On the first day, participants completed encoding under three condition and an immediate memory test (free recall, yes/no recognition test, and the source monitoring test). Participants were not informed that the delayed memory test would conduct. One week later, participants completed free recall, yes / no recognition test, and the source monitoring test as a delayed memory test (encoding was not done). AQ was conducted after the memory test on the first day, and WAIS-Ⅲ was administered one week later after the delayed memory test.

Results

Free recall

Figure 2 shows the free recall rate by group, condition and retention time. The free recall score was calculated by dividing the raw number of freely recalled items by the total number of items.

Free recall scores were analyzed by using a Group × Condition × Retention time mixed analysis of variance (ANOVA). The results revealed a main effect for Group (F (1,28) $=4.74$), $p<.05$, $\eta^2_G = .07$) , Condition (F (2,56) $= 47.14$ $p<.001$, $\eta^2_G = .24$) and for Retention time (F (1,28) $= 2206.08$, $p<.001$, $\eta^2_G = .62$), but no Group, Condition and Retention time interaction (F (2,56) = 2.82. *n.s.* $\eta^2_G = .01$). Pairwise comparisons using a Bonferroni correction revealed significant differences in Verbal and Enacted ($p < .05$), Observation and Enacted ($p < .05$), and between Verbal and Observation ($p < .05$).

These results show that free recall declined in ASD compared to the control group, regardless of the retention time. Both groups ranked in the order of Enacted, Observation and Verbal, regardless of the retention time. Immediate responses were higher than delayed responses, regardless of group, or condition.

Recognition

Mean recognition scores calculated by using False Alarms and Hits are shown in Table 2. False Alarm rate was analyzed by using a Group × Retention time mixed ANOVA, which revealed a main effect of Retention time (*F* (1,28) =48.26, p <.001, η^2_G = . 19). However, there was no main effect of Group (*F* (1,28) =0.38, *n.s.* η^2_G = .01). No significant interaction was observed between Group and Retention time (*F* (1,28) = 1.73, *n.s.* η^2_G = .008). Moreover, the results did not show any group differences. Additionally, the delayed score was higher than Immediate scores, regardless of the group.

Hit scores were analyzed by using a Group × Condition × Retention time mixed ANOVA, which revealed a main effect of Condition (*F* (2,56) =72.92), p <.001, η^2_G = .36), and Retention time (*F* (1,28) =48.23, p <.001, η^2_G = .14), however, there was no main effect of Group (*F* (1,28) =1.95, *n.s.* η^2_G = .04). Moreover, no significant interaction was observed between the factors (*F* (2,56) = 1.68, *n.s.* η^2_G = .005). Pairwise comparisons using a Bonferroni correction revealed significant differences between Verbal and Enacted (p < .05), Observation and Enacted (p < .05) and between Verbal and Observation (p < .05). Furthermore, the results indicated no group differences. Both groups scored high in the order, Enacted, Observation and Verbal regardless of retention time. Immediate scored higher than delayed, regardless of group, or condition.

Source monitoring

Figure 3 shows the source monitoring rate by group, condition and retention time. Source monitoring score was calculated by diving the raw number of source monitoring items by the total number of items. Source monitoring scores were analyzed by using a Group × Condition × Retention time mixed ANOVA. The ANOVA revealed main effects for Group (*F* (1,28) =4.69, p <.05, η^2_G = .06) , Condition (*F* (2,56) =28.65, p <.001, η^2_G = .30) and Retention time (*F* (1,28) =113.79, p <.001, η^2_G = .23). A significant interaction was observed between Condition and Retention time (*F* (2,56) =4.84, p <.05, η^2_G = .02). An analysis of simple main effects for the interaction between condition and retention time revealed significant differences in Retention time among all three conditions (Verbal : F (1,28) $= 64.09$, $p < .001$, $\eta^2_G = .35$, Observation ; F(1,28) $= 11.06$, $p < .01$, $\eta^2_G = .08$, Enacted ; F(1,28) $= 55.73$, $p < .001$, $\eta^2_G = .29$). An analysis of simple main effects on the interaction between condition and retention time revealed that Condition showed significant differences in both retention times (Immediate ; F (2,56) $= 19.9$, $p < .001$, $\eta^2_G = .27$, Delayed ; F (2,56) $= 25.55$, $p < .001$, $\eta^2_G = .36$). Moreover, a pairwise comparisons using a Bonferroni correction for Immediate revealed significant differences between Verbal and Enacted ($p < .05$), Observation and Enacted ($p < .05$), and between Verbal and Observation ($p < .05$). Furthermore, pairwise comparisons using a Bonferroni correction for Delayed revealed significant differences between Verbal and Enacted ($p < .05$), and Verbal and Observation ($p < .05$), but no significant differences between Observation and Enacted (*n.s.*).

These results suggested that source monitoring was poorer in ASD compared to the control group, regardless of the retention time. Both groups scored high in the order of Enacted, Observation, and Verbal. Immediate scored higher than Delayed, regardless of group, or condition. This suggests that the observation condition was not affected by the progress of time.

Discussion

The main purpose of this study was to clarify the causes of declining memory of self in ASD. First, we investigated whether people with ASD properly encoded what they have experienced. Second, we investigated whether ASD people could appropriately perform source monitoring of their experiences. Third, a week later, we conducted a free recall test, a recognition test, and a source monitoring test to verify retention (storage) for the memory of self in the episodic memory of people with ASD. The present study showed that the enactment effect was demonstrated in both ASD and TD during free recall, recognition and source monitoring tests. Memory performance in ASD was significantly lower than in TD in all the encoding conditions of free recall and source monitoring tests, although the results of the recognition test revealed no differences between ASD and TD. There were no differences between ASD and TD in the forgetting function.

In the present study, we hypothesized that encoding would be conducted appropriately, and an enactment effect would be observed in ASD, because brain regions such as the motor cortex and parietal lobe (Masumoto et al., 2015; Masumoto et al., 2006; Russ et al., 2003) involved in the enactment effect are not the areas of the brain that are abnormal in ASD people (Hippocampus, Amygdala, Striatum, Superior temporal gyrus, Prefrontal cortex; (Goh & Peterson, 2012; Ben Shalom, 2009). In this study, the enactment effect was observed in people with ASD, and the results supported our hypothesis. Bowler, Gardiner and Berthollier, (2004) have reported that the recognition memory of people with ASD declines when encoding becomes more complicated. Whereas, enacted encoding is conducted effortlessly and automatically (Cohen, 1983; Knopf, Mack, Lenel, & Ferrante, 2005; Masumoto et al., 2006). Our results suggest that the decline of self-related memory in ASD is not caused by a decline in the processing of enacted encoding.

By contrast, the comparison between groups showed that performance in ASD was lower than performance in TD, regardless of the condition of free recall or source monitoring. In free recall, memory reconstruction is required such that memories of experienced events must be recalled in detail. However, there was no recognition related difference between the groups that did not require memory reconstruction. Moreover, Hare et al. (2007) have reported that ASD participants show no difference in memory performance from TD participants when cues such as letters are provided. Thus, it is suggested that the decline in performance in ASD shown in free recall reflects a decline in detailed memories for experienced events. We hypothesized that people with ASD would have lower performance in source monitoring than people with TD because people with ASD have an abnormality in the prefrontal cortex, which plays an important role in source monitoring. The results supported our hypothesis. It should be pointed out that abnormalities in the prefrontal cortex of people with ASD are related to autonoetic consciousness which reminisces the detailed context of events experienced by the self (Bowler, Gardiner, Grice, & Saavalainen, 2000), as well as the executive function for identifying information sources (Bennetto, Pennington, & Rogers, 1996). As mentioned above, results of previous and the current study suggest that the decline of self-related memory in ASD might be related to a problem in memory that details information regarding experiences, as well as in the memory about the context of information (source monitoring).

On the other hand, the delay test conducted after one week showed no difference in the degree of forgetting between ASD and TD in free recall, recognition, or source monitoring. We hypothesized that people with ASD have an abnormality in the hippocampus (Maier et al., 2015) and that the degree of forgetting in people with ASD would be higher than in TD. The results did not support this prediction. There is no consistent evidence suggesting an abnormality in the hippocampus of people with ASD. There are reports that the hippocampus of people with ASD is small (Via, Radua, Cardoner, Happe, & Mataix-Cols, 2011). However, there are also reports that it is large in people with ASD (Schumann CM, 2004). A small hippocampus means a decline in memory function (Ohnishi, Matsuda, Tabira, Asada, & Uno, 2001), whereas a large hippocampus suggests unimpaired memory function (Woollett & Maguire, 2011). In this study, we did not assess hippocampus size of the participants. Therefore, further studies are needed to elucidate the relationship between hippocampal abnormalities and the degree of forgetting.

Limitations and future directions

Previous studies have pointed out that the enactment effect is robust in TD (Masumoto et al., 2006; Russ et al., 2003). The results of this study also indicated that the enactment effect was observed in ASD even though our sample size was not large. However, we have to be cautious about the symptom bias in ASD. Further research using a larger sample is required.

Brain imaging and neuropsychological studies have revealed brain regions related to the enactment effect and have also clarified information processing related to the enactment effect. Additionally, many studies have demonstrated the abnormal brain physiology of ASD people. Thus, we developed the hypotheses of this study based on previous research on brain functions. However, we did not measure brain activities in this study. Therefore, future studies using brain imaging techniques are necessary to examine the validity of the interpretation of our results.

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Table 1. Participant characteristics

	ASD n = 14	TD n = 16	
Age in years	30.5 (6.86)	27.88 （10.1）	$t = 0.84$, *n.s.*, $r = .16$
Education in years	15.9 (2.96)	14.5 (0.82)	$t = 1.67$, *n.s.*, $r = .30$
Full scale IQ	103.64 (9.94)	106.38 (12.58)	$t = -0.65$, *n.s.*, $r = .12$
Verbal IQ	103.50 (13.28)	106.19 (15.86)	$t = -0.50$, *n.s.*, $r = .10$
Performance IQ	102.79 (9.31)	105.19 (10.03)	$t = -0.68$, *n.s.*, $r = .13$
AQ total score	34.29 (5.06)	15.44 (4.56)	$t = 10.67$, $p < .001$, $r = .88$

Note : IQ＝Intelligence Quotient （Standard Deviations）
AQ＝Autism-Spectrum Quotient

Table 2. Hit and False Alarm scores in the recognition test

		Hit			False Alarm
		Verbal	Observation	Enacted	
ASD	Immediate	.58 (.22)	.81 (.17)	.96 (.04)	.11 (.17)
	Delayed	.46 (.26)	.67 (.20)	.74 (.20)	.26 (.22)
TD	Immediate	.67 (.21)	.86 (.14)	.97 (.05)	.12 (.17)
	Delayed	.56 (.18)	.75 (.17)	.85 (.13)	.34(.21)

（Standard Deviation）

Sentence	**Yes / No**		**Condition**		
Clapping hands	Yes	No	Verbal	Observation	Enacted
Clear throat	Yes	No	Verbal	Observation	Enacted
Cross legs	Yes	No	Verbal	Observation	Enacted
Wave good-bye	Yes	No	Verbal	Observation	Enacted
Tapping chest	Yes	No	Verbal	Observation	Enacted
Sound a tooth	Yes	No	Verbal	Observation	Enacted
Folding arms	Yes	No	Verbal	Observation	Enacted
⋮	⋮	⋮	⋮	⋮	⋮

Figure 1. Recognition test and source monitoring test

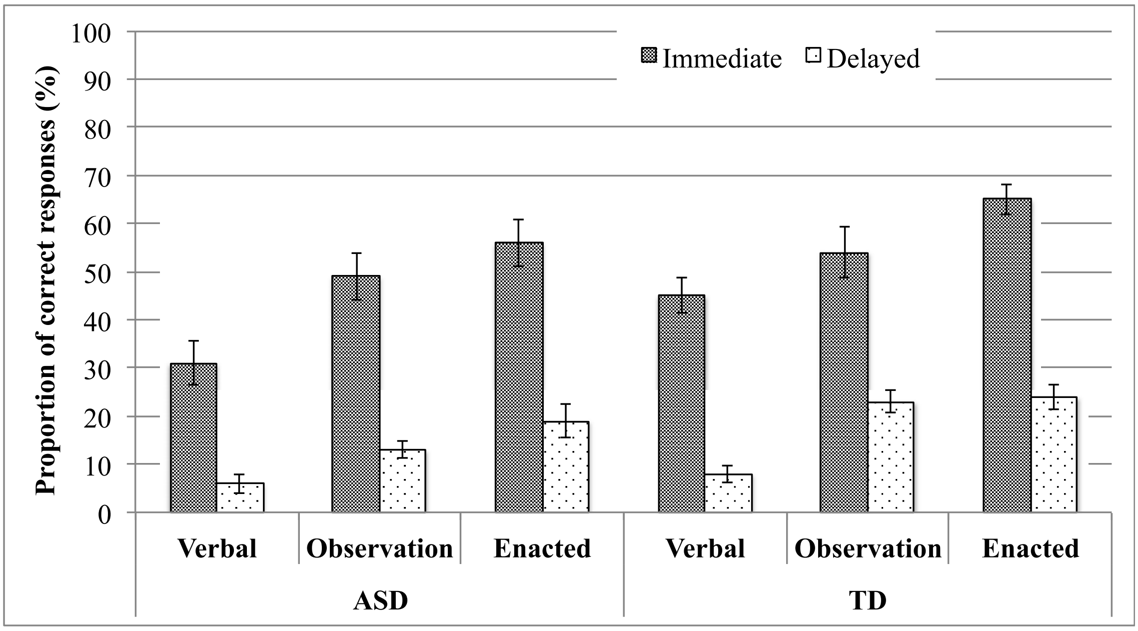

Figure 2. Mean proportion of correctly recalled sentences by Free recall in the two groups.*Error bars* represent mean ±SEM

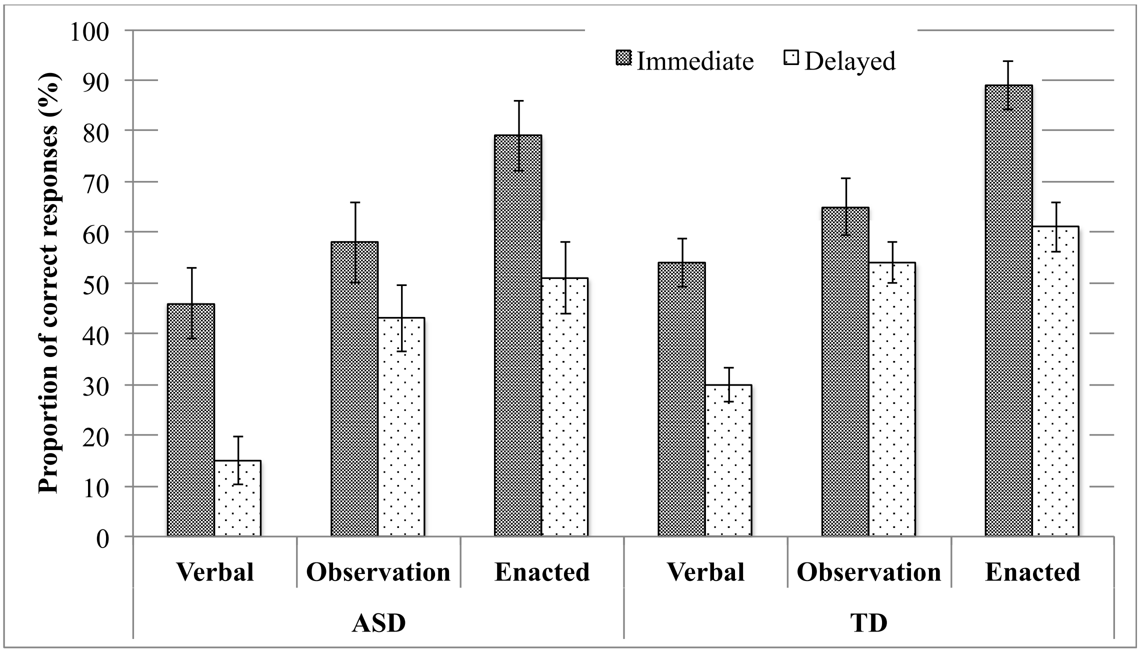

Figure 3. Mean proportion of source monitoring in the two groups. *Error bars* represent mean ±SEM