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Correlations between Syntactic Development and Verbal Memory in the Spoken Language of Children with Autism Spectrum Disorders and Down Syndrome: Comparison with Typically Developing Children

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Abstract

Correlations between syntactic development and verbal memory of children with intellectual disabilities (ID) are not well understood. These correlations were investigated in children with Autism Spectrum Disorders (ASD) with intellectual disabilities and children with Down Syndrome (DS). Thirty-seven children with ID (11 with ASD, 16 with DS, and 10 with ID not falling under ASD or DS) and a control group of typically developing (TD) children (N = 58) participated. Their verbal short-term memory was assessed using the digit span tasks. Verbal long-term memory was assessed using Rey's Auditory Verbal Learning Test (AVLT) and syntactic understanding and expression tasks. Syntactic understanding and expression scores of the disability groups were significantly lower than TD children of the same mental age (MA). AVLT's immediate recall scores were significantly lower in children with ASD, whereas, in children with DS, the digit span forward scores and immediate and delayed recall AVLT scores were significantly lower than in TD children of the same MA. Verbal short-term memory assessed by AVLT in children with ASD and the small capacity of verbal short-term memory in children with DS are correlated with syntactic development.

Keywords

Intellectual Disabilities, Autism Spectrum Disorders, Down Syndrome, Language Development, Verbal Memory

1. Introduction

Previous studies (Ito, 1998; Rondal, 1995) have indicated that the delay in the syntactic development of children with intellectual disabilities (ID) was larger than that predicted by their mental age (MA) and the mean length of utterances (MLU). It has been reported that children with ID have significantly lower scores on morphologically and syntactically complex aspects of language, compared to typically developing (TD) children with equal MA or MLU (Ricks & Wing, 1975; Pierce & Bartolucci, 1977; Tager-Flusberg, 1981; Chapman, Schwartz, & Kay-Raining, 1991; Chapman, Seung, Schwartz, & Kay-Raining, 1998; Miller, 1988). Moreover, it is possible that factors other than the intellectual development level, such as the characteristics of the disability and individual differences, might affect syntactic development (Otomo, 2001).

One of the factors that might affect syntactic development is short-term phonological memory, which is known to be an essential cognitive function for acquiring language (Baddeley, Gathercole, & Papagno, 1998), which corresponds to the phonological loop in the working memory system, proposed by Baddeley (2012). Previous studies have reported that short-term phonological memory might have been correlated with the development of syntactic aspects of language (Channell, McDuffie, Bullard, & Abbeduto, 2015; Fukamizu & Fujita, 2014; Matsumoto, 1999; 1993). For example, in relation to the comprehension aspects of language, Fukamizu and Fujita (2014) conducted a syntactic comprehension test and a nonword repetition test with 39 to 74 months-old TD children. They reported significant correlations between syntactic comprehension levels and nonword memorization, suggesting that the expansion of short-term phonological memory might facilitate the understanding of sentences with more complex syntactic structures. Moreover, it has been suggested regarding the expressive aspects of language that phonological short-term memory level might be one factor in predicting MLU of spoken language (Adams & Gathercole, 1995; 1996). Furthermore, Baddeley et al. (1998) suggested that verbal short-term memory disorders might inhibit the acquisition of vocabulary and grammatical morphemes in the early stages of language development that could result in disorders of syntactic expression. As described above, syntactic development might be closely correlated with short-term phonological memory, which is an essential cognitive function in the development of comprehension and expression of syntax.

It has been suggested that verbal short-term memory of many children with ID could be damaged, which might somewhat limit their language development. For example, children with Down Syndrome (DS) have verbal short-term memory disorders (Baddeley, 1986; Wang & Bellugi, 1994; Jarrold & Baddeley, 1997; Kanno & Ikeda, 2002) that affect their language development, including difficulties in acquiring verbs with a critical role in connecting words (Loveall, Cannell, Phillips & Conners, 2019; Channell et al., 2015), or, difficulties in understanding and expressing grammatical morphemes (Koizumi, Saito & Kojima, 2019; Miolo, Chapman & Sindberg, 2005). On the other hand, it has been reported that abilities such as understanding vocabulary and sentences, as well as reading and writing words and sentences in individuals with DS are similar to individuals with ID, suggesting that verbal short-term memory might not affect these abilities in individuals with DS (Nummine, Service, Ahonen & Ruoppila, 2001), which is inconsistent with the findings by Baddeley et al. (1998). This difficulty might be affected not only by the phonological short-term memory capacity, but also by the phonological long-term memory capacity and other cognitive processing functions including converting short-term memory to long-term memory, memory retrieval, and semantic information processing, among others.

Previous studies have reported the following characteristic profiles of children with Autism Spectrum Disorder (ASD) based on the Wechsler Intelligence Scale subtests. Children with ASD have high "Digit Span scores," which require phonological encoding and recall, whereas they have low "Comprehension," which requires using the context (Happe, 1994; Kamio & Toichi, 2003; Lincoln, Courchesne, Kilman, Elmasian & Allen, 1988). Moreover, Fein et al. (1996) investigated short-term memory of preschool children using language materials with different levels of semantic structure complexity (numbers, sentences, and stories) and reported that children with ASD accompanied by intellectual disabilities and children with low nonverbal intelligence quotient (NALIQ) had identical memory for numbers, whereas ASD children's memory for sentences and stories was significantly lower than that of NALIQ children. The above findings suggest that children with ASD tend to have difficulties in encoding linguistic information having a complex semantic structure, although they can efficiently encode information on numbers. Therefore, some children might have difficulties in understanding and expressing complex sentences and conversations, although they seem to acquire ample vocabulary normally and do obtain high digit span scores, which is a conventional procedure for assessing verbal short-term memory.

In the present study, the development of memory in children with ASD or DS was investigated by comparing them with TD children of the chronological age of 4 - 6 years. Moreover, correlations between phonological memory and syntactic development were also examined.

2. Methods

2.1. Participants

Thirty-seven children with ID with chronological age (CA) ranging from 6 years and 7 months to 18 years and 3 months and having a MA of 4 years or older were divided into three groups: 11 with ASD, 16 with DS, and 10 with ID not falling under ASD or DS. Interviews with teachers and guardians established that all the participants spoke more than 2 - 3 words on a daily basis, did not have any hearing impairments that interfered with daily conversation and had a diagnosis of ASD, DS, or another clinical condition.

The control group consisted of 58 TD children ranging from CA 4 years and 0 months to 6 years and 7 months. The TD group was divided based on CA as a 4-year-old group, a 5-year-old group, and a 6-year-old group, compared with the ID groups having a similar MA. CA, MA, Intelligence Quotient (IQ), and other data for each group are shown in Table 1.

The research was approved by the Human System Ethics Committee of the University of Tsukuba and conducted with the consent of the participant and guardian. Participation was solicited, and data was collected from special education schools, disability centers, Down Syndrome parent groups, university educational advisory offices, and nursery schools in the Kanto area.

2.2. Procedures

2.2.1. Syntax Comprehension Tasks

The Japanese Test for Comprehension of Syntax and Semantics (J.COSS; Nakagawa, Koyama, & Suga, 2010) was used to assess grammar understanding among the participants. J.COSS is a grammar understanding test that is based on the Test for Reception of Grammar (TROG; Bishop, 1989) and L' É.CO.S.SE (Lecocq, 1996) and standardized based on native Japanese speaking children from 3 to 12 years old (N = 390). Procedures and structure are drawn primarily from TROG, but additional items unique to Japanese have been added for number words, case markers, and multi-element combination sentences (Nakagawa, Koyama, & Suga, 2005).

Tests were administered one-to-one with the examiner instructing the participant to "point to the correct picture" from among four choices. Other procedures and scoring were conducted following the J.COSS administration manual,

Table 1. Participant characteristics.

		target group			control group		
					TD		
		ASD	DS	ID	4 years	5 years	6years
		(n = 11)	(n = 16)	(n = 10)	(n = 16)	(n = 19)	(n = 23)
CA	Range (months)	89 - 208	104 - 217	79 - 219	48 - 59	60 - 69	72 - 79
	Mean (months)	150.6	163.4	155.9	52.3	64.1	74.4
	SD (months)	33.8	30.7	47.1	3.8	3.2	2.1
MA	Range (months)	60 - 102	57 - 80	50 - 88	48 - 59	60 - 69	72 - 79
	Mean (months)	78.5	67.8	70.9	52.3	64.1	74.4
	SD (months)	14.9	7.4	12.8	3.8	3.2	2.1
IQ	Range (months)	35 - 83	26 - 62	30 - 78	-	-	-
	Mean (months)	56.5	43.1	49.5	-	-	-
	SD (months)	14.6	8.3	18.1	-	-	-

*MA of TD children may show lower or higher MA values than CA. We consider that the mean of MA developed at the same level as the mean of CA. Therefore, we described the same value as the mean of CA in the mean of MA. Using a one-way ANOVA, there was no significant difference between MA and CA in ASD, DS and ID groups.

and calculations were made for correct answer rates per item as well as the number of passed items (maximum 20, minimum 0).

2.2.2. Syntax Expression Tasks

Syntax expression tasks (**Table 2**) were taken in part from the assessment tasks used in previous research (Koizumi et al., 2019).

A total of 27 task sentences were decided for collecting naturally spoken responses from the participating children, based on a preliminary test conducted with 12 healthy adults (graduate students in their 20s) who were asked to make statements such as "X is doing Y" or "X is doing Y with Z" in reference to illustrated cards depicting actions by familiar animals or people.

Table 2. Task statements (Koizumi, Saito, & Kojima, 2019).

"***ga***" = the subjective case	"***ni***" = the case indicating the attached place
Neko ***ga*** *naiteiru* (a cat **is** crying)	*Usagi ga basu* ***ni*** *notteiru* (a rabbit is riding **on** the bus)
Tori ***ga*** *neteiru* (a bird **is** sleeping)	*Kuma ga isu* ***ni*** *suwatteiru* (a bear is sitting **on** a chair)
Saru ***ga*** *okotteiru* (a monkey **is** angry)	*Kaeru ga happa* ***ni*** *notteiru* (a frog is riding **on** a leaf)
"***wo***"* = the objective case (Irreversible Sentences)	"***kara***" = the case indicating the starting place or time
Saru ga ringo ***wo*** *tabeteiru* (a monkey is eating an apple)	*Inu ga kuruma* ***kara*** *oriru* (a dog is getting **out of** the car)
Usagi ga bôru ***wo*** *nageteiru* (a rabbit is throwing a ball)	*Saru ga reizouko* ***kara*** *aisu wo dasu* (a monkey is taking out ice cream **from** the refrigerator)
Panda ga te ***wo*** *aratteiru* (a panda is washing his hands)	
"***wo***"* = the objective case (Reversible Sentences)	*Buta ga tana* ***kara*** *hako wo toru* (a pig is unloading a box **from** the shelf)
Nezumi ga tori ***wo*** *oikakeru* (a mouse is chasing a bird)	"***de***" = the case indicating the tools
Usagi ga saru ***wo*** *tataiteiru* (a rabbit is hitting a monkey)	*Panda ga supûn* ***de*** *tabeteiru* (a panda is eating **with** a spoon)
Usagi ga kuma ***wo*** *okoshiteiru* (a rabbit is waking a bear up)	*Inu ga syaberu* ***de*** *ana wo hour* (a dog is digging a hole **with** a shovel)
"***de***" = the locative case	*Tori ga tonkachi* ***de*** *tataiteiru* (a bird is hitting a nail **with** a hammer)
Kuma ga kouen ***de*** *asondeiru* (a bear is playing **in** the park)	
Nezumi ga kawa ***de*** *sakana wo tutteiru* (a rat is fishing **in** the river)	
Panda ga pûru ***de*** *oyoideiru* (a panda is swimming **in** the pool)	

*Case particles and the voice, which were the objects of analysis are shown in bold. "wo" = the accusative case: In English, the accusative case is expressed by placing a noun after a verb. In Japanese, on the other hand, it is expressed by placing "wo" after a noun.

Procedures and scoring method were also based on Koizumi et al. (2019), and criteria for assessment were established as: "acquired" for 2 or more correct responses out of 3, "somewhat acquired" for one correct response, and "not acquired" for all else to calculate the number of acquired case markers (7 total).

2.2.3. Auditory Short-Term Memory Assessment

Auditory short-term memory and working memory were assessed through forward and backward digit span. Total score and span units were determined in accordance with the procedures and scoring method of the Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV; Wechsler, 2003; The Japanese WISC-IV publication committee, 2010). Rather than the digit span list provided in WISC-IV, an original list of 2 to 9 digits was created for this study. After providing a first and second series, the task was discontinued if the participant responded incorrectly for the same digit for both series.

2.2.4. Auditory Long-Term Memory Assessment

The Modified Rey's Auditory Verbal Learning Test (AVLT) for Japanese children was used to assess immediate recall for short-term memory, delayed recall for long-term memory, and recognition (the ability to recognize whether something was previously known) (Shiba et al., 2006).

The Modified Rey's Auditory Verbal Learning Test (AVLT) for Japanese children (herein referred to as "AVLT") relies on the standard methods of the AVLT by Spreen and Strauss (1998) but has been adapted for preschool-age children in terms of the number and type of words and method of instruction. Words in AVLT developed by Shiba et al. (2006) were selected by considering the following conditions by referring to the words used in the original AVLT (Spreen & Strauss, 1998) and the words used in AVLT adopted for adult clinical settings in Japan (Konno, 2001; Tanaka, 1998); 1) high frequency and familiarity and understandable to 2 - 3-year-old children, 2) 2 - 4 mora length words, 3) well-balanced word categories, and 4) obstructive nouns used in the recognition test include words semantically or phonologically similar to the words in the original list. The delayed recall (the 7th trial) was conducted 20 minutes after conducting the 6th trial.

Calculations of immediate recall (first trial), delayed recall (seventh trial), and recognition rate (Forrester & Geffen, 1991; Shiba et al., 2006) was analyzed to contemplate the relationships between syntactic development and three primary components of memory: short-term memory, long-term memory, and recognition.

The recognition rate was calculated as the percentage of false positives (FP), that is, the total items in entire recognition test (33 words) that were falsely recognized from the interference list or falsely recognized obstructive nouns using the following formula: 0.5 (1 + (Hit Rate-FP) (maximum 1.0, minimum 0.5)). The proportion of words recognized on list A was taken as the Hit Rate.

2.2.5. Intellectual Ability Assessment

The Tanaka-Binet Intelligence Scale (Tanaka Institute for Educational Research,

2003) was used for calculation of MA and IQ.

3. Results

Tables 3-5 show the results of testing and task performance for each TD age group and each disability group.

Table 3. Syntax comprehension from the viewpoint of grammatical functions.

Grammatical functions	No.	Iteams	ASD	DS	ID	TD		
						4 years	5 years	6 years
			(n = 11)	(n = 16)	(n = 10)	(n = 16)	(n = 19)	(n = 23)
the number of components	1	nouns	100.0	100.0	100.0	100.0	100.0	100.0
	2	adjectives	100.0	100.0	100.0	100.0	100.0	100.0
	3	verbs	100.0	100.0	100.0	100.0	100.0	100.0
	4	two-factor combining sentences	100.0	100.0	100.0	100.0	100.0	100.0
	5	negative sentences	100.0	87.5	100.0	100.0	100.0	100.0
	6	three-factor combining sentences	100.0	93.8	100.0	93.8	100.0	100.0
	10	sentences combining multiple-factors	45.5	31.3	50.0	31.3	73.7	87.0
perspectives	7	reversible sentences	100.0	62.5	80.0	81.3	100.0	100.0
	14	passive sentences	36.4	12.5	10.0	25.0	36.8	56.5
conjunction particles	8	not X but also Y	63.6	37.5	30.0	68.8	63.2	91.3
	9	X, but Y is different	45.5	25.0	40.0	31.3	63.2	73.9
	11	both X and Y are different	18.2	18.8	20.0	31.3	36.8	56.5
particle strategies	12	position words	36.4	12.5	10.0	37.5	57.9	73.9
	15	comparative expressions	18.2	0.0	0.0	18.8	31.6	60.9
	19	nominative particle	0.0	0.0	10.0	6.3	15.8	34.8
sentence structures	13	subject modifier (left-branching)	9.1	6.3	10.0	18.8	47.4	52.2
	17	predicate modifiers	0.0	0.0	0.0	0.0	15.8	39.1
	20	subject modifier (center-embedded sentences)	0.0	0.0	0.0	0.0	0.0	0.0
numerical expressions	16	numeral	63.6	12.5	0.0	0.0	5.3	39.1
	18	plural form	63.6	12.5	20.0	18.8	10.5	69.6
The average number of passed items			11.0	8.1	8.8	9.6	11.6	14.3
(*SD*)			(2.0)	(2.0)	(1.6)	(2.5)	(2.3)	(3.1)

*The results were significantly lower than 50%.

Table 4. The mean number of acquired case particles.

		"*ga*"	"*wo*"		"*de*"	"*ni*"	"*kara*"	"*de*"	total
			Irreversible	Reversible					
ASD	Mean	2.0	1.8	1.4	1.8	1.6	0.6	1.3	4.8
(n = 11)	SD	(0.0)	(0.4)	(0.9)	(0.6)	(0.8)	(0.8)	(0.8)	(1.6)
DS	Mean	1.9	1.4	0.8	1.0	1.6	0.3	0.9	3.1
(n = 16)	SD	(0.3)	(0.7)	(0.8)	(0.8)	(0.7)	(0.7)	(0.9)	(1.7)
ID	Mean	2.0	1.5	1.3	1.2	1.6	0.8	1.1	4.3
(n = 10)	SD	(0.0)	(0.7)	(0.9)	(0.9)	(0.8)	(0.9)	(1.0)	(1.9)
4 years	Mean	1.7	1.2	1.2	1.9	2.0	1.3	1.8	4.9
(n = 16)	SD	(0.7)	(0.9)	(0.8)	(0.3)	(0.0)	(0.9)	(0.4)	(1.5)
5 years	Mean	2.0	1.5	1.5	1.9	1.9	1.6	1.9	5.8
(n = 19)	SD	(0.0)	(0.7)	(0.7)	(0.2)	(0.3)	(0.7)	(0.5)	(1.2)
6 years	Mean	2.0	1.8	1.6	1.8	1.9	1.8	1.8	6.0
(n = 23)	SD	(0.0)	(0.5)	(0.7)	(0.5)	(0.4)	(0.5)	(0.6)	(1.0)

*The results were significantly lower than 1.50.

Table 5. Average score and SD for each memory task.

Task			ASD		DS		ID		TD					
									4 years		5 years		6 years	
			(n = 11)		(n = 16)		(n = 10)		(n = 16)		(n = 19)		(n = 23)	
			Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
Digit Span	Forward	Total score	6.8	(1.5)	4.1	(1.6)	4.7	(1.6)	4.7	(1.4)	5.1	(1.2)	5.8	(1.5)
		Span units	4.7	(0.8)	3.4	(0.8)	3.5	(0.7)	3.6	(0.8)	3.9	(0.7)	4.1	(0.8)
	Backward	Total score	3.5	(1.6)	2.0	(1.5)	2.3	(2.4)	0.9	(1.2)	2.2	(1.3)	3.0	(1.6)
		Span units	3.0	(1.3)	2.0	(1.2)	2.2	(1.8)	1.1	(1.3)	2.2	(1.1)	2.6	(1.1)
AVLT	Recll	1st (Immediate Recall)	2.4	(1.4)	1.6	(1.0)	2.5	(2.1)	2.1	(1.7)	2.6	(1.4)	3.7	(1.7)
		2nd	4.4	(2.4)	3.3	(1.0)	4.3	(1.8)	3.5	(1.7)	4.1	(1.1)	5.1	(1.6)
		3rd	6.5	(2.2)	3.7	(1.7)	5.3	(1.9)	3.8	(2.0)	5.0	(2.1)	6.1	(2.2)
		4th	6.0	(3.4)	5.0	(2.1)	6.1	(1.8)	4.5	(2.2)	5.2	(2.2)	5.9	(2.6)
		5th	7.1	(2.1)	5.2	(2.2)	6.2	(1.4)	4.6	(2.1)	5.6	(2.0)	7.0	(2.3)
		6th (After Interference Recall)	4.7	(3.0)	3.7	(2.5)	5.8	(1.3)	3.3	(2.3)	4.5	(2.4)	5.7	(2.5)
		7th trial (Delayed Recall)	4.7	(2.9)	3.4	(2.4)	5.2	(1.8)	3.6	(2.4)	4.8	(2.1)	5.8	(2.5)
		Interference Recall	4.3	(2.0)	2.5	(1.2)	3.2	(2.3)	3.1	(1.4)	2.9	(1.5)	4.1	(1.9)
	Recognition	Correct Recognition	5.9	(3.7)	7.3	(2.4)	7.0	(2.6)	6.6	(2.9)	8.1	(2.2)	8.8	(1.7)
		Number of words falsely recognized from the interference list	7.8	(2.9)	4.4	(3.3)	6.6	(2.0)	7.3	(2.4)	7.1	(2.9)	8.7	(2.0)
		Number of words falsely recognized from the obstructive nouns	10.5	(3.9)	6.9	(4.2)	9.9	(2.2)	11.2	(3.2)	11.2	(3.2)	12.0	(1.8)
		Recognition rate	0.8	(0.2)	0.6	(0.2)	0.8	(0.1)	0.8	(0.2)	0.8	(0.2)	0.9	(0.1)

3.1. Relationship between Various Types of Memory and Syntax Understanding and Expression (TD Children Results)

One-way ANOVA was used with age as an independent variable and the number of passed J.COSS items as a dependent variable to determine if there was a difference in the development of syntax understanding between age groups; a significant difference was revealed ($F(2) = 15.09$, $p < 0.01$, $\eta^2 = 0.35$). Bonferroni multiple comparisons also revealed significant differences between each age group (4 years old and 6 years old: $p < 0.01$, 5 years old and 6 years old: $p < 0.01$). The same procedures used with syntax expression also indicated a significant difference ($F(2) = 4.44$, $p < 0.05$, $\eta^2 = 0.14$). Bonferroni multiple comparisons revealed a significant difference between the 4-year-old group and the 6-year-old group ($p < 0.05$). This suggested that in the TD group, performance on syntax understanding and expression improves with increasing age and that it becomes possible to understand and express more complex structures grammatically.

Next, a 3 (4 years old, 5 years old, 6 years old) × 5 (forward scores, backward scores, immediate recall, delayed recall, recognition) two-way ANOVA was conducted with age and memory type as independent variables and performance on each memory task as dependent variables to determine types of memory that influence the development of syntax understanding and expression. The results indicated a significant main effect of age ($F(2) = 19.46$, $p < 0.01$, $\eta^2 = 0.06$) and memory type ($F(4) = 69.29$, $p < 0.01$, $\eta^2 = 0.45$), whereas interactions were not confirmed ($F(8) = 1.37$, *n.s.*, $\eta^2 = 0.02$). Simple main effect tests indicated a significant main effect of age for each age group (4-year-old group: $F(4) = 17.26$, $p < 0.01$; 5-year-old group: $F(4) = 22.87$, $p < 0.01$; 6-year-old group: $F(4) = 35.15$, $p < 0.01$), and Bonferroni multiple comparison showing that higher scores were achieved by 5 years old more than 4 years old, and 6 years old more than 4 years old and 5 years old, suggests that performance for each memory type improves with increasing age. Simple main effect tests for memory type indicated significance for backward scores in digit span tasks and AVLT immediate recall and delayed recall (respectively, $F(2) = 7.96$, $p < 0.01$; $F(2) = 4.95$, $p < 0.01$; $F(2) = 9.46$, $p < 0.01$), which suggests that performance improves with increasing age. There was no significant difference, however, for forward scores in digit span tasks and AVLT recognition (respectively, $F(2) = 2.47$, *n.s.*; $F(2) = 0.07$, *n.s.*), suggesting that there is no remarkable change between age groups.

The above findings indicate that performance on memory tasks improves significantly with increasing age, except for forward-task scores in digit span tasks and AVLT recognition. This suggests that the development of complex syntactic understanding and expression may be most related to performance on backward scores digit span tasks and immediate recall and delayed recall AVLT tasks.

3.2. Relationship between Various Types of Memory and Syntax Understanding and Expression (ASD and DS Results)

Delayed types of memory in the ID groups were considered through comparison against TD group results. Kruskal-Wallis H-tests were conducted to compare each disability group against the TD groups to determine any differences in syntax understanding and expression tasks. Significant differences were revealed for all disability groups compared to the TD groups for syntax understanding and expression ($p < 0.01$ and $p < 0.05$, respectively). To determine the degree of delay, Mann-Whitney U-tests were conducted for comparison of performance between each of the TD age groups and each of the disability groups (**Figure 1**, **Figure 2**). The results indicated that the ID group had lower scores for the understanding aspect, compared to the TD groups with a CA of 5 and 6 years ($U = 20.79$, $p < 0.01$; $U = 33.58$, $p < 0.01$, respectively). Moreover, the ID group had lower scores in the expression aspect than the TD group with a CA of 6 years ($U = 21.00$, $p < 0.01$). The ASD group and the DS group were compared against the TD groups by using the same analysis, which indicated that the ASD group had lower scores both understanding and expression aspects than the TD group with a CA of 6 years ($U = 18.93$, $p < 0.05$; $U = 17.96$, $p < 0.05$, respectively). The understanding was significantly lower in the DS group compared to the CA 5 and

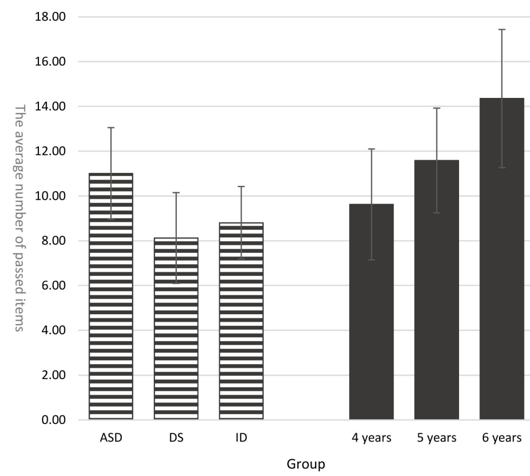

Figure 1. Average number of items passed by J.COSS.

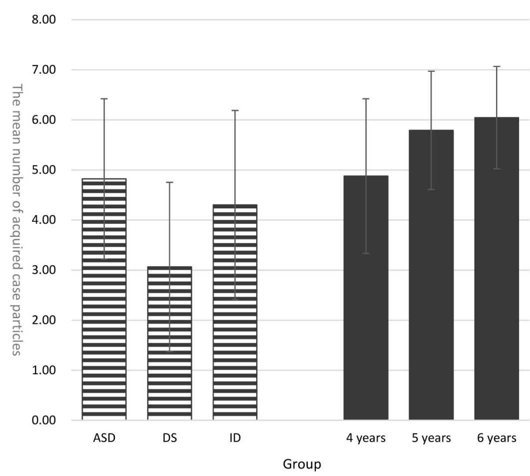

Figure 2. The mean number of acquired case particles.

6-year-old TD group (respectively, $U = 26.32$, $p < 0.01$; $U = 39.27$, $p < 0.01$), and significantly lower for expression compared to CA 4 years old, 5 years old, and 6 years old in the TD group (respectively, $U = 20.20$, $p < 0.01$; $U = 27.70$, $p < 0.01$; $U = 33.71$, $p < 0.01$).

Next, a 2 × 5 two-way ANOVA was conducted to compare the disability groups and TD groups of the same MA and determine what types of memory are delayed. Although there were significant main effects for both target ($F(1) = 6.95$, $p < 0.01$, $\eta^2 = 0.02$) and memory type ($F(4) = 32.33$, $p < 0.01$, $\eta^2 = 0.40$) among the ID groups, there was no interaction ($F(4) = 0.32$, *n.s.*, $\eta^2 = 0.00$). Using the same method of analysis to compare the ASD group to TD groups of the same MA, although there was no significant difference for the main effect of target ($F(1) = 0.57$, *n.s.*, $\eta^2 = 0.00$), results revealed a significant difference for the main effect of memory type ($F(4) = 41.73$, $p < 0.01$, $\eta^2 = 0.47$), and further, interaction ($F(4) = 2.62$, $p < 0.05$, $\eta^2 = 0.03$). Simple main effect tests for memory type revealed a significant difference for AVLT immediate recall ($p < 0.05$) and significantly lower performance on AVLT immediate recall in the ASD group compared to TD groups of the same age. In the DS group, although the main effects of both target ($F(1) = 13.11$, $p < 0.01$, $\eta^2 = 0.04$) and memory type ($F(4) = 36.87$, $p < 0.01$, $\eta^2 = 0.44$) were both significant, there was no interaction ($F(4) = 1.19$, *n.s.*, $\eta^2 = 0.01$). The results of multiple comparisons using the Bonferroni method indicated that the DS group had significantly lower digit span forward task scores, as well as AVLT immediate and delayed recall scores than the TD groups with the same MA ($p < 0.05$; $p < 0.05$; $p < 0.01$, respectively).

Next, comparisons were made between the three disability types to identify disability characteristics. Kruskal-Wallis H-tests comparing syntax understanding and expression performance among the three groups revealed significant differences (respectively, $p < 0.01$; $p < 0.05$). Bonferroni multiple comparisons indicated that there was a significant difference only for the combination of ASD group and DS group concerning both understanding and expression tasks and that the DS group had significantly lower performance compared to the ASD group (respectively, $p < 0.01$; $p < 0.05$).

A 3 (ID group, ASD group, DS group) × 5 (forward scores, backward scores, immediate recall, delayed recall, recognition) two-way ANOVA was conducted using target and memory type as independent variables and performance on each of the memory tasks as dependent variables to identify any differences in performance by memory type. Although the main effects of target ($F(2) = 10.52$, $p < 0.01$, $\eta^2 = 0.06$) and memory ($F(4) = 37.94$, $p < 0.01$, $\eta^2 = 0.43$) were both significant, there was no significant interaction ($F(8) = 1.70$, *n.s.*, $\eta^2 = 0.04$). Bonferroni multiple comparisons indicated significantly lower performance in the DS group than in the ID group and the ASD group ($p < 0.05$; $p < 0.01$). Moreover, a significant difference was shown in the digit span forward task and AVLT delayed recall (respectively, $p < 0.01$; $p < 0.05$), whereas no significant difference was shown in other tasks.

4. Discussion

This study examined correlations between syntactic development and phonological memory for the spoken language in children with ASD and DS having intellectual disabilities by comparing them with TD children.

It has been suggested that syntactic abilities and verbal memory of TD children, especially, the digit-span backward scores, as well as immediate recall and delayed recall scores on the AVLT, increase with age. However, significant age-dependent differences have not been observed in the digit-span forward and AVLT recognition tasks.

Uehara (2008) suggested that the short-term memory capacity for a numerical series increases from 2 to 3 digits from 2-year-old to 3-year-old TD children. However, then the rate of increase declines, such that they can remember four numbers around the age of 5 years and five numbers after reaching 6 years of age. It is suggested that the development of verbal short-term memory in TD children might be rather slow. A previous study has indicated that the immediate recall score on the AVLT of preschool TD children increased only slightly or did not change significantly (Shiba et al., 2006; Bishop, Knights & Stoddart, 1990). The results of the current study also indicated no significant changes in the mean values of each age group (**Table 5**). The above findings suggest that the phonological short-term memory capacity of preschool TD children might not change significantly and might not influence the development of syntactic comprehension and the expression of morphologically and syntactically complex aspects of language.

On the other hand, the syntactic comprehension and expression scores of ASD and DS groups were significantly lower than the TD groups with the same MA. Moreover, the AVLT immediate recall scores of the ASD group, and the digit span forward task scores, AVLT immediate and delayed recall scores of the DS group, were significantly lower than the TD groups with the same MA. This suggests that the development of syntactic comprehension and expression in the complex aspects of children with ID might be affected by the verbal memory ability requiring semantic language information processing, such as AVLT immediate and delayed recall scores.

Fein et al. (1996) reported differences in language scores (numbers and words) of children with ASD. The results of the current study (**Table 5**) also suggest that children with ASD could easily encode phonological level information such as numbers, whereas it is rather difficult for them to encode lexical level information with complex semantic structures. The above results suggest that AVLT scores evaluating lexical memory might correlate more highly with syntactic development than digit span task scores evaluating phonological level memory. The results of this study indicated that high scores for understanding complex grammar and expression were not always observed despite having high digit span scores. Furthermore, short-term memory processing related to phonemes, such as numbers and meaningless sounds, might be different from processing short-term memory related to semantic language information.

On the other hand, it was difficult for children with DS to encode phonological and lexical level language information, suggesting that their verbal short-term memory might be more significantly damaged, compared with other disabilities. Moreover, the number of delayed recalls in the DS group was significantly lower than in the ASD, ID, and TD groups with the same MA, suggesting that DS children's verbal long-term memory might also be damaged. The poor verbal long-term memory of children with DS might be caused by the problems in their verbal short-term memory. A previous study has reported that children with DS showed lower scores for recalling words presented earlier in the word-list task, compared to the words presented later (Jarrold, Baddeley, & Hews, 2000). Yuzawa (2011) interpreted the above result as indicative of the limited verbal short-term memory capacity of children with DS, which prevents them from retaining the memory of words presented earlier. The DS group in this study showed significantly lower digit span forward and AVLT immediate recall scores than the TD group with the same MA, which is suggestive of the small verbal short-term memory capacity in children with DS. Children with DS might convert less information into long-term verbal memory because of the small capacity of their short-term verbal memory, which might damage their long-term verbal memory and influence their linguistic development. Therefore, short-term verbal memory disorders in children with DS might have severe effects on their syntactic development because of the above considerations.

Recently, the following hypothesis has been proposed, and previous studies have explained it through case studies (Martin & He, 2004; Martin & Allen, 2008; Hanten & Martin, 2000). The verbal short-term memory is composed of a short-term phonological store that is involved in the phonological loop and a short-term semantic store that is involved in the retention of words and clauses. According to the above hypothesis, children with ASD might have a similar or a larger phonological short-term store than TD children with the same MA, although their semantic short-term store is damaged. On the other hand, children with DS might have a smaller phonological short-term store capacity and the semantic short-term store might be significantly damaged.

The present study indicated differences in the verbal short-term memory depending on the disability type. As shown in **Table 3**, children with each disability type had significantly lower scores than TD children in morphologically and syntactically complex aspects, such as passive sentences, position words, and conjunctive particles, i.e., items requiring semantic language information processing. On the other hand, children with ASD could nearly completely understand sentences with a simple structure, such as three-word sentences, negative sentences, and reversible sentences, whereas some children with DS could not understand simple sentences. Moreover, many of the children with DS had difficulty using various grammatical morphemes in the expression tasks and often used short and simple sentences or words (**Table 4**). The results above suggest that the small semantic short-term store capacity of children with ASD might affect their syntactic development, whereas the small phonological short-term store capacity of children with DS might affect their syntactic development. Therefore, tasks involving simple sentence structures, such as 2 - 3-word sentences, might be useful for children with ASD, whereas such tasks might be difficult for children with DS. It is necessary to examine interventions for children with DS using different communication tools, such as signs, symbols, and pictures, and verbal communication.

5. Conclusion

The present study suggests that processing abstract cognitive functions such as short-term and long-term memory related to semantic linguistic information is necessary to facilitate the development of comprehension and expression of morphologically and syntactically complex sentences. The results indicated that short-term phonological memory capacity measured by digit span forward tasks was not correlated with syntactic development. However, there might be specific correlations. Previous studies have indicated that the digit span forward scores were correlated with the phonological loop, which is a sub-system of working memory (Soma, 1997) that plays the role of temporarily retaining verbal information. The results of the present study indicated almost no difference in the results of the digit span forward task among the groups other than children with ASD. The participants could sufficiently understand sentences having simple structures consisting of 2 - 3 words. Digit span forward scores might be correlated with the comprehension or expression of short sentences with simple structures consisting of 2 - 3 words, although they were not correlated with the comprehension or expression of sentences with complex syntactic structures. Therefore, digit span forward scores could be used as an index for predicting the memory capacity of retention, i.e., the length of sentences that can be understood or expressed. When using each memory task, a digit span forward task might be used to measure the length of sentences, and the AVLT might be used to measure the comprehension of the complexity of sentences.

This study examined correlations between the evaluation of a part of verbal memory and syntactic development using a digit span task and AVLT. However, detailed verbal memory was not examined in this study; for example, the rate of memory fixation through repeated learning, among others. It is suggested that future studies should examine the correlations between verbal memory and syntactic development in detail by developing tasks for assessing verbal memory according to the type of disability.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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