


Syntactic development and verbal short-term memory of children with autism spectrum disorders having intellectual disabilities and children with down syndrome

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Abstract

Background and aims: Previous studies suggest that syntactic development in children with intellectual disabilities (ID) is positively correlated with verbal short-term memory (VSTM). This study investigated the characteristics of syntactic development and their relationships of VSTM in children with ID based on type.

Methods: The participants were children with ID ($N = 34$), including 14 children with autism spectrum disorders (ASD), 20 with Down syndrome (DS), with chronological ages from 8 years 10 months to 18 years 4 months and nonverbal mental ages (MA) of over 4 years, and typically developing (TD) children ($N = 21$) with chronological ages from 5 years 0 months to 5 years 10 months. They were assessed using VSTM, syntactic comprehension, and expression tasks.

Results: The results showed that both the ASD and DS groups performed significantly lower on the syntactic comprehension task and the syntactic expression task than the TD group with the same nonverbal MA in the complex aspect of grammatical structure. In the VSTM task, the ASD group showed significantly lower performance in sentence and story repetition tasks than the TD group of the same nonverbal MA. The DS group showed significantly lower performance in forward digit span, and word, nonword, sentence, and story repetition tasks than the TD group of the same nonverbal MA.

Conclusions: These results suggest that children with ASD have difficulty in understanding and remembering linguistic information with complex semantic structures, and children with DS have a small capacity for VSTM, affecting their syntactic development.

Keywords

Intellectual disabilities, autism spectrum disorder, down syndrome, syntactic development, verbal short-term memory

Introduction

Development of syntactic aspects and verbal short-term memory in typically developing children

In Japanese, grammatical morphemes, such as particles and auxiliaries used after nouns and verbs, refine sentences and ensure comprehension (Saito, 2001; Yokoyama, 2008). Previous studies suggested that the development of syntactic

aspects is closely related to verbal short-term memory (VSTM), both in typically developing (TD) children and in children with intellectual disabilities (ID) (Adams & Gathercole, 1995, 1996; Dufva et al., 2001; Fukamizu & Fujita, 2014; Matsumoto, 1999), and VSTM plays an important role in constructing sentences. VSTM corresponds to the phonological loop in the working memory system proposed by Baddeley (2012), which is important for language acquisition (Baddeley et al., 1998).

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For example, Fukamizu and Fujita (2014) conducted a syntactic comprehension task—non-reversible sentences, reversible sentences (basic word order, stirred word order), left-branching sentences, and center-embedded sentences—and a nonword repetition task on 37 TD children aged 39–74 months. The results showed a significant correlation between syntactic comprehension level and nonword repetition, suggesting that sentences with more complex syntactic structures can be comprehended with the expansion of VSTM. However, several reports suggest no relationship between VSTM and sentence semantic comprehension (Hanten & Martin, 2000; Willis & Gathercole, 2001). For example, Willis and Gathercole (2001) examined VSTM (nonword repetition, digit span) and sentence processing skills in 4- and 5-year-old TD children and found that VSTM correlated with sentence repetition tasks, but not with sentence comprehension tasks.

The discrepancies in the above results may be due to differences in the task sentences used or the structure and content of the VSTM task. Previous studies have suggested that VSTM may have separate stores for phonological and semantic information (Hanten & Martin, 2000; Martin & Allen, 2008), with the former storing information such as digit span and the latter storing information such as words and sentences.

Alloway and Gathercole (2005a) investigated the ways in which VSTM relates to accuracy in sentence repetition by asking younger elementary school students to recall active or passive voice and embedded sentences modifying the subject or the target word. Moreover, the results were compared between groups with high and low performance on VSTM tasks (nonword repetition, digit span, and word repetition). The results showed that the group with higher VSTM performance could correctly retain structural aspects of sentences, such as word order and inflectional markers. However, they made more errors in lexical substitutions, such as omissions and insertions, than the group with lower VSTM performance. This procedure used by Alloway and Gathercole (2005a) is similar to Fukamizu and Fujita (2014); both examined VSTM tasks on phonology and various sentences with different sentence structure complexity. This suggests that VSTM, especially for phonology, may contribute to the correct retention of sentence structure, such as word order and inflectional markers.

Boyle et al. (2013) examined the role of verbal working memory in syntactic comprehension using a sentence comprehension task (active sentences, passive sentences, and subject or object relations clauses), a VSTM task (nonword repetition), a syntactic task (sentence repetition), and a measure of working memory (backward digit span) in 50 TD children aged 4–6 years and 6 months. The results suggest that TD children have difficulty understanding non-canonical sentences such as passive sentences and object-relations clauses, and that sentence repetition tasks influence performance on such sentences. Considering

this result based on the ideas of Hanten and Martin (2000) and Martin and Allen (2008), the semantic storage of linguistic information, rather than phonological information, plays a vital role in understanding sentences with complex structures. The sentence repetition task can measure the episodic buffer proposed by Baddeley (2000) (Alloway et al., 2004; Baddeley & Wilson, 2002). The episodic buffer has also been hypothesized to be a temporary storage system that can integrate information from VSTM, visuospatial sketchpad, and long-term memory, and recent studies have suggested that it may play a role in supporting syntactic comprehension (Alloway & Gathercole, 2005b; Boyle et al., 2013; Kidd, 2013).

The above overview of VSTM and syntactic development in TD children has not yet been fully elucidated, and issues remain to be addressed. Therefore, the influence of VSTM on syntactic development in TD children must be examined in more detail.

Development of syntactic aspects and VSTM in children with autism spectrum disorders

It has long been noted that children with autism spectrum disorders (ASD), with or without ID, experience problems with syntactic aspects, such as perfect tense and passive sentences (Kover et al., 2014; Modyanova et al., 2017; Stockbridge et al., 2014; Tager-Flusberg, 1981; Wittke et al., 2017). According to Nakagawa et al. (2013), children and adults with ASD and ID have significantly lower comprehension of active and passive sentences than TD children controlled for vocabulary age. Regarding expression, children with ASD have less grammatically complex speech with the same nonverbal IQ and vocabulary age (Eigsti et al., 2007). Also, children with ASD make mistakes when making utterances, such as omissions or echolalia (Roberts et al., 2004), erroneous use of postpositional particles, and inversion of the subject (Kumagai, 1986).

Apart from the development of syntactic aspects, many studies claim that children with ASD also perform poorly in VSTM compared to TD children (Alloway et al., 2016; Gabig, 2008; Habib et al., 2019; Schuh & Eigsti, 2012). For example, Fein et al. (1996) found that preschool children with ASD and ID and those with non-autistic, low nonverbal intelligence quotient (NALIQ) performed better on VSTM (numbers), syntactic expression (sentences), and narration (stories) tasks with different complexities of language structures. Children performed similarly for numbers but significantly lower for sentences and stories than NALIQ children. Due to the complexity of verbal information, these difficulties have also been observed in children with ASD who do not have ID (Baron-Cohen, 2003/2005; Boucher et al., 2012; Minshew & Goldstein, 2001). VSTM is considered a predictor of language skills

in children with ASD (Talli, 2020). This suggests that some children with ASD, regardless of ID, may have difficulties understanding and expressing complex sentences and conversational exchanges, even if they perform well on a digit task, a classic procedure for measuring VSTM, and have a rich vocabulary. In other words, it can be predicted that children with ASD have some kind of impairment in the process of semantic processing of linguistic information. As a result, they may show some difficulties in comprehension and memory in morphologically and syntactically complex aspects. Therefore, to examine the relationship between the development of syntactic aspects and VSTM in children with ASD, it is necessary to differentiate between the phonological and semantic aspects of VSTM and examine how each of them influences language development.

Development of syntactic aspects and VSTM in children with down syndrome (DS)

Previous studies have shown that children with down syndrome (DS) have difficulties in comprehension and expression in complex grammatical aspects, and delays in the development of syntactic aspects. For example, their performance was not significantly different in lexical comprehension compared to TD children with the same nonverbal mental age (MA), whereas it was significantly lower in syntactic comprehension (Abbeduto et al., 2003; Vicari et al., 2000). Children with DS may have poor development of syntactic aspects relative to their lexical development. This developmental difference in vocabulary and syntactic comprehension was confirmed in a study by Chapman et al. (1991), who stated that with age, lexical comprehension outperforms syntactic comprehension performance among children and people with DS. Conversely, the expression aspect of children with DS shows a significant delay in both vocabulary and syntax compared to cognitive development (Chapman et al., 1998; Finestack & Abbeduto, 2010). In particular, the development of syntactic aspects shows delays compared to TD children and does not develop as expected from MA and vocabulary development (Koizumi et al., 2019).

Many previous studies have shown that children with DS have deficits in VSTM (Jarrold et al., 2000; Kanno & Ikeda, 2002a), and the relationship with the development of syntactic aspects has been examined (Laws, 2004; Miolo et al., 2005; Penke & Wimmer, 2020; Seung & Chapman, 2004). For example, longitudinal studies conducted with adolescents and young adults with DS (Chapman et al., 2002; Connors et al., 2018; Laws & Gunn, 2004) have shown that the development of syntactic aspects declines or does not change significantly with age. Furthermore, they report that VSTM also declines, revealing significant deficits in syntactic aspect development and VSTM. In addition, Laws and Gunn (2004) showed

that VSTM plays an important role in developing syntactic comprehension only in young adults, indicating that the development of syntactic aspects and VSTM are related.

Contrarily, some previous studies have suggested that VSTM may not be related to the development of syntactic aspects in children with DS (Fortunato-Tavares et al., 2015; Nummine et al., 2001). For example, it has been shown that people with DS in adulthood perform poorly on tasks related to VSTM, but that their verbal abilities, such as vocabulary and syntactic comprehension, are no different from those of developmentally disabled people with the same nonverbal IQ, suggesting that VSTM may play a minor role in these abilities (Nummine et al., 2001).

In summary, many studies have shown that children with DS have impaired VSTM. However, the relationship between the development of syntactic aspects and VSTM in children with DS is still debated. For example, when examining the relationship between the development of syntactic aspects and VSTM, we believe that the focus should be on the content of the tasks used and their influence on procedures. Penke and Wimmer (2020) investigated the relationship between syntactic comprehension and VSTM using three syntactic comprehension tasks with different procedures (TROG-D, passive sentences, and object wh-questions) and a non-word repetition task. The results showed that TROG-D and passive sentences showed a relationship with VSTM, but object wh-questions did not, indicating that VSTM is affected differently depending on the content of the task. Thus, as the results change depending on the task structure, we believe that consideration of the detailed task setting and effects is necessary for examining the relationship between syntactic aspects or VSTM.

Purpose of this study

The present study aimed at investigating the characteristics of syntactic development and their effects on VSTM in children with ID based on developmental condition type. Children with ID possess some impairment in the development of syntactic aspects and VSTM and these aspects differ depending on the developmental condition type, such as ASD or DS. However, in Japan, although quantitative research methods have yielded some findings, the impact of VSTM on the language activities of children with ID, specifically on the development of syntactic aspects, has not been sufficiently examined. Therefore, it is important to explain their syntactic development regarding cognitive aspects such as VSTM and MA and to compare the results with previous overseas studies. This will provide clues for more effective language instruction and support. In Europe and the US, where languages are different, empirical research on the actual status of disabilities has been accumulated and various findings have been presented, and categorized by type of developmental condition, such as ASD, DS, specific language development

disorder, and Williams syndrome. In Japan, however, the characteristics of each type of developmental condition have not yet been fully clarified. In addition, although there have been many studies on syntactic comprehension and VSTM (e.g., Frizelle et al., 2019; Laws & Gunn, 2004; Witecy & Penke, 2017), few have focused on the expressive aspects which have not been sufficiently examined. It is important to accumulate empirical research on disabilities, such as clarifying the characteristics by developmental condition types, such as ASD or DS, and examining syntactic development level or verbal short memory from MA through comparisons with TD children with controlled MA. This is meaningful for language instruction and supports present knowledge. Therefore, this study aimed to clarify: (1) the characteristics of syntactic development and VSTM by developmental condition type by comparing two groups of children with ASD or DS with ID, controlling for chronological age and nonverbal MA and (2) the relationship of VSTM on the development of syntactic aspects through a comparison among the aforementioned groups.

Methods

Participants

A total of 34 children with ID whose nonverbal MA ranged from 4 years and 1 month to 6 years and 11 months, and chronological age ranging from 8 years and 10 months to 18 years and 4 months were included in the study. They were classified into two groups: children with ASD (14 children: 10 boys and 4 girls) and children with DS (20 children: 8 boys and 12 girls). In addition, the teachers and parents were interviewed to determine that the participants were able to express at least two to three words on a daily basis, and that they did not have hearing impairment that

would interfere with daily conversation. The details of the target group, including chronological age and nonverbal MA, are shown in Table 1.

The control group consisted of 21 children (13 boys and 8 girls), aged between 5 years 0 months to 5 years and 10 months with no medical diagnosis and no intellectual developmental delays according to the teachers of the children.

To examine whether there were differences in the MA of each developmental condition type group and the chronological age of the TD children, one-way analysis of variance was conducted with the independent variable being the groups and the dependent variable being the MA of the developmental condition type groups and the chronological age of the TD children. The results showed no significant differences. This suggests that the group of children with ASD, the group of children with DS, and the group of TD children have nearly identical MA.

We recruited collaborators through representatives of special-needs schools, educational institutions, nursery schools in the Kanto region, and parent associations in three prefectures outside the Kanto region.

Contents and procedures of the tasks

The following individual tasks were conducted in-person for children with TD and online for those with ID. In the case of in-person meetings, the research was conducted individually in a rented room at a nursery school or other facility where the research was conducted. The online research study was conducted with the prior verbal or written explanation that anonymity would be protected by using symbols for names so that the target children's personal information would not be identified. (e.g., ability to communicate orally, continuously concentrate on a computer or tablet screen for a certain period). Moreover, to determine whether they were capable of conducting this study appropriately, we set up practice questions for each of the counting and nonword repetition tasks; if the children could answer them correctly, they were included in this online study. If the children could not answer the practice questions correctly, they were excluded from this study. The tasks in this research study assignment took approximately 1 h, including breaks.

Syntactic comprehension tasks

The Japanese Test for Comprehension of Syntax and Semantics (J.COSS; Nakagawa et al., 2010) was used to assess the children's comprehension of Japanese grammar. J.COSS is based on the Test for Reception of Grammar with TROG (Bishop, 1989) and L'É.CO.S.SE. (Lecocq, 1996). It is a Japanese version of the two tests, standardized with 390 Japanese-speaking children aged between 3 and 12 years. It comprises Part I: Vocabulary Comprehension and Part II: Sentence Comprehension.

Table 1. Participant characteristics.

	ASD (N = 14)	DS (N = 20)	TD (N = 21)
Chronological age			
Range (months)	106–220	123–208	60–70
Mean (months)	167.29	170.20	65.71
SD (months)	31.65	22.35	2.59
Nonverbal MA			
Range (months)	49–83	58–81	—
Mean (months)	68.50	66.25	—
SD (months)	9.79	6.21	—
IQ			
Range (months)	27–65	30–49	—
Mean (months)	42.71	39.45	—
SD (months)	11.74	5.38	—

Using the t-test, there was no significant difference between ASD and DS groups in chronological age, IQ, or nonverbal MA.

Note. ASD = autism spectrum disorders, DS = down syndrome, MA = mental age, TD = typically developing.

The latter evaluates the ability to understand Japanese grammar and has 20 grammar items, including negative sentences, three-element sentences (three-word sentences), replaceable sentences (reversible sentences), and passive sentences. There were four questions for each item (80 questions in total). Moreover, numerals, case particles, and multi-element sentences were added as Japanese-specific items (Nakagawa et al., 2005).

The procedure was conducted one-on-one between the examiner and the target child. The examiner read out the question, and the child was asked to choose one correct picture out of four choices and answer the question orally or by pointing. The scoring method was based on the J. COSS manual. If a child answered all four questions in an item correctly, they “passed,” but if a child made a mistake in any, the item was “not passed” by the child. Furthermore, the average pass rate (the percentage of children who passed the items) and the number of passed items (maximum: 20; minimum: 0) were calculated for each item.

Syntactic expression tasks

We measured children’s syntactic expression ability using a partially modified version of our syntactic expression task (Koizumi et al., 2019), based on tests designed to examine children with DS (Saito, 2002, 2003). Saito (2002) discussed six types of case particles (subjective case “ga,” objective case “wo” [non-reversible and reversible sentences], the locative case “de,” the attached place case “ni,” the starting place or time case “kara,” and the tools case “de”) and two types of voices (passive and causative) as the main grammatical morphemes of sentences. Morphemes were used to create the text. The procedure was conducted according to Saito (2002, 2003). The children were shown picture cards and asked orally, “what is this doing?” to encourage them to express themselves at the sentence level. If the target case could not be elicited, we gave a word (e.g., if the child answered only “sitting” to the picture of a bear sitting on a chair then we pointed to the card and said, “This is a chair. Please add the word ‘chair’ to make a story.” In this study, even if the test sentence was not completely expressed, it was regarded as a correct answer if the case particle and the expression of the voices were used correctly. The evaluation criteria were as follows: when two sentences among three were correct, it was regarded as “acquired,” and “not mastery” otherwise. We calculated the total number of cases (maximum: 7; minimum: 0) and voices (maximum: 2; minimum: 0).

VSTM tasks

In this study, we examined VSTM, by dividing it into phonological or semantic memory, referring to the ideas of Hanten and Martin (2000) and Martin and Allen (2008).

Assessment of phonological VSTM

1. Digit span task (forward and backward): We assessed the memory for phonological information using the originally developed digit-span list consisting of two to nine digits following the WISC-IV’s (2003/2010) procedures and scoring methods. We calculated the total scores (maximum: 16; minimum: 0), and the maximum number of digits that the participant could repeat.
2. Nonword repetition task: We assessed the memory for phonological information using the nonword repetition task developed by referring to Kakihana et al. (2009), and Kanno and Ikeda (2002b). The participants were told: “I will say some funny words. Please listen carefully and imitate them,” and then encouraged to repeat their words. The task words were up to 2, 3, 4, 5, and 6 moras words (3 words each), and the total score (maximum 15, minimum 0) and the maximum number of moras that could be repeated (span) were determined, respectively. The grading criterion in the maximum number of moras that could be repeated was defined as the maximum number of moras that could be repeated if at least 2 out of 3 trials were answered correctly.

Assessment of semantic VSTM. We prepared three types of tasks: a VSTM task (word repetition), a syntactic expression task (sentence repetition), and a measure of working memory (story repetition) with different memorization loads.

1. Word repetition task: Referring to Rey’s Auditory Verbal Learning Test for young children (Shiba et al., 2006), which considers word selection and procedures so that preschool children can conduct the test, the present study prepared a total of 15 words consisting of 2, 3, 4, 5, and 6 moras (3 words each) with high frequency and familiarity for young children. This was based on the “Basic research on the fundamental vocabulary used for educational purposes (The National Institute for Japanese Language, 2009),” adopting the word selection criteria used by Shiba et al. (2006). The examiner instructed the examinee to listen and repeat the examiners’ words. We calculated the total scores (maximum: 15; minimum: 0), and the maximum number of moras examinees could repeat.
2. Sentence repetition task: We developed a sentence repetition task that included 15 sentences composed of two to six clauses by modifying parts of the words and referring to the sentence structures used by Otomo (2011). Procedures and scoring methods were the same as in the word repetition task, calculating the total scores

(maximum: 15; minimum: 0) and the maximum number of repeatable clauses.

3. Story repetition task: We assessed memory related to stories using the “memory of story” in MacCarthy Scales of Children’s Abilities, following procedures and scoring methods used by Toyota and Sawada (1990) and calculated the total scores (maximum: 11; minimum: 0).

Assessment of intellectual ability levels

We conducted the Goodenough Draw-a-Man Test (DAM; Kobayashi and Ito, 2017) to calculate the nonverbal MA. DAM measures cognitive functions such as MA and the personality intelligence quotient (DAM-IQ) based on a child’s drawing of a person and is reliable and valid. It also examines the cognition of body parts and the proportions of each part, including body image, with more detailed perspectives and knowledge, making it an excellent measure of behavioral cognitive abilities that do not require verbal responses. Furthermore, DAM was re-standardized in 2017 for 1,720 children between the ages of 3 and 10 years to respond to changes in drawing tendencies over time.

The procedure is as follows: the child is handed an A4 version of the test paper and a pencil and is told to “Draw a picture of one person from head to toe. Please do it well.” The MA was calculated according to the manual.

Analysis method

SPSS version 28 was used for analysis. Since the results of the Shapiro-Wilk test indicated normality of the data in this study, one-way analysis of variance was used to examine whether there were differences in performance on various tasks related to syntax, or VSTM. If differences were found, multiple comparisons using the Bonferroni method were used to determine which combinations showed differences. Pearson’s product-rate correlation coefficient was used for each group to examine correlations in syntactic aspect development and VSTM. As many associations were under investigation, multiple comparisons were accounted for by using a false discovery rate (FDR). Furthermore, the MA of the TD children group was considered equivalent to their chronological age as an average, following Tanaka’s (2001) analysis method. Therefore, in this study, DAM was not administered to TD children, but data were collected and compared for TD children with chronological ages that fell within the range of MA for children with ID.

Ethical considerations

We conducted this study after obtaining approval from the ethics committee of the first author’s institution and the

consent of the institutions concerned. Moreover, it was conducted after providing verbal explanations to collaborators, and verbal or written explanations to their guardians, and obtaining their consent.

Results

Comparison of performance in syntactic comprehension and expressive ability

The results of the J.COSS for each group are shown in Table 2. To examine whether there were differences in performance on the syntactic comprehension task among the groups, one-way analysis of variance was used, with the independent variable being the groups and the dependent variable being the number of items passed by the J.COSS. The results showed significant differences ($F(2,52) = 17.50, p < .001, \eta^2 = 0.40$). Moreover, results of multiple comparisons showed that children with ASD and DS groups performed significantly lower than the TD children group with the same nonverbal MA ($p = .007$ and $p < .001$, respectively).

Moreover, to examine how each developmental condition type group differed regarding grammatical functions from TD children group with the same nonverbal MA, we classified grammatical functions into six categories. We then conducted the one-way analysis of variance, referring to the classification of grammatical functions by Nakagawa et al. (2010). Hence, compared to the children with the same nonverbal MA who were TD, the ASD group performed significantly lower in conjunctive particles and particle strategies, while the DS group performed significantly lower in the number of components, perspectives, conjunctive particles, particle strategies, and sentence structures (Table 2).

The average numbers of case particles and voices acquired by each group are shown in Table 3. The same procedure examined syntactic expression, and significant differences were found ($F(2,52) = 23.70, p < .001, \eta^2 = 0.48$). The results of multiple comparisons showed that children in ASD and DS groups performed significantly lower than the TD children group with the same nonverbal MA (both, $p < .001$). Moreover, multiple comparison tests for voices indicated that children with ASD and DS scored significantly lower than the TD children group with the same nonverbal MA (both, $p < .001$).

Comparison of performance on VSTM tasks

The results of the VSTM tasks for each group are shown in Table 4. The one-way analysis of variance was used to examine what types of memory lags were observed among the groups, with the independent variable being the groups and the dependent variables being the various

Table 2. Syntax comprehension from the viewpoint of grammatical functions.

Grammatical functions	No.	Items	ASD	TD	F	η^2	DS	TD	F	η^2
			(N = 14)	(N = 21)			(N = 20)	(N = 21)		
The number of components	1	Nouns	100.00	100.00	0.85	0.00	100.00	100.00	11.22***	0.04
	2	Adjectives	92.86	100.00			100.00	100.00		
	3	Verbs	92.86	100.00			100.00	100.00		
	4	Two-factor combining sentences	100.00	100.00			100.00	100.00		
	5	Negative sentences	78.57	100.00			85.00	100.00		
	6	Three-factor combining sentences	85.71	100.00			75.00	100.00		
Perspectives	10	Sentences combining multiple-factors	42.86	52.38			0.00	52.38		
	7	Reversible sentences	64.29	100.00	2.61	0.04	30.00	100.00	10.85**	0.12
14	Passive sentences	28.57	23.81	25.00			23.81			
Conjunction particles	8	Not X but also Y	14.29	52.38	5.66*	0.05	5.00	52.38	33.46***	0.22
	9	X, but Y is different	28.57	52.38			5.00	52.38		
Particle strategies	11	Both X and Y are different	7.14	23.81			0.00	23.81		
	12	Position words	28.57	52.38	5.66*	0.05	10.00	52.38	24.75***	0.17
	15	Comparative expressions	0.00	38.10			0.00	38.10		
19	Nominative particle	21.43	19.05	0.00			19.05			
Sentence structures	13	Subject modifier (left-branching)	7.14	47.62	1.44	0.01	0.00	47.62	15.35***	0.11
	17	Predicate modifiers	0.00	14.29			0.00	14.29		
	20	Subject modifier (center-embedded sentences)	0.00	0.00			0.00	0.00		
Numerical expressions	16	Numeral	21.43	14.29	1.77	0.03	5.00	14.29	1.75	0.02
	18	Plural form	28.57	33.33			20.00	33.33		
The average number of passed items (SD)			8.43 (3.08)	11.24 (2.96)			6.60 (1.31)	11.24 (2.96)		

*** $p < .001$, ** $p < .01$, * $p < .05$.

Note. ASD = autism spectrum disorders, DS = down syndrome, TD = typically developing.

Table 3. Comparison of the number of acquired case particles and voices by groups.

		Case particles		Voices	
		Mean	(SD)	Mean	(SD)
ASD	(N = 14)	3.43	(1.50)	0.57	(0.76)
DS	(N = 20)	3.00	(1.56)	0.40	(0.75)
TD	(N = 21)	5.48	(1.29)	1.71	(0.46)

Note. ASD = autism spectrum disorders, DS = down syndrome, TD = typically developing.

tasks in memory. The results showed that there were significant differences in all tasks except the digit span backward (Table 4). Results of multiple comparisons showed that the group of children with DS performed significantly lower than the group of children with ASD and the group of TD children in digit span forward ($p = .009$ and $p = .008$, respectively). In word repetition tasks, the group of children with DS performed significantly lower than the group of children with ASD and the group of TD children ($p = .038$ and $p < .001$, respectively). On the nonword repetition tasks, the group of children with DS performed significantly lower than the group of children with ASD and the group of TD children

($p = .003$ and $p < .001$, respectively). In sentence repetition tasks, the group of children with ASD performed significantly lower than the group of TD children ($p = .048$), and the group of children with DS performed significantly lower than the group of children with ASD and the group of TD children ($p = .002$ and $p < .001$, respectively). In story repetition tasks, the group of children with ASD and the group of children with DS performed significantly lower than the group of TD children ($p = .038$ and $p < .001$, respectively).

Relationship between the development of syntactic aspects and VSTM

The correlation between the development of syntactic aspects and VSTM was examined using Pearson's product-rate correlation coefficient (Table 5). For the ASD group, a significant positive correlation was found between the syntactic comprehension aspect and digit span backward ($r = 0.54$, $p = .047$), sentence repetition tasks ($r = 0.58$, $p = .028$), and story repetition tasks ($r = 0.67$, $p = .008$). However, no significant correlation was found between the syntactic expression aspect and VSTM.

Table 4. Average score and sd for the verbal short-term memory (VSTM) tasks.

Tasks	ASD (N = 14)		DS (N = 20)		TD (N = 21)		F	η^2		
	Mean	(SD)	Mean	(SD)	Mean	(SD)				
Digit Span	Forward	Total score	5.50	(2.59)	3.65	(0.93)	5.33	(1.53)	6.76**	0.21
		Span units	4.14	(1.41)	3.30	(0.86)	4.05	(0.92)		
	Backward	Total score	2.93	(2.34)	1.70	(1.30)	2.00	(1.41)	2.36	0.08
		Span units	2.43	(1.74)	1.85	(1.18)	1.95	(1.28)		
Free Recal	Words	Total score	14.86	(0.36)	14.45	(0.69)	15.00	(0.00)	7.96***	0.23
		Span units	6.00	(0.00)	6.00	(0.00)	6.00	(0.00)		
	Nonwords	Total score	10.64	(3.25)	7.05	(3.02)	11.48	(2.77)	12.29***	0.32
		Span units	4.93	(1.14)	3.65	(1.39)	5.14	(1.20)		
	Sentences	Total score	6.79	(3.04)	3.25	(1.71)	9.14	(3.28)	23.86***	0.48
		Span units	3.43	(1.40)	2.00	(0.73)	4.14	(1.01)		
	Stories		3.29	(1.98)	2.45	(1.47)	5.05	(2.36)	9.19***	0.26

*** $p < .001$, ** $p < .01$, * $p < .05$.

Note. ASD = autism spectrum disorders, DS = down syndrome, TD = typically developing.

Table 5. Correlation between syntactic development and VSTM.

VSTM Tasks	ASD (N = 14)		DS (N = 20)		TD (N = 21)		
	Syntactic comprehension	Syntactic expression	Syntactic comprehension	Syntactic expression	Syntactic comprehension	Syntactic expression	
Forward	<i>r</i>	0.27	0.52	0.10	0.10	0.49	0.48
	<i>p</i>	0.35	0.06	0.69	0.66	0.02	0.03
Backward	<i>r</i>	0.54	0.56	0.33	0.22	0.74	0.61
	<i>p</i>	0.05	0.04	0.16	0.36	<.001	0.00
Words	<i>r</i>	-0.15	0.30	0.27	0.41	—	—
	<i>p</i>	0.62	0.30	0.25	0.07	—	—
Nonwords	<i>r</i>	0.41	0.20	0.28	0.40	0.56	0.47
	<i>p</i>	0.15	0.49	0.23	0.08	0.01	0.03
Sentences	<i>r</i>	0.59	0.46	0.47	0.34	0.67	0.51
	<i>p</i>	0.03	0.10	0.04	0.15	<.001	0.02
Stories	<i>r</i>	0.67	0.39	0.24	0.47	0.24	0.26
	<i>p</i>	0.01	0.17	0.32	0.04	0.31	0.27

The correlation between the outcome of syntactic development and VSTM were examined by Pearson's product-rate correlation coefficient analysis to obtain correlation coefficient (*r*) and *p* value.

Bolded measures indicate measures that remained a significant difference after False Discovery Rate (FDR) correction for multiple comparison.

Note. ASD = autism spectrum disorders, DS = down syndrome, TD = typically developing, VSTM = verbal short-term memory.

Using the same method of analysis as above, we examined the results for the DS and TD groups. We found that for the DS group, there was no significant correlation between the development of syntactic aspects and VSTM.

In the case of the group of TD children, significant positive correlations were found between the syntactic comprehension aspect and digit span forward ($r = 0.49$, $p = .024$), digit span backward ($r = 0.74$, $p < .001$), nonword repetition tasks ($r = 0.56$, $p = .008$), and sentence repetition tasks ($r = 0.67$, $p < .001$), and between the syntactic expression aspect and digit span forward ($r = 0.48$, $p = .027$), digit span backward ($r = 0.61$, $p = .004$), nonword repetition tasks ($r = 0.47$, $p = .033$), and sentence repetition tasks ($r = 0.51$, $p = .019$).

Discussion

Comparison between the ASD and TD

The results of this study showed that, compared to the children with the same nonverbal MA, those with ASD: (1) did not perform significantly differently in the phonological short-term memory task, but performed slightly worse in the semantic short-term memory task, (2) were able to understand sentences with a simple structure almost accurately, but had difficulty understanding those with a more complex structure, and (3) had difficulty using case particles and voices correctly regarding expression. Previous studies also confirmed this difficulty due to the complexity

of linguistic information (Boucher et al., 2012; Fein et al., 1996; Gabig, 2008; Minshew & Goldstein, 2001). Therefore, it can be inferred that children with ASD have sufficient memory capacity to retain linguistic information but may show difficulties in understanding, expressing, and remembering sentences with semantically and syntactically complex aspects, such as passive sentences and conjunctive particles. One of the characteristics of language and communication in children with ASD is that they tend to interpret things literally without considering the context (Happé, 1997; Jolliffe & Baron-Cohen, 1999). The results of the analysis showed that children with ASD are more likely to find it difficult to process semantic information. Moreover, the analysis also revealed that the performance on the sentence repetition task had a positive effect on the development of syntactic aspects in children with ASD. The results are similar to those reported in a study of TD children aged 4–6 years (Boyle et al., 2013) and a study of children aged 7–11 years with learning disabilities (Alloway & Gathercole, 2005b), suggesting that episodic buffers play an important role in the development of syntactic aspects. In other words, the results of this study could have suggested that good performance on VSTM tasks, as measured by digit span and nonword repetition tasks, does not necessarily translate into good performance on complex aspects of grammatical comprehension and expression.

However, it does not show that VSTM, such as digit span, is completely unrelated to the development of syntactic aspects, but may affect the development of syntactic aspects in a different way than linguistic short-term memory for semantic and syntactic aspects. Alloway and Gathercole (2005a) examined the relationship between VSTM and accuracy in sentence repetition by comparing high and low performance groups on three VSTM tasks (nonword repetition, digit span, and word repetition) in which younger elementary school students were asked to repeat sentences in the active and passive voice and embedded sentences that modify the subject and object. As a result, they reported that groups with higher performance in VSTM are better able to correctly retain structural aspects of sentences, such as word order and inflectional markers, than groups with lower performance. In addition, Fukamizu and Fujita (2014) suggest that as VSTM expands, it allows for the comprehension of sentences with more complex syntactic structures. This suggests that linguistic short-term memory, especially linguistic short-term memory for phonology, contributes to the correct retention of sentence structure.

These findings suggest that linguistic short-term memory for phonology and linguistic short-term memory for semantic and syntactic aspects may affect the development of syntactic aspects in different ways. In future, when examining the development of syntactic aspects or the influence of VSTM, it is important to consider the

impact of the task as described by Penke and Wimmer (2020).

In addition to the above results, the results of the present study showed that the group of TD children with a chronological age of 5 years had a significant positive correlation between their performance on the syntactic expression aspect and the nonword repetition task as well as the sentence repetition task. The nonword repetition task, in which children are asked to repeat nonwords (words not in the dictionary) presented phonetically, can measure VSTM. However, the nonword repetition task also measures the skill of processing the input speech into individual phonemes (Snowling, 2000), suggesting that the nonword repetition task assesses VSTM as well as phonological processing ability (Archibald & Gathercole, 2006; Kakihana et al., 2009; Martin & Gupta, 2004). Such operations usually become possible around the age of four (Amano, 1986). In other words, the nonword repetition task includes meta-linguistic activities such as the sounds included in the stimulus word and the order of their arrangement. Even when we understand or use a sentence correctly, we need certain meta-linguistic abilities, such as paying attention to content and function words, and understanding whether their connections and word order are correct (Takahashi & Nakamura, 2020). It is thought that such manipulations were conducted in the TD group, and that is why the performance on the nonword repetition task positively affected the development of the syntactic aspect.

Comparison between the DS and TD

Syntactic comprehension and expression scores and VSTM scores in children with DS were significantly lower than those in TD children with the same nonverbal MA. Moreover, the VSTM of children with DS was phonologically and semantically poor, suggesting that they might have significant deficits in terms of syntactic development and VSTM. This suggests that the development of syntactic aspects and VSTM are significantly impaired in children with DS, which is similar to the findings in previous studies (Chapman et al., 1998, 2002; Finestack & Abbeduto, 2010; Jarrold & Baddeley, 1997; Jarrold et al., 2000; Laws, 2004; Laws & Gunn, 2004).

Jarrold et al. (2000) conducted a word list task and reported that reproduction scores for words presented later were higher. Yuzawa (2011) interpreted these results as indicative of their small VSTM capacity which attenuated initially presented words. Purser and Jarrold (2005) also pointed out that children with DS have less storage capacity for VSTM. This study also found that children with DS generally performed lower on VSTM tasks, such as digit span and nonword repetition, compared to the TD children with the same nonverbal MA, suggesting that the VSTM capacity of children with DS is small. Baddeley et al. (1998) stated that VSTM deficits hinder children from acquiring

vocabulary and grammatical morphemes in the early stages of language development, causing syntactic expression impairments. Additionally, in terms of comprehension, as previous studies have suggested, children's VSTM capacity must be considerably larger to be able to grasp the entire sentence correctly (Alloway & Gathercole, 2005a; Fukamizu & Fujita, 2014).

This suggests that children with DS may have performed poorly on syntactic comprehension and expression tasks due to the limited amount of linguistic information they could retain due to their limited VSTM capacity. The results of this study indicate that the impairment of VSTM, as observed in children with DS, seriously impacted the development of the syntactic aspect of DS, and that VSTM capacity is essential for syntactic development.

However, two children with DS could almost correctly use the grammatical morphemes employed in this survey. Kishaba (1998) identified children with ID who use case particle strategies, understand "ga" or "wo," and process reversible sentences using case particles as a clue. Moreover, Matsumoto (1999) stated that individuals using case particle strategies acquired psychological sentence patterns (Matsumoto & Furutsuka, 1994), including information about them, which reduces the VSTM load because they do not need to memorize each case particle. Witecy and Penke (2017) also suggested that grammatical comprehension in individuals with DS might be correlated with VSTM and understanding function words. Function words in Japanese, e.g., "ga," "wo," and "de," are often expressed by one character, which might prevent children with DS having VSTM difficulties from perceiving function words as sounds and understanding them. However, some children with correct grammatical knowledge might not have any difficulties in understanding the meaning of sentences and expressions, despite having poor VSTM.

Conclusions

This study suggests that children with ASD have a similar or larger phonological short-term memory capacity than TD children with identical nonverbal MA. However, the semantic short-term memory capacity of the former is relatively small, and they have difficulty processing semantically and syntactically complex verbal information adequately. Therefore, they do not always obtain high scores in complex grammatical comprehension or expression tasks, despite high scores in phonological short-term memory tasks, including digit span or nonword repetition tasks. Children with DS generally have a small VSTM capacity, which affects their syntactic development. The results of this study suggest that even with the same MA and chronological age, there are differences in the capacity of VSTM by developmental condition type, which may affect the development of syntactic aspects in different

ways. We also believe that the results of this study may provide useful insights for planning effective language instruction and support that considers the characteristics of individuals and their disabilities.

However, we used nonverbal MA, as assessed by the DAM. A further limitation of this study is that we did not test for nonverbal MA or language skills in TD children. Future research should include testing for abilities in nonverbal aspects such as those measured by the Raven Color Matrix Test and the WISC-VI (e.g., visual cognition, spatial cognition, fluid reasoning ability).

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