Original Article

Working Memory in Japanese Children With Learning Disabilities: Assessment Using the Japanese Short Form of the Swanson Cognitive Processing Test

Yeonhee HWANG* and Toru HOSOKAWA**

The purpose of the present study was to investigate whether or not Japanese children with learning disabilities (LD) have deficits in working memory capacity. The working memory performance of children with LD ($N = 12$) in 2 age groups (3rd-4th and 5th-6th grades of elementary school) was examined using the Japanese short-form of the Swanson Cognitive Processing Test (JS-CPT), and compared with that of children without LD. The results showed that, as expected based on prior developmental studies, the performance of the children with LD on the JS-CPT was lower than that of the children without LD on the verbal and visual-spatial subscales for both age groups, and there was a significant increase in scores on the JS-CPT as the children's grade advanced, regardless of the presence or absence of LD. These findings are consistent with results of previous studies carried out with English-speaking children.

Key Words: working memory, Japanese short form of the Swanson Cognitive Processing Test (JS-CPT), children with learning disabilities

Working memory is defined as a processing resource of limited capacity involved in the preservation of information while simultaneously processing the same or different information (Swanson, 1999). Everyday examples of working memory tasks include listening to the sequence of events in a story while trying to understand what the story means. Working memory is distinguished from the related concept of short-term memory, in that it reflects both processing and storage (Baddeley, 1986). The term "short-term memory" is typically used to describe situations in which a small amount of material is held passively (e.g., a digit-span task) and then reproduced in an untransformed fashion.

Numerous studies have reported that children with learning disabilities (LD) have working memory deficits (e.g., De Jong, 1998; Siegal & Ryan, 1989; Swanson, 1993) which can lead to significant academic underachievement. However, the few studies (e.g., Muroya, Maekawa, Hosokawa, & Futakami, 2006; Muroya, & Okazaki,

* Tohoku Fukushi University

** Tohoku University

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2006) that have investigated Japanese children with LD employed Daneman and Carpenter's (1980) reading span task to assess the working memory of children with LD. The Daneman and Carpenter (1980) reading span task requires participants to read sentences aloud and at the same time memorize the last words. The sentences are presented in sets of increasing size, and the task is continued until the participant can no longer recall all the last words in a set size.

Baddeley (1986) suggested that working memory tasks require the simultaneous processing and storage of information of various contents, such that both verbal and visual-spatial ability are tapped. The Japanese short-form of the Swanson Cognitive Processing Test (JS-CPT) (Hwang, Hosokawa, Swanson, Ishizaka, Kifune, Ohira, & Ota, 2003) was recently developed to assess both verbal and visuospatial ability in the working memory of Japanese children with LD. The reliability and concurrent validity of the JS-CPT have been reported in a previous study (Hwang et al., 2006).

The purpose of the present study was to compare working memory of Japanese children with LD with that of children without LD using JS-CPT and investigate whether deficits of working memory are also found in Japanese children with LD.

Method

Participants

Participants in the present study were 12 Japanese children with LD (9 boys, 3 girls; mean chronological age, 10.2 years, $SD=1.2$ months). The children were recruited from a parents' organization for children with LD and two elementary school resource rooms in S. city, in northeastern Japan. Teachers and parents gave informed consent for the participation of the children in the present research.

In Japan, although most of the children with LD are placed in general education classrooms, some children with LD are instructed in resource rooms for students with speech impairments. Of the twelve children with LD who participated in the present study, ten were currently being served in resource room programs for children with speech impairments.

In the present study, LD was operationally defined as: (1) a full scale IQ greater than 70 on the Japanese Wechsler Intelligence Scale for Children, 3rd edition (WISC-III; Azuma, Ueno, Fujita, Maekawa, Ishikuma, & Sano, 1998); (2) Kyoken-shiki Achievement Test scores in Japanese language or mathematics or both at or below the 31st percentile; (3) a diagnosis of possible LD made by a physician or a resource room teacher; and (4) no reported history or evidence of brain injury. All the children were native speakers of Japanese.

Working-Memory Tasks

The Japanese short-form of the Swanson Cognitive Processing Test (Hwang, Hosokawa, & Ishizaka, 2003) was administered to the children to assess their working memory capacity. This test is composed of two verbal and two visual-spatial working memory tasks. A critical feature of the tasks is that they require the preservation of

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information during the processing of different information. The processing of this other information is assessed by asking participants a comprehension question about the material to be remembered, whereas storage is assessed by accuracy of item retrieval (Swanson, 1995). The participants' working memory score is the number of the last item set recalled or reproduced in which the process question was answered correctly according to the Swanson Processing Test's original scoring.

However, Miyake, Emerson, and Friedman (1999) have claimed that highly discrete measures of individual differences, such as traditional reading span tasks, are not optimal, since they reduce variance due to the inability to measure differences that might exist among participants. Furthermore, Swanson (personal communication, July 3, 2003) has suggested that partial credit scoring be used¹⁾ for young children and children with extreme learning difficulties, because their scores have a very limited range. Therefore, we employed both the Swanson Processing Test's original scoring and partial credit scoring for the Japanese short form of the Swanson Processing Test. Each task administered is described briefly below.

Verbal Working Memory

Semantic association. The purpose of the semantic association task is to assess participants' ability to organize words into abstract categories. Participants are presented a set of words, asked a process question, and asked to recall the words that go together. For example, words to be categorized include pants, carrot, belt, and tomato. The process question is, "Which word, 'carrot' or 'banana', was in the list of words?" The difficulty ranges from two categories of two words to four categories with four words each.

Auditory digit sequence. The purpose of the auditory digit sequence task is to assess participants' ability to remember numerical information embedded in a short sentence. Prior to being administering each item, participants are shown a figure depicting four strategies for recalling numerical information. These strategies are rehearsal, chunking, associating, and elaborating information. After all the strategies have been explained, participants are presented numbers in a sentence context. A sample sentence is, "Imagine you are a taxi driver and suppose somebody wanted to have you drive them to the hospital at 2-9 Kita Street". The examiner then asks a process question. The process question is, "What is the name of the street?" After participants select from the pictorial array the strategy that best approximates how they will attempt to remember information, the examiner asks them to recall the numbers in the sentence in the correct order. The range of difficulty is 3 digits to 14 digits.

Visual-Spatial Working Memory

Visual matrix. The purpose of the visual matrix task is to assess participants' ability to remember visual sequences within a matrix. Participants are given 5 sec to study a matrix containing a series of dots. The matrix is then removed, and participants are asked a process question, such as, "Are there any dots in the first

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column?” To ensure that participants understand the concept of “column”, the examiner points to the first column of a blank matrix. After they answer, the participants are given a blank matrix and asked to reproduce the correct sequence of dots in its boxes. The matrices range in difficulty from 4 squares and 2 dots to 45 squares and 12 dots.

Mapping and directions. The purpose of the mapping and directions task is to assess whether participants can remember a sequence of directions on a map that has no verbal labels. The examiner presents participants with a street map containing lines connected to a number of dots that illustrate the direction a bike would go to get out of the city. The dots represent stoplights, and the lines represent the direction the bike should go. After the participants study the map for 10 sec, the map is removed, and a process question is asked, such as, “Were there dots in the first street?” Participants are then shown pictures illustrating strategies with which they might remember the sequence and are asked which strategy they will use. The pictures represent elementary (begin by filling in the dots and then draw the lines), global (start with the design and then fill in the dots), sectional (do the parts of the street they remember and then try to put the rest together), or backward processing of patterns (start from the place where the bike rides out and then work backwards). Finally, participants are asked to reproduce the route (the lines, dots, and arrows) on a blank map. The range of difficulty is from 2 to 20 dots.

Procedure

Participants were tested individually at their schools by the authors and graduate students from Tohoku University. All examiners were trained prior to testing the children. Two sessions were required for each child. During the first session (approximately 20 min), data on the JS-CPT were obtained. In the second session, the Kyoken-shiki Achievement Test, an achievement test used widely in Japan, was administered (80 min). This test is designed to measure achievement in the curriculum content commonly taught in grades 1 through 9 in Japan. It contains two subtests: Japanese language (listening, speaking, reading, writing, grammar, and Chinese characters) and mathematics (numbers and operations, geometry, measurement, and algebra). We also obtained the children’s most recent scores on WISC-III from tests administered by their resource room teachers or clinical psychologists.

Results

Age-Group Comparisons

For the purpose of the statistical analysis, the children were divided into two age groups, younger (third and fourth graders, $N=7$) and older (fifth- and sixth-graders, $N=5$). The mean age for the younger group was 9.4 years ($SD=7.3$ months) and for the older group, 11.3 years ($SD=8.8$ months). These and other characteristics of the participants are shown in Table 1.

A comparison was made between the two age groups on both the original and

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TABLE 1 Characteristics of Participants ($N=12$)

	Younger Group			Older Group		
	N	M	SD	N	M	SD
Chronological age	7	9.42	7.33	5	11.33	8.80
Verbal IQ	7	84.43	11.84	5	95.40	6.58
Performance IQ	7	83.71	25.23	5	86.20	15.71
Full Scale IQ	7	82.43	12.16	5	90.20	5.81
Japanese language	7	32.14	8.65	5	40.25	3.10
Mathematics	7	24.71	5.47	5	40.00	4.83

Note. Japanese language and mathematics scores are standardized scores ($M=50$ and $SD=10$), based on grade.

the partial scoring procedures (see Table 2). With the original scoring, the means and standard deviations of the JS-CPT total scores were 2.00 ($SD=1.63$) for the younger children, and 7.00 ($SD=0.71$) for the older children. The means and standard deviations on the individual subtests (Semantic Association, Visual Matrix, Auditory Digit Sequence, and Mapping and Directions) were 0.00 ($SD=0.00$), 2.00 ($SD=1.63$), 0.00 ($SD=0.00$), 0.00 ($SD=0.00$), respectively, for the younger children and, 1.00 ($SD=0.71$), 3.80 ($SD=0.84$), 0.80 ($SD=0.84$), 1.60 ($SD=0.89$), respectively, for the older children.

A Mann-Whitney U-test performed across task scores revealed a significant difference between age groups on JS-CPT total scores ($U=.00$, $p<.01$). Significant differences were also found for the Semantic Association ($p<.01$), Visual Matrix ($p<.05$), Auditory Digit Sequence ($p<.05$), and Mapping and Directions ($p<.05$) subtests.

With the partial scoring method, the means and standard deviations of the JS-CPT total scores were 3.57 ($SD=1.97$) for the younger children, and 9.64 ($SD=0.14$) for the older children. The means and standard deviations on the individual subtests (Semantic Association, Visual Matrix, Auditory Digit Sequence, and Mapping and Directions) were 0.53 ($SD=0.23$), 2.53 ($SD=1.82$), 0.14 ($SD=0.24$), 0.40 ($SD=0.28$), respectively, for the younger children and, 1.64 ($SD=0.71$), 4.46 ($SD=0.86$), 0.80 ($SD=0.84$), 2.24 ($SD=1.25$), respectively, for the older children.

A Mann-Whitney U-test performed across task scores revealed a significant difference between age groups on JS-CPT total scores ($U=.00$, $p<.01$). Significant differences were also found for the Semantic Association ($p<.01$), Visual Matrix ($p<.05$), and Mapping and Directions ($p<.01$) subtests. However, no significant differences between the younger and older children were found in the raw scores on the Auditory Digit Sequence subtest. These results indicate that the scores of the children with LD on the JS-CPT significantly increased with age.

Ability Group Comparisons

We employed the data from children without learning disabilities which we had

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TABLE 2 Means and Standard Deviations on the Japanese Short Form of the Swanson Cognitive Processing Test's (JS-CPT) Original and Partial-Credit Scoring, by Age Group and Ability Group

Scoring	Younger ($n=113$)				Older ($n=41$)			
	LD		Non-LD		LD		Non-LD	
	7		106		5		36	
Number of Participants	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Verbal Working Memory								
Original Scoring								
Semantic Association	0.00	0.00	0.85	0.64	1.00	0.71	1.22	1.02
Auditory Digit Sequence	0.00	0.00	0.76	0.90	0.80	0.84	1.33	1.12
Partial Credit Scoring								
Semantic Association	0.53	0.23	1.50	0.68	1.64	0.71	1.87	1.08
Auditory Digit Sequence	0.14	0.24	1.18	0.89	0.80	0.84	1.76	1.17
Visual Working Memory								
Original Scoring								
Visual Matrix	2.00	1.63	3.45	1.42	3.80	0.84	4.11	1.62
Mapping and Directions	0.00	0.00	1.24	1.03	1.60	0.89	1.81	1.35
Partial Credit Scoring								
Visual Matrix	2.53	1.82	4.01	1.47	4.46	0.86	4.66	1.69
Mapping and Directions	0.40	0.28	1.76	1.10	2.24	1.25	2.39	1.29
Total Score								
Original Scoring	2.00	1.63	6.32	2.44	7.00	0.71	8.42	3.07
Partial Credit Scoring	3.57	1.97	8.45	2.60	9.64	0.14	10.67	3.13

Notes. LD=children with learning disabilities; Non-LD=children without learning disabilities.

obtained in our previous study (Hwang et al., 2006), in order to compare the performance on the JS-CPT of the children with LD in the present study with children without LD. The children without LD (142 children, 72 girls and 70 boys) were attending two elementary schools in Japan. They ranged in age from 8.8 to 12.8 years (third to sixth grade), with a mean age of 10.0 years ($SD=10.5$ months). As in the present experiment, they were divided into two groups on the basis of grade, resulting in a younger group ($N=106$, third and fourth graders, mean age=9.6 years, $SD=3.75$) and an older group ($N=36$, fifth and sixth graders, mean age=11.1, $SD=6.17$).

Table 2 shows the means and standard deviations of JS-CPT scores by ability group and age group, on both original scoring and partial credit scoring.

With respect to the results from the partial scoring method, a multivariate analysis of variance (MANOVA) across task scores indicated a significant main effect of ability group ($F(4,147)=4.58, p<.01$). A subsequent analysis of variance revealed a significant difference between ability groups on the Semantic Association, ($F(1,150)=6.47, p<.05$), Auditory Digit Sequence, ($F(1,150)=11.78, p<.05$), and

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TABLE 3 Percentage of Strategy Selection for Children With and Without LD

	Children With LD (<i>n</i> = 12)	Children Without LD (<i>n</i> = 142)
Auditory Digit Sequence		
1. Rehearsal	16.7%	36.6%
2. Chunking	8.3%	8.5%
3. Association	0.0%	23.9%
4. Elaboration	0.0%	5.6%
5. No choice	75.0%	25.4%
Mapping and Directions		
1. Information About Elements	25.0%	47.2%
2. Global Information	8.3%	32.4%
3. Sectional Information	16.7%	4.2%
4. Backward Processing	0.0%	0.7%
5. No choice	50.5%	15.5%

Note. LD=learning disabilities.

Mapping and Directions subtests ($F(1,150)=4.62, p<.05$). The main effect of ability group for Visual Matrix subtest did not reach significance, ($F(1,150)=3.19, p<.07$).

These results indicate that the children without LD outperformed the children with LD on a majority of the measures of working memory. A MANOVA across JS-CPT tasks, as a function of age group, was also significant ($F(4,147)=5.97, p<.001$). All univariate ANOVAs were significant ($p<.05$). The older age groups had higher working memory scores than the younger age groups overall.

The results from the use of the original scoring method were statistically comparable to those from the partial credit scoring.

Ability Group Comparisons on Strategy Selection

To determine if the ability-group difference found might be due to a meta-cognitive knowledge of strategies, strategy selections of the participants were analyzed. The percentage of each type of strategy that was selected as a function of ability group is shown in Table 3. For the Auditory Digit Sequence task, the choices (pictorial representations) reflected (1) Rehearsal, (2) Chunking, (3) Association, (4) Elaboration, and (5) No Choice. For children without LD, Rehearsal was the most frequent strategy. In contrast, for children with LD, No Choice was the most frequent (75.0%). For the Mapping and Directions task, the choices reflected (1) Information About Elements, (2) Global Information, (3) Sectional Information, (4) Backward Processing, and (5) No Choice. For children without LD, Information About Elements (focusing on dots) was the most frequent choice. For children with LD, No Choice was the most frequent.

Because the sample size was too small for division into subgroups based on strategy selection for statistical analysis, we divided the subgroups into two groups, Choice and No Choice, and carried out Fisher's exact test. For both Auditory Digit

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Sequence and Mapping and Directions subtests, No Choice responses were more frequent than the other strategies for the children with LD ($p < .01$).

Discussion

The results of the present study indicate that working memory performance of the children with LD was inferior to that of the children without LD on both verbal and visual-spatial working memory tasks. This finding, i.e., that deficits in working memory are a characteristic of children with LD, is in agreement with similar findings obtained in English-speaking populations.

Most of the studies that have been carried out with Japanese children with LD (e.g., Muroya et al., 2006; Sai, Igarashi, & Murohashi, 2006) employed Daneman and Carpenter's (1980) reading span task or variations of that test, including components such as operating and listening. Salthouse (1990), whose review of the literature indicated that correlations between working memory tasks were low ($r < .25$), suggested that several working memory tasks should be included, in order to obtain reliable measurement. The four tasks of the JS-CPT tap verbal and visual-spatial processing and are designed to conform with Baddeley's (1986) definition of working memory tasks: "require simultaneous processing" and "measure various contents" (pp. 34-35).

The results of the present study also indicate that the younger children both with and without LD had significantly smaller working memory capacity than did the older children with and without LD. This finding is consistent with a large body of evidence indicating that working memory capacity increases with age.

A comparison of strategy selection between the children with and without LD revealed that No Choice was the most frequent of the strategies chosen by the children with LD. Previous studies that used the English version of the JS-CPT (S-CPT; Swanson, 1994; Swanson, Ashbaker, & Sachse-Lee, 1996) reported that children with LD did not select significantly different strategies from children without LD.

Swanson (1994) reported that for the Auditory Digit Sequence task, Rehearsal was chosen more frequently than other strategies by children both with and without LD. However, slow learners were more likely to choose No Choice and Chunking. Moreover, they tended to select an Isolated Information strategy for the Mapping and Directions task.

This pattern, which occurred for the slow learners in the Swanson (1994) study, was similar to what we obtained for the children with LD in the present study. One possible explanation of this result lies in differences in the criteria used to identify LD in these two studies. Swanson (1994) defined children with reading disabilities as those having a reading test score less than the 25th percentile and math subtest scores greater than the 40th percentile, and children with verbal IQ scores below 90 were dropped from his study. On the other hand, he defined slow learners as those children having reading and math scores less than the 25th percentile and a full IQ score between 70 and 90 ($M = 86.04$). In the present study, children with LD were

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defined as those with Japanese, mathematics, or both scores at or below the 31st percentile, and IQ scores greater than 70 ($M=85.67$). That is, the criteria used to define the slow learning sample in the Swanson (1994) study were similar to those used for the children with LD in the present study.

Although students with LD are the largest category of students receiving special education in the U.S., Japan has just started conducting national research for establishing standards of selection and teaching methods for children with LD. Therefore, children receiving some of their education in resource room programs in Japan tend to have severe learning disabilities.

In summary, consistent with a number of studies conducted with English-speaking populations, the present study found that the working memory performance of Japanese children with LD was less good than that of children without LD on both verbal and visual-spatial working memory tasks. However, it is not clear at the present time whether children with reading disabilities exhibit significantly weaker verbal working memory than visual-spatial working memory skills, and whether children with arithmetic learning difficulties are impaired on visual-spatial working memory.

Further research is needed to examine the relation between working memory and LD subtypes, using a larger sample size. In Japan, the JS-CPT could contribute to this.

Endnote

- 1) The span score partial credit is assigned differently for the verbal working memory and visual-spatial working memory measures. For the verbal working memory measures (semantic association, auditory digit sequence), if the child can not meet the first level but answers the process question correctly, partial credit (0.50) is awarded. Additional points are added for items recalled, for example, 0.05 for one item, 0.10 for two items, and 0.15 for three items. For the visual-spatial working memory measures (visual matrix, mapping and directions), if the child can not meet the first level but answers the process question correctly, 0.05 is given for each item (e.g., dot, mark) placed in the correct location or box. However, the number of items in the wrong place is subtracted. Each wrong dot means a loss of 0.05 points.

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