Characteristics of Executive Function in Children With Autism Spectrum Disorders Compared With Typically Developing Children

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The present study aims to examine the problem of executive function in children with autism spectrum disorders (ASD) who do not have an intellectual disability in comparison with typically developing children. Participants were 20 children with ASD (ten second-graders, ten third-graders) but without intellectual disability and 20 typically developing children. The conducted executive function tasks were two inhibition tasks and two planning tasks. The results showed that in one inhibition task and both planning tasks, scores of children with ASD were significantly lower. Moreover, in one planning task, the third-grade results were significantly higher. From these results we are able to determine that children with ASD is presented with difficulties and possible strategies for overcoming those difficulties—in terms of inhibition and planning. We are also able to show how it compares with typically developing children of the same age even if there is no intellectual disability among the children with ASD. Additionally, the possibility that this situation develops in accordance with age is suggested.

Key Words: autism spectrum disorders, executive function, inhibition, planning

Introduction

Cognition research on children with autism spectrum disorders (ASD) has shown the difficulties of central coherence, selective attention (Frith, 1989), meta-representation (Leslie, 1987), emotional cognition (Hobson, 1993), and so forth. Various cognitive difficulties have also been pointed out with regard to executive function.

It is assumed here that “executive function” refers to the capability to maintain a mental state conducive to performance of future oriented problem solving (Ota, 2003). The precise definition of the constituent factors of executive function varies among researchers. Lezak (1982) suggested four elements: formulation of an intention or identification of a goal, planning, taking action or execution of plan, and achieving success. Welsh and Pennington (1988) suggested three elements that inhibit a particular reaction, namely intention to postpone the reaction until a more opportune moment, strategizing a series of actions, and self-representation of the subject, including related stimulus information coded by memory, a desirable target state, and so forth. Zelazo, Carter, Reznick, and Frye (1997) presented a series of flows on a three-element model: plan, execution, and evaluation. Suggested by Miyake, Friedman, Emerson, Witzki, Howarter, and Wager (2000) is a model with three elements including inhibition control, shifting, and updating as constituent factors. The tasks of the executive function are classified according to the measured aspect. Inhibition is the capability to inhibit a habitual reaction that is carried out involuntarily, and Stroop test is a typical task for measuring inhibition. Inhibition is further classified into delayed inhibition and conflict inhibition. Shifting is a function connected to maintenance of cognitive pliability and formation of a concept in a problem-solving task, such as the Wisconsin Card Sorting Test (WCST) or the Dimensional Change Card Sort (DCCS) test. These determine the order in which information is categorized and may be considered con-
flict-inhibition tasks (Carlson & Moses, 2001). Planning is a function that maintains representation for task achievement and guides successful action. Tower of Hanoi (ToH) and Tower of London (ToL) are typical planning tasks. Working memory is a function that temporarily holds information required to plan action and make decisions. Reaction-delay tests, text span, and counting span are typical tasks used to test working memory (Pennington & Ozonoff, 1996).

Extensive research has been done on executive function in children and adults with ASD. Griffith, Pennington, Wehner, and Rogers (1999) conducted eight executive function tasks on visual working memory and shifting with 18 autistic children and a control group of 17 children with developmental disorders other than autism, all from 40 to 61 months old. There was no significant difference in the results from either groups, showing that executive function difficulty is not particular to autism.

Russell, Jarrold, and Hood (1999) conducted a day-night task for children with ASD, children with Metachromatic Leukodystrophy (MLD), and typically developing children with a verbal mental age (VMA) match of five to eight years old. The children with ASD showed almost the same results as did the typically developing children. Moreover, Ozonoff and Jensen (1999) found that, when WCST, ToH, and Stroop test were conducted for children with ASD, children with attention-deficit/hyperactivity disorder (AD/HD), and children with Tourette’s syndrome, the WCST and ToH results were inferior in the group with ASD compared to others, but the results of the Stroop test did not differ among groups. Ukena, Hashimoto, and Deguchi (2009) compared the results of DCCS for typically developing children aged three to five years old and pervasive developmental disorder (PDD) children aged two to six. No significant difference was seen in either group. This work and Ota’s (2003) meta-analysis of executive function research on children and adults with ASD suggest that children and adults with ASD, despite of differences with typically developing children regarding shifting and planning, do not show difference regarding inhibition, although as yet there aren’t enough studies to be able to form any conclusive results.

Executive function has also been examined in terms of its relation with theory of mind (ToM). Research has been done on typically developing children younger than school age (Carlson & Moses, 2001; Carlson, Moses, & Breton, 2002; Carlson, Moses, & Claxton, 2004; Frye, Zelazo, & Palfai, 1995; Hughes, 1998; Ogawa & Koyasu, 2008, 2010). With typically developing infants, aspects of executive function such as inhibition, planning, working memory, and cognitive flexibility showed much change among three to five years old, and it was suggested that this developmental change was related to development of the theory of mind. Moreover, in particular, the abilities of inhibition and working memory contribute greatly to the gaining of theory of mind (Carlson & Moses, 2001; Carlson et al., 2002, 2004; Ogawa & Koyasu, 2008, 2010).

In prior research on the typically developing infant, it is shown that executive function capability also sees much development around the time it is supposed that theory of mind is gained. Happé (1994) suggested that 50% of typically developing children who attain a VMA to the age of four will pass a false-belief task. In contrast, children with ASD who gained theory of mind would exceed a 50% passage rate when they have reached a VMA of 9.2 regardless of chronological age. It is possible that children with ASD solve theory of mind task using representations coded in language (Beppu & Nomura, 2005; Happé, 1994). This possibility of representation by linguistic analogy in children with ASD is considered to be possible by about nine years of age, and to imply changes in executive function made possible by mental development. It is expected that this development of theory of mind take place in children without ASD as well (around 9 years old). The results of the executive function tasks are not examined in this focus.

In the current study, executive function tasks are conducted for children with ASD without intellectual disability and typically developing children of around nine years of age, with the aim of verifying the following two hypotheses. First, even if children with ASD do not have delay in intellectual development, they will score lower on executive function than typically developing children. Second, between second grade (seven to eight years old) and third grade (eight to nine years old), the results of executive function tasks in children with ASD will improve.

From the knowledge of previous research, it is indicated that inhibition and working memory among aspects of executive function affect acquisition of theory of mind in typically developing children.
On the other hand, it is clear that children with ASD, although the ability of inhibition, such as DCCS and Stroop task, are maintained, show difficulties with planning ability such as ToH, and in gaining of theory of mind. Therefore, it is expected that for children with ASD, the relation between inhibition and theory of mind seen in typically developing children will not be seen, but a certain relation will be seen between planning ability and theory of mind.

Inhibition subject and planning subject tasks from Carlson et al. (2004) were conducted by both children with ASD and typically developing children.

Method

Participants

Children with ASD. Participants in the experimental group consisted of ten children in the second grade and ten children in the third grade. All the children were males, and they were in regular classes in Japanese elementary schools. The children were diagnosed by physicians as having ASD. The average verbal intelligence quotient (VIQ) score (WISC-III) was 93.8 (range 68–119), and the average performance IQ (PIQ) score (WISC-III) was 94.4 (range 66–115). The average ASD screening questionnaire (ASSQ-R) score was 26.95 (ASSQ-R scores over 19 indicate a strong possibility of ASD).

Typically developing children (control group). The participants in the control group consisted of ten children in the second grade and ten children in the third grade. They were all males and in regular classes in Japanese elementary schools. None of them had been diagnosed with any developmental disorders, and their teachers judged that they had no problems of behavior or learning.

Table 1 Percentage of Children who Passed Theory of Mind Tasks

<table>
<thead>
<tr>
<th>Task</th>
<th>ASD Group (n=20)</th>
<th>Control Group (n=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2nd Grader</td>
<td>3rd Grader</td>
</tr>
<tr>
<td>Task of balls</td>
<td>50%</td>
<td>70%</td>
</tr>
<tr>
<td></td>
<td>(5/10)</td>
<td>(7/10)</td>
</tr>
<tr>
<td>Task of cards</td>
<td>10%</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>(1/10)</td>
<td>(5/10)</td>
</tr>
<tr>
<td>Task of baked sweet potatoes</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>(0/10)</td>
<td>(0/10)</td>
</tr>
</tbody>
</table>

Note. ASD: Autism Spectrum Disorder.
them, respectively, and presented the task as follows.

To begin, the experimenter asked the children to mimic five actions (“touch your ears, clap your hands, touch your feet, touch your head, touch your nose”).

Next, the bear card was shown, and children were instructed to carry out what the bear said; then, the wolf card was shown, and children were instructed not to do what the wolf said. A few practice rounds followed, with presentation of the bear card being accompanied by an instruction to, for example, “touch your nose,” in a high voice, and the wolf card being accompanied by an instruction to, for example, “touch your tummy,” in a low voice. When a child followed all the commands of the bear and ignored those of the wolf, it was considered that the child had passed the exercise. A rule check was performed when the participant failed five successive wolf tasks. The following ten tasks were shown to the children who were able to complete the afore mentioned exercises: bear: “stick out your tongue;” wolf: “touch your ears;” bear: “touch your tooth;” wolf: “touch your eye;” bear: “clap your hands;” wolf: “touch your feet;” bear: “touch your head;” wolf: “touch your tummy;” bear: “touch your nose;” and wolf: “flutter your hand.” The score range is from 0 to 15, and the average score of a three- to four-year-old child in Carlson et al. (2004) is 13.13.

Whisper. Based on the whisper task (Carlson et al., 2002, 2004; Kochanska et al., 1996). Children were asked to whisper the name of characters from a popular animated series shown continuously throughout the task; the character answered in its own voice. Although children were excited, it was required that their actions be controlled. Ten characters depicted on laminated 10 cm × 14 cm cards were brought out. As an exercise, the experimenter pointed to the children and said in a whisper, “Please whisper your name.” Subsequently, the experimenter whispered, “You’ll see the cards of various characters; please whisper the name of the character.” Children were shown the cards continuously and told to say if they did not know the name. The score range is from 0 to 2, and the average score of a three- to four-year-old child in Carlson et al. (2004) is 1.93.

Tower of Hanoi. The task is based on Welsh (1991) and Carlson et al. (2004); selected as a planning task. The rules of the task dictates that three disks stacked on a rod is only movable one at a time to one of the three rods, and a larger disk cannot be placed on top of a smaller disk, and the disks must always be stacked on a rod. Children should move the disks to form a target state based on the rule. It is required in the case of task execution that a reaction should be formed intentionally. A board of wooden rectangles (18 cm × 7 cm) meets the rod at the center of the board and has rods at intervals of 5 cm (4.3 cm in height). Disks came in three sizes/colors (large, 4.5 cm, red; middle, 3.5 cm, yellow; and small, 2.5 cm, blue). The game was taught as follows. While an experimenter explains the equipment to the children, he or she says, “The big disk must not be put on the small disk of the same stick. But a small disk can be put on a big disk. Only one disk of one rod can be moved at once, and the disk must always be stacked on a rod.” Then, the experimenter puts a red disk on a blue disk, asking, “Is this okay?” The same question is asked as the experimenter moves two disks at once and then places a disk on the board. When the child was not aware that all these things were not allowed, the rules were explained once again. Then, the experimenter pointed to a card depicting all three disks moved to the right-hand rod and said, “Please move the disks until they are the same as this.” Six levels of the task were conducted. Each task level is shown in Fig. 1. The score range is from 0 to 6, and the average score of a three- to four-year-old child in Carlson et al. (2004) is 2.09.

Children were given two chances to complete each stage in order to progress to a more advanced level.

Truck Loading. The task was based on Fagot and Gauvain (1997) and Carlson et al. (2004); selected as a planning task. This task required children to deliver letters of several differing colors to houses with the corresponding color. The houses stand along a one-way path, and a letter must always be delivered from the top of a loading platform. Therefore, when loading a platform with a letter, it is necessary to stack it

\[
\begin{array}{cccccc}
1. & 2. & 3. & 4. & 5. & 6. \\
S & M & L & S & M & L \\
\end{array}
\]

(L: Large size disk, M: Middle size disc, S: Small size disk)

Fig. 1 Task Levels of Tower of Hanoi
in an order contrary to the order in which the houses are placed. It was required that children consider how to deliver most efficiently.

The road was in the shape of an ellipse and was drawn on paper (38 cm × 54 cm). The game was taught as follows, using as materials the houses and letters made from pasteboard and construction paper as well as a toy mail van. It was explained in yellow letter: “This is a mail van. Please put the letter on the loading platform.” While running the mail van along the road, the experimenter explained, “This town has only one-way traffic. A mail van passes along this way.” Then, yellow and blue houses were arranged in a pair, and it was explained, “Here are two houses. You are going to invite the people who live in them to a party. Please deliver the yellow letters of invitation to yellow houses and blue letters of invitation to blue houses. You have to distribute the letters of invitation so that everybody may come to a party. The quickest method is to go through the town only one time. You can only take letters from the top of the loading platform. So, the top letter of invitation is distributed to the first house, and the following letter of invitation is distributed to the next house.” Next, the letters were stacked on the loading platform with a blue letter on the bottom and a yellow letter on the top (an order contrary to the order of the houses). Then, children were asked, “Can we take a letter from under the loading platform?” This question is asked again until they can answer correctly. Letters are then delivered, and after the first exercise the yellow and blue houses are changed to red and black houses. Children are invited to load and deliver the letters, and when they succeed with two houses, more are added, one house at a time (finally adding up to five houses). Children were permitted two chances to complete each task. If they were successful they could progress to the next stage. The children were graded on their ability to load in an order contrary to the order in which the truck delivers the letters of invitation to each house.

Self-correction in the loading stage was accepted. When a child was once mistaken, feedback was given (“You have to distribute from the top always”), the letter was taken from the loading platform, and the truck was returned to the start point. The score range is from 0 to 4, and the average score of a three- to four-year-old child in Carlson et al. (2004) is 1.82.

### Analysis Method

All tasks were scored based on Carlson et al. (2004).

**Bear/Wolf.** Reactions to each “wolf direction” were scored from 0 to 3 points (0: followed directions completely; 1: followed directions partially; 2: carried out an action different from the directions; 3: did not act). The score of the five wolf directions was considered as the child’s score (0–15 points). Since one second-grader and one third-grader among the children with ASD refused to participate, a reaction could not be recorded, so these children were excluded from the analytic object. The joint of each reaction analysis by one author and one consultation person produced a coincidence rate of 100%. In addition, the number which divided the congruous numbers of reactions by the total number of reactions was 100.

**Whisper.** Each trial was scored 0 to 2 points (0: shouted; 1: replied in a normal voice; 2: whispered). A total of ten trials were added and divided by 10 to acquire the final score (0–2 points). Since one second-grader and one third-grader with ASD refused to participate, a reaction could not be recorded, so they were removed from the analysis. The coincidence rate of evaluation of a reaction was 98.5%.

**Tower of Hanoi.** All 6 levels were scored (2–7 times a disk could be moved). The highest level a child attained during trial was considered as the child’s score (0–6 points). The coincidence rate of reaction evaluations was 100%.

**Truck Loading.** All 4 levels (2–5 houses) were scored. The highest level that a child attained during trial was considered as the child’s score (0–4 points). The coincidence rate was 100%.

### Results

Average score and standard deviation (SD) of each task according to group (ASD or control) are shown in Table 2.

In each executive function task, analysis of variance (ANOVA) of two factors, presence of ASD and grade level, was conducted. The results of ANOVA are shown in Tables 3–6.

The result of the ANOVA in the Bear/Wolf task is shown in Table 3. There was a significant interaction between the presence of ASD and grade ($F(1, 36)=4.78, p<.05$). On the analysis of simple effects, the presence of ASD factor was significant at
the second-grade level only \((F(1, 36)=7.55, p<.01)\), accounting for the low average score of the second-grade children with ASD. The grade factor was significant in ASD group only \((F(1, 36)=7.55, p<.01)\), since the second-grader’s average score was lower than the third-grader’s average score.

The result of the ANOVA in the Whisper task is shown in Table 4. There was no significant interaction \((F(1, 36)=.37, n.s.)\). Main effect of presence of ASD factor was significant \((F(1, 36)=7.21, p<.05)\). The average score of the ASD group was significantly lower compared to the control group. Main effect of grade factor was not significant \((F(1, 36)=.08, n.s.)\).

The result of the ANOVA in the Tower of Hanoi task is shown in Table 5. There was no significant interaction \((F(1, 36)=.37, n.s.)\). Main effect of presence of ASD factor was significant \((F(1, 36)=32.75, p<.001)\). The average score of the ASD group was

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**Table 2 Mean Score and SD of Tasks**

<table>
<thead>
<tr>
<th>Task (Range)</th>
<th>ASD Group (n=20)</th>
<th>Control Group (n=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2nd Grader (n=10)</td>
<td>3rd Grader (n=10)</td>
</tr>
<tr>
<td></td>
<td>Mean Score SD</td>
<td>Mean Score SD</td>
</tr>
<tr>
<td>Bear/Wolf (0–15)</td>
<td>13.1 15</td>
<td>14.1</td>
</tr>
<tr>
<td>Whisper (0–2)</td>
<td>3.22 0</td>
<td>2.35</td>
</tr>
<tr>
<td>Tower of Hanoi (0–6)</td>
<td>1.7 1.82</td>
<td>1.77</td>
</tr>
<tr>
<td>Truck Loading (0–4)</td>
<td>4.44 0.36</td>
<td>0.38</td>
</tr>
</tbody>
</table>

**Table 3 ANOVA of Bear/Wolf**

<table>
<thead>
<tr>
<th>Factor</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASD or not</td>
<td>19.60</td>
<td>1</td>
<td>19.60</td>
<td>2.89</td>
<td>n.s.</td>
</tr>
<tr>
<td>2nd Grader</td>
<td>51.20</td>
<td>1</td>
<td>51.20</td>
<td>7.55</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>3rd Grader</td>
<td>.80</td>
<td>1</td>
<td>.80</td>
<td>.11</td>
<td>n.s.</td>
</tr>
<tr>
<td>Grade</td>
<td>19.60</td>
<td>1</td>
<td>19.60</td>
<td>2.89</td>
<td>n.s.</td>
</tr>
<tr>
<td>ASD</td>
<td>51.20</td>
<td>1</td>
<td>51.20</td>
<td>7.55</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Not ASD</td>
<td>.80</td>
<td>1</td>
<td>.80</td>
<td>.11</td>
<td>n.s.</td>
</tr>
<tr>
<td>Mutual Action</td>
<td>32.40</td>
<td>1</td>
<td>32.40</td>
<td>4.78</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>Error</td>
<td>244.00</td>
<td>36</td>
<td>6.77</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. SS: Sum of Squares, df: Degree of Freedom, MS: Mean Square.

**Table 4 ANOVA of Whisper**

<table>
<thead>
<tr>
<th>Factor</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASD or not</td>
<td>1.64</td>
<td>1</td>
<td>1.64</td>
<td>7.21</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>Grade</td>
<td>.02</td>
<td>1</td>
<td>.02</td>
<td>.08</td>
<td>n.s.</td>
</tr>
<tr>
<td>Mutual Action</td>
<td>.02</td>
<td>1</td>
<td>.02</td>
<td>.08</td>
<td>n.s.</td>
</tr>
<tr>
<td>Error</td>
<td>8.18</td>
<td>36</td>
<td>.22</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. SS: Sum of Squares, df: Degree of Freedom, MS: Mean Square.
significantly lower compared with that of the control group. Moreover, main effect of grade factor was also significant \((F(1, 36)=10.80, p<.01)\). The average score of the second-graders was significantly lower compared with the third-graders’ average score.

The result of the ANOVA in the Truck Loading task is shown in Table 6. There was no significant interaction \((F(1, 36)=.04, n.s.)\). Main effect of presence of ASD factor was significant \((F(1, 37)=5.21, p<.05)\). The average score of the ASD group was significantly lower compared with the control group. Main effects of grade factor was not significant \((F(1, 36)=.04, n.s.)\).

The above results are summarized as follows. First, the analysis for each executive function tasks between a group of children with ASD and a control group showed that the children with ASD had significantly lower scores in the Whisper, Tower of Hanoi, and Truck Loading tasks. Moreover, in the Bear/Wolf task, the scores of the second-graders with ASD were significantly lower. Secondly, the difference in score between the grades of the children for each executive function task shows that the third-graders’ results were significantly higher for the Tower of Hanoi. In the Bear/Wolf task, only the third-graders with ASD had significantly higher scores. No difference in score was seen between grades in the Whisper and Truck Loading tasks.

**Discussion**

From the result of this report, a possible obstacle is seen in terms of lower inhibition capability in children with ASD, which could be seen in the Bear/Wolf and Whisper tasks.

In previous research on children and adults with ASD, inhibition capability is maintained and score difference is not seen compared with a control group (Griffith, Pennington, Wehner, & Rogers, 1999; Ozonoff and Jensen, 1999; Russell, Jarnold, & Hood, 1999). This was different in the current study.

Why was this difference seen? Russell et al. (1999) showed that children with ASD have difficulty compared with typically developing children in doing tasks in which they need to memorize a new rule and follow it, and in tasks requiring a nonverbal reaction. It is reported that problem is not seen in the tasks which do not require children to memorize rules taught verbally and tasks in which the children must react verbally even when it is necessary to memorize rules. The Stroop task and day-night task that were carried out in previous research involve memorization of new rules and verbal response. Therefore, according to Russell et al. (1999), there will be no conflict between memorizing rules and reacting in children and adults with ASD, and it may be thought that results were not influenced. On the other hand,
the Bear/Wolf task carried out in this study contained a new rule, namely, not following what the wolf says while following the bear's exact verbal instructions. As the reactions were nonverbal, it is thought that this accounts for the low scores in the ASD group.

As for the Whisper task, although it involved verbal response, the results of the ASD group were significantly low compared with those of the control group. As a cause, we must consider the influence of ambiguous directions on children with ASD. The reaction needed in a whisper task is only to whisper the name of a character in response to a prompt; understanding of a complicated rule is not needed, and once the children have memorized the “whisper rule,” there are no further special instructions needed to complete the task. It is known that children with ASD have difficulty with ambiguous directions and ambiguous context (Frith, 1989). Therefore, it may be possible that the difficulty was seated in the lack of an unambiguous model or precedent for what it would look like to “whisper” a character's name.

A difficulty with planning is also possibly seen in the ASD results from the Tower of Hanoi and Truck Loading tasks. This difficulty is in accordance to prior research (Bennetto, Penington, & Rogers, 1996; Hughes, Russell, & Robbins, 1994; Ota, 2003; Ozonoff & Jensen, 1999; Ozonoff & McEvoy, 1994; Ozonoff, Pennington, & Rogers, 1991a, 1991b). Moreover, in Carlson, Moses, and Breton (2004), which carried out Tower of Hanoi in the same way as this study, the average score of three- and four-year-old children was 2.09 points. The second-graders with ASD in this research had an average score of 2.1 points, a result mostly in agreement with the typically developing children in Carlson et al. (2004). This does still imply planning difficulty in children with ASD. Moreover, it is required in Tower of Hanoi and Truck Loading to carry out a nonverbal reaction according to a new rule; in that sense, this result is in agreement with Russell et al.'s (1999) result as well.

Tower of Hanoi is a task of problem solving. When a disk is moved, a child needs to maintain the representation of a target that does not presently exist (Ota, 2003). Moreover, Tower of Hanoi is a task with a fully specified problem space. A problem space is a complex representation, involving, for example, an initial state, a target state, and an operation object, and problem-solving can be regarded as the process that searches for the chain connecting an initial state and a target state in a problem space (Matsui, 2001).

In this study, the target state was shown by the card, and although the initial state also existed before it, children needed to form two or more representations employing visual information about the chain between the two states. In Truck Loading, the required rule consists at least of plurality, the color of a house, the color of a letter at hand, and the correspondence of two sequences. Both Tower of Hanoi and Truck Loading present the possibility that cognitive load became too large for children with ASD, who show difficulty with central coherence and meta-representation, and their results were low compared with the typically developing group.

In this study, a ceiling effect was seen in the control group of typically developing children in the results of the Bear/Wolf, Whisper, and Truck Loading tasks. Many children in the ASD group also had high scores in these tasks. Since task difficulty was low, any difference between grades might have been too small to detect. After taking this point into consideration, the variation in the difference between the grades in Bear/Wolf and in Tower of Hanoi is considered. In Bear/Wolf, a significant difference was seen by grade only within the ASD group. In the control group, all the second-graders scored perfectly, and, since almost all the third-graders were also perfect, it is thought that a significant result difference did not arise between grades in the group. The ASD second-grader's average score was 13.1 points, which was almost the same as the 13.13 average score of a three-to four-year-old child in Carlson et al. (2004) with the same procedure. Carlson and Moses (2001) see that working memory capability is needed to some extent in order to operate two or more thinking processes simultaneously in tasks like conflict inhibition. Moreover, Nakamichi (2007) has shown that, in infancy, increase of linguistic working memory capacity relate closely to development of conditional reasoning or deductive inference. Russell et al. (1999) have pointed out the complications of linguistic working memory in children with ASD, which can also be inferred from the ASD group's scores on the Bear/Wolf task in this study. If a certain amount of linguistic working memory is required for this task, it is possible that memory develops between second and third grade. Moreover, it is proven that children with ASD are not late in intellectual development when compared with typically developing children, yet children
with ASD are likely to gain theory of mind in their second or third grades along with a possible ability to carry out representation or to perform a linguistic analogy, as well as an increased capacity of linguistic working memory, whereas typically developing children acquire this at the age of 4. However, it is difficult to acquire definitive knowledge on this matter from the framework of this study.

In Tower of Hanoi, since the difference between grades was evident in the scores, it is suggested that capability in planning, which is needed by Tower of Hanoi, develops according to age. When Tower of Hanoi's adjusted version was used by Klahr and Robinson (1981), a four-year-old child managed a problem that usually needs two to three movements, a five-year-old child managed one that usually needs four movements, and a six-year-old showed that a scenario that needs six movements could be managed. In this study, the second-graders in control group solved the problem which needed five or six movements on average, and most of the third graders were able to complete tasks which required seven movements. The possibility that planning capability will progress with age is suggested also from this. Moreover, the ASD second-graders’ average score was 2.1 points, and was almost the same as the 2.09 average scores of three- to four-year-old children in Carlson et al. (2004). However, the ASD third-graders’ average score was 3.7 points, which greatly improves from second graders’ results. Furthermore, they show progress on being able to operate two or more representations. Moreover, the influence of working memory can also be inferred from this result.

Children with ASD, despite of no evident delay in intellectual development, have difficulty employing capacities such as inhibition or planning compared with typically developing children of the same age; therefore, hypothesis 1 was supported. Moreover, a possibility that their abilities developed in accordance with age was suggested, supporting hypothesis 2.

In the typically developing children, the processes and goals of executive function shows much development between ages three to five, when it is supposed that theory of mind is gained, and it is shown clearly that developmental change is related to development of theory of mind. This study targeted 9 year-old children with ASD who do not show delay in intellectual development because it had been hypothesized that those children with linguistic competence may have gained theory of mind. It was shown that many executive function tasks, such as planning and conflict inhibition, increase in ease and sophistication between second and third grades; the influence of this increase of working memory capacity was already inferred from previous literature. In connection with this, the capability to carry out representation or to perform a linguistic analogy using language processes, and a possibility that this will affect acquisition of theory of mind can be considered. However, this research cannot make that conclusion.

The following two points are raised as subjects for further research. First, in respect to the difficulty of an executive function task, since inhibition tasks in particular were low in difficulty, it could be considered that the difference in score between groups or grades was difficult to affirm. In order to more conclusively examine difficulty to perform executive function in children with ASD, it is necessary to develop and implement tasks of a difficulty level on the child’s actual condition. Moreover, it is thought that it is necessary also to examine linguistic and visual working memory, as well as to examine the role of a cognitively flexible viewpoint or one capable of holding two or more representations.

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