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<th><strong>Title</strong></th>
<th>The role of spatial working memory capacity in text comprehension</th>
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<td><strong>Abstract</strong></td>
<td>In this study, the role of individual differences in working memory capacity with regard to text comprehension was investigated using the situation model perspective (Zwaan &amp; Radvansky, 1998). One hundred and eight students participated in the study and gave a listening span test (LST) that tapped their verbal working memory, a dot matrix task (DMT) that tapped their spatial working memory, and completed a text comprehension task that tapped the construction of the text base and the situation model. The alternatives in the text comprehension task were of two types: text base (henceforth Text Base) and the situation model (henceforth Situation Model). Participants were required to recognize items and report their retrieval state. They had the option to recognize items from the text (In Text) or to make a guess (Guess). It was found that the DMT significantly and positively correlates with the retrieval rates in the conditions of Text Base and Situation Model, and that the correlation between the LST and the retrieval rates were smaller. This result suggests that spatial working memory plays a more important role in text comprehension. Furthermore, the predictive power of the DMT on the Situation Model was larger than that of Text Base. This result suggests that spatial working memory plays a more crucial role in the construction of the situation model. In addition, working memory tasks negatively correlated with the retrieval rates in the Guess condition, although these tasks positively correlated with the In Text retrieval rates. These results suggest that working memory plays an important role in the retrieval of episodic text memory and a restrictive role in the retrieval of semantic text memory.</td>
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In this study, the role of individual differences in working memory capacity with regard to text comprehension was investigated using the situation model perspective (Zwaan & Radvansky, 1998). One hundred and eight students participated in the study and gave a listening span test (LST) that tapped their verbal working memory, a dot matrix task (DMT) that tapped their spatial working memory, and completed a text comprehension task that tapped the construction of the text base and the situation model. The alternatives in the text comprehension task were of two types: text base (henceforth Text Base) and the situation model (henceforth Situation Model). Participants were required to recognize items and report their retrieval state. They had the option to recognize items from the text (In Text) or to make a guess (Guess). It was found that the DMT significantly and positively correlates with the retrieval rates in the conditions of Text Base and Situation Model, and that the correlation between the LST and the retrieval rates were smaller. This result suggests that spatial working memory plays a more important role in text comprehension. Furthermore, the predictive power of the DMT on the Situation Model was larger than that of Text Base. This result suggests that spatial working memory plays a more crucial role in the construction of the situation model. In addition, working memory tasks negatively correlated with the retrieval rates in the Guess condition, although these tasks positively correlated with the In Text
retrieval rates. These results suggest that working memory plays an important role in the retrieval of episodic text memory and a restrictive role in the retrieval of semantic text memory.

I. Introduction

Working memory is a construct in cognitive psychology that refers to temporarily retained information and coordinates various cognitive processes (Baddeley, 2000). Working memory also plays an important role in text comprehension. According to the meta-analysis conducted by Daneman and Merikle (1996), complex span tests, which measured individual differences in working memory capacity, positively correlated with text comprehension, and the correlation coefficients were approximately .40. Friedman and Miyake (2000) further reported that working memory capacity could predict the construction of a situation model. Situation models are integrated mental representations of the state of affairs based on the text and thought to have an important role in language comprehension (Zwaan & Radvansky, 1998).

However, recent data has suggested that working memory does not have a relationship with situation model processing. For example, Radvansky and Copeland (2004) reported that individual differences in working memory capacity could not predict the situation model processing but could predict the score of text base processing. Sasaki and Suzuki (2008a) also reported that the working memory span could not predict the score of the contemporary Japanese literature section of the National Center Test for University Admission, the alternatives of which were believed to tap the construction of the situation model.

Based on these results, a relationship between working memory capacity and text comprehension were investigated using the text base and the situation model perspectives (Zwaan & Radvansky, 1998).
II. Methods

1. Participants

One hundred and eight undergraduate students participated in the study (\(M\) age = 19.8; \(SD = 2.46\)). Of these, 31 were men and 77 were women. Ninety-two students gave the listening span test (LST) and 73 students gave the dot matrix task (DMT). Eighty-eight participants completed the text comprehension task but the data of only 86 participants was used because two participants responded items less than 50%.

2. Tasks

The LST and DMT were used to measure the individual differences in working memory capacity. In addition, a text comprehension task was performed.

2.1. Listening span test

In this study, a group-administered LST (Sasaki & Suzuki, 2008b) was used. LST was believed to tap verbal working memory.

The task was composed of words and sentences. Words were used for memory tasks, and sentences were used for processing tasks. The words were primarily from the nonfood category (e.g., medicine, daughter, etc.). Words were also selected from Amano and Kondo (1999) to create sentences. The level of familiarity of all the words used in the memory tasks was over six (very high), with each word being three mora in length.

In the processing tasks, the sentences were composed using words on two themes: food (e.g., milk, potato, etc.) and artifacts (e.g., pencil, robot, etc.). These words were used for creating the theme of the sentences. The familiarity level of all the words used in the sentences was over six (very high), with each word being four mora in length. The duration of the presenting sentences was seven seconds per sentence and that of the presenting words was two seconds per word. The stimuli were digitally recorded as an audio CD.

In each trial, participants had to hear a sentence and a word presented
after the sentence. On hearing the sentence, participants had to evaluate whether the theme of the sentence was food or not. If the theme was food, participants had to write down “O” in the response A3 (297mm × 420mm) sheet. If the theme was not food, participants had to write down “X.” Following the presentation of sentences and words, participants had to immediately write down the words in the same order as they appeared in the presentation upon being given the instruction “please answer.” If the instruction “please stop answering” was given, participants had to stop writing.

The listening span was gradually increased from two to five in this task, and three trials were conducted in each span condition. The time given for answering ranged from four seconds (in a two-span condition) to ten seconds (in a five-span condition). The total time for conducting all trials was approximately 12 min.

2.2. Dot matrix task

The DMT was first created by Miyake, Friedman, Rettinger, Shah, & Hegarty (2001) and was then known as the spatial working memory span test. Participants performed simple calculations and memorized targets simultaneously, similar to the original operation span test (Turner & Engle, 1989). In this study, a group-administered version was created by the method explained below.

Firstly, participants were required to verify a matrix equation. Each equation contained two matrices that were composed of dots and lines and a quadrangle-shaped operator. In the matrix equation display, an addition, a subtraction, and an impossible equation were presented, as illustrated in Figure 1. Participants were given six seconds to verify the operators in each equation by circling “+”, “−”, or “Neither.” Secondly, participants had to view a sequence of equations and then provide the order in which the operators appeared by writing numbers in parentheses below the operators. The time given for answering ranged from six seconds (in a two-span condition) to fifteen seconds (in a five-span condition). The matrix equation was printed in an A5 (148mm × 210mm) sized booklet. Participants wrote their responses in this booklet in synchronization with beeps and slides created using MS PowerPoint 2000.
There were three trials in each span condition, which progressively increased in size from two to five. The total time was approximately seven minutes.

2.3. Text comprehension task

A novel entitled Honkaku shousetsu (Mizumura, 2002) available in the contemporary Japanese literature section of the National Center Makeup Test for University Admission (National Center for University Entrance Examinations, 2005) was used as the text in this task. Items were created in the manner explained below.

Two types of items were created (See Table 1). The first was text base items (Text Base), the descriptions of which were the same as the text. The

<table>
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<tr>
<th>Condition</th>
<th>True Item</th>
<th>False Item</th>
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<tbody>
<tr>
<td>Text Base</td>
<td>Jim saw Yusuke came out of my house from behind me, and Jim opened his eyes subtly. Next, Jim returned his expression to the shy expression for the world.</td>
<td>Jim saw Yusuke came out of my house from behind me, and Jim opened his eyes subtly. Next, He returned his expression to the discontented expression for the world.</td>
</tr>
<tr>
<td>Situation Model</td>
<td>When Jim saw I and Yusuke came out of my house together in afternoon, he changed his facial expression just a little.</td>
<td>When Jim saw I and Yusuke came out of my house together in afternoon, he opened his eyes subtly because he wonder our relationshin.</td>
</tr>
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</table>
second type was situation model items (Situation Model), the descriptions of which were guessed from the text but not written in the text. Ten correct items and ten incorrect items were created for each type.

In each item, participants had to answer two questions. The first question was related to the correctness of the item. In this question, participants had to circle either “True” or “False.” The second question was allocated to measure the awareness of participants. In this question, participants had to circle the options “In Text” or “Guess.” “In Text” meant that the participants had an episodic text memory. “Guess” meant that the participants had no choice but to use their semantic text memory instead of their episodic text memory.

When performing the text comprehension task, the experimenter read the text out loud and participants listened and silently read it alongside. The time given for reading was nine minutes. After reading, participants answered questions on each item. The time given for answering was fifteen minutes.

3. Procedure

The working memory and text comprehension tasks were performed with a large group. The text comprehension task was performed first, followed by the LST one week later and DMT two weeks later.

III. Results

1. Scoring

The scores of the LST and DMT were considered as accumulations of those trials in which participants responded in the correct order (Engle, Tuholski, Laughlin, & Conway, 1999). The mean of the LST was 9.74 (SD = 1.66) and that of the DMT was 6.47 (SD = 2.05). The text comprehension score was classified into True-Positive, False-Negative, True-Negative, and False-Positive (See Table 2). Formulas by Higham (2002) were used to calculate the retrieval rates (See Table 3).
2. Text comprehension

A two-way ANOVA was performed on the retrieval rates (See Table 4). The main effect of the Item (Text Base or Situation Model) was significant: $F(1, 85) = 123.8, p < .001, \eta_p = .59$. The main effect of Awareness (In Text or Guess) was also significant: $F(1, 85) = 257.7, p < .001, \eta_p = .75$. In addition, the interaction effect was also significant: $F(1, 85) = 181.6, p < .001, \eta_p = .68$. The simple main effects of Item were significant in both the Awareness condition. In the Text condition, the retrieval rate in the Text Base condition was larger than that in the Situation Model condition: $F(1, 170) = 296.8, p < .001, d = 3.7$. However, inverse tendency was found in the Guess condition. The retrieval rate in the Situation Model condition was larger than that in the Text Base condition: $F(1, 170) = 37.9, p < .001, d = 1.3$. This interaction suggested that the response in the Situation Model condition included more Guess responses than that in the Text base condition.
3. Correlation analysis

Pearson’s correlation coefficients between the working memory tasks and the retrieval rates of the text comprehension task were calculated (See Table 5). The correlation coefficients between the DMT and the retrieval rates in the In Text condition were larger than those between the LST and the retrieval rates. This result suggested that the spatial working memory task could predict text comprehension better than the verbal working memory task. Furthermore, the predictive power of the DMT on the Situation Model was larger than that of Text Base. This result suggested that spatial working memory task could predict the construction of the situation model better than that of the text base.

In addition, all the correlation coefficients in the Guess condition were negative. Both working memory tasks significantly and negatively correlated with the retrieval rate in the Text Base condition, and the DMT marginally correlated with that in the Situation Model condition. This result suggested that participants with a large working memory capacity made fallacious recognitions when they had to guess the contents of the text.

Table 4. Retrieval Rates in Text Comprehension Task (N = 86)

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<tr>
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<th>Text Base</th>
<th>Situation Model</th>
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<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>In Text</td>
<td>0.68</td>
<td>0.17</td>
</tr>
<tr>
<td>Guess</td>
<td>0.14</td>
<td>0.11</td>
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Table 5. Correlation Coefficients between Working Memory Tasks and Retrieval Rates of Text Comprehension Task

<table>
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<tr>
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<th>Situation Model</th>
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<tr>
<td></td>
<td>In Text</td>
<td>Guess</td>
</tr>
<tr>
<td>LST&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.17 †</td>
<td>−.23 *</td>
</tr>
<tr>
<td>DMT&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.24 *</td>
<td>−.30 *</td>
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Note. *n = 73, *n = 58. **p < .01, *p < .05, †p < .1 (one-tailed).
IV. Discussion

In this study, the relationship between individual differences in working memory capacity and text comprehension were investigated. This study showed that individual differences in spatial working memory capacity could positively predict the text comprehension score when participants could answer In Text, and that individual differences in working memory capacity negatively correlated with the text comprehension score when participants had no choice but to guess their answer.

This study also showed the strong relationship between spatial working memory and text comprehension in the In Text condition. This result suggested that spatial working memory plays a more important role in text comprehension than verbal working memory. Furthermore, the correlation coefficient in the Situation Model condition was larger than that in the Text Base condition when participants could remember contents in text. This result suggests that spatial working memory plays a more important role in constructing the situation model. Because visuospatial working memory has an impact on imagery (Logie, 1986; Quinn & McConnel, 1996), the influence of individual differences in spatial working memory may reflect in the construction of the situation model.

In addition, all the correlation coefficients between working memory capacity and the retrieval rates in the In Text condition were positive and those between working memory capacity and the retrieval rates in the Guess condition were negative even though the coefficients of the LST were smaller. This result suggests that working memory has a strong relationship with the retrieval of episodic text memory and a weak relationship with that of semantic text memory. Clarys, Isingri, and Gana (2002) reported that working memory capacity could positively predict the “remember” response that related to episodic memory but could not predict the “know” response that related to semantic memory. Furthermore, Sasaki (2007) reported that working memory capacity played a more important role in the use of episodic cues rather than semantic cues. Based on these studies, it is considered that the present results are due to the characteristics of working memory that can function when episodic memory can be used and cannot function when semantic memory is used instead.

This prediction is believed to explain the reasons for working memory
not being able to predict the processing in the situation model in some of the previous studies (e.g., Radvansky & Copeland, 1998; Sasaki & Suzuki, 2008a). Because the scores in previous studies contained the component of semantic memory, the predictive power of the working memory tasks might have weakened.

References

Sasaki, T., & Suzuki, K. (2008a). Daigakunyuushi center shiken gendaibun no
tokuten ni taisuru shuudanshiki listening span test no yosokuryoku [The predictive power of the group listening span test in the contemporary Japanese literature section of the National Center Test for University Admission]. Proceedings of 50th Annual Meeting of the Japanese Association of Educational Psychology, 291. (in Japanese)