Verbal memory span, visual memory span, and their correlations with cognitive tasks

SHIN-ICHI ICHIKAWA
Junior College of Economics, Saitama University, Urawa, Saitama 338

Immediate memory spans of 82 students were measured through the recall of digit sequences and dot-in-matrix patterns. The reliabilities of both spans were very high, while the correlation between the spans was low ($r = .209$). In addition, the same subjects were given eight kinds of cognitive tasks (Word Relation, Maze, Addition, Shape Series, Anagram, Space Relation, Number Series, and Mental Rotation) selected from intelligence tests. The two spans were correlated with the performance of each task in different degrees. Results of the factor analysis showed that the digit span had a high loading value on the "verbal" factor, while the span with dot patterns loaded the "visuospatial" factor. It is suggested that the capacities of those verbal and visual immediate memory are independent to each other from the point of view of individual difference, and that they have distinct roles in problem solving.

Key words: immediate memory span, visual memory, recall of patterns, capacity of imagery, intelligence test, problem solving, correlation analysis.

Immediate memory span, originally devised by Jacobs (1887), has often been measured through the recall of digit sequences (Woodworth, 1938). The span indicates an ability to retain meaningless material that seems to be unrelated to thinking. However, measurement of span is often included in an intelligence tests, and it has been shown that in children span increases with age and very low span often indicates retardation. Kubota (1965), moreover, suggested that span has a particular role even in normal subjects' thinking or reasoning. Thinking process sometimes involves the retention of several elements whose relationship is at first unclear. Span indicates the mental effort to keep attention to unrelated items before the correct solution is discovered. In fact, significant correlations between intelligence and immediate memory have been reported in some investigations (Cohen & Sandberg, 1977; Kubota, 1965; Wechsler, 1974).

However, research has been limited to the investigation of verbal immediate memory while that of visual memory remained neglected. Recently Ichikawa (1982a) proposed a method for measuring "visual" memory span by means of the recall of matrices containing several numbers of dots therein. The proportion of perfectly recalled patterns was a monotonically decreasing function of the number of dots, when matrix size was $5 \times 5$ or $6 \times 6$. Consequently, visual memory span can be defined as the number of dots in the pattern which a subject perfectly recalls with a probability of 0.5. However, the recall of dot patterns should not be referred to as "visual" memory if subjects verbally encode and retain the positions of dots.

The present study is concerned with the validity of visual memory span measured through the recall of dot-in-matrix patterns. If the visual span expresses the capacity of visuospatial representation...
rather than that of verbal immediate memory, then the correlation between visual span and digit span should be considerably weak. Furthermore, it is expected that the two spans should be correlated with different types of cognitive tasks assuming that the tasks require temporal preservation of verbal and visual information in different degrees.

Measurement of Span

Method

Subjects. The subjects were 50 students of Tokyo Woman's Christian University and 32 of Saitama University (24 males and 58 females total). They had normal, or corrected-to-normal vision.

Materials. For measuring "verbal" memory span, six series of digit sequences were used. One series consisted of seven sequences whose length was six through 12 (Fig. 1). These sequences were randomly produced with the following restrictions in order to eliminate too easy sequences to memorize. (a) Same digits should not appear within any sequence made of four digits (e.g., "...1741..."). (b) More than three ordered digits should not appear successively (e.g., "...234... "). (c) Same digits should not appear at the beginning and at the end of a sequence (e.g., "7...7").

"Visual" memory span was measured using six series of dot-in-matrix patterns. As shown in Fig. 2, one series consisted of six patterns, each of which contained three through eight dots in a 5 x 5 grid. The following two restrictions were adopted to exclude patterns which were too easy to memorize; (a) "equivalence set size (ESS)", representing the degree of symmetry, should be eight; (b) "concentration along row or column direction (CRC)", representing the degree of concentration of dots in particular rows or columns, should be smaller than a critical value (the mean for 50 randomly produced patterns minus the standard deviation for them). These two variables have proved to be effective to control recall performance for dot-in-matrix patterns (Ichikawa, 1981, 1982a).

Procedure. The experimental sessions were carried out in a classroom.

Fig. 1. A sample series of digit sequences used to measure verbal memory span.

193716
4893460
92815907
325098501
5168043852
68307120568
861958190873

Fig. 2. A sample series of dot-in-matrix patterns used to measure visual memory span.

\[
\text{ESS} = \text{the number of patterns resulted from mirror image reflection and 90°-step rotation (Garner & Clement, 1963). More symmetric patterns have smaller ESS values. On the other hand, CRC is defined as } 1-(1-CR)(1-CC), \text{ where CR and CC are concentration of dots along row or column direction, respectively. "Concentration" is derived from redundancy in the information theory. For example, let } d_i = \text{number of dots contained in row } i(1 \leq i \leq m) \text{ and let } p_i = d_i/d, \text{ where } d \text{ is the total number of dots in a matrix. Then, }
\]

\[
\text{CR} = 1 - \left[ \sum_{i=1}^{m} p_i \log_2 \left( \frac{1/p_i}{\log_2 m} \right) \right].
\]
stimulus material was projected on a screen for 4 s, and the subjects were asked to reproduce it on a response sheet immediately after the presentation. The numbers of digits or dots were printed beside the blank grids in the answer sheet to avoid the subjects being confused. The series of digit sequences and those of dot patterns were presented alternatively, with the first series being digit series. Ascending order was always employed within a series. Prior to an experimental session, the subjects were instructed to recall all digits or dots in a presented stimulus, since only perfect reproduction would be regarded as a correct response. The experimental session lasted for about 20 min.

Results and Discussion

As stated above, only a perfectly recalled digit sequence or a dot pattern was considered to be a correct response: A digit sequence was counted correct only if the digits were written in their correct serial positions. The proportion correct pooled over all subjects is presented in Tables 1 and 2. It appears that the proportion of correct responses is a decreasing function of the number of digits or dots. This fact reconfirmed Ichikawa's (1982a) proposition that we can represent visual memory span in terms of the number of dots in the pattern which a subject perfectly recalls with a probability of 0.5.

The summation method (Guilford, 1954) was employed to calculate individual spans. Figure 3 is a scattergram of the 82 subjects' verbal and visual spans. For verbal span, the mean was 8.60 and standard deviation (SD) was .83, while the mean and the SD for visual span were 5.75 and 1.01, respectively. The correlation coefficient between verbal and visual spans across subjects was .209, which was not statistically significant, $t(80)=1.91$, $p>.05$. This low correlation could not be accounted for by the reliability of the measurement, since the Spearman-Brown reliability coefficients by means of the split-half method (divided into odd and even series) were considerably high: .840 and .793 for verbal and visual spans, respectively.

Hakoda and Ichikawa (1981) also reported that the recall performance for letters was not correlated with that for position information. In Condition 1 of their experiment, 8-letter sequence or 8-dot-in-4 x 4-matrix patterns were visually presented and immediately recalled. In Condition 2, the stimuli containing eight letters in a 4 x 4 matrix were presented and the subjects were required to reproduce either letters or their locations according to the

---

3 Ichikawa (1982b) plotted verbal and visual spans as functions of presentation time, and found that there existed a plateau at 2 to 8-s presentation in each graph. The height of this plateau is nearly equal to so-called memory span (nine digits and six dots, respectively), which indicates not the rate of reading or encoding but the limitation of memory. The stimulus duration employed in the present experiment, i.e., 4 s was a representative of this plateau.
The correlation coefficient between letter recall and position recall across 34 subjects were .022 and -.036 under Conditions 1 and 2, respectively. Although the correlation observed in the present experiment was not as low as that in Hakoda and Ichikawa's results, it still suggests that verbal and visual spans represent different memory abilities, and that there exist two independent immediate memory mechanisms. If so, they may play different roles in problem solving. Several cognitive tasks were performed to examine such a working hypothesis.

### Cognitive Tasks

**Method**

Eight kinds of cognitive tasks were given to the same subjects who participated in the previous span test. All tasks but T5 (Anagram) were chosen from Japanese intelligence tests (Table 3); example problems are presented in Fig. 4. Originally, these tasks were not made to measure memory ability, but appeared to require verbal or visual immediate memory to some degree. T1, T3, T5, T7 seemed to be correlated with verbal span, and T2, T4, T6, T8, with visual span, since it was intuitively suspected that the kind of required memory depended on whether the material was verbal or visual.

<table>
<thead>
<tr>
<th>Task</th>
<th>Source</th>
<th>Time (min)</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 (Word Relation)</td>
<td>Tanaka (1958)</td>
<td>2.5</td>
<td>29.04</td>
<td>5.07</td>
</tr>
<tr>
<td>T2 (Maze)</td>
<td>Tanaka (1962)</td>
<td>2.5</td>
<td>13.78</td>
<td>1.13</td>
</tr>
<tr>
<td>T3 (Addition)</td>
<td>Tanaka (1962)</td>
<td>3</td>
<td>45.11</td>
<td>14.38</td>
</tr>
<tr>
<td>T4 (Shape Series)</td>
<td>Tanaka (1962)</td>
<td>3</td>
<td>21.02</td>
<td>3.08</td>
</tr>
<tr>
<td>T6 (Space Relation)</td>
<td>Ushijima (1961)</td>
<td>3</td>
<td>9.70</td>
<td>1.58</td>
</tr>
<tr>
<td>T7 (Number Series)</td>
<td>Tanaka (1962)</td>
<td>5</td>
<td>15.99</td>
<td>3.47</td>
</tr>
<tr>
<td>T8 (Mental Rotation)</td>
<td>Ushijima (1961)</td>
<td>3</td>
<td>11.71</td>
<td>3.32</td>
</tr>
</tbody>
</table>

These tasks were performed in a classroom after the measurement of span.

### Results and Discussion

Means and SDs of the tasks are presented in Table 3. Table 4 is a correlation matrix of two kinds of memory spans and eight cognitive tasks. Generally speaking, the correlation coefficients between performance of a span test and that of a cognitive task was not so high. As shown in Fig. 5, however, the correlations suggest some interesting findings which are summarized as follows:

(a) T1 (Word Relation) and T5 (Anagram) were correlated with verbal span.
while T2 (Maze) and T8 (Mental Rotation), with visual span. These results are easy to understand, considering the nature of the tasks.

(b) T3 (Addition) was equally correlated with both verbal and visual spans, though mental arithmetic is often regarded as a verbal task.

(c) T4 (Shape Series) and T7 (Number Series) were correlated with visual span rather than with verbal span. This was interesting in that digits were used as material in T7.

(d) T6 was correlated with verbal span rather than with visual span, though it was named "Spatial Relations Test" in the original intelligence test. Probably this task requires verbal immediate memory to retain the sentences in a problem. Thus, verbal span and visual span were

---

**Fig. 4.** Example problems in the cognitive tasks. T1: Choose a word from four alternatives to form similar relations of the two words. (In this example, " ear: hear = eye: close, tears, see, or glasses ".) T2: Draw a line from the entrance to the exit. T3: Sum four digits. T4: Complete series of shapes. T5: Make four-letter words. T6: "D is on the right side of C. C is on the left side of B. B is behind A. Which is D?" T7: Complete series of numbers. T8: Choose the figure which cannot be superposed onto the left one by rotation.
Table 4
Correlation matrix of span and cognitive tasks

<table>
<thead>
<tr>
<th></th>
<th>Ver.</th>
<th>Vis.</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>T5</th>
<th>T6</th>
<th>T7</th>
<th>T8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal span</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual span</td>
<td>.209</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>.202</td>
<td>.014</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td>.070</td>
<td>.361**</td>
<td>.124</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T3</td>
<td>.262*</td>
<td>.253*</td>
<td>.199</td>
<td>.089</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T4</td>
<td>.171</td>
<td>.296**</td>
<td>.269**</td>
<td>.309**</td>
<td>.262*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T5</td>
<td>.280*</td>
<td>.100</td>
<td>.237*</td>
<td>.182</td>
<td>.223*</td>
<td>.365**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T6</td>
<td>.259*</td>
<td>.125</td>
<td>.505**</td>
<td>.306**</td>
<td>.089</td>
<td><em>280</em></td>
<td>.242*</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T7</td>
<td>.233*</td>
<td>.322**</td>
<td>.433**</td>
<td>.222*</td>
<td>.383**</td>
<td>.295**</td>
<td>.336**</td>
<td>.471**</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>T8</td>
<td>.107</td>
<td>.312**</td>
<td>.167</td>
<td>.425**</td>
<td>.171</td>
<td>.291**</td>
<td>.273*</td>
<td>.391**</td>
<td>.283*</td>
<td>1</td>
</tr>
</tbody>
</table>

* p < .05  ** p < .01

Correlation with Visual Span

Correlation with Verbal Span

Fig. 5. Correlation coefficients between span and each cognitive task across subjects. (Open circle: simple correlation. Closed circle: partial correlation by controlling the other span.)

Fig. 6. Factor loadings in the factor analysis for verbal span, visual span, and performance of cognitive tasks.

Correlation with performance of several cognitive tasks in different degrees, though all correlations are not in accordance with the prediction before the experiment. In addition, factor analysis of all ten variables was carried out to show that the spans are especially fundamental variables. Figure 6 presents Varimax-rotated factor loadings of the principal component solution. Verbal and visual spans load the first factor which is interpreted as “verbal” factor and the second factor “visuospatial” factor, respectively.

General Discussion

It has been strongly suggested by the selective interference effect that visual information is processed in a form other than that of verbal information. Brooks (1968) showed that the time needed to describe retained line diagrams and sentences depends on the mode for recall. The task interpolated in retention interval selectively interferes with verbal and visual information (den Heyer & Barrett, 1971; Hakoda & Nakamizo, 1975; Ichikawa, 1982b; Meudell, 1972). The performance of a verbal task remains unaffected by carrying a visuospatial load but is affected carrying a verbal-auditory load (Henderson, 1972; McLeod, 1977).

These findings are in agreement with
the view that modality-specific processing systems may exist (Kosslyn, 1980; Paivio, 1971). The results of the present study suggested that the individual capacities of such processors are determined independently: If immediate memory for a digit sequence and for a dot pattern were performed by using a common central resource, a subject with high digit memory would have high pattern memory. Actually the correlation between the two kinds of immediate memory was found to be very low. It should be noted, however, that this result does not necessarily mean complete separation of verbal and visual short-term stores. In fact, Hakoda and Ichikawa (1981) found a decrement in the accuracy of recalled letters and their positions in a matrix when subjects were asked to memorize both simultaneously. We cannot help suspecting that a common resource is shared at least along one of the processing stages, i.e., encoding, retention, or retrieval.

Finally, it was suggested earlier that visual immediate memory plays a role in cognitive processes. It is further suggested that the visual span test using dot-in-matrix patterns can be employed as an objective test to measure imagery capacity or vividness. Compared with self-rating tests which are sometimes said to be contaminated by such a factor as social desirability (Di Vesta, Ingersoll, & Sunshine, 1971), the reliability and the validity of visual span seem to be considerably high. It could be argued that visual span is not a very good predictor for performance in a cognitive task which need the use of imagery, since merely retaining a dot pattern as an image is different from controlling it. However, as shown in the present study, visual span is one of the most fundamental measures for assessing visuospatial ability. It is likely that high imagery capacity results in skillful imagery control, if visualization and manipulation of images share to some extent the same resource. This notion may be advanced in the framework of working memory (Baddeley & Hitch, 1974) as its visual version.

References


Ichikawa, S. 1982b Verbal and visual recall span curves between 1 ms and 1 min. Psychological Research, 44, 269-281.

Jacobs, J. 1887 Experiments on "prehension".
Mind, 12, 75-79.

(Received March 1, 1983; accepted Sept. 11, 1983)