CHAPTER II

EXPERIMENT I

Method

Subjects

Twenty-four graduate students at Chulalongkorn University served in Experiment I. They were randomly assigned to condition.

Material and List Construction

The To-Be-Remembered Item (TBRI) consisted of one noun and three modifiers which clarified the selected noun in three attributes, i.e. the characteristic attribute, the chromatic attribute and the numerical attribute; followed by a string of eight digits. In order to control the time of presentation, word length was determined in a pilot study and hence resulting in two-syllable words for noun and modifiers, and one-syllable words for digits. This string of speech signal was empirically proved to exceed the memory span in normal person when such signals or words were encoded in STM as discrete units (or chunks). Mathematical design for pattern of item construction resulted in 24 patterns which were due to the permutative combination of four alternatives N, M1, M2 and M3 as shown in table 1.

TABLE 1

PATTERNS OF TBRI*

	Words				Random Digits							
1	N	M1	M2	M3	-	-	-	-	-	-	-	-
2	M1	N	M3	M2	-	-	-	-	-	-	-	-
3	M2	M3	N	M1	-	-	-	-	-	-	-	-
4	M3	M2	M1	N	-	-	-	-	-	-	-	-
5	N	M1	M3	M2	-	-	-	-	-	-	-	-
6	M1	N	M2	M3	-	-	-	-	-	-	-	-
7	M2	M3	M1	N	-	-	-	-	-	-	-	-
8	M3	M2	N	M1	-	-	-	-	-	-	-	-
9	N	M3	M1	M2	-	-	-	-	-	-	-	-
10	M1	M2	N	M3	-	-	-	-	-	-	-	-
11	M2	M1	M3	N	-	-	-	-	-	-	-	-
12	M3	N	M2	M1	-	-	-	-	-	-	-	-
13	N	M2	M1	M3	-	-	-	-	-	-	-	-
14	M1	M3	N	M2	-	-	-	-	-	-	-	-
15	M2	N	M3	M1	-	-	-	-	-	-	-	-
16	M3	M1	M2	N	-	-	-	-	-	-	-	-
17	N	M2	M3	M1	-	-	-	-	-	-	-	-
18	M1	M3	M2	N	-	-	-	-	-	-	-	-
19	M2	N	M1	M3	-	-	-	-	-	-	-	-
20	M3	M1	N	M2	-	-	-	-	-	-	-	-
21	N	M3	M2	M1	-	-	-	-	-	-	-	-
22	M1	M2	M3	N	-	-	-	-	-	-	-	-
23	M2	M1	N	M3	-	-	-	-	-	-	-	-
24	M3	N	M1	M2	-	-	-	-	-	-	-	-

* this pattern was constructed by means of permutative combination. N is a noun, M1, M2, M3 are modifiers for the clarification of characteristic attribute, chromatic attribute and numerical attribute, respectively.

To eliminate the effect of learned material, each item was designed to consist of a new set of noun and modifiers. But, as a result, the factor of discrepancy of between-item difficulty occured and must be equated or eliminated. The problem was solved by a systematic organization in which each set of noun and modifiers occured in all of the twenty-four patterns, thus equated the between-item difficulty; but each set still appeared once in a list, therefore a list consisted of twenty-four sets of noun and modifiers, and the number of the lists determined by the design was twenty-four lists in which each consecutive item varied as in the patterns shown in table 1.

The criterion for the selection of noun and modifiers was under the qualfication of being concrete, vivid and distinctive, but not familiar enough for guessing. This criterion led to the selection of geometrical names and their characteristic attribute (M1) accompanied by the chromatic and numerical attributes (M2, M3) which appropriated for such criterion. But some other concrete nouns were also selected for the comparison of the data.

Procedure

In order to control speed of presentation, the constructed lists of TBRIs were recorded in a casscette tape. The speed of presentation was about 100 words per minute which was empirically accepted as the normal speaking rate. Ss were required to perform immediate-serial recall verbally. The recall of words and digits in TBRIs were recorded in the provided answer sheets by the experimenter simultaneously.

Each S performed on a list of 24 TBRIs, one by one, with a resting period of approximately 15 seconds between items, therefore the effect of interference of the encoded TBRIs would be eliminated. Each S served in Experiment I for approximately 10-15 minutes. No reward was given to the S.

Results of Experiment I

Memory Span Analysis

The data of TBRI recall in Experiment I were reorganized and analyzed in the form of fixed-N-position in order to show the differential recall capacity of each pattern of varied-M-position. The mean number of words recall of each pattern are presented in table 2.

TABLE 2

WORDS RECALL CAPACITY

Number of M prior to N	Mean number of words recalled
0	9.45
1	8.68
2	8.38
3	8.37

The differences of the mean numbers of words recall were tested for significance by means of ANOVA for single factor experiments with repeated measures on the same elements.[1] The results are summarized in table 3.

TABLE 3

ANALYSIS OF VARIANCE

Source of variation	SS	df	MS	F
Between people	95.42	23	4.15	
Within people	46.64	72	0.65	
Treatment	18.47	3	6.16	15.02**
Residual	28.17	69	0.41	
Total	142.06	95		

The $F_{.99}(3,69) < 4.13$, thus the overall differences of mean number of words recall are significant at a .01 level test because of the effect of the treatment.

Tests on differences between pairs of means are performed by means of Newman-Keuls method[2]. The results are summarized in table 4.

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[1] B.J. Winer, Statistical Principles in Experimental Design, (Tokyo; McGraw Hill Kogakusha, 1971), pp. 261-296.

[2] Ibid.

TABLE 4

TESTS ON DIFFERENCES BETWEEN PAIRS OF MEANS

Number of M prior to N	Total	3	2	1	0
		200.99	201.18	208.35	226.84
3	200.99	-	0.19	7.36	25.85
2	201.18		-	7.17	25.66
1	208.35			-	18.49
0	226.84				-
$q_{.99}(r,60)$			3.76	4.28	4.60
$\sqrt{nMS_{res}}\,q_{.99}(r,60)$			11.81	13.44	14.44

	3	2	1	0
3	-	-	-	**
2			-	**
1			-	**
0				-

TABLE 5

TEST FOR TRENDS

T	3	2	1	0	$\sum c^2$	$n\sum c^2$	C	MS	F
Total	200.99	201.18	208.35	226.84					
Linear	-3	-1	1	3	20	480	84.72	14.95	36.46
Quadratic	1	-1	-1	1	4	96	18.30	3.49	8.51
cubic	-1	3	-3	1	20	480	4.34	.04	0.10

The overall recall probability of the presented words in each position is illustrated in figure 1. Each line illustrates variation of recall probability of the grouped items of fixed-N-position at the identical order. Notice the fluctuation of the lines between position 6-11.

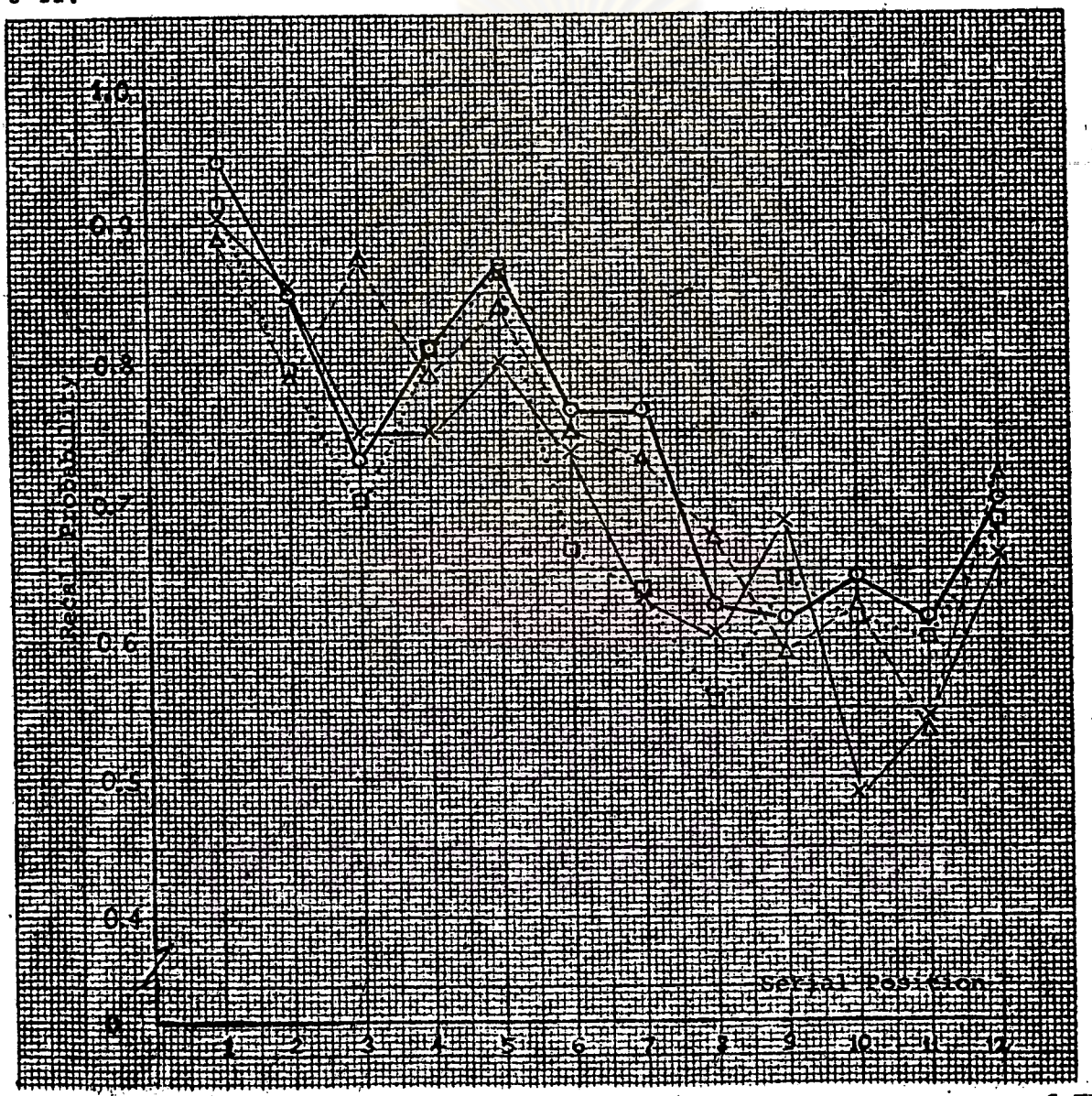

Fig. 1. Recall probability on serial position of the four patterns of TBRIs.

○—○ = N - - - ; ✕—✕ = - N - - ; △—△ = - - N - ; □—□ = - - - N.

Conditional Error Probability

In order to verify the hypothesis of chunking of words in TBRI, another method of analysis called conditional error probability was utilized to illustrate the error probability of modifier recall, given that the noun was not recalled. There was a total number of 365 errors entered this method of analysis. The results are presented in table 6.

TABLE 6

CONDITIONAL ERROR PROBABILITY OF MODIFIER RECALL

Position of N	Type of M	Conditional Error Probability
N - - -	M1	0.16**
	M2	0.11**
	M3	0.12**
- N - -	M1	0.30**
	M2	0.34**
	M3	0.26**
- - N -	M1	0.33**
	M2	0.35**
	M3	0.19**
- - - N	M1	0.47
	M2	0.38**
	M3	0.29**
	AVERAGE	0.26**

Apparently, none of the numerical value of conditional error probability presented in table 6 exceeds a value of 0.5, the chance level. The overall (average) conditional error probability is 0.26,

**Significant at .01 level of test for goodness of fit by χ^2.

which is remarkably low, and when using chi-square test for goodness of fit, the difference is significant at a level of 0.1 test. This evidence shows no corresponding increment between the error of N and the error of M.

It is also noticeable that the minimum conditional error probability of all three types of modifiers occurs in condition that N is at the first position (M1 = 0.16, M2 = 0.11, M3 = 0.12). This results shows a highly competitive displacement between N and M in memory span.

For comparison of the conditional error probability ; the results in table 6 were plotted in figure 2.

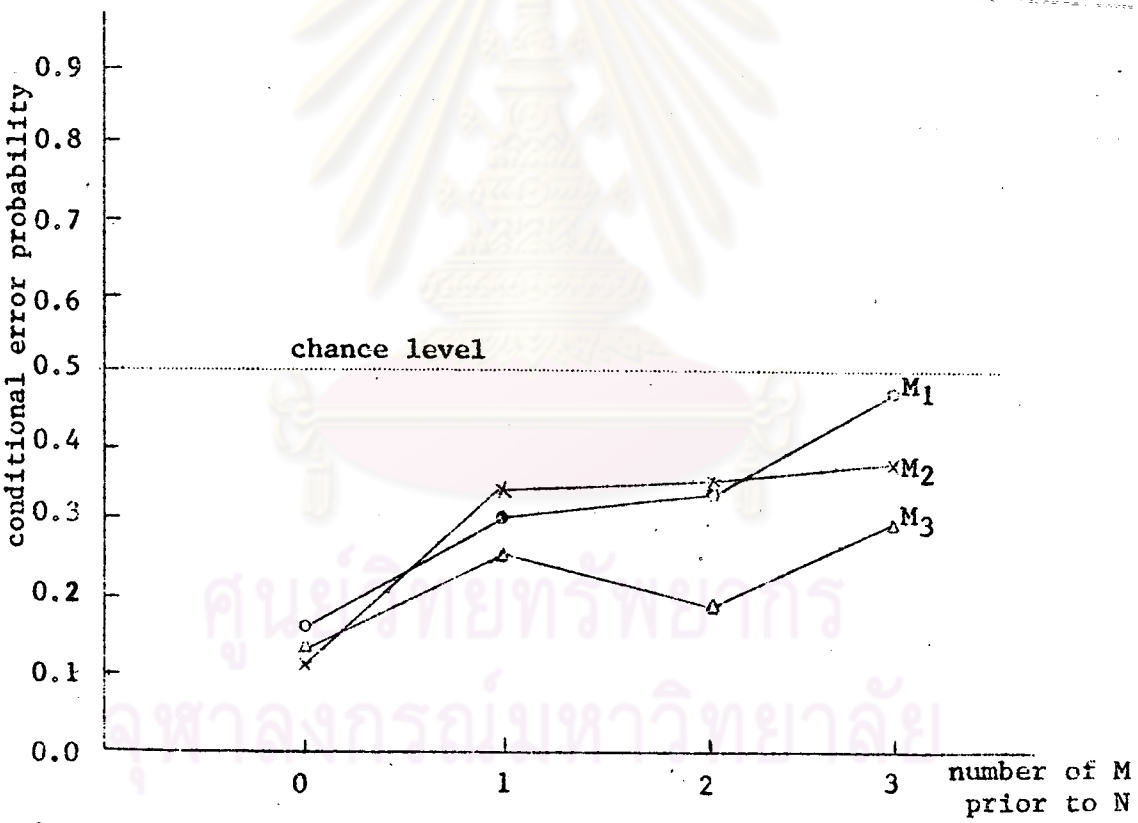

Fig. 2. Conditional error probability. Notice that none of the points is higher than the chance level and the minimum values of all three types of modifier co-exist at the items that N is on the first position.

Position Reversion Analysis

Owing to the serial recall technique used in experiment I, the obtained data could be analyzed for investigation on the error of position of words in the item recalled. There was a total number of 1.14 errors of this type. The percentages of position reversion in item recall of the four fixed-N-position patterns are presented in table 7.

TABLE 7

PERCENTAGES OF ERROR OF POSITION IN SERIAL RECALL

Position of N	Percentage of N-M reversion
N - - -	1.75
- N - -	16.67
- - N -	41.37
- - - N	40.21

As shown in table 7, the percentage of error of position of word in item recall is noticeably low in the first pattern. This pattern is congruent to the syntactic rule of the right-hand-branching language. When the numbers of modifier prior to noun increase, the percentages of noun-modifier reversion correspondingly increase.

Discussion on the Results of Experiment I

In experiment I, it was hypothesized that the modifier positions in TBRIs would effect semantic encoding in STM in the way that chunking economy would be different, which was due to the chunking mechanism which is serial and delayed where modifiers preceed noun, but where modifiers follow noun the mechanism is instantaneous. As for a quantitative verification in immediate serial recall paradigm, the hypothesis predicts the following quantitative results;

1. The increment of word recall capacity varies as a reciprocal function of the number of modifiers prior to noun in the TBRIs, or in a mathematical statement,

$$C_{wr} \propto \frac{1}{n_m} \qquad \text{.....(1)}$$

where C_{wr} = word recall capacity

n_m = number of modifiers prior to noun

2. The conditional error probability of each pattern is much more than the chance level, or in a mathematical statement,

$$p(\bar{M}|\bar{N}) \gg 0.5 \qquad \text{.....(2)}$$

which implies that

$$p(\bar{M}|\bar{N}) \gg p(\bar{M}|N) \qquad \text{.....(3)}$$

where $p(\bar{M}|\bar{N})$ = error probability of modifier given that noun is not recalled

$p(\bar{M}|N)$ = error probability of modifier given that noun is recalled

Furthermore, the increment of conditional error probability varies as a reciprocal function of the number of modifiers prior to noun, or in a mathematical statement,

$$p\ (\bar{M}|\bar{N}) \propto \frac{1}{n_m} \qquad \text{.....(4)}$$

The results of memory span analysis as shown in table 2, 3 and 4 indicate a differential effect and the test for trends indicates a much more linear variation, thus, support the hypothesis that modifier positions in TBRIs effect encoding in STM, and it can be concluded that $C_{wr} \propto \frac{1}{n_m}$ as predicted in (1).

But quite contradictory to the prediction in the second statement, the results of conditional error probability as shown in table 6 indicates no corresponding increment between the error of modifier and noun. The overall $p\ (\bar{M}|\bar{N}) = 0.26$ which is very much lower than the chance level. Furthermore, as shown in figure 2, $p\ (\bar{M}|\bar{N}) \ll p\ (\bar{M}|N)$ at the pattern that noun preceeds modifiers. This result indicates a highly competttitive displacement and implies that the error is due to failure of chunking of words in TBRIs. It is also indicated that the increment of conditional error probability varies as a linear function of the number of modifiers prior to noun, or

$$p\ (\bar{M}|\bar{N}) \propto n_m \text{ .....for } p\ (\bar{M}|\bar{N}) < 0.5$$

Combining to the results of position reversion analysis in table 7 and recall probability on serial position in figure 1, these results co - suggest an effect of coding mechanism (see figure 2) which can be interpreted as a zero order reorganization where noun preceeds modifiers

in the TBRI, a first order reorganization where a modifier proceeds noun, a second order reorganization where two modifiers preceed noun, and a third order reorganization where three modifiers preceed noun in the TBRIs.

Results of position reversion analysis suggest a syntactic reorganization because the TBRI is a string of words in a right-hand-branching language and position reversion in the recalled item shows a tendency of shifting noun to the first position. There are only two out of 114 errors in position reversion that shift noun from the first position to the second position. It can be concluded that the proposed hypothesis of reorganization in coding process is a syntactic reorganization.

The alternative hypothesis for the explanation of the results of the present experiment will be discussed later in chapter III in order to combine to the results of experiment II.