Reaction time and short term memory: Implication of negative set —1

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High speed exhaustive scan hypothesis was investigated using a modified Sternberg's RT technique. The difference of information processing methods under the varied response patternse established before carrying out the experiment was not substantiated in the findings. It was found that the mean RT of positive response without negative response and that of positive response with negative response increase approximately parallel with increasing of positive set size and that their characteristics are the same. The only difference in the response conditions that could be emphasized was that positive response without negative response was faster than positive response with negative response, but the logarithmic slopes of the functions relating the RT to size of the memory set did not replicate the Sternberg's hypothesis.

Sternberg (1966) developed an ingenious technique to investigate error-free memory, though experiments on human memory had principally measured performance in terms of errors.

In the Sternberg's task, the subject first memorizes a short series of symbols. These specified symbols are called the positive set. Then, he is shown a test symbol. He must decide whether it is a member of the previously presented stimuli (the positive set). If it is, he makes a positive response (yes response), for example, by pressing one of two buttons. If it is not (the negative set), he makes a negative response (no rseponse) by pressing the other button. The reaction time (RT) is measured from the onset of the test stimulus to the response. In his experiments, Sternberg found that the mean RT increased approximately linearly with positive set size or memory load (M), $RT=A+B(M)$, and the rate of increase was the same in both positive and negative responses.

According to his interpretation, the fact that positive and negative latency functions have equal linear slopes means that in determining the appropriate response for a test symbol, the subject scanned the memorized symbols in serial and exhaustive fashion : even when matching has occurred, scanning continues through all the symbols in the memory storage.

Among many experiments, which followed Sternberg's work to investigate his findings, is indicated the obvious discrepancy concerning the form of the functional relationship between RT and positive set size. Hoving et al (1970), Wingfield & Branca (1970), and Harris & Fleer (1970) have supported the Sternbreg's findings, but, Smith (1967), Swanson & Briggs (1969), Briggs & Swanson (1970), Swanson

(1974), and Homa & Fish (1975) have found the relationship between RT and positive set size to be logarithmic rather than linear.

In Sternberg's experiments (1963, 1966), it also was shown that the size of negative set had not any influence on the latencies of both positive and negative responses, and the variation of positive set only affected the RT. But, Swanson (1970) indicated that the type of negative set neglected in Sternberg's hypothesis was important in determining which relationship (a linear or logarithmic relationship) will result.

In the present experiment, how the reaction time (RT) functions will be influenced by the difference of response pattern will be investigated.

Sternberg divided the organization of the S-O-R formula in the short-term memory experiment condition into four stages. The following figure shows the information processing stages supposed in the short term memory (STM) experiment condition.

	(1)		(2)		(3)		(4)		
Stimulus	⟶	encoding	⟶	serial comparison	⟶	decision	⟶	decoding response function	⟶ Response

Under the STM task situation, the subject encodes the stimulus into a symbol of information of his own (Stage 1). Then he will compare it with items stored in the memory storage (Stage 2). He will make the binary decison (Stage 3) and transfer the decision to the physical response (Stage 4).

The following factors are considered as those influencing the reaction time at each stage.

Stage 1 stimulus legibility.

Stage 2 size of the positive set.

Stage 3 pattern of response.

Stage 4 relative frequency of response.

In experiment 1 of this study special attention will be given to stages 3 and 4.

As in other STM choice reaction experiments, Sternberg used yes-or-no responses, or same-or-different responses, with single-item tests. In such a case the subject has to pay attention to two response at the same time. This raises a question. Doesn't this alternative of response affect the reaction time function? If the experiment is concerned with the condition of the stimulus in the STM task, the ideal response way should be the simplest one. Accordingly, if the exeriment in which the subject has only to pay attention to one response produces different results from the experiment with two responses, the result of Sternberg's experiment should be considered as a special result, compounded with stimulus variables and response variables.

Switch plans here indicate the kinds of decision response (Fig. 1.).

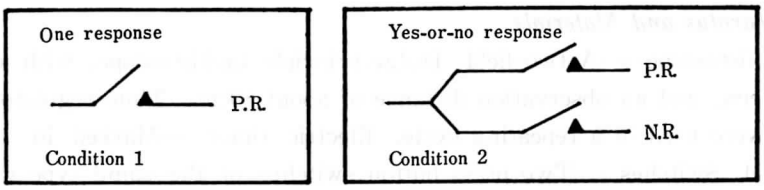

Fig. 1. Models of the decision pattern

In condition 1, the button is pressed only when the test item is the same as any one of the memorized items. The circuit can be termed a quite simple one. In condition 2, the positive response button is pressed when the test item is the same as any one of the memorized items and the negative response button is pressed when the test item is different from any of the memorized items. But in this circuit, there are many other possibilities of response. The positive response button may be pressed for a negative set item. The negative response button may be pressed for a positive item. Both switches may be pressed for a positive set item or for a negafive set item. So this circuit can be termed a quite complex one.

Moreover, it can be supposed that in condition 1, the subject will try to extract the positive stimulus (figure or target) from the negative stimulus (ground or noise) confronting to the series of exposures of the test stimulus, and that in condition 2, the subject will try to classify whether the test stimulus is a positive or a negative one. In any case, if there is a difference in the information processing way between the two conditions, there will be a possibility that the RT function will be affected.

METHOD

Using the same experimental procedure, two conditions varying only the response patterns, are set up.

In condition 1, the response pattern required the subject to pay attention to the positive set item (which was the target letter and critical element), and did not need to respond to the negative set item (the non-target letter, noise element).

Under condition 2, the subjects had to pay attention to both positive and negative responses, and to make a binary response (yes–or–no response).

For both these conditions, the effect of response pattern to reaction time was investigated. The reaction times obtained were of three kinds, which were i. positive response time under condition 1 (P1), ii. positive response time under condition 2 (P2), and iii. nega-tive response time under condition 2 (N). The changes of reaction times of these three kinds were measured, increasing the number of positive set items, 1–2–3–4.

Apparatus and Materials

Tachistoscope——A two-field, Dodge-principle tachistoscope, with a 22cm. × 21cm. screen, and an observation distance of about 80cm. Time regulator——Four channels were used in a repeating cycle. Electric timer——Marked in hundredths of a second. Switches——Two press-button switches of the same type were used. To cancel out the possible error caused by the difference of the mechanism of the switches, the total of R. T. measurements was halved. Oscillator and speaker—— These were arranged to make the buzzer sound of 330Hz from the speaker.

Presentation of visual stimuli

The visual stimuli were displayed briefly (150ms) on the screen of the tachistoscope at regular intervals. At the same time, the timer began operation, so that it checked the reaction time for the subject to press the button. Four seconds before the exposure of the stimulus, a warning buzzer sounded for two seconds to alert the subject, leaving a pause of a further two seconds. The period for one complete trial is 14 seconds, so the pattern for one trial is shown in Fig. 2.

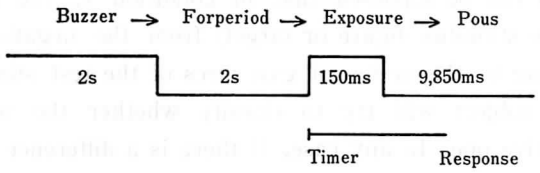

Fig. 2. Presentation of visual stimuli

The recording of the reaction time and the changing of the stimulus material was accomplished in the remaining 9,850 ms, before the warning buzzer for the next trial.

Procedure

Before the experiment, training trials were conducted. At first, the subject was asked for a simple reaction to accustom him to the experimental set, and the response pattern. Next, by using the letters S, R and X, sample experiments were performed to explain the process of the main experiment.

Suggestions to the subject for a sample experiment were as follows : —

"Two seconds after a two second buzzer warning, a letter will be shown briefly. Press the buttons according to the directions I give you."

Instructions when the positive set involves one letter only.

1a. "If the letter you see is S, press button 1 as quickly as you can, with the index finger of your right hand. Be careful not to make a mistake."

1b. "If the letter you see is S, press button 2 as quickly as you can, with

the index finger of your left hand. Be careful not to make a mistake."

Instructions when the positive and negative set involve one letter respectively.

2a. "If the letter you see is S, press button 1 as quickly as you can, with the index finger of your right hand, but, if you see another letter, press button 2 as quickly as you can, with the index finger of your left hand. Be careful not to make any mistakes."

2b. "If the letter you see is S, press button 2 as quickly as you can, with the index finger of your left hand, but, see another letter, press button 1 as quickly as you can, with the index finger of your right hand. Be careful not to make any mistakes."

Instructions when the positive set involves two letter.

1a. "If the letter you see is either S or R, press button 1 as quickly as you can, which the index finger of your right hand, without making any mistakes."

1b. "If the letter you see is either S or R, press button 2 as quickly as you can, with the index finger of your left hand, without making any mistakes."

Instruction when the positive set involves two letters and the negative set involves one letter.

2a. "If the letter you see is either S or R, press button 1 as quickly as you can, with the index finger of your right hand, but, if you see another letter, press button 2 as quickly as you can with the index finger of your left hand, without making any mistakes."

2b. "If the letter you see is either S or R, press button 2 as quickly as you can, with the index finger of your left hand, but, if you see another letter, press button 1 as quickly as you can, with the index finger of your right hand, without making any mistakes."

After completing the training trials, the subject has become familiar with the procedure to be followed in the experiment.

The main experiment will require two special separate one-hour periodes. In the first period, positive set 1 and positive set 2 will be operated. In the second, positive set 3 and positive set 4 will be operated. The letters used in the positive sets are F, H, K and N, and in the negative set, M only is used.

To equalize the probablility of responses, the occurrence of the positive and negative set is equalized. For each subject under each condition, the reaction time is measured twenty times. The experimental sessions divided in two equal parts, to counterbalance the possible differences of using left and right hands. In this way, eight separate sections of response are recorded in about one hour session, as shown in Table 1. To reduce the effect of training, sections are presented in random order, with two-minute intervals between sections.

Table 1 Design of the experiment

First Session					Second Session				
M	(1)	F	(2)	F H	M	(3)	F H K	(4)	F H K N
C	1	2	1	2	C	1	2	1	2
Trials 1 10	P. R. by R. H.	P. R. by R. H. N. R. by L. H.	P. R. by R. H.	P. R. by R. H. N. R. by L. H.	Trials 1 10	P. R. by R. H.	P. R. by R. H. N. R. by L. H.	P. R. by R. H.	P. R. by R. H. N. R. by L. H.
Trials 1 10	P. R. by L. H.	P. R. by L. H. N. R. by R. H.	P. R. by L. H.	P. R. by L. H. N. R. by R. H.	Trials 1 10	P. R. by L. H.	P. R. by L. H. N. R. by R. H.	P. R. by L. H.	P. R. by L. H. N. R. by R. H.

※P. R. =Positive response
R. H. =Right hand
M=Memory set size
N. R. =Negative response
L. H. =Left hand
C=Condition

Subject

Six university students served as the subject.

RESULTS

The mean reaction times of all the subjects for each condition were plotted in Fig. 3, as a function of memory set size (M) or memory load. In the analysis of the reaction time data, three of the four main effects were significant. Reaction times of P1 were faster than those of P2, $F(1.5) = 13.03$, $P < 0.05$; Reaction times increased with memory load (M), $F(3.15) = 12.56$, $P < 0.01$; Response condition P1 vs. P2 × memory load (M) interaction was not significant, $F(3.15) = 0.60$, $P > 0.05$; Reaction times of P2 were faster than those of negative set (N), $F(1.5) = 43.28$, $P < 0.01$; Reaction times increased also with memory load (M), $F(3.15) = 11.33$, $P < 0.01$; Response condition P2 vs. N × memory load (M) interaction was not significant, $F(3.15) = 1.33$, $P > 0.05$.

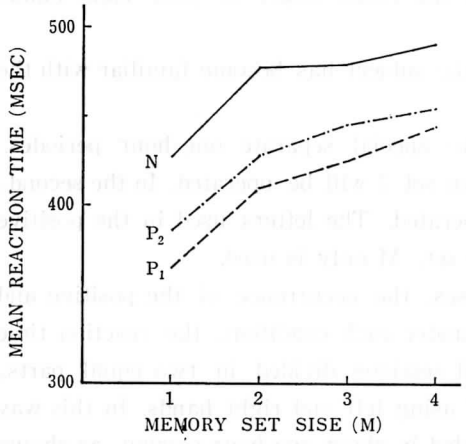

Fig. 3. RT as a function of positive set size

DISCUSSION

It is ascertained from analysis of variance that positive response without negative response is faster than positive response with negative response, and, because the response pattern×memory load interaction is not significant, the mean RT slopes of P1 and P2 as a function of increase of the positive set size are approximately parallel, and their characteristics are the same. The analysis of Pearson's correlation for P1 and P2 shows r=0.989. From these facts, the differences of the information porcesses cannot be identified, and it should be thought that the methods of information processes for both reaction patterns would be the same.

It is supposed, from this result seen clearly in the parallel functions of P1 and P2 in the graph, that the information processing method used in the condition of positive response without negative response should have a similar mechanism to one used in the condition of yes-or-no response. So the above mentioned switch models of the decision pattern, it seems, are better to be revised as shown in Fig. 4.

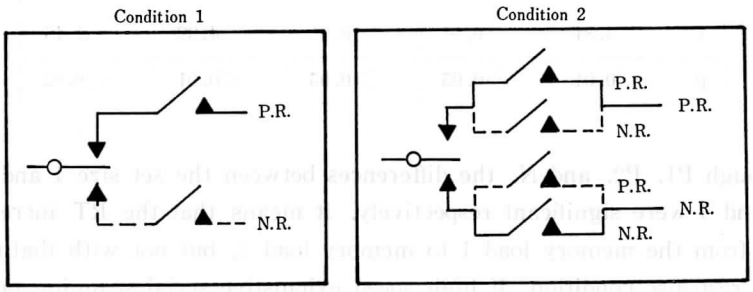

Fig. 4. Revised models of the decision pattern
○—shows a switch presenting decision.

In both models it is presumed that the subjects are performing binary decision in the response situation. Under condition I, inhibition inevitably forms part of the response pattern. Under condition 2, however, the subject is to confront to the two sets of response, and to make the decision, using those sets. If the model be supposed a electric circuit, the switch may be thought a electric resistance. So all the electric resistance under condition 2, it seems, is larger than that under condition 1. As a voltage (e. g. a processing capacity of imformation) in circuit is regarded to be constant, a current intensity under condition 2 is smaller than that under condition I. Considered in this way, it could be explained that the reaction time of P2 is later than that of P1.

From the variance analysis for positive response 2 and negative response, under condition 2, it is ascertained that the RT of the positive response is shorter

than the RT of the negative response, and, because the response pattern × memory load interaction is not significant, the mean RT slopes of P2 and N as a function of increase of the positive set size also are approximately parallel, and their characteristics are the same. The Pearson's correlation for P2 and N is r=0.943. The differences of reaction time between P2 and N response are about 30–50 ms. For these reasons it could be concluded that memory scanning took place exhaustively. The two variance analyses reported that the RTs increased with memory load, but the functions did not increase linearly, so the t-test was applied to examine the differences between the RTs of the items. The results are shown in Table 2.

Table 2 The differences between the RTs of the items

Pair of Set Size		1 — 2	2 — 3	3 — 4	1 — 3	1 — 4	2 — 4
P1	t	4.71	1.68	1.43	6.19	4.06	1.83
	p	<0.01	>0.05	>0.05	<0.01	<0.01	>0.10
P2	t	5.80	1.32	0.43	3.76	4.57	1.60
	p	<0.01	>0.05	>0.05	<0.02	<0.01	>0.05
N	t	4.81	0.01	0.61	4.39	3.46	0.48
	p	<0.01	>0.05	>0.05	<0.01	<0.02	>0.05

Through P1, P2, and N, the differences between the set size 1 and 2, 1 and 3, and 1 and 4 were significant respectively. It means that the RT increased with increasing from the memory load 1 to memory load 2, but not with that more than 2. In each response condition, if high speed exhaustive serial scanning proposed by Sternberg had occured, the mean RT slopes as a function of increase of the memory load should have been linear. In this experiment, the results obtained did not replicate the Sternberg's hypothesis. Some other factors, it seems, modified the information process.

Swanson & Briggs (1969) found that the mean RT of the subjects on whom speed of response had been emphasized, was faster than that of those on whom accuracy had been stressed, and Hale (1969) obtained similar results. Smith (1967) and Homa & Fish (1975) indicated the effect of familiarity on the RT. Neisser (1964) came to similar conclusions, by using visual scanning. This matter will be investigated in the following experiments.

References

Hale, D. J. 1969. Speed-error tradeoff in a three-choice serial reaction task. Journal of Experimental Psychology 81 : 428–435.

Harris, G. J., & Fleer, H. A. 1970. High speed memory scanning in mental retardates, Evidence for a central processing deficit. Journal of Exprimental Child Psychology 17 : 452–9.

Homa, D., & Fish, R. 1975. Recognition time in long-term memory as a function of repetition, lag, and identification of positive and negative search sets. Journal of Experimental Psychology 104 : 71–80.

Hoving, K. L., Morin, R. E., & Konick, D. S. 1970. Recognition reaction time and size of the memory set : A developmental study. Psychonomic Science 21 : 247–248.

Neisser, U. 1964. Visual Search. Scientific American 210 : 94–102.

Smith, E. E. 1967. Effects of familiarity on stimulus recognition and categorization. Journal of Exprimental Psychology 74 : 324–332.

Sternberg, S. 1966. High-speed scanning in human memory. Science 153 : 652–654.

Sternberg, S. 1975. Memory scanning : New findings and current controversies. Quarterly Journal of Experimental Psychology 27 : 1–32.

Swanson, J. M., & Briggs, G. E. 1969. Information processing as a function of speed versus accuracy. Journal of Exprimental Psychology 81 : 223–229.

Swanson, J. M. 1974. The neglected negative set. Journal of Exprimental Psychology 103 : 1019–1026.

Wingfield, A. W., & Branca, A. A. 1970. Strategy in high-speed memory search. Journal of Exprimental Psychology 83 : 63–67.