Reaction time and short term memory: Implication of negative set —2

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High speed exhaustive scan hypothesis was investigated using a modified Sternberg's RT technique. The RTs were measured under the conditions being asked for positive response and negative response strictly separately, and designed to reduce a training or familiarity effects of visual stimuli. The results were as follows: (1) The negative responses were made later than the positive responses at each level of memory set size. (2) Mean RT was a linear function of memory set size, with the linear functions for positive and negative stimuli having the same slope. The facts supported the Sternderg's theory. (3) But, the obvious serial position effects that Sternberg's model could not interpreted were found.

In the previous experiment (1977), under the two conditions (1 and 2) varying only the response patterns, the reaction times (RTs) were measured at each level of memory set size. The mean RT of positive response without negative response was faster than that of positive response with negative response significantly, at each level of the memory set size. The negative response appeared to effect only the zero intercept, since the mean RT of positive response without negative response and that of positive response with negative response increased approximately parallel with increasing of the memory load. So, in the present experiment, it is the first problem to investigate, whether the RT of the positive response, and that of the negative response become the same or not, if the two are measured under the experimental condition that the subject is asked for only one response (positive or negative). To ascertain this matter, positive response and negative response must be measured strictly separately under the same experimental condition, and compared.

Furthermore, the RT functions obtained in the previous experiment differed from the results of Sternberg's experiment. Accrding to the Sternberg's theory, the condition of the previous experiment is regarded as that producing a linearity of the RT functions. But, the logarithmic slope of the RT functions, instead of a linear slope, was found. It means that a time taken for processing information does not change, although an amount of information increases. Baddeley and Ecob (1973) observed faster recognition of repeated items using Sternberg's varied-set RT technique. Swanson (1974) who obtained similar results to ours, considered the dimension of familiarity as a possible factor justifying logarithmic slope. Homa and Fish (1975) also showed the effect of familiarity on the RT by repeating the displaying of the stimulus. Neisser (1964) came to similar conclusions, by using visual scanning, and suggested the multiplicity of thought for multiple scanning, which can process much information at the same time.

In the previous experiment, some reasons that had increased a familiarity of visual stimuli were as follows: 1. The whole variety of stimuli treated by the subject were only five letters F H K N and M. 2. M was the only letter ocurring in the negative set. Thus, too many trials were repeated in one set task (twenty trials with one task).

The second purpose in the present experiment was to examine the RT functions under the experimental conditions, designed to reduce an effect of training or familiarity.

METHOD.

In order to reduce the training effect, which seems to produce a familiarity, the device was applied. First, the kinds of stimulus were increased to eight kinds of letters F H K N M X Z and A. The positive set was selected from these, and the remainder formed the negative set. From the classification of the negative set by Swanson (1974), the set applied here may be called a type of Complementary Negative Set. Though the experimental procedure was the fixed set method, as in the previous experiment, the number of trials presented in one task was reduced to ten trials, instead of twenty trials used in the previous experiment. For the first aim of this experiment, two different experimental conditions were set up. Under the condition A, the subject was asked to press the button only when the test item was the same as the memorized item. Under condition the B, the subjects were asked to press the button only when the test item was not the same as any of the memorized items. So, in each condition, there was only a single response pattern, and the attention of the subjects was fixed on each response pattern. In this experiment, the change of RT was measured, varying the memorized set size, the number of items 1 2 3 and 4, under the different conditions, A and B.

Apparatus.

One press-button switch was used this time. The other equipments were identical to those of the previous experiment.

Materials.

Visual stimuli used the letters F H K M N X Z and A, which were of about the same recognition thresholds respectively.

Design.

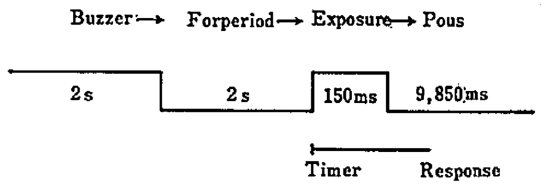

Fig. 1. Presentation of visual stimuli

The pattern and the period for one complete trial were the same as those of the previous experiment (Fig. 1). The probability of occurrence was preserved at 50% for both positive and negative sets. The number of the negative set items always was set as four, under both condition A and condition B. The negative set were selected from the remainder at random, after the positive set was determined from the eight letters. Therefore, the negative set always had four items, although its membership was changed. In the instructions, accuracy was emphasized, and each time the subject made a mistake, the instruction on accuracy was repeated.

Procedure.

After the training of simple reaction had been carried out, the process of preliminary experiment was explained, using the sample letters S and R. The instructions given were as follows: "Two seconds after a two second buzzer warning, a letter will be shown briefly. Press the button according to the instructions I will give you. The reaction time will be measured, so press the button as quickly as you can, making sure that you do not make a mistake. Under condition A, press the button when the letter you see is S, without making any mistakes. Under condition B, press the button, if the letter you see is not S, without making any mistakes." The main experiment was carried out in two sessions, the conditions A and B. To counterbalance the possible effect of time error, half of the subjects performed the task under the condition A first, while the others performed the task under the condition B first. The RTs were measured twenty times, for each memory set size, under the conditions A and B, for each subject, and four tasks were applied for each memorized item. The experiment was carried out so that the size of the memorized items increased from one to four (Table 1).

Table 1 Design of the experiment

Memory set size		1	2	3	4
Trial	1 … 5	F	K. N	H. M. X	K. Z. X. H
Trial	1 … 5	H	M. X	Z. F. H	F. M. N. A
Trial	1 … 5	K	A. Z	K. N. A	X. A. K. N
Trial	1 … 5	N	H. F	M. F. K	Z. M. H. F

To examine the serial positition effect, the stimulus items were recorded. Instructions were on the same lines as in the training session.

Subjects.

The six subjects were drawn from among university students, three of whom had participated in the previous experiment.

RESULTS.

The mean RTs of all the subjects for each positive set size are plotted in Fig. 2, each representing 120 measurements. The analysis of variance for three factor design was carried out for the RTs of both conditions (A and B). The positive response was found to be faster than the negative response. $F(1, 5)=19.78^{**}$, $P<0.01$. The RTs increased with memory load. $F(3, 15)=61.14^{**}$, $P<0.01$. The response conditions × memory load interaction was not significant. $F(3, 15)=1.83$. $P>0.05$. When the function of linear regression was applied, the function was $Y=330+55.8X$ for positive response, and $Y=416+49.3X$ for negative response. Fig. 3 shows the serial position effects (the primacy effects).

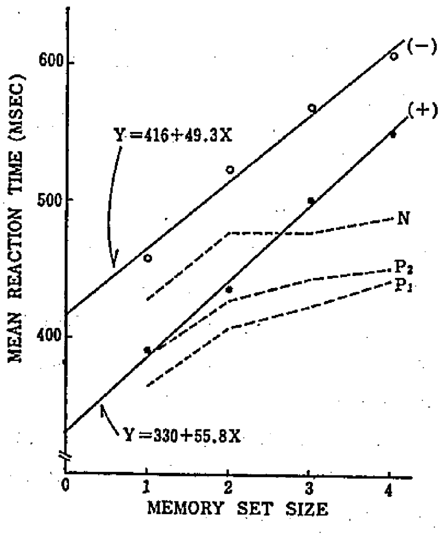

Fig. 2. The mean RTs as a function of positive set size, and the lines fitted by least squares
The dotted lines represent the results of the previous experiment.

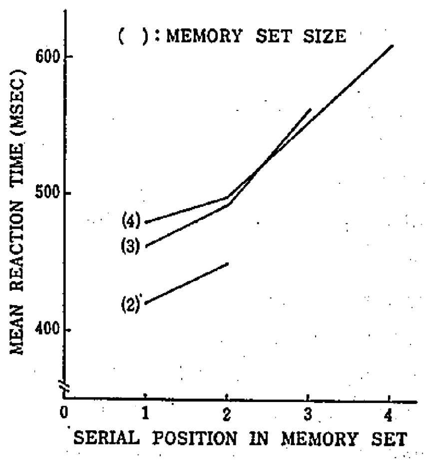

Fig. 3. The serial position effects

DISCUSSION

The result of the analysis of variance showed that the positive response was faster than the negative response, and from the points of interception of the linear regression, the difference was 86ms. This difference is greater than the difference between positive response and negative response in the previous experiment (about 30–50ms). It was confirmed that negative response inevitably took place later than positive response. Negative response is, it seems, more troublesome task than positive response. Let us consider the error response.

Though accuracy was stressed in the instructions, the errors were frequent, and the errors for negative responses were more frequent than those for positive response. In total, positive response errors were 23, and negative response errors were 51. If compared with the errors of condition 2 in the previous experiment, in which positive response errors were 16, and negative response errors were 19, the task in which the subject was asked, using the instruction, "Press the button if the letter you see is not F H or K," provides more difficulty than the negative response in the task, in which the instructions were, "Press button 1, if the letter you see is F H or K, and press button 2, if you see another letter." The positive response errors here were more frequent than the positive response errors of condition 1 in the previous experiment, both having the same response condition. It seems to show that the element of training was eliminated in the present experiment (Homa and Fish, 1975).

As can be seen in Fig. 2, the mean RTs of positive response and negative response increase approximately linearly with the memory set size. The t-test was applied to examine the RT differences between the pairs of all memory sizes. The results are shown in the table 2. Significances were obtained for all the pairs of numbers in the memorized items. The response conditions × memory set size interaction was not significant. This fact indicates that the RT memory load profiles shown for the response conditions are parallel. From the line of linear regression, the rate of increase of the mean RT was 55.8ms per item for positive response, and 49.3ms per item for negative response. Pearson's correlation was $r=0.98$.

From these data, it could be thought that Sternberg's exhaustive serial scanning was applied for the present classification task, which was designed to decrease a training or familiarity effect. But, if a training or familiarity effect appeared in the performing of the task, some other types of scanning (possibly, based on

Table 2 The RT differences between the pairs of all memory set sizes

Pair of set size		1–2	2–3	3–4	1–3	1–4	2–4
Positive response	t	5.89	5.57	3.87	6.72	5.84	4.98
	p	<0.01	<0.01	<0.02	<0.01	<0.01	<0.01
Negative response	t	12.73	6.77	8.51	12.71	12.23	8.17
	p	<0.001	<0.01	<0.001	<0.001	<0.001	<0.001

familiarity) would be applied as the information processing method. The linear slopes shown by solid lines in Fig. 2 represent the former, and the logarithmic slopes shown by dotted lines the latter. Neisser (1964) suggested the multiple scanning, and Swanson (1974) and others (Atkinson and Juola, 1972; Briggs and Swanson, 1969; Juola, Fishler, Wood, and Atkinson, 1971) processing on the basis of a class dimension.

The linear function relation RT obtained in the present experiment supported the Sternberg's theory, but the present experiment presented the evidences of the serial position effects shown in Fig. 3. The statistical significance of these results was determined by the t-test. These are shown in Table 3.

Table 3 The t-test for the serial position effects

Memory set size (4)

Pair of position	1–2	2–3	3–4	1–3	1–4	2–4
t	3.80	2.14	2.10	2.16	3.99	2.13
p	<0.05	>0.05	>0.02	>0.05	<0.01	>0.05

Memory set size (3)

Pair of position	1–2	2–3	1–3
t	4.51	2.99	3.56
p	<0.05	<0.05	<0.05

Memory set size (2)

Pair of position	1–2
t	3.25
p	<0.05

Sternberg's theory cannot account for the serial position effects. It leads us to expect flat serial-position functions. In this experiment, however, the matter is particularly embarrassing for the theory, since a procedure that produced set size function that were linear and parallel also gave rise to serial position effects. The serial position effects are clearly inconsistent with the Sternberg's exhaustive serial scanning theory. Sternberg (1975) says that unhappily for the model, data from a few experiments whose gross features are consistent with the model have also shown serial-position effect. The memory set size functions that are linear and parallel, and the serial position effects are a dilemma for the high speed exhaustive scanning theory stressed by Sternberg.

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