Effects of Similarity between Patterns and Time Parameters upon the Visual Short-Term Memory for Dot Patterns

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Visual short-term memory for abstract pattern was examined operationally by Phillips & Baddeley (1971). They used visually presented random filling cells in a square matrix as stimuli. They proposed that the capacity of visual short-term memory has its limit. And the visual short-term memory is non-verbal storage and is not tied to spatial position. The visual short-term memory is not feasible against masking and retains the information longer than iconic memory (Phillips 1974).

They examined in detail about how the visual short-term memory works. The functions of visual short-term memory should be examined using various kinds of patterns, since the visual informaion has a wide variety. It is important to define the visual information itself in order to clarify what kind of information is retained in the visual short-term memory. Then it becomes possible to infer its function from performances on memory tasks.

Among methods to measure non-verbal memory quantitatively, recognition is superior to recall, since the former reproduces less distorted pictures than those by the latter. Recognition is usually tested by presenting a test pattern after a study pattern, and then asking the subject whether the test pattern is something he has seen before. A test pattern is usually similar to a study pattern in recognition, and the subject has to judge whether two patterns are same or different. Consequently, the most important problem in recognition tasks is what kind of stimulus pattern is presented. And further it is necessary to define the similarity between patterns before the stimulus patterns are prepared for experiment.

The similarity has a close connection with the methods of producing a series of stimulus patterns. Attneave & Arnoult (1956), Fitts, Weinstein, Rappoport, Anderson & Leonard (1958), and LaBerge & Lawrence (1957) have studied the properties of forms which are generated by statistical rules and which can be distorted by other rules. These methods have wider generality because the distortion rules themselves can be related to judged similarity. LaBerge & Lawrence (1957) constructed a number of such forms and found monotonic relations between their statistical distortion rules and similarity as inferred from recognition studies. Posner

(1964) made several kinds of dot patterns by using the original patterns and distorted them by statistical rules. The original pattern consisted of a triangle, and letters M and F, and a random pattern, all made of nine dots within a 30×30 matrix. Subjects learned to classify these dot patterns which were distortions of an original pattern (Posner & Keele 1968). The degree of distortion from the original pattern was calculated from the number and probability of cells to which a given dot could move.

As for the effects of the similarity upon the performance on psychological tasks, Anderson & Leonard (1958) showed systematic relations between the level of statistical constraint governing the generation of their figures and ease of performing recognition, naming, and reconstruction tasks. Such series of stimulus patterns produced by statistical distortion rules were also applied to the question of generalization in the rote-learning transfer design (Posner 1964), and concept learning (Posner, Goldsmith & Welton 1967).

Visual information in non-verbal memory has a wide variety and how the visual memory works seems to be greatly influenced by what kind of stimulus pattern is presented. Therefore, the purpose of this study in the first place is to define stimulus patterns and similarity between patterns operationally. The square pattern made of five dots is used as the original pattern in the present investigation. The original pattern is transformed gradually by the systematic rule to generate the set of stimulus patterns. And then, the present investigation intends to specify how the visual short-term memory works under the various kinds of time parameters, using these stimulus patterns. The effect of masking patterns which disturb the retention of iconic memory upon the memory tasks is also examined.

In Experiment 1, the perceived distance between two levels of distortion was measured by assigning the number from zero to four in order to clarify the relation between physical distance and psychological similarity. In Experiment 2, the effects of similarity between patterns and SOA upon dot pattern recognition was investigated. In Experiment 3, the effect of interference of masking pattern upon recognition tasks was investigated.

Experiment I

The purpose of this experiment was to obtain psychological relations between physical distance and subjective similarity under the condition that two dot patterns were compared to each other. The number from zero to four was assigned in proportion to the perceived distance between two patterns. Sets of stimulus patterns were generated by distorting a square which consisted of five filled dots.

Method

Subjects. ....The subjects were 20 undergraduate girl students, and the experiment was conducted individually for each subject.

Materials. ....A five dot square was constructed by placing a dot on each of four corners and a dot in the center of regular square. The diagonal of the square was 3cm and the viewing distance was about 40cm, therefore each stimulus pattern substended a visual angle of approximately 1.6 degrees.

Stimulus patterns were generated by distorting the original square pattern systematically, the center dot always being fixed in the pattern. The other four dots were moved various distances independently along each x and y axis, until the total distance of movements of dots was attained the values being predetermined according to each condition. The total distance of movement could represent the physical distance of each pattern from the original square in the experiment. The directions of the movement of the dots were limited in order to eliminate the parallel shifting, contracting and extending of patterns.

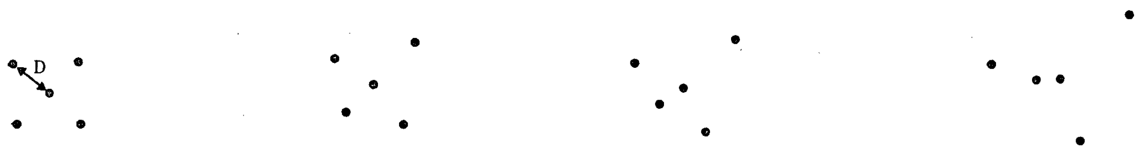
The total distance of movement of four dots was set at the value of 0.25 (D), 0.5 (D) and the identical distance (D) between the center dot and another dot. Degree of distortion of study pattern and test patterm from the original square is shown in Table 1. "0.25 D pattern" means the pattern which is distorted from the original square with 0.25 D distance. Table 1 also shows the physical distance between study pattern and test pattern in the experiment. "0.25 D difference" means 0.25 D physical distance between two patterns. Accordingly, the values of D indicate both the degree of distortion of each stimulus pattern from the original square and the degree of physical distance between study pattern and test pattern. There are two kinds of comparison between the study pattern and test pattern in Table 1. One is the instance in which the same pattern is used as the study pattern and test pattern, and they appear in the diagonal line on the table. These responses are in "same response category", since we get correct answers when we judge that they are same. The other comparison is when the test pattern is different from the study pattern, and they are in the columns apart from the diagonal line. These responses are in "different response category", since we get correct answers when we judge that they are different. The different response category further consists of two kinds of combination of study pattern and test pattern.

Table 1.

Physical distance between study pattern and test pattern in Experiment 1.
(D means the difference between the center dot and another dot in the square.)

Study pattern / Test pattern	0.25 D pattern	0.5 D pattern	1.0 D pattern
0.25 D pattern	0 (identical)	0.25 D difference	0.75 D difference
0.5 D pattern	0.25 D difference	0	0.5 D difference
1.0 D pattern	0.75 D difference	0.5 D difference	0

As for 0.5 D difference condition, one is that 0.5 D pattern is presented as study pattern and 1.0 D pattern is displayed as test pattern, and the other is the reverse. Fig. 1. shows the original square pattern and examples of three levels of distortion, .25 D pattern, .5 D pattern and 1.0 D pattern.



Original pattern　　0.25 D pattern　　0.5 D pattern　　1.0 D pattern

Fig. 1. Original square and examples of stimulus patterns.

Procedure. ....The experiments were conducted on line to a MELCOM 70 computer, and the patterns were presented on the graphical display unit. At the beginning of each trial, a fixation point appeared on the screen, and subjects triggered the onset of the display sequence by stepping on a pedal switch. Each subject was seated at a table with a panel of five microswitches. The five buttons were assigned to the five stages of similarity judgment from zero to four in order.

The study pattern was presented for one second. The test pattern was either identical with the study pattern or differed in the degrees of .25 D, .5 D, .75 D or 1.0 D as shown in Table 1. The test pattern was displayed immediately after the study pattern until the subject made her response. The exposure time of the test pattern was under the control of the subject. Subjects were instructed to give each pair of patterns a number from zero to four which represented the subjective difference between two patterns in similarity of configuration. If the test pattern appeared identical with the study pattern, the subject was told to give the number zero. If they were completely different, the subject was told to call it number four. The subject was told that five kinds of numbers, zero, one, two, three and four could be used. The 20 subjects performed 20 trials each, trying four times each for five levels of similarity between patterns.

Results

The basic results of this experiment are shown in Fig. 2. In this graph the average value of judgement on the degree of perceived distortion is plotted as a function of the level of physical distance between study pattern and test pattern. The function is quite linear as shown in the figure. Thus perceived distance can be viewed as a linear function of objective distance. Consequently, it is supposed in the present investigation that the physical distance which is expressed by D difference can be used to show the subjective similarity between patterns.

If the study pattern and test pattern have their own roles in comparison, asymmetry will take place when the roles of two patterns are exchanged. The asymmetry occurs when a certain stimulus serves as a reference point among stimuli,

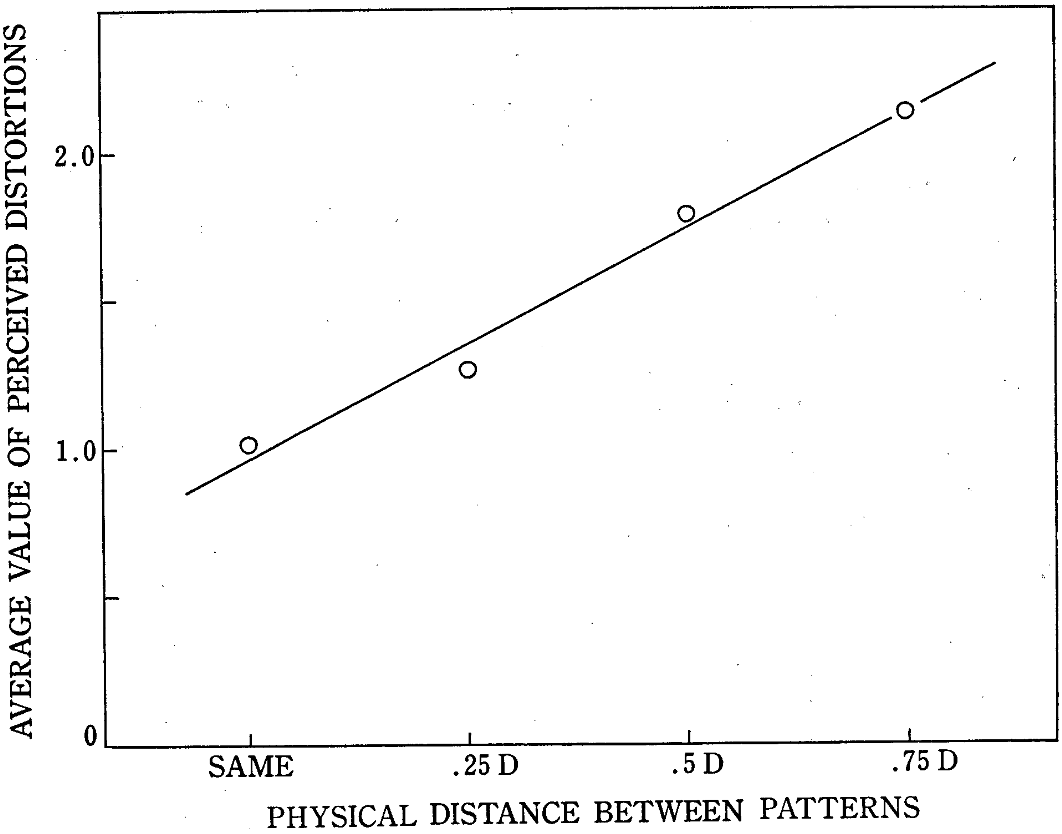


Fig. 2. Average value of perceived distortions as a function of physical distance between patterns.

since the relation between reference point stimuli and other stimuli is not symmetrical (Rosch 1975, Tversky 1977). Asymmetry was not apparent in Experiment 1.

Experiment II

It is demonstrated in Experiment 1 that the linear relation is held between physical distance and subjective similarity among sets of dot patterns. The physical distance is calculated by the total distance of movement of four dots. Accordingly, the subjective similarity between study pattern and test pattern can be represented by the physical distance between two dot patterns in the experiments. Influence of the similarity between patterns and exposure time upon the recognition task was investigated in Experiment 2.

Method

Subjects.........The subjects were 20 undergraduate girl students who joined Experiment 1. Half of them were randomly assigned to a short exposure time group (from 15 msec to 100msec), and the other half were assigned to a long exposure time group (from 100 msec to 400 msec).

Materials.........The same sets of five dot patterns made of the square as in Experiment 1 were utilized in Experiment 2. Three kinds of patterns, .25 D pattern, .5 D pattern and 1.0 D pattern were used. Therefore the similarity between study pattern and test pattern took four values, 0, .25D difference, .5 D difference and .75 D difference in Table 1.

Pocedure. ....The 20 subjects were randomly divided into two groups. The ten subjects in the short exposure time group performed the recognition tasks where the exposure time of study pattern took the following four values, 15 msec, 30 msec, 50 msec and 100 msec. The other ten subjects in the long exposure time group performed the tasks which took the following four values, 50 msec, 100 msec, 200 msec and 400 msec.

The test pattern was displayed immediately after the study pattern was extinguished. The subject was asked to answer "same" if two patterns were judged the same, and was asked to answer "different"if they were judged different from each other. The two buttons were assigned to the two kinds of answers and the places of buttons were balanced in trials. The test pattern was presented until the subject made her response. The exposure time of each test pattern was under the control of the subject and the reaction time was represented by the exposure time of the test pattern as shown in Fig. 3. The ten subjects performed a total

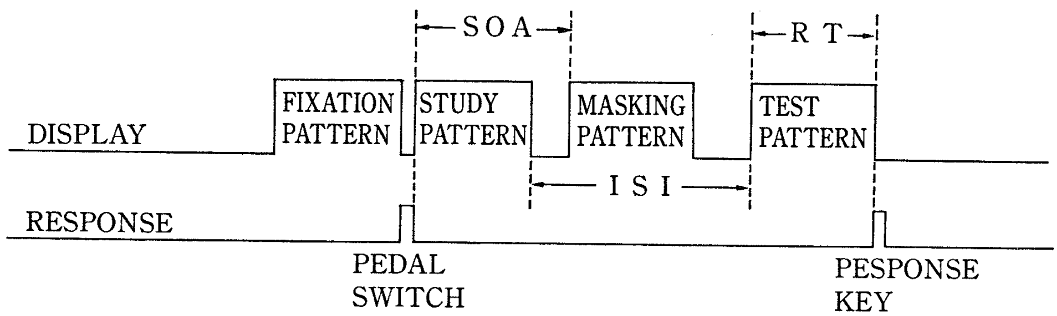


Fig. 3. Presentation of visual stimuli and time parameters.

of 64 trials each, trying four times each for four levels of similarity between patterns and four values of exposure time of study pattern.

Results and Discussion

The percentage of correct responses over all subjects are shown in Fig. 4. Mean percentage of correct responses are plotted as the function of similarity between patterns and exposure time. The effect of exposure time of study pattern upon recognition tasks depends on the level of similarity between the study pattern and test pattern. Short exposure time of the study pattern and close similarity between patterns make the recognition task difficult. The proportion of correct responses has no significant difference in spite of the variety of exposure time in the case that the condition is .5 D difference or .75 D difference. On the other hand, the proportion of correct responses is influenced by the exposure time

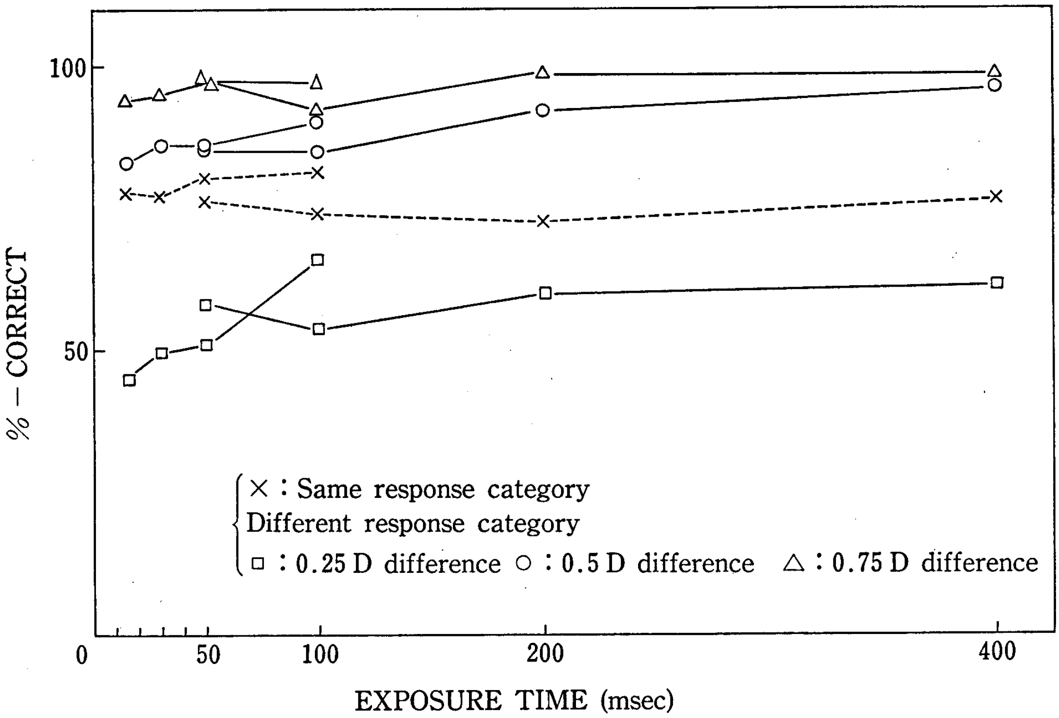


Fig. 4. Percentage of correct responses in Experiment 2.

of the study pattern when the condition is 0.25 D difference.

These experimental conditions consist of two kinds of combination of study pattern and test pattern in the different response category. As for 0.25 D difference condition, one is that 0.25 D pattern is presented as study pattern and 0.5 D pattern is displayed as test pattern, and the other is the reverse. Namely, the former condition is that the less distorted pattern from the original pattern is used as a study pattern, and the latter condition is that the more distorted one is used as a study pattern. There is a slight tendency in Experiment 2 that the latter condition has a higher percentage of correct responses than the former condition. However, the difference is not significant.

The recognition task has two stages of information processing in these experiments. The first stage is learning a study pattern and the second one is a comparison between the study pattern and test pattern. There are possible reasons at each stage why the percentages of correct responses of test patterns are different between the above two conditions. At the first stage of learning, one pattern will be more difficult to conceive precisely than the other. However, there was no significant difference between patterns in Experiment 2, as for the percentage of correct responses in the same response category. Consequently, the above mentioned difference between two conditions could not be ascribed to the failure of the first stage. Then, there is the problem of asymmetry at the second stage of comparison. The slight dominancy of the latter condition suggests the possibility that the study pattern was utilized as the reference stimulus in comparison.

The interval between the study pattern and test pattern can be controlled operationally by using the visual masking pattern in order to examine the stage where the main decrease of correct responses occurs in Experiment 3.

Experiment III

The random dot pattern was presented as visual masking to control more exactly the duration of the study pattern, and the effect of exposure time and visual masking was examined in Experiment 3. The asymmetry of similarity judgment in recognition performance was also investigated.

Method

Subjects.……The same 20 subjects who participated in Experiment 2 were also participants in Experiment 3. They were divided into the same two groups as they were in Experiment 2. The short exposure time group and long exposure time group were composed of the same members as in Experiment 2.

Materials.……The similarity between the study pattern and test pattern was limited to the case of 0 and 0.5 D difference, since only 0.5 D pattern and 1.0 D pattern in Table 1 were used in Experiment 3. The visual masking pattern was a random dot pattern made of 256 points, and was exposed after a variety of interval since the study pattern disappeared.

Procedures.……The interval between the study pattern and test pattern was always fixed for one second and the masking pattern was exposed for 150 msec between them. In the short exposure time group, the exposure time took four values, 15 msec, 30 msec, 50 msec and 100 msec, and the initiating point of the masking pattern after the extinction of the study pattern took three values ; 0 (immediately after), 25 msec and 50 msec. Four values of exposure time and three values of initiating point resulted in a total of twelve test conditions. As for the long exposure time group, four values of exposure time (50 msec, 100 msec, 200 msec and 400 msec) and two values of the initiating point of visual masking (0 : immediately after and 50 : 50 msec after) resulted in a total of eight test conditions. Each subject took four tests for each of the conditions. The test pattern was presented until the subject made her response and the reaction time was represented by the exposure time of the test pattern.

Results and Discussion

The percentages of correct responses over all subjects are shown in Fig. 5. The percentage of correct responses decreases in comparison to the results of Experiment 2 where no masking pattern was presented, only when the study pattern was exposed for less than 100 msec. The decrease of correct response indicates that a part of information processing is disturbed by the visual masking pattern. The degree of disturbance is influenced by the initiating point of the visual mask-

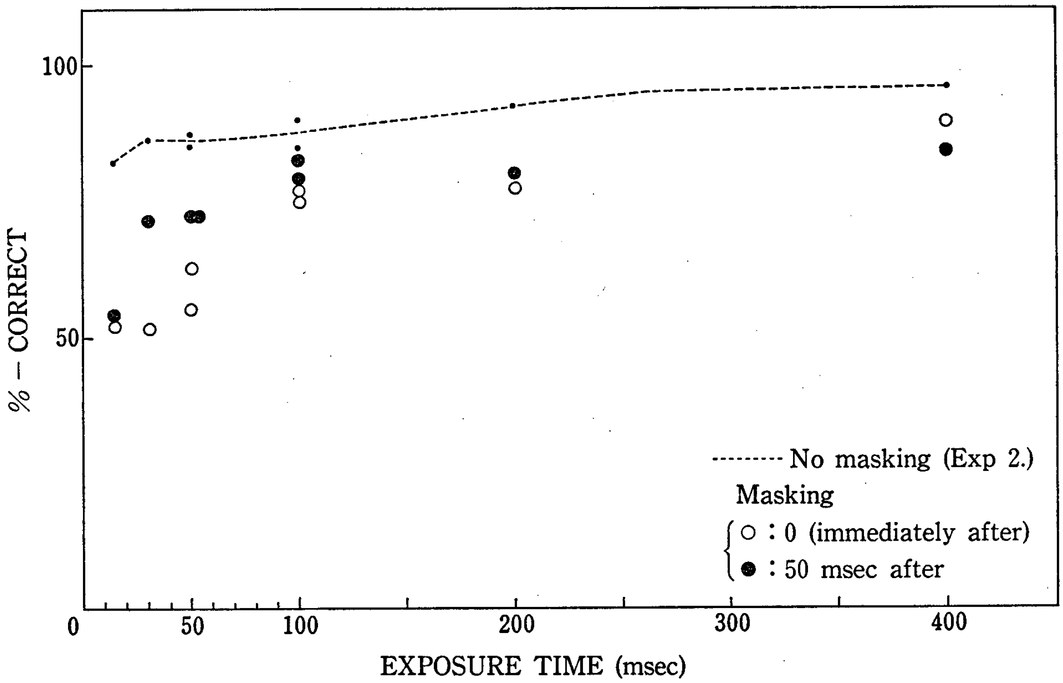


Fig. 5. Percentage of correct responses in Experiment 3.

ing pattern. The percentage of correct responses decreases more when the masking pattern is exposed immediately after the study pattern disappeared, than when the masking pattern is exposed 50 msec after the study pattern is extinguished, as shown in Fig. 5. Visual masking and its initiating point after the elimination of the study pattern has a large effect on the accuracy of recognition perfomance especially when the exposure time is short, but it has little effect when the exposure time is more than 200 msec.

As regards time components, the concept of Stimulus Onset Asynchrony (SOA) seems to be useful to describe precisely the characteristics of visual information processing. SOA means the total amount of processing time, which is calculated by summing up the stimulus exposure time and the interval between the study pattern and masking pattern. These two time parameters are combined into one parameter SOA. When the masking stimulus is presented immediately after the extinction of the study pattern the SOA is shorter, even if the duration of the study pattern is the same. If the duration is shorter the SOA is shorter, when the masking pattern is displayed after the same interval. The interference effect caused by various initiating points of visual masking pattern is expressed unitarily by plotting the percentage of correct responses with SOA as the axis of abscissa.

The percentage of correct responses in the same response category is shown in Fig. 6. There is no significant difference between 0.5 D pattern and 1.0 D pattern when SOA is more than 50 msec. On the other hand, 0.5 D pattern can be recognized more exactly than 1.0 D pattern when SOA is less than 50 msec.

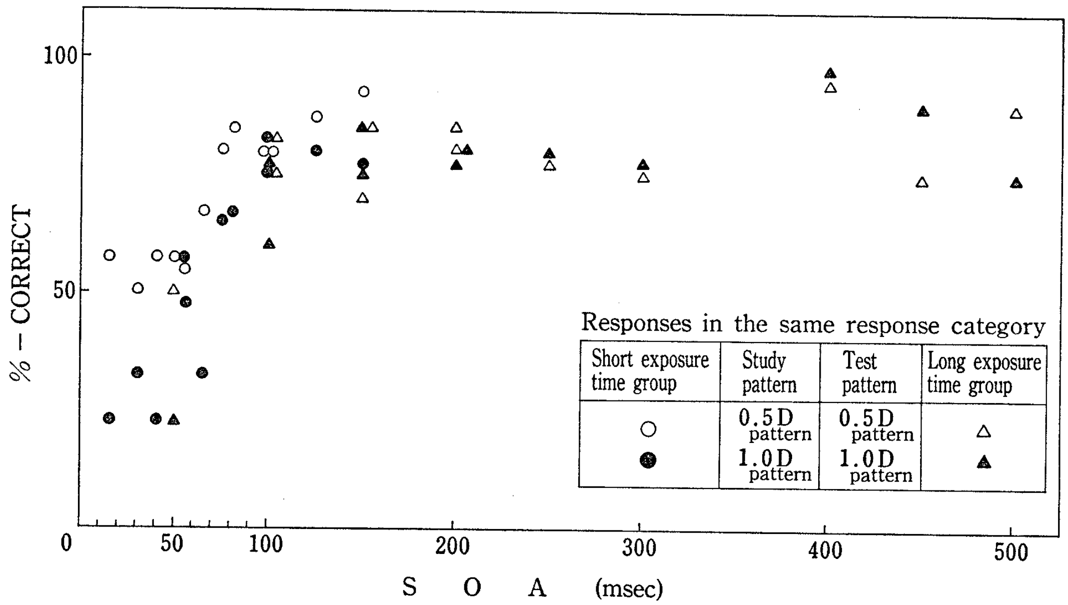


Fig. 6. Percentage of correct responses in the same response category (Experiment 3).

These results suggest that there is significant difference between learning of 0.5 D pattern and that of 1.0 D pattern especially when SOA is short. It means that the less distorted pattern from the original pattern can be learned and retained more exactly than the more distorted pattern where SOA is less than 50 msec. Accordingly, one of the reasons why a less distorted pair of patterns results in a higher percentage of correct responses than the other is that the less distorted pattern from the original square is easier to learn.

The percentage of correct responses in the different response category is

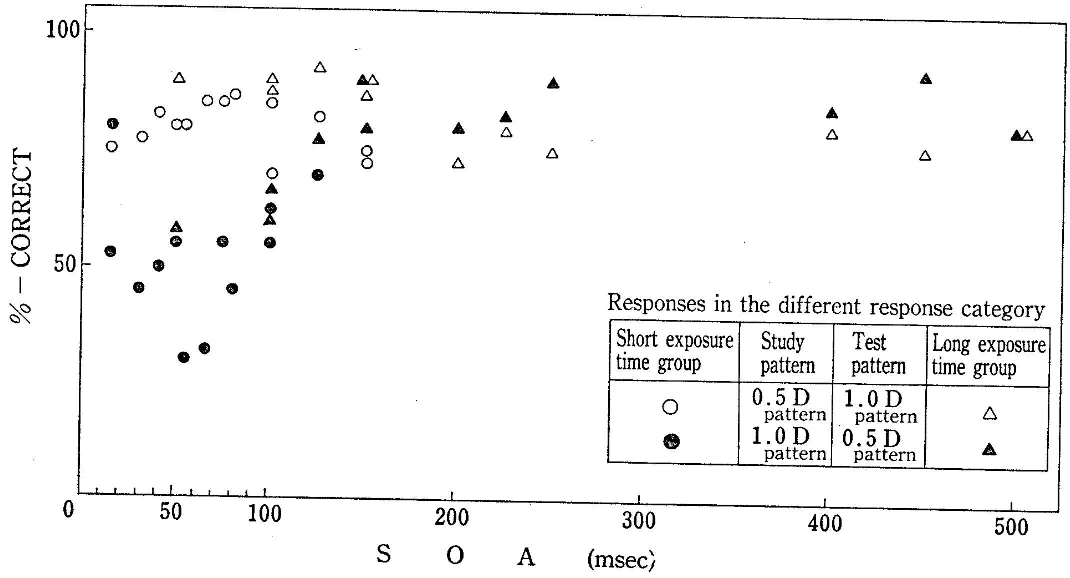


Fig. 7. Percentage of correct responses in the different response category (Experiment 3).

shown in Fig. 7. Asymmetry of judgment is now apparent in the pair of stimulus patterns, 0.5 D pattern and 1.0 D pattern. The percentage of correct responses in the different response category is higher in the condition where 0.5 D pattern is displayed as a study pattern and 1.0 D pattern is displayed as a test pattern than in the reverse condition, in the case that SOA is less than 100 msec.

There are two possible reasons why the condition where 0.5 D pattern is displayed as a study pattern is superior to the reverse condition. One reason is that 0.5 D pattern is learned and retained more precisely than 1.0 D pattern in the different response category as well as in the same response category. This explains well the reason of superiority in the case that SOA is less than 50 msec.

And then, the asymmetry is also clear in the case that SOA is from 50 msec to 100 msec. The asymmetry seems to result from the comparison between two patterns, because there is no difference as for responses in the same response category where SOA is from 50 msec to 100 msec. Subjects seem to use 0.5 D pattern more often as reference point stimulus, since 0.5 D pattern can be studied more easily than 1.0 D pattern as shown in the same response category. These results suggest that the less distorted pattern is utilized more often as reference point stimulus in comparison. Deviates which have smaller deviation from the original pattern supposed to be used more often as the reference stimuli in relation to which other more deviate stimuli are judged as pointed out by Rosch (1975). Experimental studies are further required with regard to the characteristics of patterns which are utilized as reference point stimuli.

Conclusions

It is most important in recognition tasks where visual patterns are compared to each other that both the way in which the stimulus patterns are generated and the definition of similarity between patterns are clear. A five dot square was used as the original pattern in the present investigation, and the deviates were generated by moving four corner dots various distance independently. The way in which these patterns are generated has an advantage namely that it is simple and possible to be utilized repeatedly. It was demonstrated that the physical distance between distorted patterns has a linear relation to the subjective similarity between patterns. And then, the physical distance from the original pattern is valid in expressing the psychological distance.

Visual short-term memory was measured by recognition tasks and it is suggested that the retention is mainly influenced by the similarity between patterns. The retention in visual short-term memory is characterized by the concept of asymmetry and reference point stimulus. If one pattern is more easily studied and remembered than the other pattern, the former should have some characteristics which discriminates it from the other. If we have some basic schema in mind and conceive and remember other stimulus by making comparisons with it, the original pattern will be one type of schema (Mizuno 1985).

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Abstract

A five dot square and the deviate stimulus patterns are generated operationally to examine the characteristics of visual short-term memory. The linear relation is held between physical distance and subjective similarity among sets of dot patterns in Experiment 1. It has been proved that the subjective similarity between dot patterns can be expressed by the physical distance from the original pattern. Influence of similarity between patterns and exposure time upon the recognition tasks is investigated in Experiment 2. The results indicate that the performance in recognition is mainly determined by the similarity between patterns. The random dot pattern is presented as visual masking to control more exactly the duration of the study pattern in Exepriment 3. It is suggested that deviates which have smaller deviation from the origial pattern is learned more easily and is used more often as the reference point stimulus in comparison.