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EFFECTS OF KIND OF NOISE LETTERS AND THEIR RELATION TO RESPONSE OF SELECTIVE LETTER IDENTIFICATION

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An experiment was performed to elucidate the mechanism by which the noise letters exert their interfering effects on selective identification of a target letter. Ten undergraduate students were required to identify a target from a visual display of three letters arranged in a circle. The reaction time of pressing buttons to the target was measured under combined conditions of noise letters and assignment to response. The results supported the response level hypothesis that the noise letters exert their interfering effects, because they require the response incompatible with the target after having received processing by a feature analyzer. Further, it was indicated that the former results inconsistent with the response level hypothesis were artifacts caused by the selection of the stimulus letters.

In a selective letter identification task, subjects are required to identify a target letter from a visual display of letters arranged on an imaginary circle centered on a fixation point. According to the data of accuracy and reaction time for identification of the target, the task was affected by the number of noise letters in the display, the spatial distance between a target and the next noise letter, and the spatial arrangement of letters (Eriksen, & Hoffman, 1972a, 1972b; Eriksen, & Rohrbaugh, 1970; Sonoda, Sato, & Sakuma, 1975; Watanabe, 1983).

The mechanism by which noise letters exert their interfering effects on target identification was explained by either of the following hypotheses. A processing level hypothesis ascribed the interfering effects to the processing level. Estes (1972) maintained that noise letters bring about the effects by delaying the processing of the target owing to competition for a processing unit such as a feature analyzer with the target. A response level hypothesis ascribed the effects to the response level. Eriksen and his associates (Collegate, Hoffman, & Eriksen, 1973; Eriksen, & Hoffman, 1973) maintained that noise letters bring about the effects by requiring a response incompatible with the target after having received processing in parallel with the target.

Eriksen and Hoffman (1973) carried out an experiment to elucidate the mechanism underlying selective letter identification. Test stimuli used were visual displays which were constructed by placing capital letters (A, H, M, and V) variously in 12 clock positions of an imaginary clock face. Subjects were required to respond in two ways, namely, to push the switch left if the target was an A or a U, and right

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if it was an H or an M. The reaction time was longer in response-incompatible (RI) condition where the noise letters next to the target result in the response opposite to the target, than in response-compatible (RC) condition where the noise letters result in the same response as the target. The result supported the response level hypothesis.

In addition to the above results, Eriksen and Hoffman (1973) obtained results inconsistent with the response level hypothesis. The hypothesis predicts that noise letters should exert their interfering effects only in RI condition. However, the effects were also found in RC condition. That is, the reaction time was longer in RC condition than in single-target (S) condition where a single target was displayed. Hoffman (1975), who performed an experiment similar to that of Eriksen and Hoffman (1973), also obtained the results which were partly inconsistent with the response level hypothesis. The reaction times were longer in neutral (N) condition where the noise letters were neutral to the target and in character-like (C) condition where the noise letters were marks similar to letters, than in S condition though the noise letters in N and C conditions were indifferent to the response of the target.

The above inconsistent results can be interpreted in the following way. According to the study on similarity of capital letters by Gibson (1969) and Podgorny and Garner (1979), the letters (A, M, N, and V) used by Eriksen and Hoffman (1973) were similar in form. Consequently, the noise letters in RC condition were similar to those in RI condition, and thus the apparent interference possibly occurred even in RC condition. It was possibly true with the results obtained by Hoffman (1975), because his stimulus letters were formed by combining various subsets of a seven-segment display, and thus his letters in N and C conditions were similar to the letter in RI condition.

The present study tried to examine the mechanism by which noise letters exert their interfering effects on selective letter identification by performing an experiment using the method similar to that of Eriksen and Hoffman (1973). A visual display was constructed of three letters from two pairs of capital letters (C, O; E, F) which were similar within a pair but dissimilar between the pairs. The examples are shown in Fig. 1.

Two variables, assignment to response and noise letters, were introduced. A variable of assignment to response was concerned with the way to assign four letters to the two response buttons. In crossed-assignment (CA) condition, each member of a pair of two similar letters (C, O; E, F) was assigned to a different response button. That is, C and E were assigned to one button, and F and O to the other one. In uncrossed-assignment (UCA) condition, a pair of two similar letters (C, O) were assigned to one button, and the other pair (E, F) to the other button. Consequently, the noise letters which resulted in a different response were similar in CA condition but dissimilar in UCA condition.

A variable of noise letters was concerned with the kind of noise letters arranged together with a target. The noise letters were: the letters which were the same as the target in same-as-target (ST) condition; those which were different from the

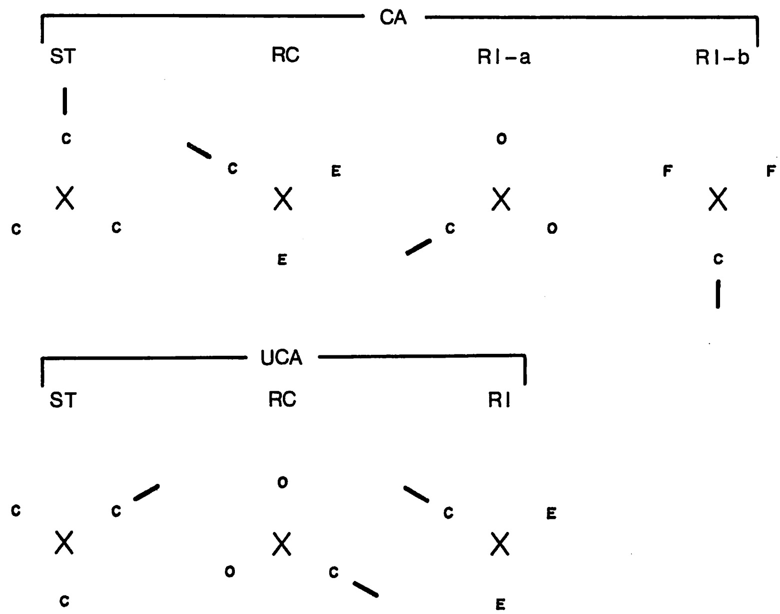

Fig. 1. Examples of the stimulus displays for three conditions of noise letters: same-as-target (ST), response-compatible (RC), and response-incompatible (RI) under two conditions of assignment to response: crossed-assignment (CA) and uncrossed-assignment (UCA). RI condition under CA condition was further divided into two conditions: RI-a, in which the noise letters were similar to a target, and RI-b, in which they were not so.

target but resulted in the same response as the target in RC condition; those which resulted in the response opposite to the target in RI condition. RI condition under CA condition was further divided into the following two conditions: RI-a, in which the noise letters were similar to the target, and RI-b, in which they were not so. This division was introduced to test whether the difference was found in interfering effects between RI-a and RI-b conditions because the noise letters were similar to the target in RI-a condition.

The response level hypothesis predicts that the reaction time will be the longest in RI condition and the shortest in ST condition of all the conditions of noise letters under either condition of assignment to response. If the preceding interpretation was true of the inconsistent results obtained by Eriksen and Hoffman (1973) and by Hoffman (1975), then the reaction time in RC condition would be variable depending upon a condition of assignment to response. The reaction time in RC condition would be longer than that in ST condition under CA condition, but equal to that in ST condition under UCA condition.

Method

Subjects: The subjects were (9 male and 1 female) undergraduates from Kyushu Institute of Design. All had normal or corrected-to-normal vision.

Apparatus and stimuli: Stimuli were displayed with a two-field tachistoscope, which consisted of

Kodak slide projectors and Ralph Gerbrands Company G-1166 shutters. The distance of a translucent rear projection screen was 110 cm from the subject who sat at a table with his head located on a chin-rest. The projection field was masked by black flockpaper in a circle of about 5°12′ of visual angle in diameter which was centered on a small black fixation cross. The luminance of both fields was maintained at about 80 cd/m^2. A fixation cross 30′ of visual angle in height was always presented throughout the session. The time schedule of stimulus presentation was controlled by 3-channel digital timer. Reaction times were measured in ms using an electronic time counter from the onset of the test stimulus to the subject's button pressing.

The test stimulus consisted of three of the capital letters C, E, F, and O (obtained from Helbetica Medium of Letraset). The letters were arranged in either three positions of 2, 6, 10 o'clock, or 4, 8, 12 o'clock on an imaginary circle 2°24′ of visual angle in diameter centered on a fixation cross as shown in Fig. 1. Two variables, assignment to response and noise letters, were introduced as mentioned above.

Each of the letters subtended 12′ of visual angle in height. A test stimulus was accompanied by a line indicator 32′ of visual angle which indicated a target. It was placed 24′ of visual angle from the target on an extension of an imaginary radius from the center of the test stimulus through the target. Each letter was separated from the other by 1°48′ of visual angle intercontour distance.

A total of 24 test stimuli were prepared for practice trials with 8 stimuli for each condition of noise letters, in addition to 144 stimuli for main trials with 48 stimuli for each condition of noise letters. Special care was taken that the four capital letters should appear equally frequently on an imaginary circle as a target.

Procedure: The subject got ready for a trial with the thumb of each hand resting on one of the two response buttons. A 2-sec buzzer urged the subject to focus a fixation cross on the screen. When the fixation cross appeared in good focus, the subject started each trial by stepping on a footswitch. One second later, a test stimulus was presented for 2 sec.

Two kinds of instructions were prepared for each condition of assignment to response. In CA condition, the subject was instructed to push the right (left) button if the target was C or E, and the left (right) one if the target was F or O. In UCA condition, the subject was instructed to push the right (left) button if the target was C or O, and the left (right) one if the target was E or F. The assignment of the letters to the response buttons was counterbalanced across subjects in each condition of assignment to response.

The subject was tested individually in the dark room in two sessions with a session under either condition of assignment to response. A session consisted of 96 practice trials and two blocks of 5 warm-up and 72 main trials. Four repetitions of 24 practice test stimuli were used for practice trials and the last five test stimuli of each block were used for warm-up trials. A five minutes' rest was given after practice trials and between blocks. The subject was instructed to respond as quickly as possible while avoiding error. Two minutes were given for dark adaptation before each session. Half of the subjects were tested under CA condition first and the rest under UCA condition first. The order effect of noise letters was counterbalanced within a subject and across subjects. Error trials were rerun together following each block.

Results

Correct reaction times were used as data after being averaged for each subject through 48 (24 each in RI-a and RI-b conditions) main trials in each condition. Figure 2 shows the mean reaction times averaged for 10 subjects in each condition of assignment to response as a function of noise letters.

Since the t-test found no significance between the reaction times in RI-a and RI-b conditions ($t(9)=.22$), the reaction time averaged across these two conditions was used as data for RI condition under CA condition from then on. A three-way analysis of variance (assignment to response, noise letters, and subject) found

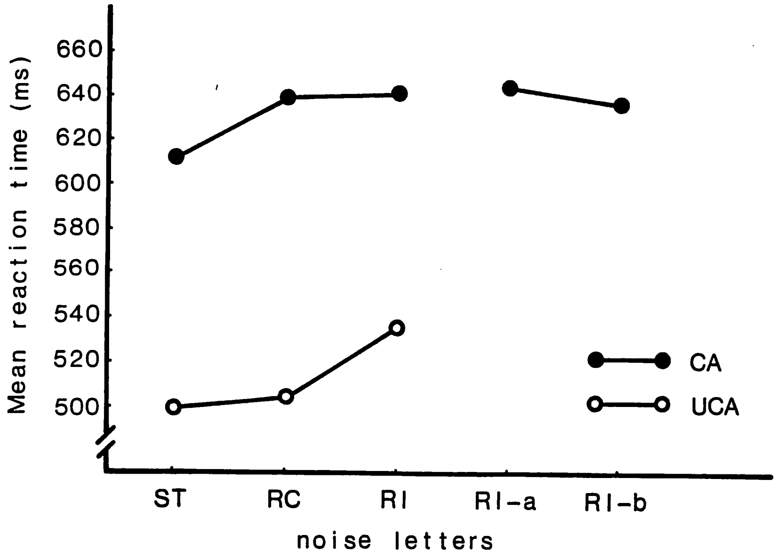

Fig. 2. Mean reaction times for each condition of assignment to response under each condition of noise letters.

significant effects of main factors of assignment to response ($F_{1,9}=75.23$, $p<.001$) and noise letters ($F_{2,18}=12.67$, $p<.001$) and significant interaction effect of these ($F_{2,18}=10.68$, $p<.002$).

The t-tests were carried out for each pair of conditions of noise letters under each condition of assignment to response. Under CA condition, the reaction times were significantly longer in RC and RI conditions than in ST condition respectively ($t(9)=7.11$, $p<.001$; $t(9)=3.47$, $p<.01$), while no significance was found between the reaction times in RC and RI conditions ($t(9)=.29$). Under NCA condition, the reaction time was significantly longer in RI condition than in ST and RC conditions respectively ($t(9)=3.92$, $p<.01$; $t(9)=3.77$, $p<.01$), while no significance was found between the reaction times in ST and RC conditions ($t(9)=.91$).

Discussion

The results obtained were almost consistent with the prediction. First, the reaction time was longest in RI condition and shortest in ST condition of all the conditions of noise letters under either condition of assignment to response. The noise letters arranged together with a target required the response opposite to the target in RI condition. In ST condition, the noise letters, being the same as the target, required the same response as the target. The results support the response level hypothesis because the strongest interfering effects were found in RI condition.

Secondly, the reaction time was variable depending on the condition of assignment to response, in RC condition where the noise letters were different from the target but required the same response as the target. Under CA condition where the noise letters in RC condition were similar to those in RI condition, the reaction time in RC condition was longer than that in ST condition and equal to that in RI condition. Under UCA condition where the noise letters in RC condition were dissimilar to those in RI condition, the reaction time in RC condition was equal to that in ST condition.

The results show that the interfering effects in RC condition are determined by whether or not the noise letters are similar to those in RI condition. The results are, therefore, compatible with the preceding interpretation of the inconsistency. After all, the results obtained by Eriksen and Hoffman (1973) and by Hoffman (1975) which were inconsistent with the response level hypothesis were artifacts caused by the selection of stimulus letters. The results show further that the noise letters, only if similar to the noise letters requiring the response opposite to the target, can cause as strong interfering effects as those requiring the response opposite to the target. The results also support the response level hypothesis, because they indicate the importance of relation between responses of target and noise letters. However, the process in which the similarity causes such strong effects is unclear in the present study.

On the other hand, the processing level hypothesis can be tested in the following way. The hypothesis predicts that the reaction time will be longest in ST condition of all the conditions of noise letters under either condition of assignment to response. This is because the noise letters the same as the target should compete most for the feature analyzer with the target. It predicts further that the reaction time will be longer in RI-a condition under CA condition and in RC condition under UCA condition than in the other conditions except ST for the same reason. However, the results were inconsistent with the prediction as mentioned above and rejected the hypothesis.

Incidentally, the reaction time was markedly longer in CA condition than in UCA condition. The results might be explained in the following way. In UCA condition, one set of letters (C, O) assigned to one response were similar, and that dissimilar to the other set of letters (E, F) assigned to the other response. In this condition, selection of the response should be based on the simple criterion whether the letter has curved or straight elements. Thus the determination of response to the target should be completed early in the human information processing system. In CA condition, one set of letters (C, E) assigned to one response was similar to the other set of letters (F, O) assigned to the other response. In this condition, selection should be based on the complex criteria whether the letter is opened or closed if it has curved elements, and whether the number of horizontal lines are two or three if the letter has straight elements. Thus the determination of response should be completed late in the system. The time lag of the determination might be reflected in the longer reaction time in CA condition.

There is another possible explanation for the results. Under CA condition, the target itself might have exerted its interfering effect actively upon determination of response because the target letter was similar to the letters requiring the response opposite to the target. This explanation is consistent with the above facts that the noise letters, only if being similar to those requiring the response opposite to the target, can cause as strong interfering effects as those requiring the response opposite to the target. In addition, there is a possibility that the noise letters the same as the target exert their interfering effects in ST condition under CA condition because the noise letters were similar to those in RI condition. At any rate, the present study gave unclear explanation for the difference in the reaction time between CA and UCA conditions. Further explanation should be tried in the next study.

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