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| journal or publication title | Tohoku psychologica folia |
| volume | 36 |
| page range | 101-110 |
| year | 1978-03-20 |
| URL | http://hdl.handle.net/10097/00064928 |

Tohoku Psychologica Folia
1977, 36(1-4), 101-110

# INTERFERENCES OF VISUAL NOISES WITH THE PERIPHERAL MATCHING OF LETTERS

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Mackworth's peripheral matching paradigm (N.H. Mackworth, 1965) was replicated in two experiments, using several types of visual noises.

The results of these experiments revealed that not only the extra letters but also the other type noises such as the random-dot-patterns, and the redundant noise that was the array of the same letters, and the compound patterns that were made by putting a letter on another, were effective in interfering with the matching of three targets; one letter is presented at a fixation point and two were bilaterally presented. And these detrimental effects of noise were independent of the absolute retinal position of the bilateral targets.

Then, as the strength of interference varied with the types of visual noise, it was suggested that there were some different interferences of noises in the visual information processing; one at a level where letters were to be processed, and another at more peripheral level. And these results were discussed in the schema of Neisser's two-levels of attentional processes and in the dichotomy of visual masking; the cognitive masking and the sensory masking.

## INTRODUCTION

There have been many articles showing that a letter embedded in a letter string has been less legible than a single letter, especially in peripheral visual field. Mackworth (1965) reported that the 'Visual noise' letters interfered with the peripheral matching. He presented tachistoscopically three target letters for 100msec.: one at a fixation point, two on both sides of the foveal target, and the subject had to decide whether the foveal target letter (N or C) had occurred on both sides. When the extra unwanted letters (noise) had been added to the display, the percentage of correct matching decreased. In particular, the performance had been interfered considerably by the visual noise when the bilateral targets were presented peripherally. Mackworth interpreted such a result in term of the 'Useful field of vision'. According to his explanation, the useful field of vision was defined as the area around the fixation point where simultaneously supplied information can be stored and read out immediately. And when too much information is given, this field should become narrow so as to avoid overloading.

Some others also found that a set of letters could not be legible if they were not closer to a fixation point than a single letter, and referred to some interaction among the adjacent letters (Woodworth & Schlosberg, 1954 ; Woodrow, 1938). Bouma (1970, 1973) found that an embedded letter could not be recognized accurately like a single letter unless the distance between the adjacent letters should be greater than 1/2 of the distance of the target from the fixation point. But for the end letter of a string, it would be recognized even if it was presented far from the fixation point. As for the good performance for the end letter regardless of its absolute retinal position, it is said that its high score is due to only one-side interaction. And both Mackworth and Bouma found that the outer adjacent letter interfered more with the identification of the target than the inner letter, and they suggested the interference in the direction from periphery to the fovea.

Then, the distribution of errors in recognizing a letter becomes "W" as a function of retinal position, when the letter string is presented across the fixation point; i.e. a foveal letter and a two-end letter show good scores. This serial position effect could be obtained even if a long observation excluded the effects of the directional scanning or memory (Townsend, Taylor, & Brown, 1971; Taylor & Brown, 1972). Therefore, they suggested this effect was due to a lateral masking. Haber & Standing (1969) showed adding parenthesis to the outside of a letter string decreased the performance for the end letters while it did not influence the other letters. They explained this was due to the reduction of metacontrast.

Thus, it is suggested that the effect of visual noise upon the identification of the target letter is confounded with some different level interferences. The purpose of this study is to find out the evidence about these different level interferences of visual noise in the visual information processing.

## General Method

In general, the experimental method was the same as the Mackworth's peripheral matching paradigm. Subjects had to decide whether bilaterally presented two letters are physically identical with simultaneously presented foveal target letter. Experimental variables were display width: how far the peripheral targets were separated from the fixation point, and the kind of noise elements. The reasons why I had used this method were as follows. First, when an experimenter indicated a target orally to a subject, it is impossible to identify the strategy of the subject; whether the subject performs the task by name matching or physical matching based on his visual image or by any other way. And when the targets are presented successively, matching includes some intervening of memory. Now, by this method, it is clear the task is matching a foveally presented letter with simultaneously presented peripheral letters; i.e. a physical matching. Second, subject cannot move his regard during an exposure and besides he cannot previously fixate specific position nor direct his attention to one area, because he should identify the central target first and compare it with two bilaterally presented letters immediately.

## Experiment I

Experiment comprised two display modes: horizontal display and vertical display.

*Subjects*:

For each display mode, ten subjects engaged in the experiment. These 20 subjects were undergraduates and graduate students, and all had normal vision or corrected to normal vision.

*Apparatus*:

Stimuli were presented on TKK-TR type three-field tachistoscope, at 2.18 ft-L intensity.

*Stimulus materials*:

Stimuli consisted of matching stimuli and noise stimuli. Matching stimuli comprised targets and pseudo-targets, and were made from dry-transfer symbols DECA-dry n. 26, 7mm hight: at 80cm, the visual angle was 0.5°. Target was N or C, and pseudo-target was one of curvilinear letters (e.g. B,G,S) for the target N and rectilinear letters (e.g. A,H,Z) for the target C. N or C was presented on fovea at every trial. Bilateral stimuli were one of three combinations; (1) two were the same as the foveal target, (2) one was the same and the other was a pseudo-target, and (3) two were both pseudo-targets. Bilateral stimuli were equally separated from the fixation point. The display width was the visual angle of these two bilateral stimuli centered on the foveal target, and was 2° or 6° for horizontal display and 2° or 4° for vertical display.

Noise stimuli were random-dot-patterns or letters or double-letter patterns. The letter noise elements were selected randomly from alphabet that were the same dry-transfer symbols as the targets. The double-letter noise elements were made up by putting different letters on each other. The random-dot-pattern noise elements were made on $7 \times 6$ dotmatrix and its black area was much the same as the letter symbols; 8–23 dots, where one dot was one-mm square.

Thus, displays were divided into three types; (1) No-noise Display (N-Display short for it.), three matching stimuli only. (2) Random-dot-pattern-noise Display (R-Display), three matching stimuli and ten random-dot-pattern noise elements formed a line, and the visual angle of the space between the centers of these elements was one degree. Then, the display width of 13 full stimuli was about 12 degrees. (3) Letter-noise Display (L-Display), randomly selected letters took the place of the random-dot-patterns of the R-Display. (4) Double-letter-noise-Display (D-Display), randomly selected double-letter pattern was used for noise element. The examples of these displays are shown in Figure 1. The condition of the L-Display in horizontal display was a repetition of the Line-Display in Mackworth's experiment.

*Procedure*:

There were 192 displays for each subject; 96 displays had correct matching targets, and in 64 displays only one side was to match with the foveal target while the other was a pseudo-target, and in 32 displays two bilateral stimuli were both pseudo-

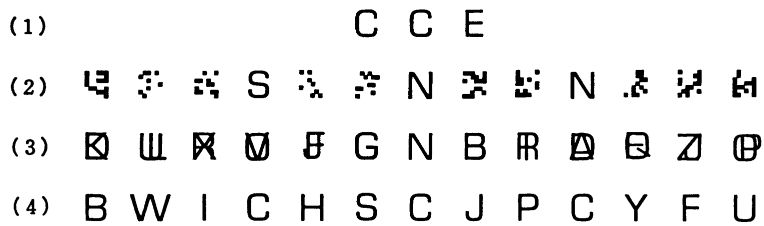

Fig. 1. The examples of horizontal displays in the experiment I. (1) No-noise Display, (2) Random-dot-pattern-noise Display, (3) Double-letter-noise Display, (4) Letter-noise Display. The targets are matching only in (4). The display widths of the targets are corresponding to 2° for (1), (3), and to 6° for (2), (4).

targes. That is, the ratio of match and non-match was 1:1. And each experimental condition (2 target × 4 noise-display × 2 display width) occurred evenly in random sequence. When the subject pushed the button after the sign of the experimenter, the samll black dot positioning on the center of a white card was exposed for 1.5 sec. Then, the stimulus display was exposed for 100 msec., followed by a blank field for 2 seconds. Observing binocularly the display, the subject had to report whether the central target had occurred bilaterally or not; it was a 2-alternative forced choice paradigm. After the subject had come to be able to recognize the targets in N-Display in some practical trials, the experimental trials began.

## Results and Discussion

Figures 2 and 3 show the average percentage of correct reports as a function of display width for each noise-display in two display modes, where the results for the target N and C are in the lump. An analysis of variance shows the main effect of noise and of dispaly width and the interaction of noise × display width are significant for both display modes (See Table 1). The results of Newman-Keul's Test are as follows:

(a) Horizontal Display

The differences between the two display widths for the same noise-display are all significant except for N-Display ($p<.01$). In the display width 2°, only the difference between L- and N-Display is significant ($p<.01$). In the display width 6°, the scores for each noise-display differs from each other significantly ($p<.01$), except the difference between D- and L-Display.

(b) Vertical Display

The statistical results about the differences between the two display widths for the same noise are the same as that of horizontal display. In the display width 2°, the score of L-Display differs from others significantly ($p<.01$ for R- and N-Display, $p<.05$ for D-Display). In the display width 4°, each display differed from each other significantly ($p<.01$).

As the performance for N-Display is considered to reflect the acuity for the

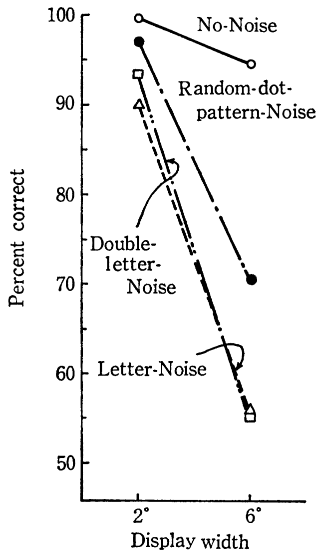


Fig. 2. Effect of visual-noise on peripheral matching as a function of horizontal display width.

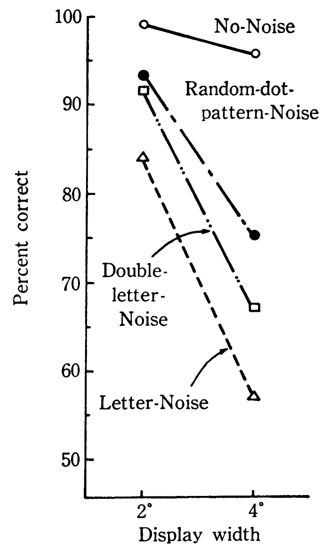


Fig. 3. Effect of visual-noise on peripheral matching as a function of vertical display width.

Table 1. Analysis of variance on the data of the experiment I.

(a) Horizontal Display

| Sources | *SS* | *df* | *MS* | *F* |
|---|---|---|---|---|
| Display width | 781.3 | 1 | 781.3 | 91.9 ($p<.01$) |
| Noise | 431.4 | 3 | 143.8 | 61.7 ($p<.01$) |
| Subjects | 57.3 | 9 | 6.4 | - |
| Width × Noise | 190.2 | 3 | 63.4 | 30.5 ($p<.01$) |
| Width × *S*s | 76.5 | 9 | 8.5 | - |
| Noise × *S*s | 62.9 | 27 | 2.3 | - |
| Error | 56.1 | 27 | 2.1 | - |

(b) Vertical Display

| Sources | *SS* | *df* | *MS* | *F* |
|---|---|---|---|---|
| Display width | 382.8 | 1 | 382.8 | 125.1 ($p<.01$) |
| Noise | 435.9 | 3 | 145.3 | 60.3 ($p<.01$) |
| Subjects | 68.8 | 9 | 7.6 | - |
| Width × Noise | 98.1 | 3 | 32.7 | 14.7 ($p<.01$) |
| Width × *S*s | 27.6 | 9 | 3.1 | - |
| Noise × *S*s | 65.2 | 27 | 2.4 | - |
| Error | 60.0 | 27 | 2.2 | - |

targets, the poor score on noise-displays for large display width cannot be due to the poor acuity in peripheral visual field. The effect of visual noise which Mackworth reported has been confirmed concerning different noise elements.

It seems that the strength of interference of visual noise with the peripheral matching will be in order of L>D>R>N, because it is considered to be due to a floor-effect that the performance for D- and L-Display is equal at horizontall display width 6°. From a viewpoint of sensory lateral masking, it should be noted that the black area of the L-noise element and of R-noise element are almost equal, while the black area of D-noise element is greater than that of L- or R-noise element generally. On the other hand, from a viewpoint of interference in the letter-processing mechanisms, the noise element of D-Display is not a letter but has some component of letter which R-Display noise element has not. Then, it is suggested that there are some different interferences of visual noises; one at a level where letters are to be processed, and the other perhaps at lower level.

However, there are some problems yet. Among them the effect of the absolute retinal position and the interference at lower level are to be studied mainly in the experiment II.

## Experiment II

In general, backward masking effect and metacontrast effect are said to be greater in peripheral visual field than in the fovea (Stewart & Purcell, 1970; Lefton, 1973). While Mackworth found little effect of the absolute retinal position on his peripheral matching paradigm, do the visual noise effects differ from the metacontrast in this point ?

On the other hand, if the effect of R-noise elements was due to some sensory masking, it would not be necessary that the noise elements differ from each other.

To reply to these problems, the experiment II was designed. Because it seemed that the results of the two display modes in the experiment I were similar to each other, only the horizontal display was to be used.

*Subjects*:

10 undergraduates and graduate students who had normal vision or were corrected to normal vison engaged in the experiment.

*Apparatus*:

Stimuli were presented on a Gerbrand tachistoscope (Model: Harvard, G–1130) which had three channels, and the intensity was at 4.1 ft-L.

*Stimulus materials*:

All stimuli were uppercase letters of a Maruzen electric typewriter (Model: 330–ELECTRIC), and the height of a letter was 3 mm; at 80 cm its visual angle was about 0.2°.

The examples of the displays in experiment II are shown in Figure 4. The matching stimuli that were targets and pseudo-targets were the same as those of the experiment I. The display widths were of two kinds: (1) the foveal target bilaterally

(1) N N N

(2) I I I C I I C I I A I I I

(3) T U A R E P N N G Y D L W

Fig. 4. The examples of stimulus displays in the experiment II. (1) No -noise Display, (2) Redundant-noise Display, (3) Letter-noise Display. The display widths of targets are corresponding to 0.7° for (1), (3), and to 2.3° for (2).

adjoined to one space by two lateral targets, and the visual angle of these three targets were 0.7° at 80 cm. and (2) the lateral targets separates from the foveal target 6 spaces, the visual angle of the display width was 2.3° at 80 cm. That is, the targets in the experiment II were all within the central visual field. The noise-display was of there types: No-noise Display (N-Display) and Letter-noise Display (L-Display) were the same as that of the experiment I. The noise elements of Redundant-noise Display (Re-Display) were all uppercase 'I's; i.e. 10 'I's were arranged with every one space in a string embedding target and pseudo-target. Procedure was the same as that of the experiment I. In 144 displays, match and non-match, target C and N, 3 types of noise-displays were evenly combined and presented in random sequence.

## Results

The average percentage of correct reports as a function of display width for each noise-display are shown in Figure 5. The pattern of reports are very similar to that of the results of experiment I.

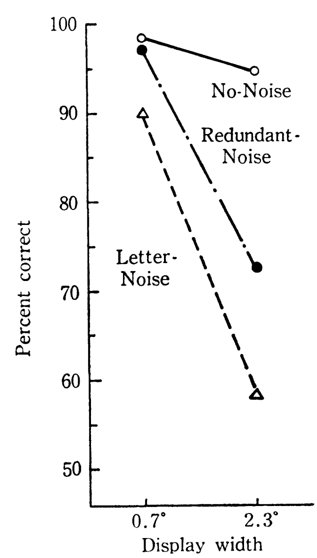


Fig. 5. Effect of visual-noise on peripheral matching as a function of display width.

Table 2. Analysis of variance on the data of the experiment II.

| Sources | *SS* | *df* | *MS* | *F* |
|---|---|---|---|---|
| Display width | 345.6 | 1 | 345.6 | 138.8 ($p<.01$) |
| Noise | 286.4 | 2 | 143.2 | 74.6 ($p<.01$) |
| Subjects | 80.7 | 9 | 8.9 | - |
| Width × Noise | 121.3 | 2 | 60.7 | 36.7 ($p<.01$) |
| Width × *S*s | 22.4 | 9 | 2.5 | - |
| Noise × *S*s | 34.6 | 18 | 1.9 | - |
| Error | 29.8 | 18 | 1.7 | - |

As a result of analysis of variance, the main effect of display width, and of visual noise and the interaction of display width × visual noise are all significant ($p<.01$). This is shown in the Table 2. Results of Newman-Keul's Test are as follows. In the display width 0.7°, the difference between L- and N-Display is significant ($p<.01$). In the display width 2.3°, Displays differ from each other significantly ($p<.01$). While N-Display does not differ significantly between the two display widths, for Re- and L-Display the performance decreased significantly at display width 2.3°.

Although the experiments were carried out under a limitation that the stimulus materials for these two experiments were not exactly the same, the Redundant noise elements show a similar effect to the Random-dot-pattern noise in the experiment I upon the performance. And, it becomes clear that such interference of visual noises seem to be not influenced by the absolute retinal position of the targets.

## General Discussion

The main results in the above experiments to be discussed are as follows. First, it becomes clear that not only the unwanted letters but also the other visual noises are effective in inteference with the peripheral matching, such as the array of the random-dot-patterns of which element has nearly equal black area to the target, the array of the same letters, and the compound patterns that are not letters but have the common components with the letters. Second, these interference of the visual noises are not influenced by the absolute retinal position of the targets.

If there were two letters between the foveal target and the lateral target having other three letters outside, the matching of these three targets was impaired so far as below the chance level in spite of their real size. That is, then the performance decreased as if the subjects could not identify the tatgets entirely. On the other hand, most subjects reported that it was relatively easy to match the targets in the random-dot-pattern noise or in the redundant noise, because the targets looked like figure against the background of noise elements. At this time, however, the results showed not a few errors in spite of their feelings. Now, this reminds me of Neisser's notion about the two-levels of attentional processes, that is, the preattentive process and the focal attention (Neisser, 1967). According to Neisser, the preattentive process which has wholistic and global nature segregates the object in the visual field so that the focal attention can examine the detail of the object. In this context of attentional processes, the detrimental effect of the random-dot-pattern noise or of the redundant noise is conceived to be independent of the preattentive process; i.e. the interference in the focal attention process. But for the effect of the letters, the subjects seemed to be not able even to segregate the targets; i.e. to have the interference in the preattentive process already.

From another view point, Harcum & Shaw (1974) proposed the notion about the two levels of masking: the cognitive masking due to the confusion of relevant stimuli with the irrelevanat stimuli, and the sensory masking. They observed the detrimental effect of the added stimuli upon the detection of a circular target, and found out the two kinds of effect of noise. That is, the general effect over the accuracy of the report and the local effect on the stimuli neighbouring with the noise. According to them, the cognitive masking is due to the interference in the read-out process from the iconic memory, while the sensory masking is due to the degradation of the icon. Well, Mackworth (1965) had mentioned that the visual image was to be formed from the center to periphery when there was overloading (cf. Chaikin, et al, 1962), but the image was to be read out inward to the center. As for this scanning process, White (1976) reported recently the evidence suggesting that the alphanumerical stimuli were to be scanned in the direction from peripheral visual field to the fixation point.

Now, the performance of the peripheral matching is considered as a result that the interactions of such peripheral processes as the spatial resolutionability or the lateral interference, and the higher processes have brought about. Then, the attentional processes above mentioned seem to operate after the visual image has been formed.

However, for the present, it should not be mentioned about the mechanisms of the processing of simultaneously presented multi-stimuli over the visual field, because such important variables as the number of elements in the display and the confusability of the target and the noise, and so on remain uncontrolled (McIntyre, Fox, & Neale, 1970; Estes, 1972; Eriksen & Hoffman, 1973; Strangert & Brännström, 1975). After due consideration about these problems, the spatial interaction will be able to be organized into a theory of visual information processig.

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(Received October 30, 1977)