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INTERACTION BETWEEN TWO LETTERS IN VISUAL PERCEPTION

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Abstract. Letters were exposed by tachistoscope for 17 msec to adult subjects. In Experiment I, single letters were exposed. The proportion of errors differed strongly for particular letters. In Experiment II pairs of letters were exposed. The first letter of a pair was recognized more easily than when exposed alone in Experiment I. In Experiment III pairs of letters were exposed but the subject's task was to recognize only one letter of the pair. Both, first and second letters of the pair were then recognized better than in Experiment I. The results were interpreted in terms of facilitatory and inhibitory effects occurring on different levels of the visual system.

INTRODUCTION

In researches undertaken by psychologists on mutual interaction of objects situated simultaneously in the visual field (1, 17, 18, 26), inhibitory effects are mainly found. However, there are some stimulus situations where facilitatory interactions may be expected, e.g., between two letters.

Authors usually analyzed the interaction between graphic characters solely in terms of data relating to a situation where several characters are simultaneously exposed (2, 3, 18). Yet a definite answer to the question as to what kind of interaction takes place between letters can be obtained only when the results of the perception of several letters are compared to the results obtained on letters presented alone. This comparison was sought by Bouma in 1970 (1). He found that the characters

mutually inhibit each other in perception — a result contrary to expectations from practice in reading. A possible explanation is that the author presented the stimuli at distances beyond the normal reading range of sharp focus. As Buswell and Ruediger (6, 25) showed the area contained in one fixation does not exceed 4° on the average.

Our experiments avoided this objection by using foveal vision. We aim to investigate the role of complex visual patterns in the perception of their component elements and to examine the controversial question of parallel vs. sequential processing of information of simultaneously presented stimuli (7).

EXPERIMENT I

This experiment investigated the relative perceptual difficulty in reading particular letters presented alone.

Method

Twenty five printed characters of the Latin alphabet were used, sans-serif characters of Helvetica type, black on a white background. The angular size of the letters was adjusted in such a way as to fit into fovea; vertically 1°10′ and horizontally 58′.

Each stimulus presentation was preceded by a rectangular illuminated patch (of 80 lux and 23° x 16° in size) with a fixation spot. The fixation spot disappeared after 1.5 sec. Then after 0.5 sec a single letter appeared a little below the place, where previously the fixation spot was shown. The subjects were asked to focus sight below the spot. Time of letter exposure was 17 msec. Letters were exposed in random order in 15 element series. Each letter was exposed five times. The popular music was played during the intervals between series (1.5 min). After each display, the subjects reported what letter had been exposed on the screen. Each subject participated in experimental sessions on two successive days. Twenty eight students with normal eyesight were examined; 15 males and 13 females, between 18 and 26 years of age.

Results

The index of difficulty for letter recognition was the number of recognition errors made. Two kinds of errors occurred: substitution of one letter for another, and omissions of the type "I don't know" if the subject could not recognize the figure on the screen. As a high correlation was established between the two kinds of error ($r = 0.6$ significant at a level of $\alpha = 0.01$), it may be assumed, that the mechanism of their occurrence

is the same; in further analysis they will therefore be treated jointly. The order of perceptual difficulty of letters was established by calculating the mean per cent of errors for a given letter by all subjects.

Analysis of the results revealed that letters in fact differ greatly from one another as to difficulty of recognition. In Fig. 1 single letters are presented according to increasing difficulty from left to right [1]. In case of the letter Ł, subjects made on the average 10 times as many mistakes as with the easiest letter D.

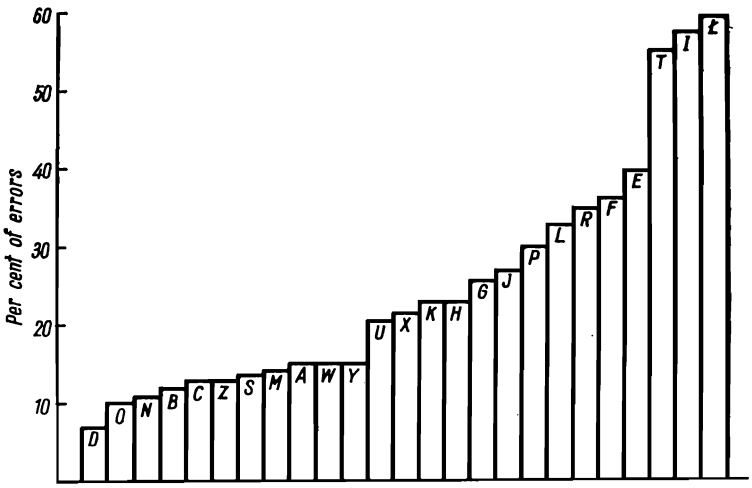

Fig. 1. Mean percentage of errors for single letters.

EXPERIMENT II

Once the relative perceptual difficulty of single letters was established, the aim of the second experiment was to compare the difficulty of reading single letters presented in isolation with that of reading the same letters presented simultaneously in pairs.

Method

In the experiment, 120 different pairs of letters were used. Among them were 95 meaningless pairs, and 25 pairs constituting short Polish words. Physical features of the stimuli were all the same as for the first experiment. The angular size of the space between letters did not exceed 8′. The letters were paired at random.

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[1] Difficulty of letter recognition is not related to frequency of letter appearance in Polish words ($r = 0.04$).

Each pair was exposed separately, only once for each subject. The conditions of the display were identical to those in the first experiment. The fixation spot was placed above the middle of the graphic figure. The task of the subjects was to read the letter pair aloud immediately after it appeared. The session lasted from 120 to 150 min. In this experiment the same persons participated as in the first experiment.

Results

The mean number of errors made by all the subjects in recognizing letters in both first and second positions in the pair was compared with the mean number of errors made when the same letters were exposed separately. The results presented below were elaborated without separation the data between group of meaningless and sensible pairs of

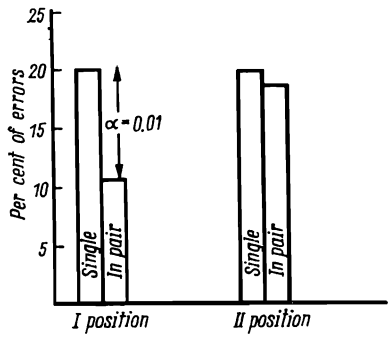

Fig. 2. Mean percentage of errors for single and paired letters in I and in II position.

letters. This is justified by the fact that in our experiment, where sensible and meaningless pairs of letters were mixed up and presented randomly, we obtained almost identical member of errors for each group of pairs.

Figure 2 presents the relation between perceptual difficulty measured by mean per cent of errors and the position occupied by the letter in the pair. As we see, letters in the first position are much better read than the same letters read separately [2]. These data suggested, that the presence of a second letter is a factor facilitating the legibility of the first letter.

This supposition is supported by analyses based on calculation of probability. On the basis of the distribution of wrong and right answers for perception of a particular single letter (Experiment I), the probability of right or wrong answers was calculated for that letter as member of a pair. If for instance we take into account the pair UE and we know

[2] This superiority is not due to the learning effect since half of the subjects started with recognition of single letters (Experiment I) and the other half with recognition of the pairs of letters (Experiment II).

that U in 20% was read incorrectly whereas E in 40% was read incorrectly we can calculate that probability of incorrect reading of both the letters is 1/5 x 2/5 = 2/10. Such calculation was done for all the possible types of performances (Fig. 3) that is: both the letters read correctly (I category); first letter wrongly — second correctly (II category); first letter correctly — second wrongly (III category) and both the letters read wrongly (IV category). The expected values were than compared to obtained values, which determined the real frequency of occurrence of a given response when a pair was displayed (Fig. 3).

It turned out, that there was a significant difference between the expected and obtained values in the two first categories. As compared

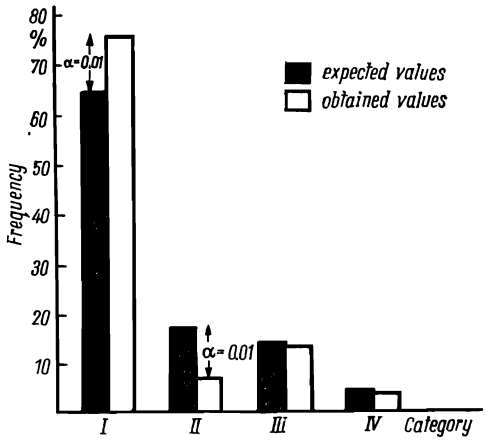

Fig. 3. The expected and obtained frequency of four types of performance. Category I, both the letters read correctly; category II, first letter read wrongly, second correctly; category III, first letter read correctly, second wrongly; category IV, both the letters read wrongly.

with the expected values the number of correct recognitions of both the letters (I category) increased, whereas the number of wrong recognition of first letter and right recognition of the second one (II category) decreased. This result shows once more the superiority of the first position over the second and supports the supposition that the first letter is facilitated by the presence of the second letter.

EXPERIMENT III

In order to establish which phase of perception the observed interactions of letters are linked with, we tried to eliminate the phase of identification of particular letters forming the pairs.

Method

The same subjects were presented the same 120 pairs of letters, but their task was to recognize only one letter of the pair: the first letter or the second one. Identification of the first and second letter was done in separate sessions. Half of the subjects started with recognition of the first letter, the other half with the second one. Single letters were also presented to the examined persons in the same sets as in Experiment I.

Results

The data obtained are given in Fig. 4. In comparison with letters exposed singly, recognition of both first and second letter improves, but in the second position the improvement is greater.

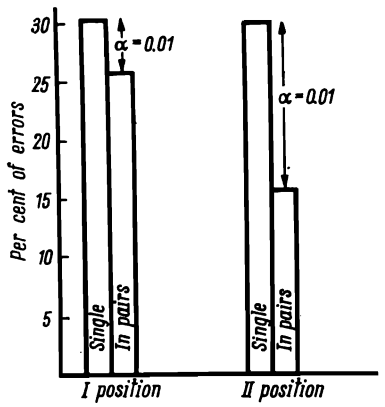

Fig. 4. Mean percentage of errors in each position when subjects read single letters or one letter of the pair in left (I) and right (II) positions.

DISCUSSION

The results of Experiment II showed that the first letter of a pair was recognized more easily than the single letter of Experiment I. These data suggest that the letter in first position is facilitated by the presence of a second letter in second position. In previous researches the reversal relation was found (1, 17, 18, 26). The authors observed inhibitory effect owing to the presence of additional letters in visual field. However, all these investigations concern phenomena occurring in peripheral parts of retina. As Mackworth (18) demonstrated, the more the peripheral part of retina is excited by letters, the stronger is the inhibitory interaction. Since in our experiments we used foveal vision it can be the crucial fact for understanding differences between our and their results. Facilitatory

interaction between two letters obtained in our experiments is not contradictory to masking phenomenon described by Mackworth and Bouma (1, 18). Both of these effects can be regarded useful from the point of view of reading optimalization. We suppose that peripheral masking causes suppressing of these signals which at a given moment are not suitable.

How to explain the superiority of the first position over the second one demonstrated in Experiment II? We tried to interpret this fact on the basis of the assumption that perception is a multiphase phenomenon. We posit three basic phases that may be distinguished in the perceptual process:

1. A phase of preliminary selection of information leading to the separation of the object's contours from the background. It is possibly based on lateral inhibition occurring mainly in the retina and lateral geniculate body.

2. A phase in which the main features of the visual pattern are distinguished such as lines, stripes, angles, crossings, endings etc. Electrophysiological investigations show that this phase is mainly connected with the function of neurons in fields 17 and 18 of the cortical part of the brain.

3. A phase of identification or classification related to memory, hence based on previous experience. This phase results in the recognition of the stimulus and its assignment to a definite class of objects. Konorski connects this phase with the existence of gnostic fields containing neurons or neuron groups which respond to definite classes of images (16).

We suppose that the difference observed in perception of the first and second letter in pair is induced by facilitation followed by negative effect. These interactions might be connected with different phases of visual analysis. Facilitation probably occurs at earlier phases whereas negative interactions are evoked by identification process. This hypothesis is supported by comparison of the results of Experiments II and III. In Experiment III which aimed at eliminating the identification of one letter, we observed that recognition of both letters improved. It suggests that facilitatory effects are connected with earlier phases than identification. It suggests as well that the second letter of pairs exposed in Experiment II must have been deteriorated in the last phase of perception. This deterioration presumably is connected with the reading habit from left to right. The letter on the right in position can be forgotten easier because it must be stored in memory over a longer period than the first one. It is not excluded that there also occurred a proactive inhibition connected with an additional excitation evoked by the uttering of the first letter. Our data fit in with the results of other authors (12–15) who

found that when a few letters are presented simultaneously at both sides of visual field — the letters at the left field are better recognized. The investigators (3–5, 10, 11, 20, 22) showed (as we did) that the left–right reading habit is the factor which causes the superiority of the left side over the right one.

The present data offer information as to one further problem, which has been particulary stressed in work of the late sixties and early seventies. The question is whether information originating from several objects exposed simultaneously is analysed in nervous system in sequence or in parallel. Some authors are of the opinion that many phenomena can be explained only by the parallelism of processes analysing simultaneously presented stimuli (19, 21, 24). Other authors claim that analysis of stimuli develops sequentially (8, 9, 22). Dick (7) advanced a concept based on the assumption that parallel and serial processes are not mutually exclusive, and might be connected with different phases of information analysis. He suggested that first phases of perception connected with visual analysis of the characters run in parallel, whereas the identification runs serially.

Our data seem to fit well into this general hypothesis, at the same time enhancing it with additional information. At the first phases of visual perception information on the two-letter picture is transmitted to higher stages of nervous system in a simultaneous manner. Testifying to this is the fact that to read two letters correctly does not require a longer exposition time than for reading each one separately (see also 23). We suppose that identification of two letters proceeds in a sequential way because of being based on the verbal system which possesses this kind of organization. This involves negative consequences for elements reproduced further. In Experiment II it caused a lowering of number of correct answers in the perception of second position letters.

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