Selective mechanisms in visual perception

KENT GUMMERMAN¹ AND HARRY MUNSINGER
UNIVERSITY OF CALIFORNIA, SAN DIEGO

The notion of perceptual tuning is investigated by presenting alternatives either before, after, or both before and after a tachistoscopic stimulus. Study 1 (N = 12) showed that identification accuracy is best with alternatives both before and after the stimulus, poorest with alternatives after the stimulus, and intermediate with alternatives only before the stimulus. Study 2 (N = 3) indicated that performance with alternatives both before and after the stimulus varies according to where S is permitted to fixate prior to each exposure. The possibility of a central tuning mechanism was not strongly supported.

To test the hypothesis that perceptual modification or selective "tuning" can occur in tachistoscopic identification tasks, Lawrence and Coles (1954) provided sets of four alternatives either before or after a stimulus presentation. Their principal test for modification of perception was based on the assumption that a selective process can function only when the S knows the alternatives before the stimulus is shown. If perceptual tuning exists, therefore, it should facilitate performance when alternatives precede the stimulus but not when they follow the stimulus.

Lawrence and Coles suggested, however, that failure to obtain better performance in the alternatives-before (Before) condition than in the alternatives-after (After) condition is not sufficient grounds for rejecting the tuning notion: A second process, operating on the memory trace of the stimulus, could be facilitating performance in the After condition just enough to match tuning's facilitation in the Before condition. Lawrence and Coles's method for investigating this "two-factor hypothesis" makes the following assumptions: In the After condition, the actual percept of the stimulus is not available for choice; only the relatively impoverished memory trace can be used. If the alternatives provided are quite dissimilar, even this memory trace should be sufficient to permit discrimination between the alternatives. With similar alternatives given after the stimulus, however, the fading memory trace should be inadequate for discrimination. In the Before condition, on the other hand, selective tuning should always facilitate performance, regardless of the similarity of the alternatives. Thus an interaction between Before-After and

similar-dissimilar alternatives should occur if two factors are involved. Performance should be approximately equal in the conditions Before-dissimilar, Before-similar, and After-dissimilar, with poorer performance in After-similar (see Fig. 1).

Lawrence and Coles were mistaken in devising this interaction as a test for selectivity in the absence of a Before-After difference: The interaction, as described above, cannot be obtained unless there is a main effect of Before-After. A simple plot of the interaction and main effect can demonstrate this fact, and it is also not difficult to show that the sum of squares for the Before-After main effect must be equal to the sum of squares for the interaction. Given that there is no Before-After main effect, therefore, the interaction can provide no additional information.

The relevance of the interaction is questionable even when there is a significant main effect. To show this, a detailed analysis of events during and following stimulation is needed. First it must be understood that the stimulus information available to the perceptual system outlasts the physical stimulus, persisting as a fading visual image (e.g., Sperling, 1960; Neisser, 1967) as suggested in Fig. 2. The finished percept that the S can use for decision-making, however, is not the same as this visual image. The percept, P, depends on (a) the total area, A, under the visual image clarity function and (b) the efficiency, ϵ , with which perceptual processing of the visual image proceeds. Consistent with Lawrence and Coles's general conception of tuning, we identify perceptual tuning with this efficiency of perceptual processing. If tuning exists, knowledge of the stimulus alternatives enhances ϵ to a maximum (we will assume $\epsilon = 1.0$ for this situation), and lack of knowledge allows only a low level of efficiency (assume $\epsilon = .5$).

The total stimulus information, A, is weighted by ϵ to produce P, the finished percept. We make the simple assumption that A and ϵ combine multiplicatively: $P = \epsilon A$.

Peculiarities of the Before-After task may halt stimulus information processing during certain time intervals, temporarily reducing ϵ to 0 and consequently reducing the strength of the finished percept. First, Ss may elect to delay all processing until they know the alternatives (Lawrence & Coles, 1954; Brown, 1960). Assuming that this

knowledge arrives at Time a in Fig. 2, this means that $\epsilon = 0$ during the interval labeled I—i.e., $\epsilon_I = 0$. Second, the act of perceiving and processing the alternatives may cause an interruption in the processing of the stimulus information. Assuming that this act occupies the interval labeled II (from a to b), $\epsilon_{II} = 0$. We assume, finally, that ϵ_{III} is always at maximum—either 1.0 (assuming tuning exists) or .5 (assuming no tuning).

Since ϵ can change value, the strength of the finished percept cannot be expressed simply by ϵA ; this product must be taken for each time interval and then summed. That is, $P = \sum \epsilon_i A_i$ ($i = I, II, III$).

We can now evaluate P, assuming either presence or absence of three variables: perceptual tuning ($\epsilon = 1.0$ if alternatives known, $\epsilon = .5$ otherwise) vs no perceptual tuning ($\epsilon = .5$ for alternatives known and unknown), delay of processing ($\epsilon_I = 0$) vs no delay, and interruption of processing ($\epsilon_{II} = 0$) vs no interruption. This is done in Table 1, which shows both ϵ_i and P for each of the eight possible conditions. For this table, the values for A_i shown in Fig. 2 are assumed: $A_I = .3$, $A_{II} = .6$, $A_{III} = .1$.

Having computed percept strengths, the effect of similarity of alternatives must be taken into account. One approach is to assume—as Lawrence and Coles imply—that there exist critical values of percept strength required for stimulus identification (at or above these values identification can occur, and below them it cannot) and that the

Fig. 1. The relation between performance and time of presentation of alternatives that Lawrence and Coles's (1954) "two-factor hypothesis" predicts, plotted separately for dissimilar and similar alternatives (solid lines) and their average (broken line).

Fig. 2. Assumed relations between time and physical stimulus intensity and visual image clarity.

critical value for dissimilar alternatives is lower than for similar alternatives. In this case, a Lawrence and Coles interaction can occur whether perceptual tuning is assumed or not. For example, consider the conditions with interruption of processing but no delay (see Table 1), and let the critical P values be .20 for dissimilar alternatives and .30 for similar alternatives. With tuning (actual P values are 1.00 for Before and .25 for After), identification can occur for Before-similar ($1.00 > .30$), Before-dissimilar ($1.00 > .20$), and After-dissimilar ($.25 > .20$), but not for After-similar ($.25 < .30$). With no tuning (actual P is .50 for Before and .20 for After), identification can occur for Before-similar ($.50 > .30$), Before-dissimilar ($.50 > .20$), and After-dissimilar ($.20 = .20$), but not for After-similar ($.20 < .30$). With or without tuning, the interaction is obtained.

Another feasible approach to the effect of similarity—one that produces no Lawrence and Coles interaction—involves weighting the obtained percept strength, P , by an index, δ ($0.0 \leq \delta \leq 1.0$), which reflects the

dissimilarity of the alternatives (i.e., the ease with which a choice can be made). Then the probability of a correct choice is proportional to δP . For example, selecting $\delta = .75$ for dissimilar alternatives and $\delta = .50$ for similar alternatives, the values of δP for each of the eight conditions under consideration are given in Table 2. A Lawrence and Coles interaction is never obtained; in fact, interactions in the opposite direction often occur.

We believe, therefore, that the interaction between Before-After and similar-dissimilar has no bearing on the existence of perceptual tuning even when there is a Before-After main effect. Thus, no similarity analyses were made in the experiments reported here.

In their experiment, Lawrence and Coles found no main effect of Before-After and also, as should have been expected, no interaction. They rejected the notion of perceptual selectivity.

Egeth (1967) criticized Lawrence and Coles's experimental procedure because their alternatives were verbal (written

words) rather than pictorial. Egeth suggested that verbal alternatives cannot provide sufficient information for Ss to know what features are critical for deciding which alternative was actually presented. Using Lawrence and Coles's design, Egeth and Smith (1967) showed pictorial alternatives either before, after, or both before and after the stimulus. They found that the Before task was quite different from the After and Before-and-After tasks; remembering the alternatives and how to designate them when responding was a difficult problem in Before. Consequently, identification accuracy in the Before condition was no greater than in the After condition. Before-and-After accuracy, however, was significantly greater than After accuracy. Egeth and Smith also found a significant interaction between Before-After and similarity of alternatives. They concluded that perception can be modified when pictorial alternatives are used.

The experiments reported here used a similar Before-After design with pictorial alternatives. Lawrence and Coles and Egeth and Smith used (a) pictures of familiar objects, (b) a different stimulus and set of four alternatives on each trial, and (c) between-Ss designs. The present studies used (a) four non-meaningful stimuli throughout, (b) two of the four as alternatives on each trial, and (c) within-Ss designs. These experiments were primarily concerned with the influence of preexposure fixation—a variable not previously considered in Before-After studies—and will leave perceptual tuning, delay of processing, and interruption of processing confounded.

STUDY 1: TIME OF PRESENTATION OF ALTERNATIVES

Method

Subjects. Twelve experimentally naive undergraduates from an introductory psychology course at the University of California, San Diego, each served for a 1-h session. All had normal or corrected-to-normal vision.

Apparatus and stimulus materials. A three-field Scientific Prototype Model GB tachistoscope (viewing distance, 48 in.) was used to present all displays. The luminances of the stimulus displays (Field 2) were approximately 1.9 ft-L for white portions and 0.1 ft-L for black portions. For the alternatives displays (Fields 1 and "B"), the luminances were 5.0 ft-L for white and 0.2 ft-L for black.

The stimuli were four 3 by 3 square matrices, each with four randomly chosen cells blackened, presented on a white background (see Fig. 3). The matrices measured 27 min of visual angle on each side

Table 1
Values of ϵ_i and P for Before and After, Assuming Presence or Absence of Perceptual Tuning, Interruption of Processing, and Delay of Processing

	Perceptual Tuning		No Perceptual Tuning	
	Before	After	Before	After
Interruption				
Delay:				
ϵ_i	1.0, 1.0, 1.0	0.0, 0.0, 1.0	0.5, 0.5, 0.5	0.0, 0.0, 0.5
P	1.00	0.10	0.50	0.05
No Delay:				
ϵ_i	1.0, 1.0, 1.0	0.5, 0.0, 1.0	0.5, 0.5, 0.5	0.5, 0.0, 0.5
P	1.00	0.25	0.50	0.20
No Interruption				
Delay:				
ϵ_i	1.0, 1.0, 1.0	0.0, 1.0, 1.0	0.5, 0.5, 0.5	0.0, 0.5, 0.5
P	1.00	0.70	0.50	0.35
No Delay:				
ϵ_i	1.0, 1.0, 1.0	0.5, 1.0, 1.0	0.5, 0.5, 0.5	0.5, 0.5, 0.5
P	1.00	0.85	0.50	0.50

Table 2
Values of δP for Dissimilar Alternatives ($\delta = .75$) and Similar Alternatives ($\delta = .50$) in Before and After, Assuming Presence or Absence of Perceptual Tuning, Interruption of Processing, and Delay of Processing

	Perceptual Tuning		No Perceptual Tuning	
	Before	After	Before	After
Interruption				
Delay:				
Dissimilar	.75	.08	.38	.04
Similar	.50	.05	.25	.03
No Delay:				
Dissimilar	.75	.19	.38	.15
Similar	.50	.13	.25	.10
No Interruption				
Delay:				
Dissimilar	.75	.53	.38	.26
Similar	.50	.35	.25	.18
No Delay:				
Dissimilar	.75	.64	.38	.38
Similar	.50	.43	.25	.25

and were drawn with black ink on white index card stock.

The four stimuli produced six pairs of alternatives. The members of each pair were the same size as the stimuli and appeared side-by-side (separated by 36 min) 1 deg 30 min above the area displaying the stimulus matrices. The alternative pairs were centered on a rectangular white patch measuring 1 deg 57 min horizontally and 54 min vertically. The field presenting the alternatives was otherwise black.

The outline of a 36-min square, drawn in white on a black background, was centered around the area in which the stimuli appeared. This outline served as a focus and indicated where the stimuli were to be shown.

To keep the three experimental conditions similar, it was sometimes necessary to display a 1 deg 39 min x 54 min rectangular "dummy" white patch 1 deg 30 min above the stimulus area. (The dummy patch, which contained no black figures, was made smaller than the patch presenting the alternatives so that the two would reflect the

same amount of light.) In the Before condition, the dummy patch was shown immediately after the stimulus to produce metacontrast effects equivalent to those that might have been caused by the presentation of the alternatives in the After condition. In the After condition, the Ss saw this patch before the stimulus exposure to equate their retinal adaptation level at the time of stimulus exposure with the level produced by looking at the alternatives in the Before condition. In the Before-and-After condition, since alternatives were displayed both before and after the stimulus, no dummy patch was needed.

Procedure. Each S received all three main conditions, Before, After, and Before-and-After. The Ss were unsystematically divided into three groups of four each. The order in which each group received the conditions was counterbalanced according to a 3 by 3 Latin square. Since naive Ss typically show improvement in tachistoscopic tasks during single sessions, each group (identified by the particular order in which the conditions were given) was considered a level of a second factor in the design.

In the three main conditions, the procedure was as follows. (a) *Before-and-After:* The E began each trial by simultaneously presenting the pair of alternatives and the focus outline. The S examined the alternatives for up to 7 sec. Before this time elapsed, he looked inside the focus outline (against the black background) and pressed a microswitch trigger that simultaneously removed the alternatives and presented the stimulus. At the offset of the stimulus, the alternatives reappeared, for another 7 sec. The S made his response whenever he was ready by stating whether the stimulus was the left- or the right-hand member of the pair of alternatives. (In all conditions, the Ss were

told to guess if unsure.) (b) *Before:* The E began each trial by presenting the alternatives and focus outline for up to 7 sec. The S pressed the microswitch trigger to remove the alternatives and present the stimulus. At the stimulus offset, the dummy white patch appeared for 7 sec; the S was told to look up at the patch as though he were looking at alternatives and to respond whenever ready. (c) *After:* Again, the E began the trial. Here, however, he first presented the dummy white patch and focus outline along with instructions to look at the patch for nearly 7 sec, as though it were a pair of alternatives. Then the S removed the dummy patch and presented a stimulus by pressing the trigger. At the stimulus offset, the alternatives appeared (for 7 sec); the S responded when ready.

At the start of each session, the S adapted to low ambient illumination for 10 min. During the last minute, he was shown all four stimuli simultaneously and told to become familiar with them. The task was carefully explained to the S, and he was given 10 practice trials in the first condition he was to receive.

Each S received 25 trials in each of the three conditions. (The final 15 trials were used to determine identification accuracy, as explained below.) The order of presentation of the stimuli was determined randomly; and, given that Stimulus x was to be presented, selection among the alternative pairs ($x-y_1$, $x-y_2$, and $x-y_3$) was made randomly. In the six displays of pairs, two of the four stimuli were shown on the left twice and the right once; the other two stimuli were shown on the left once and on the right twice.

Analysis of results. For each S, the first 10 trials of each block of 25 were used to determine the exposure duration at which he could correctly identify 70% to 90% of the stimuli. This duration was used for the remaining 15 trials, and a combined score was used to obtain a better estimate of identification accuracy than would have been possible either by using a constant exposure duration for all Ss or by attaining an arbitrary percentage of correct responses. Each of these two measures presents problems when used separately. If a constant exposure duration is used for all Ss, individuals' performances can vary from chance to 100%. In these extreme cases, the validity of the score is doubtful. On the other hand, choosing and maintaining an arbitrary percentage of correct responses demands a great deal of experience in the task for the S to reach asymptotic performance. Any effect produced by lack of experience with the task, therefore, could not be observed. Since earlier work suggested that such an effect might exist, a combined score was used: The square root

Fig. 3. Matrix patterns used as stimuli in Study 1.

Fig. 4. The relation between identification accuracy and time of presentation of alternatives. Study 1.

of the per cent correct in the last 15 trials of each condition was divided by the exposure duration in milliseconds used for those trials. (Exposure duration ranged from 11 to 48 msec.) The quotient, multiplied by 100, was taken as the S's identification accuracy score for that block of 15 trials. This score, which is monotonically related to changes in exposure duration and per cent correct, has proved to be reliable (Munsinger & Forsman, 1966; Munsinger & Gummerman, 1967).

The data were analyzed in a mixed-design analysis of variance. The order of treatment presentation was a between-Ss factor, and the three times of presentation of alternatives constituted a within-Ss factor. The statistical significance of the differences between each pair of means for the Before, After, and Before-and-After conditions was assessed with the Duncan multiple range test.

Results and Discussion

As Fig. 4 shows, performance varied according to when the alternatives were shown, $F(2, 18) = 5.5$, $p < .05$. Before-and-After was better than Before, and Before was better than After; but only the Before-and-After vs After difference was reliable ($p < .05$). The poor performance in Before, relative to Before-and-After, might have been caused by response and memory difficulties much like those discussed by Egeth and Smith (1967). The order of presentation of the conditions was not significant, $F(2, 9) = .9$, but this factor did interact significantly with the time of presentation of alternatives, $F(4, 18) = 4.5$, $p < .05$. Inspection of the interaction suggested no meaningful interpretation.

The Before-and-After vs After difference suggests that a selective mechanism can facilitate performance, but the nature of this selection is still not clear. Consider two possibilities: (a) Through the operation of

central processes, the percept of the stimulus is improved when alternatives are known before the stimulus, and (b) the percept is enhanced when the alternatives precede the stimulus because the Ss are able to fixate more efficiently prior to the stimulus exposure. This second case is important because the retina's sensitivity is nonuniform. Measurements in acuity tasks (Wertheim, 1887, 1894; Weymouth et al, 1928; Ludvigh, 1941; Jones & Higgins, 1947; Mandelbaum & Sloan, 1947) and in detection tasks with tachistoscopic stimulus durations (Blackwell & Moldauer, 1958; Taylor, 1961) show gradients with maxima in the retina's central area. If alternatives are given before the stimulus, the Ss can place the most sensitive portion of the retina in the most advantageous area of the preexposure display—viz, where discriminating features will appear. If alternatives follow the stimulus, the Ss cannot know which area will produce these features and so cannot fixate as efficiently.

In Egeth and Smith's experiment, the stimuli were about 7 deg in size, and a central fixation point was available. In the Before-and-After condition, the Ss knew which stimuli could be shown and, thus, where to fixate to find a distinctive feature. In the After condition, no such fixation was available; the Ss could only stare at the fixation point, leaving the critical cues up to 3.5 deg away. At this distance the retina's sensitivity is less than 40% of the sensitivity in the center of the fovea.

In the present study, it was possible for Ss to fixate directly a single cell of the stimulus matrix and, on the basis of that single cell, to discriminate between the two alternatives. By appropriate selection of the fixated cell, they could change the identification task into a detection situation. Once they knew whether a critical cell was black or white, the discrimination task was solved. For each possible pair of alternatives, there exists at least one cell that discriminates between the members (see Fig. 3). For example, the third cell in the top row is such a discriminating feature for Pairs 1-2, 1-3, and 1-4. In the After condition, there are two ways (both rather inefficient) the Ss could have approached the task. (a) Most probably they fixated the center cell, leaving the other cells about 9 min from the foveal center. Relative sensitivity is about .80 at this distance (Jones & Higgins, 1947). (b) They might have adopted a fixation strategy similar to, though less effective than, the one discussed for the Before-and-After condition. In this rather complex strategy, which a naive S is unlikely to discover, simultaneous inspection of two cells—such as the bottom right and the one directly above it—can give full information about the stimulus. Even if this strategy is followed only in part

(inspecting only the bottom right cell, for example), the stimulus at least can be classified as either 1-2 or 3-4. None of these approaches to the After task should allow reports as accurate as in the Before-and-After task.

STUDY 2: INFLUENCE OF THE POINT OF FIXATION

This study was designed to (a) replicate the Before-and-After vs After difference using sophisticated Ss, and (b) put some of the hypotheses regarding fixation, discussed in Study 1, to direct test. The Before-and-After design was coupled with differential fixation in those conditions where it was possible.

Method

Subjects. Three well-practiced male undergraduates at the University of California, San Diego, were paid on an hourly basis to participate. All had normal vision without correction and had not previously served as Ss. Each served one hourly session per day.

Apparatus and stimulus materials. The apparatus and luminances of Study 1 were used. All displays were white against black backgrounds. The basic stimulus was a solid white square, 9 min on a side, that could appear in any one of the four corners of a 2 x 2 deg white-on-black outline square. The preexposure display is shown in Fig. 5. There were six pairs of alternatives—each of

Fig. 5. Preexposure display used in Study 2, not drawn to scale. (Letters and dimensions are shown only for exposition; the Ss did not see them. The actual display was white on a black background. Letters a through e indicate different fixation points; f and g show where the two alternatives appeared.)

the possible combinations of stimuli taken two at a time. Figure 5 shows both (a) how two alternatives were presented in the two small squares at the top and (b) the appearance of a stimulus in the upper right corner of the large square. The two alternatives appeared both before and after the stimulus in three conditions and only after the stimulus in a fourth.

The Ss responded by saying either "top left," "top right," "bottom left," or "bottom right." As in Study 1, the sequence of stimulus and alternatives presentation was determined randomly.

Procedure. There were four principal experimental conditions. In the first three, the alternatives appeared for 4 sec immediately before the tachistoscopic stimulus and for 4 sec immediately after. The Ss made the alternatives appear by pressing a microswitch held in the left hand. They pressed a second microswitch, held in the right hand, to make the stimulus appear. The alternatives reappeared after the stimulus automatically. The 4-sec viewing time was ample for the Ss to inspect the alternatives and focus on the appropriate part of the large square.

These three Before-and-After conditions differed according to where the Ss were instructed to fixate immediately before the stimulus exposure. These conditions will be abbreviated BA_0 , BA_{68} , and BA_{85} ; the subscripts refer to the distance (in minutes of visual angle) from the instructed fixation point to the points at which the stimuli appeared. In BA_0 , the Ss were instructed to fixate directly on the corner of the large square that would contain the stimulus if the left-hand alternative (the one that appeared in f in Fig. 5) were actually shown. In this condition, all relevant stimulus information appeared at a distance of 0 min from the fixation point. (If the right-hand alternative were actually shown as the stimulus, the Ss would know because nothing would appear at the point they were fixating. Thus their task, formally, was yes-no detection in this condition.) In the second Before-and-After condition (BA_{68}), the Ss were told to fixate a point halfway between the two corners of the large square indicated by the alternatives, i.e., at either a, b, d, e, or c. For the first four (a, b, d, and e), which occurred two-thirds of the time, the stimulus appeared at a distance of 60 min from the center of fixation; for the last point (c), which occurred one-third of the time, the stimulus appeared at about 85 min. Thus, on the average, the stimulus fell on the retina about 68 min from the foveal center for Condition BA_{68} . In the third Before-and-After condition (BA_{85}), the Ss were told to fixate always at the center of the large square (at c). For this case, the stimulus fell at a distance of about 85 min.

In the fourth main condition (After), the Ss always fixated at c, since the absence of alternatives before the stimulus made a more efficient fixation point impossible. (In terms of distance from the center of the fovea at which the stimuli fell, After and BA_{85} were identical.) Pressing the microswitch in the left hand presented the preexposure display, but without the two alternatives. The Ss were told to look at the two small squares as though they contained alternatives. Then, after fixation at c, the other microswitch was pressed to make the stimulus appear, followed automatically by the alternatives.

In all cases, the Ss made their responses at the offset of the alternatives that were shown for 4 sec after the stimulus.

Each S was given five practice sessions with 24 trials in each of the four main conditions. In addition, the fixation and response instructions were presented in detail each day; the Ss understood their tasks perfectly. During these five practice sessions, the E estimated the exposure duration for each S that would produce above chance but below perfect performance in every condition. The durations chosen were 25, 28, and 34 msec for Ss DL, CD, and JK, respectively. The dependent variable was per cent correct.

In each of Sessions 6 through 9, each S had 24 trials in each of the four conditions. (At the beginning of all sessions, the S adapted to reduced ambient illumination for 10 min and then received six warmup trials.) Brief rest periods were allowed between each block of 24 trials and whenever the Ss desired. The order of presentation of the conditions in these four sessions was determined according to a 4 by 4 Latin square. The procedure was repeated in Sessions 10 through 13, with the order of presentation reversed. Thus each S had 192 test trials in each of the four conditions.

On the basis of differential retinal sensitivity alone, we would expect identification accuracy to be highest in BA_0 , somewhat lower in BA_{68} , and lowest in BA_{85} and After (BA_{85} and After should be equal). If BA_{85} is higher than After, some nonperipheral factor—such as a perceptual selection mechanism—may be operating (assuming that the fixation instructions are followed perfectly).

The design consisted of three within-Ss factors: (a) the four main conditions, BA_0 , BA_{68} , BA_{85} , and After, (b) the first four test sessions vs the last four, to see whether or not the Ss were at asymptotic performance, and (c) the order within sessions that each condition was presented—first through fourth—to see whether or not performance changed within sessions because of either warmup or fatigue factors. For each effect, the error term used was the interaction between Ss and the

effect. The homogeneity of these error terms was established with Bartlett's test. Duncan's multiple range test was used to assess the statistical significance of differences between each pair of means, for the first factor only.

Results and Discussion

Figure 6 shows the mean scores for each S, as well as their average, for each of the four conditions of fixation. This effect was significant, $F(3,6) = 6.5$, $p < .05$. Averaged over Ss, BA_0 was significantly different from BA_{85} and After, but not from BA_{68} ; BA_{68} was significantly different from After, but not from BA_{85} ; and BA_{85} was not significantly different from After ($\alpha = .05$ for all tests).

It is clear that Before-and-After performance was better than After, just as in Study 1 and Egeth and Smith's (1967) experiment. This effect, however, seems due largely to the more efficient fixation strategies available in the Before-and-After condition.

There is some evidence (though slight) to suggest a central mechanism is operating, at least for two of the Ss: this comes from comparing performance in BA_{85} and After, where fixation is assumed to be equivalent. Any reliable advantage of BA_{85} over After (as shown by Ss CD and DL) could have been caused either by such central factors as tuning or by "cheating" on the part of the Ss—fixating more efficiently than instructed on some BA_{85} trials. Strictly speaking, the latter alternative cannot be ruled out in this experiment. Future work must take steps to eliminate fixation differences.

As mentioned earlier, the effects of perceptual tuning cannot be separated from those of delayed and interrupted processing in these experiments. One approach to this problem is to eliminate entirely the fading visual image that endures beyond the

Fig. 6. The relation between per cent correct and four combinations of fixation and time of presentation of alternatives, plotted separately for each of three Ss and their average. Study 2.

physical stimulus by always presenting a patterned masking display immediately after the stimulus. Such a display, if properly constructed, should terminate processing of the visual image information at the stimulus offset, rather than merely degrade the stimulus input (Liss, 1968; Spencer, in press; see also Kahneman, 1968), and allow an unconfounded comparison of processing efficiency in Before and After conditions. Egeth and Smith (1967) did present a visual noise display after their stimuli and obtained a significant main effect and interaction, but differential fixation was not taken into account.²

REFERENCES

- BLACKWELL, H. R., & MOLDAUER, A. B. Detection thresholds for point sources in the near periphery. USN BuShips Contract NObs-72038, Index No. 714-100, University of Michigan Engineering Research Institute Project 2455, 1958.
- BROWN, J. Evidence for a selective process during perception of tachistoscopically presented stimuli. *Journal of Experimental Psychology*, 1960, 59, 176-181.
- EGETH, H. Selective attention. *Psychological Bulletin*, 1967, 67, 41-57.
- EGETH, H., & SMITH, E. E. Perceptual selectivity in a visual recognition task. *Journal of Experimental Psychology*, 1967, 74, 543-549.
- JONES, L. A., & HIGGINS, G. C. Photographic granularity and graininess. III. Some characteristics of the visual system of importance in the evaluation of graininess and granularity. *Journal of the Optical Society of America*, 1947, 37, 217-263.
- KAHNEMAN, D. Method, findings, and theory in studies of visual masking. *Psychological Bulletin*, 1969, 70, 404-425.
- LAWRENCE, D. H., COLES, G. R. Accuracy of recognition with alternatives before and after the stimulus. *Journal of Experimental Psychology*, 1954, 47, 208-214.
- LISS, P. Does backward masking by visual noise stop stimulus processing? *Perception & Psychophysics*, 1968, 4, 328-330.
- LUDVIGH, E. Extrafoveal visual acuity as measured with Snellen test-letters. *American Journal of Ophthalmology*, 1941, 24, 303-310.
- MANDELBAUM, J., & SLOAN, L. L. Peripheral visual acuity with special reference to scotopic illumination. *American Journal of Ophthalmology*, 1947, 30, 581-588.
- MUNSINGER, H., & FORSMAN, R. Symmetry, development, and tachistoscopic recognition. *Journal of Experimental Child Psychology*, 1966, 3, 168-176.
- MUNSINGER, H., & GUMMERMAN, K. Identification of form in patterns of visual noise. *Journal of Experimental Psychology*, 1967, 75, 81-87.
- NEISSER, U. *Cognitive psychology*. New York: Appleton-Century-Crofts, 1967.
- SPENCER, T. J. Some effects of different masking stimuli on iconic storage. *Journal of Experimental Psychology*, in press.
- SPERLING, G. The information available in brief visual presentations. *Psychological Monographs*, 1960, 74 (11, Whole No. 498).
- TAYLOR, J. H. Contrast thresholds as a function of retinal position and target size for the light-adapted eye. USN BuShips Contract NObs-72092, University of California, Visibility Laboratory, Scripps Institute of Oceanography, Ref. 61-10, 1961.
- WERTHEIM, T. Ueber die Zahl der Sehenheiten im mittleren Theile der Netzhaut. *Albrecht von Graefe's Archiv für Ophthalmologie*, 1887, 33, 137-146.
- WERTHEIM, T. Ueber die indirekte Sehschärfe. *Zeitschrift für Psychologie und Physiologie der Sinnesorgane*, 1894, 7, 172-187.
- WEYMOUTH, F. W., HINES, D. C., ACRES, L. H., RAAF, J. E., & WHEELER, M. C. Visual acuity within the area centralis and its relation to eye movements and fixation. *American Journal of Ophthalmology*, 1928, 11, 947-960.

NOTES

1. Address: Department of Psychology, University of California, San Diego, La Jolla, California 92037.
2. Assuming that Egeth and Smith's masking stimulus was effective, their own results suggest that the Lawrence and Coles interaction analysis is invalid. The interaction is said to depend on a memory trace; yet, Egeth and Smith report an interaction under stimulus conditions that should have allowed no memory trace.

(Accepted for publication May 8, 1969.)