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# Perceptual Organization and Attention

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It is widely assumed that the grouping of the visual field first described by the Gestalt psychologists and the related phenomenon of texture segregation occur very early in the processing of visual information and involve preattentive processes. All the recent evidence supporting this assumption comes from visual search experiments in which the subject is actively looking for a target and attending to the stimulus. The question at issue is whether these kinds of patterns are perceived under conditions of inattention, i.e., when observers are not searching for them. We performed six experiments to determine whether texture segregation and grouping by similarity or proximity are perceived under conditions of inattention. On the first two trials subjects were asked to report the longer arm of a briefly presented cross which was surrounded by a pattern of ungrouped small elements. On the third trial and subsequent control trials these elements were configured into grouping patterns and subjects queried about them immediately following their line length reports. The results establish that neither texture segregation nor grouping by similarity of lightness or proximity are perceived under conditions of inattention. They support the conclusion that there is an earlier stage of processing than that referred to as preattentive. 

## INTRODUCTION

The Gestalt psychologists had the singular insight that the ordinary and omnipresent segregation of the visual field into units or objects was not a logical consequence of the retinal stimulation. They understood that this was an achievement of the visual system and must be the consequence of processes which intervened between the registration of stimulation and perception. These processes were believed to be based on spontaneous and autochthonous, topologically faithful, cortical activity elicited by ret-

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inal stimulation. Although not explicitly stated, it seems to follow that the factors responsible for grouping codified in Wertheimer's laws of organization, such as proximity, similarity, good continuation, and common fate, must exert their influence very early in the sequence of events responsible for perception. If this were not the case, they could not serve their designated function.

The prevailing view today has much in common with the earlier Gestalt conception. Currently it also is believed that organization occurs early in the processing sequence, prior to the stage at which attention enters the process. (See, for example, Julesz, 1981, 1984; Nakayama, in press; Triesman 1982; Pomerantz, 1981). Moreover, independent of the relevant empirical evidence, there are compelling grounds for assuming that this must be true of at least some field segregation. Since attention must be directed to something, that thing must preexist. There must be some preattentive segregation of the visual field. Current theories of visual information processing assign texture segregation, figure ground organization, and grouping by proximity and similarity of orientation and color, motion, and disparity to early vision which is considered to be massively parallel and therefore preattentive (see for example, Nakayama, in press).

In recent years there has been considerable work on the question of the relation between attention and grouping and the question of what features of visual stimulation are preattentively processed. This work has been associated primarily with the seminal research of Beck, Julesz, and Triesman (see for example: Beck, 1967, 1982; Beck, Prazdny, & Rosenfeld, 1983; Julesz, 1984; Triesman & Gelade, 1980) and their colleagues, although there are many others. The shared view of these investigators is that texture segregation and grouping are preattentive, based on parallel processing that occurs prior to and is a prerequisite for the later stages of processing that lead to object identification which is believed to require focal attention.

In much of this work patterns consisting of multiple elements are presented and observers are asked either to search for a group of elements (texture segregation) or to search for an odd element or predefined target, e.g. a slanted line, in a field of unslanted ones (pop-out experiments). The texture segregation displays are generally presented very briefly and may be followed by a patterned mask. If the texture boundary is perceived under these conditions, it is assumed to be preattentive. If, in a target search design, the reaction time (RT) is independent of the number of non-target elements in the display, it is also assumed that the underlying processes operate in parallel and are therefore preattentive.

In summary, preattentive processes are identified as those which occur early, are automatic, fast, operate in parallel across the visual field, and underlie the perception of features which "pop-out." Moreover, features which pop-out, i.e., are detected without focal attention or preattentively, are considered to be those basic to perception, in much the same way that an alphabet is basic to a language. These processes set up the potential candidates for subsequent attentional processing. Preattentive processes contrast with attentional ones which occur later, are slower, sequential, and spatially constrained, that is, are limited to only a single area of the visual field at any moment and are responsible for the identification of most conjunctions of features into a single phenomenal object.

One potentially troubling aspect of this distinction between attentional and preattentional processes is that it is based on research in which observers are required either to find the odd item or to search for some predefined feature of the visual array. This means that attention in some ordinary sense is directed to the array and to the task at hand. So, while features or texture boundaries which pop-out may be processed without focal attention, they may not be independent of the attentional mechanisms activated by the *intention* to search, where attention is deployed over the entire array, that is, is distributed.[1] In other words, none of this research examines perception under conditions of *inattention*.

What if texture segregation or classic kinds of Gestalt organization did not occur under conditions of inattention? This question is at the center of the present research. Its importance lies in the fact that only features that are perceived under conditions of inattention are likely to be serious candidates for the earliest visual processing. For if there are aspects of features of visual stimulation which serve to segregate the field and establish units for subsequent attentional processing, it would seem to be necessary that they be independent of all attention including the *intention to look for them*. Therefore, one should predict that field segregation and organization should occur in the complete absence of attention. If segregation and organization do not occur under conditions of inattention, it might become necessary not only to distinguish between attentional and preattentional processing but also to distinguish between features which require only distributed attention for their detection and those that sur-

[1] The distinction between distributed and focal attention may take several forms. For Beck (1982) the distinction is task related. He uses the term "distributed attention" to refer to tasks involving multiple elements where the location of the target element(s) is not known, whereas "focal attention" refers to tasks in which the position of the target is known. For Triesman and others distributed attention involves parallel processing and is not spatially constrained, whereas focal attention involves spatial exclusivity and sequential processing. Recently, Nakayama and Mackeben (1989) have shown that focal attention has both transient and sustained components. Braun and Sagi (1990) distinguish focal attention which is spatially exclusive and sequential from non-attentional processes evidenced by feature gradient discrimination which is not interfered with by tasks requiring focal attention.

vive even under conditions of inattention. These latter features would be candidates for the ultimate primitives of the perceptual system. In keeping with the current conventions which equate preattentive with parallel distributed processing (PDP), we have adopted the term non-attentional to describe visual processing under conditions of inattention.

Braun and Sagi (1990) also distinguished between focal and non-attentive processing. They define non-attentional as completely independent of the limited resources of focal attention. This distinction is demonstrated in a series of experiments showing that feature gradient detection, i.e., the detection of a boundary based on local feature differences, which is generally agreed to rely on parallel processing, is unaffected by a simultaneous form recognition task which requires sequential processing and focal attention. However, while the results clearly support their conclusion, they do not bear on the question of whether the feature gradient detection itself is dependent upon attentional processes evoked by the intention to perform the visual task. Both the feature gradient detection and form identification tasks were given to the observer and thus the results do not bear on the question of perception under conditions of inattention. Rather, they would seem to bear on the question of perception under conditions of *divided* attention.

To our knowledge, there is only one, virtually unknown, prior experiment which directly examined the relationship between perceptual organization and attention (Köhler & Adams, 1958). These investigators asked whether grouping by proximity occurred when observers were not attending to the pattern. Observers were required to make aesthetic judgments about small cardboard figures which were placed on top of dot patterns the observers were subsequently required to describe. The results implicated attention in perceptual grouping, since a far greater difference in relative proximity was needed before rows (or columns) of elements were perceived than when the grouping pattern was viewed without the attention-distracting task. There are, however, many methodological difficulties with this experiment. To name only two, the figure which was the focus of the distraction task in the experimental condition was placed on top of the dot grouping pattern thus obscuring it, while in the control condition where subjects only reported how they perceived the dot patterns, no obscuring figure was present. One other difference between the control and the experimental condition, which might have accounted for some of the difference between them, is that the subject was asked about the background dot patterns after six trials of judging the overlaid figures while in the control conditions subjects reported on the dot patterns after every trial.

The present research was motivated by the wish to determine what, if any, effect the direct manipulation of attention would have on texture segregation and grouping. The principle question is whether grouping or texture segregation would be perceived under conditions of complete inattention. To seek the actual answer, it was necessary to invent a method in which the critical stimulus was not implicated in the visual task. Moreover, the observers' task had to be sufficiently demanding to fully absorb attention and the critical stimulus had to be clearly visible under conditions of attention but viewed under conditions of inattention. This required using a method unlike that used by other current investigators. Before describing the several experiments, those aspects of the method which were common to all the experiments are summarized.

## GENERAL METHODOLOGY

In each of the "inattention trials," which are the principle experimental trials, the subject's explicitly stated task was to report whether the vertical or horizontal arm of a briefly presented cross was longer. The cross was always embedded in a field of clearly visible, discrete elements which surrounded it and filled the circular area described by its arms. This pattern had no bearing on the cross task and was either homogeneous or segregated. All the visual displays were controlled by a Macintosh SE microcomputer and presented on the computer monitor. The cross and texture or grouping pattern were black on a typical computer-green ground and appeared in an elliptical viewing window in the first experiments and in a circular viewing window in later experiments which, in both cases, was created by a black cardboard mask placed over the screen. Before any actual testing began, and as part of the explanation of the task, a printout of the computer screen containing the cross and its surround was shown to the subject. For the purpose of this demonstration, the surround was always homogenous.

A trial began with the onset of a small fixation mark at the center of the screen which remained visible for 1496 ms. This was immediately followed by the cross array which was visible for 200 ms. The cross was centered on the fixation mark and, when indicated in the text, was followed immediately by a densely patterned mask which completely filled the viewing area. The screen then went blank and the observer verbally reported which was the longer arm of the cross. The response was limited to a two-alternative forced choice, i.e., the observer only had the option of reporting that the horizontal or vertical arm was longer. The observer's response was recorded by the experimenter. On the third presentation of the cross display, with no forewarning, the surrounding pattern was configured into either a texture segregation or other kind of grouping pattern. (On the prior two trials the surrounding pattern exhibited no grouping.) This pattern was the critical stimulus. As soon as the screen went blank and the subject reported line length, s/he was asked about the surrounding pattern. This question was tailored to the nature of the grouping pattern. We assumed that if the observers were able to report texture segregation or grouping under these conditions, it must be independent of attention. In other words, this third trial was the critical test of whether grouping occurred under conditions of inattention. It should be noted that while the texture segregation or grouping pattern appeared for the first time on the third and critical trial, each of the two preceding trials included a pattern surrounding the cross which consisted of the same kinds of elements, so from the subject's point of view, the presence of a surrounding pattern was not surprising. Had we only introduced a pattern surrounding the cross for the first time on the critical trial, it might be possible to argue that any failure to detect the grouping on this trial was attributable to the surprise caused by the sudden appearance of a surrounding pattern. In some experiments, these first three trials were followed by a second identical triplet of trials. However, since observers were now alerted to the possibility that they might be asked about the pattern surrounding the cross, i.e. about the critical stimulus, these trials fail to meet the conditions for complete inattention. We refer to this second set of experimental trials as divided attention trials, even though the conditions for divided attention are at best implicit since we did not actually ask the subject to search for grouping on these trials. However, in some of the experiments the divided attention triad of trials was replaced by a triad of dual task trials in which the observer was explicitly asked to report on *both* the relative length of the arms of the cross *and* the surrounding grouping pattern. The critical stimulus again appeared only on the third of these trials. These trials are explicit divided attention trials and indicate whether both tasks can be achieved under the stimulus constraints that were operative. Every subject was also tested on a triplet of control trials which differed from the experimental and divided attention trials by virtue of the instructions that preceded them. These instructions directed the subject's attention to the critical stimulus, the grouping pattern, and made clear that the lengths of the arms of the cross were irrelevant. The critical stimulus again appeared only on the third of these trials. Therefore, we consider this last trial a control condition which can provide information about what can be perceived *with* attention under our conditions of brief, sometimes masked presentations. We assume that this control trial is more or less equivalent to the conditions employed in typical experiments on texture segregation or pop-out and we therefore expect that segregation or pop-out will occur. The only difference is that we allow a particular exposure interval and record the number of correct responses, whereas in most experiments involving visual search, reaction time is measured. In all cases the observers binocularly viewed the display from a distance of 50 cm with their heads stabilized by a chin rest in a room with normal ambient light.

On the basis of a large body of published work, line orientation has been determined to be one of the elementary stimulus features which is processed in parallel across the visual field and subserves preattentive texture segregation. (Beck, 1967, 1982; Beck, Prazdny, & Rosenfeld, 1983; Julesz, 1981, 1984). In addition a vertical–horizontal orientation difference along a boundary has been shown to be the most effective segregating orientation feature (Beck, 1982). It therefore seemed an obvious candidate for grouping without attention. The first experiment examines texture segregation based on a horizontal–vertical orientation difference under conditions of inattention.[2]

## EXPERIMENT 1

### *Stimuli*

The lengths of the arms of the cross varied from 4.8 to 2.6°. The difference in length between them ranged from .3 to 1.7°. There were five different cross configurations. A random subset of them were presented in each condition. The texture pattern which filled the viewing aperture was composed of small line elements which varied in length from .1 to 1.0° and were either all vertical or all horizontal (See Fig. 1) or the elements filling one of the four quadrants were rotated by 90° with respect to the elements in the other three quadrants, (See Figs. 1 and 2). There were approximately the same number of elements in each quadrant. When all

[2] The question of whether there are significant differences between texture segregation and typical Gestalt grouping patterns based on similarity and proximity is unclear although Beck (1982) has written that, "Textural segmentation is an example of what Wertheimer called similarity grouping." (p. 299)

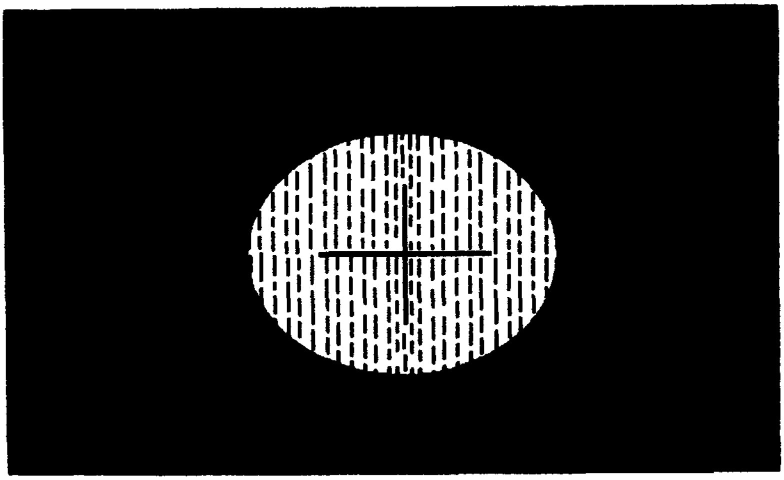

FIG. 1. An example of a homogeneous texture pattern used in Experiment 1. Range of visual angle of elements, .1–1.0°; viewing aperture, 8.3 × 7.0°.

the elements were in the same orientation, the pattern was homogenous and there was no grouping. When the elements in one of the quadrants were rotated, it appeared visually separate and was the critical stimulus. These patterns were modelled on patterns used by Olson and Attneave (1970).[3]

*Procedure*

There were three conditions, each with three trials: an experimental condition in which the observer was asked to report which of the arms of the cross was the longer, a divided attention condition which was simply a repeat of the experimental condition, and a control condition in which the observer was asked to report only whether one quadrant of the pattern surrounding the cross was different from the others. Prior to the first experimental trial, subjects were shown a printout of a cross surrounded by a homogeneous texture, and the longer arm of the cross was pointed out. On the third and critical trial in the experimental and divided attention conditions, immediately following the subject's line length response, s/he was asked whether the pattern in one of the four quadrants differed from the other three and if so, which quadrant it was. Whenever an observer responded that s/he was unsure of the answer, s/he was asked to guess which was the odd quadrant. On control trials, the observer re-

[3] The denseness of the grouping patterns should favor texture segregation since it has been shown that element separation is a critical variable (Beck, Prazdny and Rosenfeld, 1983; Sagi and Julesz, 1987).

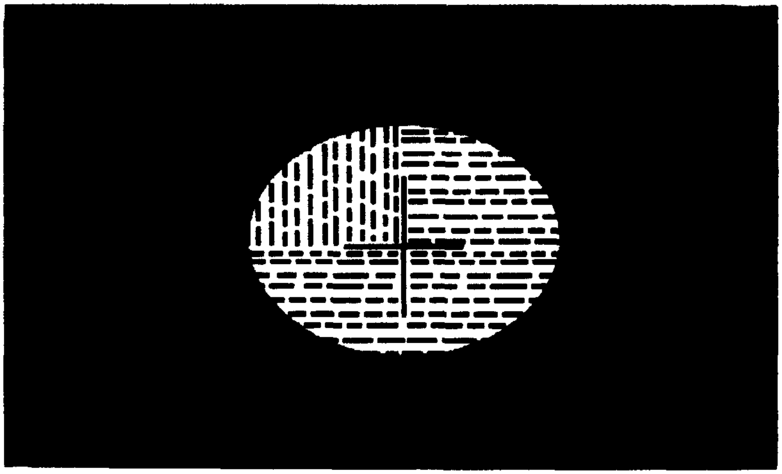

FIG. 2. An example of texture segregation patterns used in Experiments 1 and 2. Range of visual angle of elements, .1–1.0°; viewing aperture, 8.3 × 7.0°.

ported only whether one of the quadrants differed and its location. The experimental and divided attention conditions initially preceded the control condition. Subsequently, for reasons given below, we tested an equal number of subjects with the control triad first, which was then followed by the experimental and divided attention triads. When the control condition was first, the subjects were shown a printout of the computer screen showing the cross surrounded by a texture segregation pattern and the odd quadrant was pointed out. The position of the odd quadrant varied randomly with the constraint that it was never the same for two consecutive critical trials for any subject. Note that no mask followed stimulus presentations in this experiment.

*Subjects*

Forty people recruited at the New School for Social Research between the ages of 20 and 40 were tested. All enjoyed normal or corrected to normal vision. Half of the subjects were run with the experimental condition first. The other half were run with the control condition first.

*Results*

The trial by trial results from the task of discriminating the relative lengths of the arms of the cross establish that this task was possible within the time available and that the subject's performance improved with practice and, most importantly, was not degraded on the critical trial. These results are summarized in Table 1 which shows an increase in correct performance from the first trial to the third and critical trial in the experimental condition. Table 1 also summarizes the percentage of correct cross responses on the divided attention trials.

The most important results are those which indicate whether the observers correctly reported texture segregation on the third and critical experimental trial. Forty-five percent of the observers reported that one of the quadrants was different on this trial, but only 25% correctly identified its location. Neither of these results differ from what one would expect by chance. (Since subjects first had the option of reporting "same" or "different," chance is 50%, and, if they reported "different" of selecting one of four locations, chance is represented by 25% correct.)

Figure 3 summarizes the texture segregation results for the critical trials only, i.e., the third trial of each triad of trials. On the second triplet of trials, the divided attention trials, more subjects reported an odd quadrant (65%) and of those subjects, more identified its location correctly (62%) but even with the forewarning implicit in this second triad of experimental trials, only 45% of all the subjects got its location correct. The performance of these subjects, not surprisingly, improved on the subsequent triad of control trials in which the subject's only task was to report whether there was an odd quadrant and where it was. Now 95% of the subjects reported an odd quadrant and 90% correctly identified its location. This differs significantly from the percent correct on the critical experimental trial, by a $t$ test for the difference between proportions, $t_{(19)} = 5.9$, $p < .01$. (This same test was used to analyze the obtained differences in all the remaining experiments.) Thus, it would appear that while with full attention the subjects perceive the texture segregation, without

TABLE 1
Proportion Correct Cross-Judgment

| | Condition | | | | | |
|---|---|---|---|---|---|---|
| | Experimental Trial | | | Divided or Dual Trial | | |
| Experiment | 1 | 2 | 3 | 1 | 2 | 3 |
| 1 ($n$ = 10) | 65 | 85 | 90 | 90 | 95 | 95 |
| 2 ($n$ = 12) | 83 | 67 | 67 | 75 | 75 | 67 |
| 3 ($n$ = 13) | 85 | 92 | 100 | | | |
| 4 ($n$ = 20) | 65 | 90 | 100 | | | |
| 5a ($n$ = 24) | 63 | 71 | 92 | 58 | 75 | 63 |
| 5b ($n$ = 16) | 75 | 75 | 81 | 81 | 69 | 38 |
| 6 ($n$ = 20) | 55 | 60 | 85 | 55 | 60 | 65 |

*Note*. The percentage of correct line length judgements for the critical (third) trial in the experimental and divided attention or dual task conditions for all experiments.

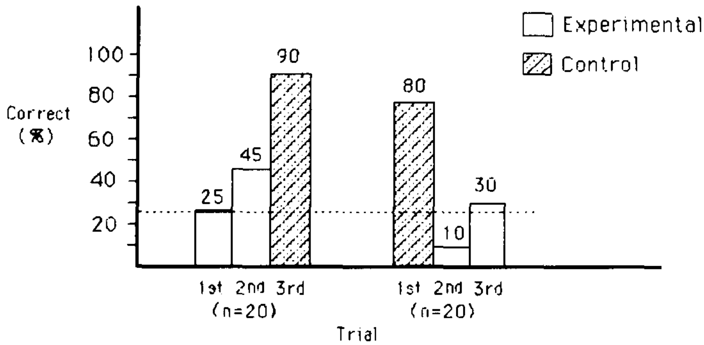


FIG. 3. The percentage of correct texture segregation judgments of Experiment 1.

it they cannot, despite the fact that no mask followed presentation of the stimulus pattern so that the effective processing interval exceeded the actual 200 ms stimulus exposure period.

Since the control trials were the third in the series, we wished to establish that the performance on these trials was not largely a matter of practice with the task but was a function of attention. We therefore tested an equal number of subjects with the control triad of trials first. This was followed by the triad of experimental trials which, in turn, was followed by the triad of divided attention trials. Since for these subjects the first trials focused the subject's attention on the texture segregation task (no mention was made of the cross task at the outset for this group of subjects), we assumed that the subsequent experimental trials, in which they were told to ignore the texture task and seek only to determine which of the arms of the cross was longer, would in fact more closely resemble divided attention trials rather than pure inattention trials.

The results from these trials are presented on the right of Fig. 3. One hundred percent of the observers were aware of the odd quadrant and 80% correctly identified its location on the third trial of the control triad when the control trials came first. Performance fell off dramatically on the subsequent critical experimental trial and improved only modestly on the divided attention trial. On the critical experimental trial which, when it came first, we consider a condition of pure inattention, 55% of the subjects reported that there was an odd quadrant and only 10% of the observers correctly identified its location. This value differs significantly from the percent correct on the control trial of 80%, $t_{(19)} = 4.76, p < .01$. (The fact that only 10% of the subjects correctly identified the location of the odd quadrant on the critical inattention trial is within the range of what one would expect by chance, $\chi^2 = 2.47, p > 05.$). On the divided attention trial, 70% of the observers reported an odd quadrant and 30% of the location responses were correct. Thus, instructing observers to ignore the texture after having had to attend to it seems to have been at least as effective, if not more effective, in limiting the subjects' attention than no mention at all of the critical pattern.

One of the questions that emerges from these results is whether the observers could perceive the texture segregation if they are asked to search for it at the same time they are asked to report which of the lines of the cross is longer. In other words, if the observers were explicitly given both tasks, could they perform them? An answer to this question would provide information about the difficulty of the tasks. So far we know that either task can be done successfully when it is the only task and that texture segregation is not perceived without attention. Results from the second, divided attention triplet in which subjects may have suspected they would be asked about the pattern surrounding the cross are at best suggestive since subjects continue to be told that their only task is the line length one. The fact that observers seem to improve on the second critical trial (45%, where chance performance is 25%) but do not do even better may reflect the fact that some but not all of the subjects actively attended to the background on these trials. The next experiment therefore included a dual task condition in which the subject was explicitly asked to report on line length *and* texture segregation.

## EXPERIMENT 2

### *Stimuli and Procedure*

We used the same stimuli that were used in Experiment 1 but added other ones of the same sort. The additional stimuli had elements which were 1.5 times thicker and in one version of this stimulus they were less densely arrayed (see Fig. 4). We thought that enlargening the elements might facilitate the perception of texture segregation. There were three conditions, each with three trials. The experimental trials were first and were exactly like the experimental trials in the first experiment. They were followed by the dual task condition in which the subjects were asked to report about line length as well as whether one quadrant of the pattern surrounding the cross differed from the other three and, if so, to locate it. Finally the subjects were run through the three control trials.

### *Subjects*

Twelve subjects from the New School For Social Research with normal or corrected to normal vision were paid for their participation. All of them were unfamiliar with the procedure. Six subjects were tested with the original patterns and six with the enlarged patterns.

### *Results*

Results of the line length task are reported in Table 1. Most important

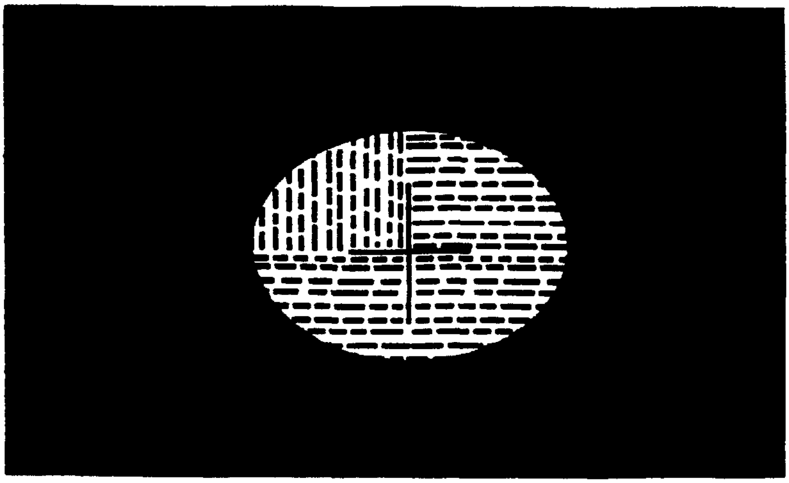

FIG. 4. Modified texture segregation patterns used in Experiment 2. Range of visual angle of elements, .1–1.0°. The elements are 1.5 times thicker than the elements in Figs. 1 and 2. Viewing aperture, 8.3 × 7.0°.

is the fact that there is no decrement in performance on the line length task in the dual task condition in which the subject is required to do both tasks relative to the comparable trial in the experimental condition where line length was the only task. The texture segregation results are given in Fig. 5.

Three of the 12 subjects correctly identified the odd quadrant on the critical trial in the experimental or inattention condition which again is what one would expect by chance and replicates the findings of the previous experiment. In the dual task condition all of the subjects correctly located the odd quadrant on the critical trial and did so with no decrement in performance on the line length task. This establishes that both tasks

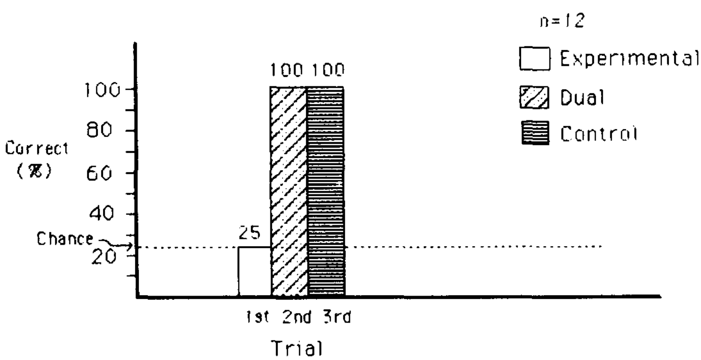


FIG. 5. The percentage of correct texture segregation results of Experiment 2.

can be done under these conditions when the intention to do so is present. There was no difference between the results using the larger and smaller patterns. All subjects, not surprisingly, correctly identified the odd quadrant in the control condition. Performance on the texture segregation task was significantly better in both the control and dual task conditions than in the experimental conditions and by the same degree, $t_{(11)} = 5.8$, $p < .01$.

## EXPERIMENT 3

This experiment examined grouping by lightness similarity and proximity under conditions of inattention.

### *Stimuli*

Like those used earlier, the stimuli in this experiment included a cross surrounded by a pattern of small elements. The various crosses used previously were used again. The patterns surrounding the cross were made up of small square elements subtending a visual angle of .37°. The non-grouping or neutral pattern which appeared in the first two trials of each triplet of trials consisted of evenly spaced, same-size black squares (see Fig. 6). There were two kinds of grouping patterns (critical stimuli). One was a proximity pattern, in which the same square elements were approximately two times closer together either horizontally or vertically and therefore were grouped into horizontal rows or vertical columns (see Fig. 7). The actual angular separations were .48 and .86°. There were two versions of this pattern, one with vertical, the other with horizontal grouping. The other kind of grouping pattern was based on lightness similarity. Half the squares were created by a black outline and the other

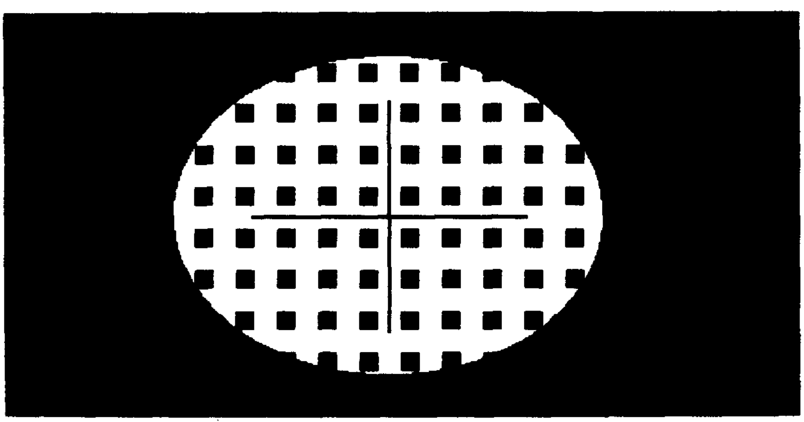

FIG. 6. Homogeneous grouping pattern used in Experiments 3–5. Visual angle of squares, .37 × .37°; visual angle of intersquare distance, 43°; diameter of visual aperture, 8.4°.

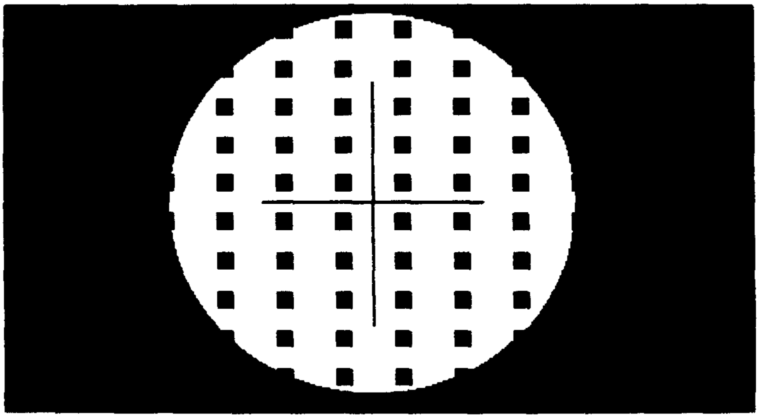

FIG. 7. An example of a proximity pattern used as a critical stimulus in Experiments 3 and 4. Vertical separation of elements, .48°; horizontal separation of elements, .86°.

half were solid black. Each square element was equidistant from every other. There were two versions of this stimulus, one arranged so that the elements formed horizontal rows, which were either all black or all outline, and the other in which the elements formed vertical columns by the same lightness similarity (see Fig. 8). The presentations of all the patterns were followed by a densely patterned mask consisting of vertical, horizontal, and diagonal lines which completely filled the area occupied by the arrays.

*Procedure*

While the general procedure was like that used in the first two exper-

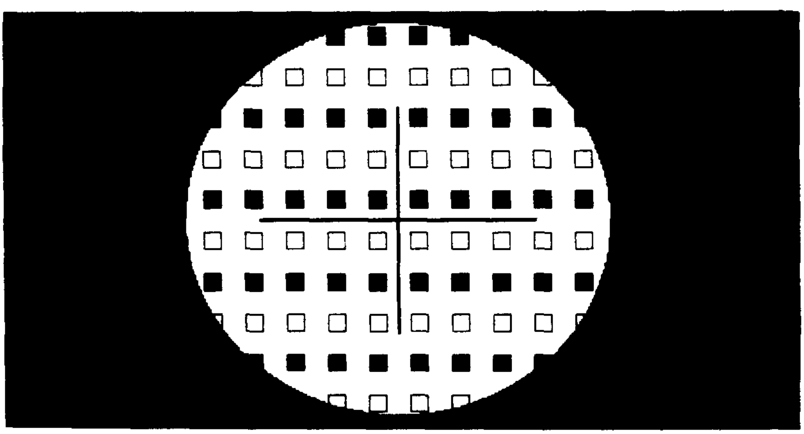

FIG. 8. An example of a similarity grouping pattern used as a critical stimulus in Experiments 3–5. Visual angle of elements, .37°; visual angle of intersquare distance, .43°.

iments, there were a number of important differences. First, all stimulus presentations were followed, without delay, by a mask. On the critical experimental trial as well as on the control trials, subjects were asked whether the pattern surrounding the cross appeared to be arranged into vertical columns, horizontal rows, or evenly spaced. On the critical experimental trial, this question was asked immediately after the observers made their line length response. Subjects again were shown a printout of the cross embedded in the evenly spaced black elements prior to testing. There were two testing conditions, an experimental and a control condition, each with three trials. (Neither a divided attention nor a dual task condition was included.) All subjects were run first on the control triplet followed by the experimental triplet. We began with the control trials in order to make sure that, at least with full attention, subjects would perceive the grouping.

*Subjects*

Thirteen subjects recruited from the New School student population with normal or corrected to normal vision participated. None had participated in an earlier experiment. Seven subjects saw similarity grouping patterns on the critical experimental trial and six subjects saw proximity patterns on these trials. The grouping pattern on the third control trial was always of the other kind, i.e., a proximity pattern if the prior critical pattern had been grouped by similarity or vice versa.

*Results*

The subjects again performed well on the line length task (see Table 1). Since there were no significant differences between subjects' grouping performance on the similarity and proximity patterns, these data were combined. In the control condition which came first, six of the subjects (46%) correctly reported the grouping, which is somewhat more than would be expected by chance. Since the observer had the option of reporting vertical, horizontal, or no grouping, chance is numerically defined as 33⅓% or 4.3 correct reports of grouping for the 13 subjects tested. On the subsequent critical experimental trial, only three subjects (23%) correctly reported the grouping, which is not different from the numerical estimate of chance.

Since with this small sample, the difference between the experimental and control trials can hardly be significant, we can draw no conclusions from this experiment. However, the fact that even with full attention, fewer than half the subjects correctly reported the grouping was troubling. This, plus some earlier pilot data, raised questions about whether the standard Gestalt illustrations of grouping by similarity and proximity on which the critical stimuli were based are normally spontaneously perceived as grouped. This question was explored in a separate experiment to be reported elsewhere but is mentioned here because all the subjects in the next experiment, which was essentially a repeat of Experiment 3, participated in this experiment immediately before being tested.[4] This experiment included repetitive presentations of all the patterns which served as critical stimuli in the main experiment, and thus we were certain that every subject now was familiar with the critical grouping patterns and, in fact, had correctly reported its grouping prior to the critical test. We assumed that this prior experience would increase the likelihood that subjects would correctly report the grouping, at least in the control condition.

## EXPERIMENT 4

### *Stimuli and Procedure*

The stimuli were the same as those used in Experiment 3. The procedure also was the same except that half the subject were tested in the experimental (inattention) condition first and half in the control (attention) condition first. Subjects in this experiment were not tested in the divided attention or dual task condition. As noted above, all subjects had first participated in the experiment described in Footnote 4.

### *Subjects*

Twenty subjects were recruited from the New School student population. All had normal or corrected to normal vision and were new to the experiment. Half the subjects saw a similarity grouping pattern on the critical experimental trial and a proximity pattern on the critical trial of the control condition. The other half of the subjects saw the similarity and proximity patterns in the reverse order.

### *Results*

Once again, subjects performed well on the line length task (see Table 1). The grouping results appear in Fig. 9. Despite the fact that every observer was familiar with the critical stimuli at the time of testing, only

[4] In this separate experiment all the stimuli from Experiment 3 plus four additional grouping patterns in which the square elements were smaller but otherwise identical to the patterns used in Experiment 3 were presented each for 200 ms. The nine patterns were presented three times in random order. On two of the presentations (either the first or second and the third), each pattern was followed by the mask used in Experiment 3. On the first two trials the subjects were simply asked to describe what the stimulus looked like. If, by the third trial, they had not indicated that the elements were arranged in columns or rows, they were specifically asked about this. By the third trial, all the subjects correctly reported the grouping in the critical stimuli used in Experiments 4 and 5.

1 of the 10 subjects (10%) for whom the inattention trials preceded the attention trials correctly reported the grouping. Only 2 of 10 subjects (20%) for whom the experimental trials followed the control trials reported the grouping on the experimental trial. Thus, despite familiarity with the grouping stimuli, only 15% of all the subjects reported grouping correctly under conditions of inattention. This number is less than what one would expect by chance if all three response options (vertical, horizontal, or no grouping) were equally probable, but they were not. Many more subjects reported seeing no grouping than either vertical or horizontal grouping even though the critical pattern was either horizontally or vertically grouped, i.e., there was a strong tendency to report no grouping. This would seem to reflect the fact that subjects simply did not perceive the grouping in this condition. Because so few subjects correctly reported grouping on the inattention trials, it is not possible to say anything about possible differences between the effectiveness of the similarity and proximity grouping patterns.

There were no differences between the number of correct responses to proximity and similarity grouping patterns in the control condition and, in contrast to the experimental condition, every subject correctly reported grouping on the critical trial in the attention control condition when it came first and seven did so when it followed the experimental trials (see Fig. 4). Since there were not significant differences in results between subjects given the experimental condition first and those who received the control condition first, the data from the two orders were combined for purposes of statistical analysis. A comparison of the results from the experimental and control trials was significant, $t_{(19)} = 6.4$, $p < 01$. This confirmed our assumption that prefamiliarizing the subjects with the grouping stimuli would increase the likelihood of correct reports of grouping on the control trials. However, the fact that it did not do so under

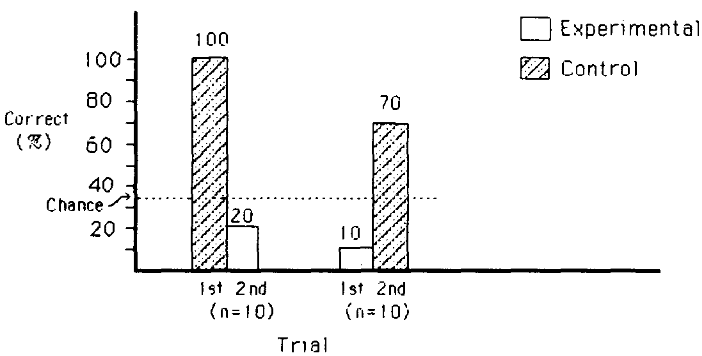


FIG. 9. The percentage of correct grouping judgments in Experiment 4.

conditions of inattention appears to be strong evidence against the view that these kinds of groupings occur without attention.

## EXPERIMENT 5a

Experiment 5a asks whether grouping by similarity and proximity can be achieved together with the line length task, i.e., under conditions of explicitly divided attention created by dual task instructions. The answer to this question provides information about the difficulty of the grouping task.

### *Stimuli and Procedure*

Stimuli and procedure were largely the same as those used in the previous two experiments. However, there were some changes. In addition to the homogenous patterns which consisted of equally spaced small black squares, we added a set of non-grouped patterns made up of randomly arranged, evenly spaced black and white squares. The inclusion of these stimuli was meant to eliminate the possible surprise component of the black and white grouping-by-similarity patterns which heretofore were embedded in triads of trials in which, on the two other (non-critical) trials in the triplet, the surround consisted of all black, evenly spaced squares. These latter surrounds were consistent with the proximity grouping patterns but not with the similarity patterns. In addition, to facilitate grouping by proximity, we increased the proximity ratio to approximately 4 to 1. The actual angular separations were .25 and .96° (see Fig. 10).

The procedure was unchanged except that the dual task condition replaced the second (divided attention) triad. In this condition subjects were asked to report both the longer line of the cross and whether the sur-

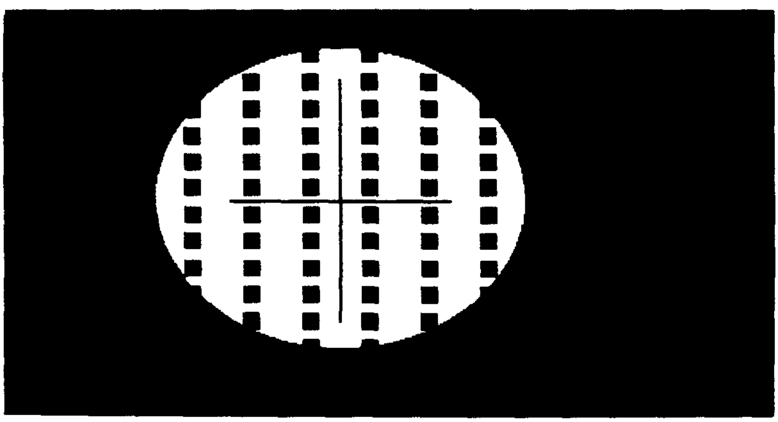

FIG. 10. The proximity pattern used in Experiments 5a and 5b. Vertical separation of elements, .25°; horizontal separation of elements, .96°.

rounding pattern was arranged as rows, columns, or appeared equally spaced or ungrouped. The dual task condition came between the experimental condition which was first and the attention control condition which was last. A mask again followed stimulus presentation.

*Subjects*

Twenty-four subjects recruited from the New School were tested. Six subjects were tested using either similarity or proximity patterns as the critical stimuli and with neutral patterns consisting of all black evenly spaced squares. Six subjects were tested using only proximity patterns with the same neutral patterns and 12 subjects were tested using only similarity patterns as critical stimuli with black and white randomly arranged squares as the neutral patterns. None of the subjects in this experiment participated in the prefamiliarization experiment described in Footnote 4 and all subjects were new to these experiments. We, nevertheless, expected subjects would perform well in the control condition since it was preceded by the experimental and dual task conditions which provided subjects with an opportunity to become familiar with the grouping patterns and the previous experiment established the effectiveness of familiarity on the control condition reports of grouping.

*Results*

The results from the critical trials in all three conditions are presented in Fig. 11. It was no longer surprising that only 1 of the 24 subjects reported grouping on the critical experimental trial. Again, most of the subjects reported seeing no grouping at all. Twenty-one subjects (88%) correctly reported the grouping on the control trial. Since there were no differences among the three subgroups of subjects given different critical stimulus patterns or different neutral patterns, we therefore combined the

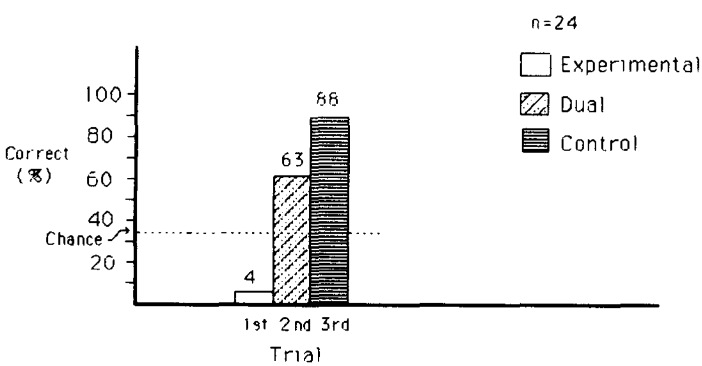


FIG. 11. The percentage of correct grouping judgments in Experiment 5a.

data. Correct grouping was achieved significantly more often on the control trial than on the experimental trial, $t_{(23)} = 10.4, p < .01$. The apparent increase over Experiment 3 in the number of observers reporting grouping on the control trials probably is due to the fact that the control trial was last rather than first and followed the dual task trial which afforded the observers a chance to become familiar with the grouping stimuli.

In the dual task condition 15 subjects (63%) correctly reported grouping on the critical trial but this was accompanied by a notable decrease in performance on the line length task (see Table 1). On the critical inattention trial where the subjects' only assigned task was to report line length, 92% of the observers correctly identified the longer arm of the cross. This is significantly greater than the 63% of the observers who correctly identified the longer line on the comparable trial in the dual task condition, $t_{(23)} = 2.23$, $p < .05$. Moreover, while 15 of the 24 observers correctly reported the grouping on the critical dual task trial, only 7 of them correctly reported the longer cross line as well. In other words, only 29% of the subjects were able to do both tasks. This result is surprising since it not only confirms the attentional demands of the grouping revealed in the previous experiment but also indicates that even with attention, perceiving grouping is difficult. Because this result was unexpected we thought it important to validate it and so ran another group of subjects in a new version of this experiment.

## EXPERIMENT 5b

### *Procedure and Subjects*

Sixteen subjects recruited from the same population but new to the experiments were tested. One quarter of the subjects were shown only proximity grouping patterns in the experimental and dual task conditions. One quarter were shown only similarity patterns in these two conditions. The remaining subjects received a proximity pattern in one of these conditions and a similarity pattern in the other. Of these subjects, half were shown a proximity pattern in the experimental condition and half a similarity pattern. The grouping pattern in the control condition was randomly assigned. The order of conditions was the same.

### *Results*

The results are consistent with those of the previous experiment. There were again no differences between reports of similarity and proximity grouping or among the several stimulus orders so we combined these data. No subjects reported any grouping at all in the critical experimental trial. Thirteen (81%) correctly reported grouping in the dual task condition while 15 (94%) did so in the control trial. The difference between the control and experimental results is significant, $t_{(15)} = 15.7, p < .01$. The absence of any reports of grouping on the inattention trial is again consistent with the fact that subjects simply do not see grouping on this trial. Eighty-one percent of the subjects reported grouping correctly on the critical dual task trial and this difference is significant. However, once again, correctly reporting the grouping on the dual task trial was at the expense of the line length task. Only 38% correctly reported line length as compared to 81% on the critical experimental trial (see Table 1) which is a significant difference, $t_{(15)} = 2.45, p < .05$. Moreover, only 4 subjects (25%) reported both the line length and grouping correctly on the dual task trial.

These results are not only surprising in their own right but with respect to the comparable results with the texture segregation patterns as well. While subjects did not report texture segregation on the critical inattention trials, they did so in the dual task condition and without obvious cost to performance on the line length task. Since a mask was not used in the texture segregation experiments but was used in the proximity and similarity grouping experiments, it seems reasonable to attribute this difference to the foreshortening of the processing interval produced by the mask. However, there is a possible alternative explanation, namely, that grouping by similarity and proximity is more attentionally demanding than texture segregation.[5]

The final experiment examines whether actual rows and columns, rather than elements grouped into rows and columns are detected under conditions of inattention. This question is important since if a pattern of horizontal or vertical lines was not to be perceived under conditions of inattention, there would be little reason to expect that a pattern of discrete small elements grouped by similarity or proximity into columns or rows would be detected. Furthermore, failure to detect actual vertical or horizontal lines would underscore the inference that their perception too entails organization, albeit a different kind. (See Rock et al., 1992.)

[5] We have some reason to suspect that grouping by similarity or proximity may in fact be more attention demanding than texture segregation. First, a preliminary study of similarity and proximity grouping involving eight observers, which differed from Experiment 5b only by virtue of the fact that no mask was used following stimulus presentations, produced results which did not differ from those of Experiment 5b. This suggests that the presence of the mask is not the source of the difficulty. Moreover, a recent report, (Sagi & Braun, 1991) provides data which support the conclusion that perceiving grouping by proximity and similarity requires attention, although texture segregation does not. Of course, their finding concerning texture segregation is at odds with the findings concerning texture segregation reported in this paper.

## EXPERIMENT 6

### *Stimuli and Procedure*

The critical stimuli consisted of either row or columns made by filling in the spaces between the square elements of the grouping patterns used in Experiment 5. Thus they were either solid black vertical or horizontal bars or alternately solid black and black outline vertical or horizontal bars (see Fig. 12). These patterns were therefore comparable to the critical grouping patterns used in the previous experiments and served as the critical stimuli. They were shown on the third trial in all three conditions. On the first two trials of each triad in each condition, the pattern sur-

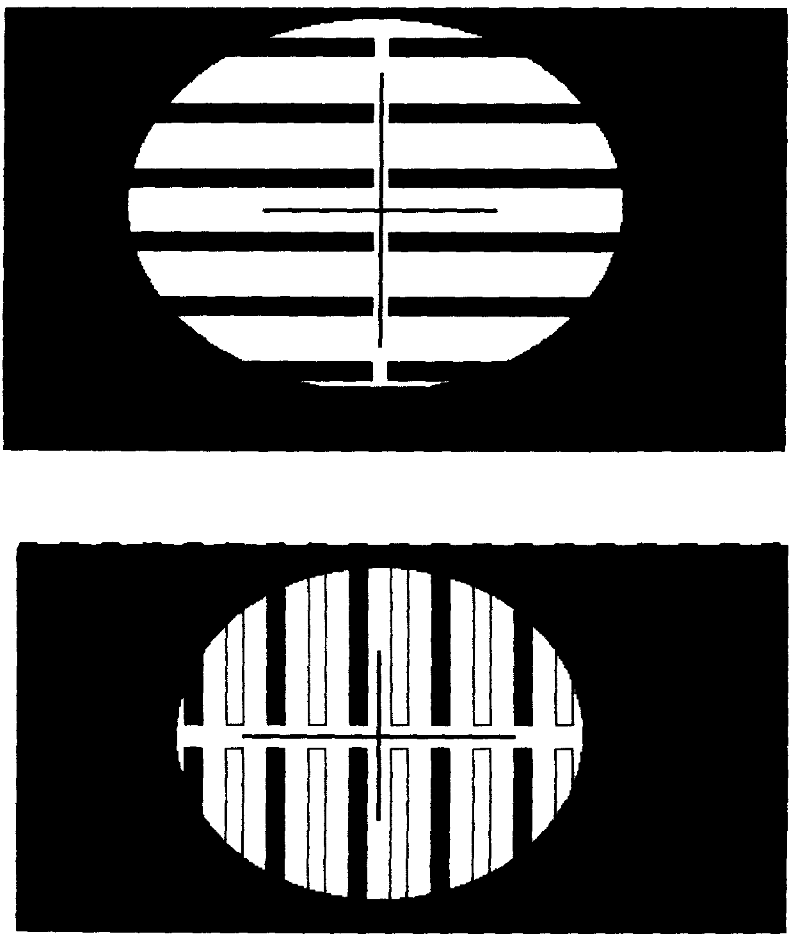

FIG. 12. Bar patterns used a critical stimuli in Experiment 6. Width of stripes, .37° (top and bottom panels); separation between stripes, .96° (top panel) and .43° (bottom).

rounding the cross was either the black evenly spaced squares (see Fig. 6) or the black and white randomly arranged squares (see Fig. 10) used in the previous experiments. If the critical pattern was black and black outline bars, the neutral patterns consisted of the black and black outlined squares. If the critical pattern was black bars only, then the neutral patterns were the black equally spaced elements. There were three conditions: experimental, dual task, and control. The experimental condition came first and was followed by the dual task and then the control condition for all subjects.

*Subjects*

Twenty subjects recruited from the same population were tested. All were new to the experiment. Half the subjects saw all black bars, half of which were vertical and half horizontal as the critical stimulus in the experimental trials. The other half saw alternating black and black outline bars evenly divided between vertical and horizontal. The dual task critical pattern was always opposite in bar orientation, e.g., horizontal if the experimental critical stimulus was vertical. For half the subjects it was of the same lightness, e.g., all black bars, and for the other half it was of different lightness, e.g., black and black outline bars followed by all black bars. The critical control patterns were randomly assigned.

*Results*

The results from the line length task are presented in Table 1. They are inexplicably lower than most of the previous results on all but the critical trial in the experimental condition. Since the first two trials in the experimental and control conditions duplicated those in previous experiments, these differences would appear to reflect subject variability. The fact that the subjects performed best on the critical trial in the experimental condition eliminates the possibility that it was the presence of the critical pattern that was responsible for the difference. There were no significant differences between the line length judgments in the experimental and dual task conditions.

Since there were no differences in bar reports as a function of the stimulus viewed, the data from the various presentation orders were combined. The bar pattern results are presented in Fig. 13. Twelve subjects (60%) correctly described the critical pattern in the experimental condition. The errors were more or less equally divided between vertical and horizontal bars and between all black and alternating black and black outline bars. The fact that 40% of the subjects incorrectly described the bars was surprising. Nevertheless, the fact that the remaining 60% correctly described them indicates that by and large they can be perceived without attention and performance here is markedly better than the per-

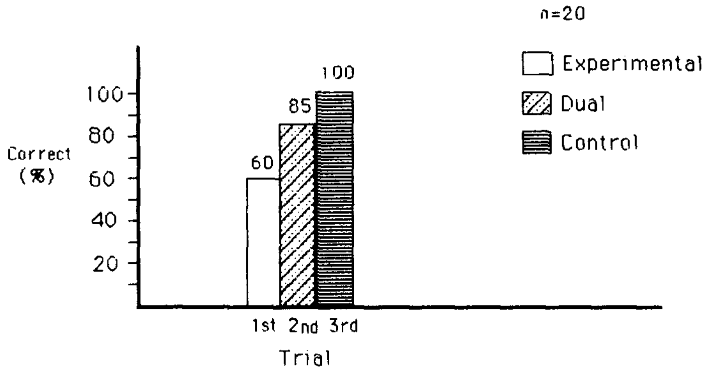


FIG. 13. The percentage of correct judgments of critical stimuli in Experiment 6.

formance on critical trials in the experimental conditions of all the previous experiments.[6] In previous experiments the best performance on the critical experimental trials was 25% correct responses and that was with texture segregation and not with similarity or proximity grouping patterns where performance was considerably worse. Seventeen of the 20 subjects correctly described the background in the dual task condition without any decrement in line length performance and all the subjects did so in the control condition. Performance on the control condition (100%) is significantly better than on the experimental trial (60%), $t_{(19)} = 3.6, p < .01$. In any event, the oriented bars appear to be perceptible even under conditions of inattention.

## DISCUSSION

The single most significant outcome of these experiments is that there is *no* perception of either texture segregation or Gestalt grouping under conditions of inattention. This is especially surprising in the case of texture segregation which is presumably based on a fundamental, low level stimulus feature, such as local orientation and which, according to all published reports (Beck, 1967; Beck, Prazdny & Rosenfeld, 1983; Braun & Sagi, 1990; Julesz, 1981, 1984; Neisser, 1967; Triesman, 1982; Triesman & Gormican, 1988), is processed in parallel, does not require focal attention, and is therefore preattentive. It is also clear that grouping by lightness similarity or proximity is not perceived under conditions of inattention. This is so despite the fact that in both dual task and experimental

[6] It is not possible to state what chance performance would be since the subjects were not given a menu of options. They were simply asked to describe the surround and were not asked whether it consisted of vertical or horizontal bars.

trials in all experiments except the last, subjects were told that the critical pattern could be a pattern of vertical columns or horizontal rows. (In the experimental trials, of course, they were told this after the patterns had been displayed.)

What do these findings mean? Can they simply be a result of a memory failure? Can the failure of subjects to report grouping or texture segregation under conditions of inattention simply be a failure of memory and not of perception? It is, of course, possible that the failure to report grouping under conditions of inattention reflects a failure to encode the appropriate representations into memory rather than an earlier processing failure. Unfortunately, nothing in these results is relevant to this issue. However, our other research concerned with the perception of basic features like color, shape, and location under conditions of inattention in which the same techniques are employed (Rock et al., 1992) indicates that certain features *are* reported under conditions of inattention. This finding lends some support to the view that the failure to achieve grouping demonstrated by the present results occurs prior to memory encoding. Were the problem a memory rather than a perceptual one, why would some aspects of the visual stimulation be encoded in memory and others not? Nevertheless, on the chance that memory is a factor, we intend to investigate this question if a suitable method to do so can be found.

These results underscore and support the link between preattentive processes and distributed attention and force us to create a new distinction: namely, we must now distinguish between attentive, preattentive, and non-attentive processing. Non-attentive processing refers to processing which does not require either focal or distributed attention nor even the intention to search. It is the processing which mut be responsible for creating the most primitive units of the perceptual system, which probably then become candidates either for parallel preattentive processing or serial attentive processing. These primitive features seem to be synonymous with those others have found to pop-out under conditions of distributed attention. In another paper (Rock et al., submitted), we report results from experiments using our inattention paradigm which indicate at least what some of these features are. So far we have established that they include both the location and color of shapeless blobs and new work suggests that short-range apparent motion is also detected under conditions of inattention (Mack, Rock, Stone, Gotham, Tang, Linnett, & Ro, 1991). Thus there appears to be perceptual processing which occurs earlier than that normally associated with distributed attention, such as is evidenced when an observer attends to an entire array of elements. These earlier, non-attentive processes are also likely to be fast, automatic, and parallel but in addition do not involve whatever brain mechanisms are correlated with intention.

Although we know intention has some role in perception (Hochberg, 1970; Peterson & Hochberg, 1983), for example, it seems to influence the reversals of reversible figures and the reorganization of fragmented figures (Reynolds, 1985), its role in perception has not been widely studied. The results of these experiments suggest that it may be of central importance. It warrants and should become the object of serious study.

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