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Perception without Attention: Results of a New Method

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Having found by the use of a new method for examining perception without attention that grouping and texture segregation do not seem to occur (see Mack, Tang, Tuma, Kahn, & Rock (1992) *Cognitive Psychology*, 24, we go on to ask what *is* perceived without attention using this new method. Our subjects receive only one inattention trial in a sequence of trials involving a visual distraction task. In addition to the distraction task in the inattention trial, subjects received a stimulus of which they had no prior knowledge or expectation and were questioned or tested directly afterward for their perception of that stimulus. Two subsequent trials containing test stimuli serve as within-subject controls. The results of a series of experiments indicate that the presence of one or more stimulus objects and their locations are preattentively perceived, as is their color, but shape is not. Because individual items are detected without attention, we conclude that perceptual organization is initially based on a principle in which connected regions of uniform stimulation are inferred to be discrete units (the principle of uniform connectedness). One striking, unexpected finding is that without attention many subjects have no awareness at all of the stimulus object, an effect we call inattentional blindness. © 1992 Academic Press, Inc.

It is generally agreed that some minimum degree of organization of the visual field must occur preattentively because as Neisser (1967) and Treisman (1982, 1988) have put it, discrete objects must first be present to serve as candidates for further processing. While the proximal stimulus, or the retinal image in the case of vision, may be thought of as a picture

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containing objects or units of various kinds, we would be guilty of committing what the Gestaltists called the experience error if we thought that the presence of such units qua stimulus aggregates accounts for their perception as units. Some internal process of organization must be responsible for the achievement of discrete phenomenal units or objects. Such organization must occur at an early stage of processing, and it has been further assumed that it is based on the Gestalt laws of grouping and figure-ground differentiation. (See, for example, Neisser, 1967; Pomerantz, 1981; Treisman, 1982, 1988.) Once that occurs we can then attend selectively to this or that unit in the field. Were such organization not to occur, there would only be a mosaic of stimulation of varying intensities and wavelengths of light.

But there has been essentially no empirical investigation to date of the assumption of the preattentive achievement of grouping on the basis of the Gestalt Laws.[1] Therefore, together with Arien Mack and her colleagues, we have been studying precisely this question, beginning with Wertheimer's (1923) laws of grouping by proximity and similarity and texture segregation presumably based on grouping by similarity (Mack, Tuma, Kahn, & Rock, 1990; Mack, Tang, Tuma, Kahn, & Rock, 1992). The method used is essentially the one we will be describing in this report.[2] Suffice it to say that the results have been negative. Without attention to the array of elements, grouping and texture segregation on the basis of either of these two laws seems not to occur. Another reason for questioning the Gestalt laws of grouping as the basis of unit formation at an early stage is that several studies have now shown that such grouping occurs at a later stage, based on the *perception* of proximity and similarity rather than on these factors defined at the level of the proximal stimulus. Such perception occurs after depth and constancy processing. See Rock and Brosgole (1964); Rock, Nijhawan, Palmer, and Tudor, (in press); Palmer (in preparation); Olson and Attneave (1970); but for the opposite conclusion, see Beck (1975).

Assuming that these findings are correct, the question then arises as to what is the basis of early-stage preattentive organization since, as suggested above, for good and sufficient logical reasons, some such organization must be presumed to occur prior to the deployment of attention or

[1] The one exception is an experiment performed by Köhler and Adams (1958) on the effect of inattention on grouping by proximity. They found that with attention distracted by another task, a higher ratio of relative proximity was required for grouping of the elements into columns or rows than was the case without such distraction. However, the experiment was not convincing for a number of reasons, such as the possibility that the result had more to do with memory than perception.

[2] This method was described in a presentation given at the annual meeting of the Psychonomic Society in November, 1990 (Rock, Linnett, Grant, & Mack, 1990).

of constancy operations. This question underlies the purpose of the experiments reported here. We sought to ascertain precisely what is and what is not perceived preattentively and thus at a very early stage of processing. The guiding hypothesis was that individual elements are perceived preattentively. By "element" we mean an interconnected region of uniform luminance (or color or texture or possibly uniformity of some other kind) such as a dot, spot, line contour, or even a larger area corresponding to this definition (see Palmer & Rock, in preparation). Since the perception of the precise shape of such an element may not be given preattentively (see Rock & Gutman, 1981; Rock, Schauer, & Halper, 1976; Butler & McKelvie, 1985; and experiments we describe here) we tentatively refer to such elements as "blobs." The elements in Wertheimer's grouping arrays fit this definition and it is interesting to note that he did not address the question of how and why these elements were perceived, but only the question of how and why they were grouped with one another.

Research into what is perceived without attention has made use of various methodologies, chief among which are procedures involving a distraction task and procedures involving a search for an element or region in a larger array. In the distraction paradigm, attention is diverted from the test stimulus by using another task. Any perception the subject achieves of the test stimulus is assumed to have been processed without attention. However, the subject knows that the test stimulus will be presented because the dual task is explained in advance, therefore, he or she can allocate some attention to it. The method does not succeed in eliminating attention. It might be best thought of as a divided-attention paradigm. With search paradigms such as those of Treisman or Julesz (see, for example, Treisman, 1988; Treisman & Gelade, 1980; Julesz, 1981a,b) and the related texture-segregation paradigm (see, for example, Beck, 1966, 1982), a unique stimulus or set of stimuli "pops out," is segregated, or is "perceived effortlessly," from among a field of distractors. When performance is not affected by increasing the number of distractors, it is assumed that the array of elements must be processed in parallel, and if this is so, it is further assumed that attention is not involved. But this assumption cannot be correct because, in fact, the subject is attending to the whole array. Thus parallel processing is not necessarily equivalent to inattention. The question remains whether these results would occur if the subject was not attending to the array.

We devised a different approach that would test inattention more directly. The method was more or less the same as the one used by Mack et al. (1992). We used a task requiring attention and simultaneously presented a test stimulus without informing the subject; but we only used one critical inattention trial and probed subjects about their awareness of the additional object directly after the trial. The subjects had no knowledge or expectation that the test stimulus was going to appear. A line-judgment task was used to engage a subject's attention. On a trial, subjects were briefly presented with two bisecting lines, one horizontal and one vertical, which we call the cross figure. The subject's task was to identify which line was the longer, if either. On critical trials a test stimulus appeared concurrently with the cross figure, after which subjects were questioned about the stimulus. Because inattention depends on subjects not expecting additional stimuli, there can be only one critical trial in which no attention whatever would be devoted to the test stimulus. In addition to a single critical inattention trial, this method is distinguished from others by the fact that in the experiments to be reported here the test stimulus is relatively an isolated one on a more or less homogeneous background instead of one or more elements among a set of many other elements.

One might object that while this method undoubtedly does shift attention away from the test stimulus, it also entails perception without expectation and the absence of intention to perceive something. However, while it is true that lack of expectation is an aspect of our method, it simply is a phenomenological fact that our subjects are not attending to the test stimulus when it appears. Whether that stimulus might then draw, elicit, attract, or capture attention once it appears is another matter, which we will try to address in the final discussion along with the role of the lack of expectation in our method. Another question that may occur to the reader at this point is how attention is distributed to the line-judgment task. If it is spatially distributed to include the empty quadrants between the lines one might maintain that some attention *is* allocated to the very region where the test stimulus will appear. This is another question we will address later.

We began by testing whether or not an additional object would be detected and went on to test whether other objects and features of objects would be processed preattentively. Many variations of the experiment were performed. A general method is described after which each experiment is discussed separately.

GENERAL METHOD

Subjects

All subjects were recruited from the university community and were compensated for their participation with candy or the like.

Apparatus and Stimuli

The experiments were run on an IBM AT personal computer connected to two monitors. The stimulus monitor was a Sony Trinitron 13-in. color monitor driven by an AT&T TARGA color graphics card. Attached to the front of the stimulus monitor was an annulus-shaped mask constructed from black cardboard. The outer diameter was 45 cm and the inner diameter was 18 cm. The mask concealed the monitor housing but displayed the maximum central circular portion of the screen. The purpose of the circular mask was to eliminate a possible effect of the rectangular frame of the monitor on the line-judgment task.

The lines of the cross were black on a white background and bisected each other at the center of the screen. With the exception of Experiment 1, the length of each was randomly selected for each trial from the following four possible lengths: 3.6 cm (2.7° visual angle), 4.4 cm (3.3°), 5.2 cm (3.9°), or 6.0 cm (4.5°). These lengths were used because random pairings of them led to roughly 75% correct performance on the line-judgment task. The width of the lines was 0.1 cm (0.1°). The luminance of the white background was 72.0 cd/m^2, and the luminance of the black lines was 3.6 cd/m^2. When colored stimuli were used they were either red, blue, or black. The red was created by setting the red phosphor at maximum intensity with none of the green or blue phosphors, and blue was the blue phosphor at maximum intensity with none of the other two. The luminance of the red was 17.0 cd/m^2 and the luminance of the blue was 10.5 cd/m^2.

Preceding the cross figure was the presentation at the center of the screen of a black, square fixation point measuring 0.2 cm (0.2°) on a side, and following the cross was the presentation of a mask. Various stimulus masks (not to be confused with the annulus-shaped occluding mask) were used and will be described in the separate experiments, but all masks were square overall and measured 6.7 cm (5.0°) on a side. Everything presented in the display, other than the mask, was always within 2.3° visual angle from the fixation point at the center of the screen. The most distant point of each test stimulus was always just inside of the 2.3° radius, and the stimulus was always centered on the imaginary 45° line that bisects the angle of a quadrant. The cross and mask were centered on the fixation point and therefore centered in the screen.

Procedure

Subjects sat 76 cm from the stimulus monitor. They were told that they would see a fixation point followed by a brief flash of a cross figure which would then be covered up by a mask. They were instructed to report whether the horizontal line or the vertical line was longer, or if the two lines were equal. The fixation point was presented for 1 s, followed by the cross for 200 ms, followed by the mask for 500 ms, after which the screen returned to blank white. On the trials with a test stimulus, its appearance and disappearance was coincident in time with the cross.

A subject received eight trials, each preceded by a ready cue from the experimenter. The order of the trials is represented in Fig. 1, which shows a scale version of possible cross figures and one possible arrangement of the blobs in the critical trials of Experiment 1. The cross alone appeared in the first three trials, but the fourth trial included a test stimulus. The subject then received two more trials with just the cross followed by the seventh trial which included a test stimulus. The eighth trial also included a test stimulus, but subjects were instructed *before* this last trial not to do the line-judgment task during this last trial.

The fourth trial was the inattention trial. Right after the trial, we again obtained a line judgment to ensure that subjects were still attending to the cross, and then questioned them about the test stimulus. We assumed that any reportable information about the stimulus on this trial must have been processed without attention. After this the subject was no longer naive. Therefore, each subject could only contribute one data point for inattention. The seventh and eighth trials were thus within-subject control trials. The seventh can be thought of as a divided-attention trial. We first obtained a line judgment and then probed the subject about the test stimulus. This would determine whether subjects could do the line judgment and process the test stimulus when they were aware of the possible presence of both. If so, their perceptual system was not overloaded by the two tasks. The eighth trial was the

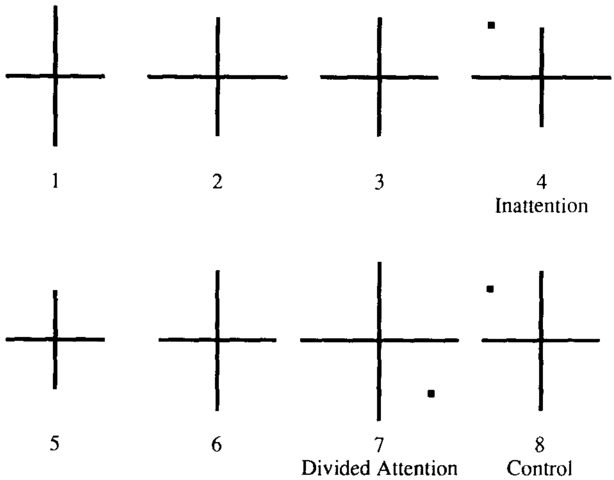

FIG. 1. The sequence of eight trials used in all experiments as well as a scale version of one possible set of cross figures and arrangement of the blobs in the critical trials of Experiment 1.

control trial: by instructing the subjects *in advance* of this trial not to do the line-judgment task, this trial would provide information as to whether or not subjects could process all the relevant information about the test stimulus given the temporal and spatial qualities of the display. That is, can the test stimulus be perceived despite its brief, masked presentation and its peripheral retinal locus when attention *is* allowed? Because each subject can only provide one data point for inattention, the results to be presented here required several hundred subjects.

Confidence ratings by subjects were used in each experiment to gauge the various responses or choices that they made regarding the test stimulus. The scale always consisted of three levels: 3 being "very," 2 being "somewhat," and 1 being "not very" confident.

Results of the Line-Judgment Task

The first data to look at are those of performance on the line-judgment task. Across all experiments except the first, i.e., for all experiments reported below in which a more difficult comparison of more nearly equal line lengths was required, performance averaged 75% correct. That is, subjects averaged about five of the seven judgments correct and these data are based on a total of 136 subjects. Thus the task was neither too easy nor too difficult. Not included here, in addition to the results of Experiment 1, are the results of some conditions of Experiment 4 (Parts 3 and 5) in which, because of procedural changes to be explained, line judgments were not obtained on all seven trials.

Figure 2 gives the data for each trial. Subjects improved over the first four trials and then remained about constant. Notice that on the fourth trial, the inattention trial, subjects are still improving, so it would seem that they did not ignore the lines to attend to the target stimulus and that

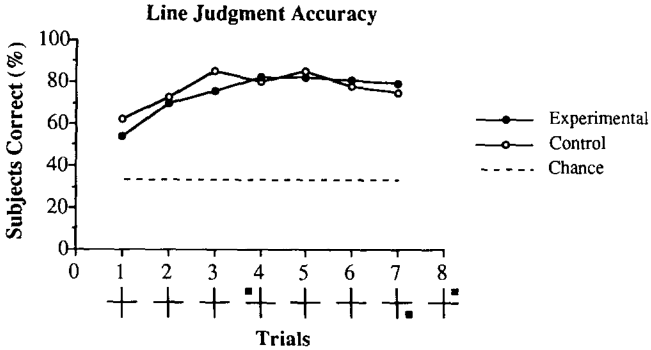

FIG. 2. Line-judgment accuracy on each of the eight trials for 136 experimental and 40 control subjects. The chance level shown of 33.3% is based on the fact that there were three possible line-length combinations, namely vertical longer, horizontal longer, or equal. The abscissa illustrates Experiment 1 in that a single blob was presented in a random quadrant on the fourth, seventh, and eighth trial, but the data given are from all experiments, in which the test stimulus on those trials was something different.

the target stimulus was not a distraction and did not draw attention to itself. These results can be compared with those of a control condition run with a separate group of 40 subjects[3] who received seven consecutive line-judgment-only trials, i.e., no test stimulus was ever presented. The two curves are very similar and coincide on the critical fourth trial, so apparently the presence of the additional test stimulus did not affect performance on the line judgments on that critical trial. This again suggests that no attention was allocated to or drawn by the test stimulus.

EXPERIMENT 1

Our first test of preattentive processing was whether or not a very small black element (which we called a blob) would be detected, and if so, would subjects know where it was located. Such a test can be thought of as probing the very basic level of perceptual processing because the question at issue is whether the mere presence of a "something" can be detected without attention.

Method

Subjects. There were 12 subjects, four females and eight males, ranging in age from 19 to 24. The median age was 20.

Stimuli. The test stimulus was a very small black square 0.2 cm (0.2° of visual angle) on a side. It appeared in one of the four quadrants created by the cross figure. In this experiment, the differences in length of the bisecting lines were such as to make the task some-

[3] The 40 subjects of the control group for the line-judgment task consisted of 19 females and 21 males ranging in age from 18 to 53. The median age was 21.

what easier than in all subsequent experiments. They were randomly paired using the following four lengths: 2.5 cm (1.9° visual angle), 3.7 cm (2.8°), 4.9 cm (3.7°), and 6.1 cm (4.6°). The mask was a grid of black horizontal and vertical lines which were as wide as the test stimulus and completely covered it and the lines of the cross.

Procedure. During the three critical trials, one blob would appear in a random quadrant. After the fourth, seventh, and eighth critical trials, subjects were asked if they had seen anything else presented at the same time as the cross. When they did report something else on any of these three trials they were then asked in which quadrant the additional object had appeared. The confidence ratings referred to above concerning subjects' level of certainty about their choice were obtained only for the last seven subjects in this first experiment. If they reported seeing nothing besides the cross, then they were asked to give a confidence rating that nothing had been shown, after which they were told what had been presented and asked to give their best guess as to where it had appeared.

Results and Discussion

The result of the somewhat easier line-judgment task used in this experiment was that overall, 83% of the judgments were correct. Turning now to the data for the critical task, 9 of the 12 subjects (75%) reported seeing some item in the inattention trial, and all of these gave the correct quadrant. One might think an equal number of subjects would, when asked, report seeing something even if no test stimulus at all was presented. However, even assuming that our subjects did not correctly perceive *what* was presented, the fact is that they always correctly perceived *where* it was, i.e., in which quadrant it was located. Consequently we did not feel it was necessary to run a control experiment in which no test stimulus was presented on critical trials. The result of nine correct and zero incorrect is very significantly different than the chance expectation of 2.25 correct and 6.75 incorrect based on guessing given the four quadrants, $\chi^2(1) = 27$, $p < .01$. Moreover, several subjects volunteered the information that what they had seen was a small dark element. This can hardly be based on guessing since the item could have been anything at all. The mean confidence rating for six subjects was 2.8.

Interestingly, three (25%) reported not seeing anything. The forced choice procedure was instigated after two subjects reported not seeing the blob. Subjects were required to say or guess in which quadrant an object might have appeared. The third such subject who reported not seeing anything and was forced to choose a quadrant did not correctly guess the quadrant. That particular subject's confidence rating that nothing had been shown was 1.0. It is worth noting, however, that confidence ratings on trials like this, where subjects report seeing nothing other than the cross, are likely to be much lower than "3" even when a subject simply has seen nothing at all. Subjects are understandably reluctant to say they are certain they have not seen anything else when asked if anything else was presented. They are not sure whether "anything else" might be something as minute as noisy dots on the screen. We will, therefore, not report these confidence ratings in each experiment, but will give the overall average of them in the Discussion section.

On the seventh or divided-attention trial, 11 subjects (92%) reported the presence and location of the blob correctly, and on the eighth or control trial, all 12 (100%) reported it correctly. The mean confidence ratings for these trials, for seven subjects, were 2.9 and 3.0, respectively.

The results demonstrate that an object in the visual field can be detected and its location known without expectation or attention. Because all subjects correctly perceived the blob in the final (control) trial, it seems clear that the task is easily performed with attention. Thus the brief 200 ms presentation, the masking of the blob, and its peripheral location on the retina do not preclude the perception of the blob when attention is present. However, performance in the inattention trial is not significantly poorer than in the control trial in that all subjects who perceived *something* in the inattention trial were correct about location, so that the absence of attention does not preclude the perception of the blob.

EXPERIMENT 2

In this experiment, one blob was placed in more than one quadrant to investigate the question of whether more than one object in quite separate locations can be detected without attention. Either two, three, or four blobs appeared in random quadrants, one per quadrant, in the same positions described under the General Method.

Method

Subjects. There were 18 subjects, 7 females and 11 males, ranging in age from 16 to 45. The median age was 21.5.

Stimuli. The test stimuli, their location, and the mask were the same as those described in Experiment 1. The line lengths associated with the more difficult line-judgment task were used in this and subsequent experiments.

Procedure. During the three critical trials, one blob would appear in either two, three, or four randomly selected quadrants. The number of blobs in the inattention trial was counterbalanced across subjects, and the numbers for the divided-attention and control trials were randomly assigned. Following the fourth, seventh, and eighth critical trials, subjects were asked if they had seen anything else presented at the same time as the cross. If so, they were then asked how many objects they had seen and then in which quadrants the objects had appeared, and also asked to give a confidence rating on their choice of number. If they reported not seeing anything besides the cross, they were asked to rate their confidence that nothing else had appeared, after which they were told that some objects had been presented and were asked to guess how many and where they had been.

Results and Discussion

On the line-judgment task, 72% of the judgments were correct. Of the 13 subjects who reported seeing something on the inattention trial, 9 of them (69%), reported the correct number, and all but one of the nine reported the correct locations. Their mean confidence rating was 2.6. This indicates that subjects can process information from more than one area in the display without attention. In the divided attention trial, all subjects reported seeing the blobs, and 14 of them (78%) reported the correct number. All of these reported the correct locations. Their mean confidence rating was 2.9. In the control trial every subject reported the blobs and their locations correctly and their mean confidence rating was 3.0. Five subjects (28%) reported not seeing anything additional in the inattention trial, and none of these reported the correct number of blobs when forced to guess.

The fact that some subjects in the inattention trial who reported perceiving something report the wrong number (9 of 13 were correct), whereas all subjects report the number correctly on the control trial, should not be taken to mean that inattention affects the perception of blob number or location adversely. All the errors on the inattention trial were of a particular kind. Of the six subjects shown two blobs in the inattention trial, four reported seeing something. All of these correctly reported seeing two items. Similarly, of the six subjects shown four blobs, four reported seeing something and all of these correctly reported seeing four items. However, of the six subjects shown three blobs, five reported seeing something, but only one correctly reported the number. The other four incorrectly reported seeing four items, one in each quadrant. It is plausible to think of this outcome as a kind of symmetry or completion effect, or response bias. Otherwise expressed, having seen three items, one in each quadrant, these subjects assumed or believed they had seen a fourth. However, when these four subjects were told that they had been shown three, not four items, none was able to guess correctly the locations of the three. Of course by this time quite a few seconds had elapsed since the presentation of the array. In any event it is important to note that all errors on the inattention trial in this experiment occurred for the condition where three blobs were presented.

It is difficult to test the result of the inattention trial statistically against some chance expectation based on guessing. Since we did not tell subjects anything about the number of elements presented or ask them to choose between 2, 3, or 4, it is unlikely that the correct number of elements would be reported on the basis of guessing. Moreover, even if subjects somehow guessed the correct number rather than perceived it, the fact that virtually all subjects reported the correct quadrants makes it even more evident that the correct perception occurred for the majority of subjects. Finally, the fact is that of those subjects who perceived *something* the only errors of number were for those who said four when given three elements. Their errors are more likely determined by some bias as suggested above than by mere guessing.

EXPERIMENT 3

This experiment seeks to extend the scope of the previous two experiments by probing further the question of the perception of multiple elements without attention. It asks a simple question, namely, whether all elements, regardless of number, are perceived without attention and localized appropriately. If attention is not required to detect the presence of an element in a given location it would seem plausible to expect that the same would be true for additional elements regardless of number. The answer to this question will be important when we consider the results of our research referred to above on the *grouping* of elements with one another, without attention. Positive results on the perception of number of elements and negative results on grouping of elements will make it clear that the crucial difference is the inability of the perceptual system to relate elements to one another on the basis of their properties when attention to the array is not present.

However, while the perception of multiple elements in different locations may not require attention, there are certain difficulties in testing this with our method. The subject will have to be tested about his or her perception of number after the critical inattention trial. It is known that even with full attention the perception (or report) of number of elements in a brief presentation is quite imprecise beyond around four elements (see for example Atkinson, Campbell, & Francis, 1976) so we can hardly expect such perception to be precise without attention. It should also be noted that our method does not probe for the precision with which the elements are located beyond the question of whether the array is localized correctly in a quadrant. In fact we deliberately test in such a way as to focus only on numerosity by rearranging element locations in a recognition test so as to rule out correct responses based on recognition of the configuration.

One or more blobs were presented in a single quadrant. A recognition test was introduced, and two groups were tested using two different sets of choices.

Method

Subjects. There were 18 subjects in part one, 8 females and 10 males, ranging in age from 17 to 44. The median age was 23.5. There were 18 subjects in part two, 3 females and 15 males, ranging in age from 18 to 39. The median age was 20.

Stimuli. The individual test stimuli and the mask were the same as those described in Experiment 1. One, 2, 3, 4, 8, or 16 black blobs were randomly arranged in one quadrant with the restriction that they each had to fall on a location covered by the black lines of the mask. One random pattern was created for each number of blobs. The same pattern was used in each quadrant but was rotated 90° for each consecutive quadrant. A recognition display was generated containing the six possible numbers of blobs in two rows of three with the stimuli in consecutive order. In part one, the six choices were the six possible test stimuli, so one of them was a configurational match as well. In part two, the six choices were each configured in a different random pattern from the test stimuli, so that the choice could not be based on the overall configuration of the blobs. (See Fig. 3.)

Procedure. The procedure for both parts was the same except for the choices in the recognition test. During the three critical trials one of the patterns of blobs would appear in

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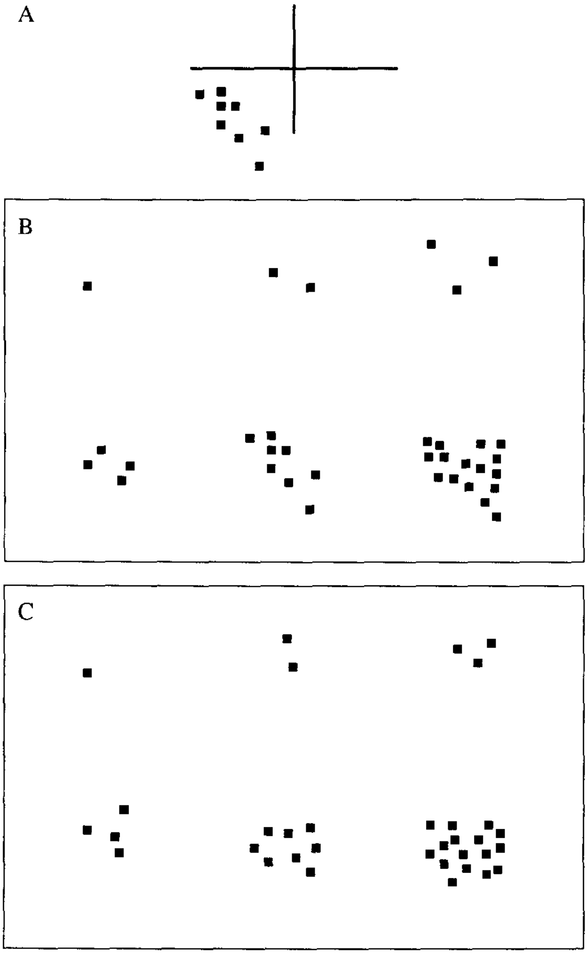

FIG. 3. (A) An illustration of the display used in Experiment 3 of a trial in which eight blobs were presented. (B) The test choices presented to subjects in Part 1 in which the configuration of the correct choice was the same as that of the stimulus presented. (C) The test choices presented to subjects in Part 2 in which the configuration of the correct choice was not the same as the stimulus presented.

a random quadrant. The number of blobs in the inattention trial was counterbalanced across subjects, while the number of blobs in the other two critical trials was randomly determined. After each critical trial, subjects were asked if they had seen anything else presented at the same time as the cross. If so, they were asked in which quadrant the test stimulus was located. (Again, in this and all other experiments, subjects knew in advance of the eighth or control trial that they did not have to judge the line lengths.) They were then shown the recognition screen and asked to choose the number of blobs they had seen. Subjects were asked how confident they were in their choice of the number of blobs seen. If the subject reported not seeing anything besides the cross, they were asked their confidence that nothing else had appeared and then told that some blobs had been presented. They were asked to give their best guess of the quadrant and then asked to give their best guess from the recognition screen as to how many blobs had been shown.

Results and Discussion

On the line-judgment task, 78% of the responses were correct in each of the two groups. As to the numerosity judgments, while we scored for exactly correct performance, we gave more weight to approximate number of blobs detected. To this end we considered as correct responses that were within one choice step of the stimulus presented. For example, if 8 blobs were presented, 4, 8, or 16 would be considered correct. The two groups (i.e., tested with either the same or different configurations) performed equally well, so their data were combined.

Most subjects detected blobs on the inattention trial, and 11 of the 31 of those who did (35%) chose the exactly correct number of blobs, which is well above the chance level of 16.7% (since there were six choices in the recognition test pattern), $\chi^2(1) = 7.9, p < .01$. The mean confidence rating for these subjects was 2.3. However even the control-trial performance was not very accurate, 19 of 36 (53%), which is not significantly greater than the 35% correct on the inattention trial, $t(30) = 1.72, p > .05$. Moreover, 12 of the 36 subjects were not completely confident of their choice in the recognition test on the control trial. Considering instead those who were correct *or* within one step of being correct, where chance is 50% when 2, 3, 4, or 8 blobs are presented, or 33% when 1 or 16 blobs were presented, 24 of the 31 subjects (77%) were correct by this criterion in the inattention trial, $\chi^2(1) = 13.5, p < .01$. Their mean confidence rating was 2.2. On the divided attention and control trials, 30 of the 36 subjects (83%) and 35 of the 36 subjects (97%) were correct, respectively, using the approximation criterion. These results also yield χ^2 values that are significantly higher than the chance level. Performance on the control trial was significantly better than on the inattention trial, $t(30) = 2.2, p < .05$. The mean confidence ratings were 2.4 and 2.7 for the seventh and eighth trials, respectively. When we correlated the number reported with the number presented in the inattention trial using the rank-difference method, we obtained a correlation of $\rho = .71, p < .01$. This method, of course, does not require exact correct responses for high correlation.

Considering all the data, we can say that subjects can detect the approximate number of items in the display without attention.

Locations were reported nearly perfectly as in the previous experiments: 30 of the 31 subjects (97%) reported the correct quadrant in the inattention trial, 36 of 36 (100%) and 35 of 36 (97%) were correct in the divided attention and control trials, respectively.

Five subjects of the total of 36 (14%) reported not seeing anything additional in the inattention trial. When forced to choose, these subjects did not guess the approximate number of blobs or the quadrant above the level of chance.

EXPERIMENT 4

This set of experiments investigated whether shape is processed preattentively. Previous findings indicate a negative answer to this question but entirely different methods were used (Rock & Gutman, 1981; Rock et al., 1976; Butler & McKelvie, 1985). In the present experiment we decided to investigate the question of the processing of color as well. Consequently, a simple geometric shape was presented in one of three colors in a single quadrant. Many variations were performed and will be described separately.

Part 1

Method

Subjects. There were 18 subjects, 10 females and 8 males, ranging in age from 17 to 36. The median age was 21.

Stimuli. Three shapes were used: a rectangle, a triangle, and a cross (see Fig. 4). The rectangle was 0.5 cm wide and 1.0 cm tall; the triangle had a base 1.4 cm long and was 0.7 cm in height; and the cross had two equal bars, one horizontal and one vertical, bisecting each other, which were 0.2 by 1.0 cm. The longest side of the rectangle subtended a visual angle of 0.8°, that of the triangle 1.1°, and that of the cross 0.8°. These figures were positioned in the quadrants such that their furthest points were 2.25° from the fixation mark and centered on the imaginary 45° line that bisected each quadrant. The stimuli were approximately equal in area. The three colors used were black, red, and blue.

The mask was a square grid containing 28 rows and 28 columns of small adjacent squares randomly assigned one of eight colors: the three stimulus colors, green, yellow, aqua, magenta, and white. The colors were generated by using all combinations of the three color phosphors set at either zero or maximum intensity. Three different masks were created, and, for each trial, one was randomly selected. The colored mask was introduced in this experiment because we were investigating the perception of color (as well as shape).

The recognition screen contained six black objects placed in two rows of three. Added to the three test stimuli were a square, a diamond, and an "X." The square was 0.7 cm on a side, the diamond was 0.7 cm on a side, and the X was 1.1 cm along a diagonal and 0.3 cm across a diagonal. The side of the square subtended a visual angle of 0.5°, the side of the diamond 0.5°, and the longest side of the X 0.8°. All six figures were nearly equal in size and area. If they were not, subjects could identify the test stimulus using non-shape criteria. All choices were black, and the order of the six objects was randomized for each presentation.

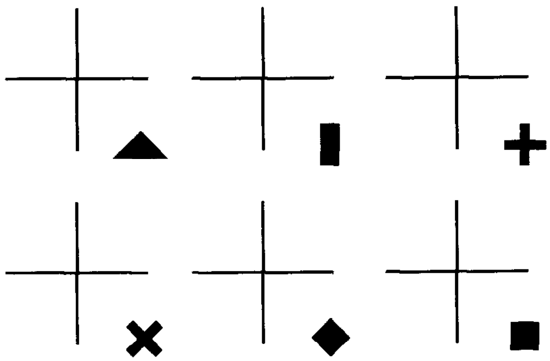

FIG. 4. The recognition-test choices used in Part 4 of Experiment 4 providing the context of the correct quadrant location (and color) for the stimulus presented. The top row illustrates the three test stimuli.

Procedure. During the three critical trials one of the colored shapes would appear in a random quadrant. The shape and the color of the stimulus in the inattention trial was counterbalanced across subjects. Each subject received each shape once and each color once in random combination for the three critical trials. After each critical trial, subjects were then asked if they had seen anything else presented at the same time as the cross. If so, they were shown the recognition screen and asked to identify the shape that they had seen. They were then asked what color it had been and in which quadrant. Subjects were asked how confident they were in their choice of the shape and then of the color. If the subject reported not seeing anything besides the cross, they were asked their confidence that nothing else had appeared and then told that an object had been presented. They were shown the recognition screen and asked to give their best guess of the shape that had been presented and then their best guess of the color and the quadrant.

Results and Discussion

On the line-judgment task, 77% of the responses were correct. Sixteen subjects (89%) reported seeing an object in the inattention trial, but of these, only 1 (6%) correctly selected the shape, which is below the level of chance of 16.7%, but not significantly so. The mean confidence rating concerning the shape choice was 2.2. There was a dramatic improvement in the divided attention trial, in that 12 of 18 subjects (67%) were correct (mean confidence rating of 2.8), and performance was 100% in the control trial (mean confidence rating of 2.9). Needless to say, performance on this control trial was significantly better than on the inattention trial, $t(15) = 15.7$, $p < .01$. The shape is easily perceived under the given conditions *with* attention, but not without. In this and all subsequent statistical evaluations of performance on the inattention trial, we look only at subjects who perceived something on the inattention trial. We then compare the proportion of subjects who perceive the property under study (in this case shape) with the proportion of these same subjects who perceive that property in the control trial.

Color, in contrast to shape, was accurately reported by 13 of the 16 subjects (81%) who had seen something in the attention trial (mean confidence rating of 2.6) by 17 of 18 subjects (94%) in the divided-attention trial (mean confidence rating of 2.9) and by all 18 subjects (100%) in the control trial (mean confidence rating of 2.9). Since a recognition test with choice of colors was not used it is clear that subjects must have perceived color correctly in the inattention trial inasmuch as a majority reported it correctly. Moreover, subjects do not perceive color any better on the control trial than on the inattention trial, $t(15) = 1.9, p > .05$. Location was correctly reported by all 16 subject in the inattention trial, by 16 of 18 subjects (89%) in the divided-attention trial, and by all 18 subjects in the control trial. The correct perception of location on the inattention trial by all 16 subjects who perceived something is obviously significantly greater than the chance expectation of 4 of 16 based on guessing, $\chi^2(1) = 48, p < .01$.

Two subjects (11%) reported not seeing anything additional in the inattention trial. When forced to choose, one subject guessed the correct quadrant, but not shape or color, and the other subject guessed incorrectly for shape, color, and location.

Accuracy of detecting location supported our previous data, and color is apparently preattentively available as well, but shape was the first stimulus property not to be processed successfully without attention in our experiments, so we tried a number of variations to see if we could improve shape performance and/or decrease color performance.

Part 2

This version incorporated a better mask for both shape and color. It is possible that the results of Part 1 were due to a more effective masking of shape than of color. Everything else remained the same.

Method

Subjects. There were 18 subjects, 11 females and 7 males, ranging in age from 12 to 50. The median age was 20.

Stimuli. The logic behind the new mask was that, because colors necessarily have a shape associated with them, a better way to mask our colors was to incorporate the stimulus shapes in various colors into the mask. The color of a red triangle, for example, will be better masked by an array of colored shapes that includes triangles than by an array of colored squares. The shape of the stimulus will also be better masked by an array of various shapes rather than by an array of squares. Perhaps accuracy of color detection will diminish when the colors are better masked. The mask was a randomly generated pattern of overlapping repetitions of the six shapes in seven different colors in addition to various white rectangles. Several small, colored rectangles were added on top of the pattern to ensure that no whole shapes were visible. All colors were the same as in Part 1. Again, three different masks were created, and for each trial one was randomly selected.

Results and Discussion

In the line-judgment task, 71% of the responses were correct. Again, most subjects, 13 of the 18 (72%), reported seeing an object in the inattention trial, but of these, only two (15%) correctly reported the shape, with chance being 16.7%. Oddly enough, the mean confidence rating is rather high, namely, 2.5. In the divided attention trial one subject reported seeing nothing additional, while 10 of the other 17 subjects (59%) were correct, and in the control trial 16 of 18 subjects (89%) were correct. The mean confidence ratings in these two cases were 2.6 and 3.0 respectively. Performance for the control trial was of course significantly better than on the inattention trial, $t(12) = 6.4$, $p < .01$. Color and location identifications were again very accurate. Color was correctly perceived in the three trials by 11 of the 13 subjects (85%) who perceived something, by 16 of 17 subjects (94%), and by all 18 (100%) of the subjects respectively (mean confidence ratings of 2.6, 2.9, and 3.0, respectively), and location by 13 (100%), 15 (88%), and 18 (100%), respectively. Color and location perception in the inattention trial were thus again very good and significantly better than what could be expected on the basis of chance. Moreover, perception of these properties was as good on the inattention trial as on the control trial.

Five subjects (28%) in the inattention trial, and one of the same subjects (6%) in the divided-attention trial, reported not seeing anything in addition to the cross. When forced to choose in these six cases, the correct shape was chosen one time (chance being one), correct color three times (chance being two), and correct quadrant two times (chance being one and one half), so accuracy here was very low.

These data were nearly identical to those of Part 1 and since the only difference in method was the new mask, Part 2 can be considered a replication. Why was shape not processed without attention in our experiments? One possible explanation could be that the line judgment is a type of shape judgment—to determine which line is longer, the overall shape of the cross figure must be processed. This processing may interfere with the processing of the shape of the test stimulus. To test this possibility, we altered the attention task from a length-discrimination to a color-discrimination task, thereby eliminating any shape-processing interference and perhaps instead interfering with the processing of the color of the test stimulus.

Part 3

A color discrimination task replaced the length discrimination task. The masks used were the same as those in Part 1; everything else remained the same as in Part 2.

Method

Subjects. There were 12 subjects, 8 females and 4 males, ranging in age from 18 to 48. The median age was 21.

Stimuli. We attempted to make the color task as equivalent to the length task as possible, so the cross figure was again used. The task was to report whether the two lines were the same or a different shade or tint of a given hue. The lines of the cross were equal in length and fixed at 4.4 cm (3.3° of visual angle). Three colors were used: green, orange, and purple, and three shades were generated for each color. The differences in shades were calibrated and pretested so that accuracy on this task was comparable to performance on the length-discrimination task. For each trial, one color hue was randomly selected, and each line of the cross was randomly assigned one of the three shades.

Results and Discussion

On the color-of-lines judgment task, 74% of the responses were correct, which is virtually identical to the average percent correct on the length-of-line judgment task for all other experiments. The majority of subjects, eight (67%), reported seeing an object in the inattention trial, but of these only two (25%) correctly reported the shape, again not much greater than the chance level of 16.7%. The mean confidence rating was 2.3. In the divided attention trial nine of 11 (82%) were correct, and in the control trial 11 of 12 (92%) were correct. The mean confidence ratings for these trials were 2.7 and 3.0, respectively. Performance on the control trial was significantly better than on the inattention trial, $t(7) = 2.42$, $p < .05$. Color was very accurately identified throughout, as was location. Color was correctly perceived in the three trials by 7 of 8 (88%), 9 of 11 (82%), and 12 of 12 (100%) of the subjects, respectively (mean confidence ratings of 2.9, 2.7, and 3.0 respectively), and location by 8 of 8 (100%), 11 of 11 (100%), and 11 of 12 (92%), respectively.

Four subjects (33%) in the inattention trial, and one of the same subjects (8%) in the divided attention trial, reported not seeing anything in addition to the cross. When forced to choose, the correct shape was chosen once, the correct color twice, and the correct quadrant once. Again, accuracy was very poor.

The color discrimination task did not affect the results. Shape was not perceived without attention, but color and location were. We thus turned our attention away from trying to reverse the results of shape and color, to just trying to improve shape performance. It is possible that identification of the shape in the recognition test is hampered by a lack of contextual cues. Making the choices appear as close to the actual display as possible would make the test more sensitive, so we added the contextual cues of color and quadrant to the choices on the recognition screen.

Part 4

Contextual cues were added to the choices in the recognition test for this experiment. All other aspects of the design were the same as Part 2 except where noted below. We returned to the line-judgment task.

Method

Subjects. There were 18 subjects, 8 females and 10 males, ranging in age from 13 to 53. The median age was 21.

Stimuli. The recognition screen now contained six cross figures, in two rows of three (see Fig. 4). The recognition shapes would appear in the correct color and quadrant as the test stimulus of that trial. As before, which of the six positions in the display each of the six alternatives occupied was randomized for each presentation.

Procedure. Because the correct color and quadrant were shown in the recognition screen, subjects were first asked what color and then in which quadrant the test stimulus had been, before they were given the recognition test for the shape of the stimulus. After that, they gave a confidence rating for their choice of shape. If the subject reported not seeing anything besides the cross, they were asked to give a confidence rating that nothing else had appeared, before they were asked to guess the color and quadrant of the stimulus and given the recognition test.

Results and Discussion

In the line-judgment task, 72% of the responses were correct. Most of the subjects, 13 (72%), reported seeing an object in the inattention trial, but of these only three (23%) correctly selected the shape in the recognition test. The three correct subjects each gave a confidence rating of 3.0, but the 10 who were incorrect had a mean confidence rating of 1.8. Contextual cues, therefore, did not improve the results for shape perception in this design. In the divided attention trial 11 of 18 (61%) were correct, and in the control trial 18 of 18 (100%) were correct (mean confidence ratings of 2.8 and 3.0, respectively). Performance on the control trial was significantly better than on the inattention trial, $t(12) = 4.8$, $p < .05$. On the other hand, color was correctly perceived in the three trials by 9 of 13 (69%), 16 of 18 (89%), and 18 of 18 (100%) of the subjects, respectively, and location by 11 of 13 (85%), 17 of 18 (94%), and 17 of 18 (94%), respectively, so color and location identifications were again very accurate. However in this case color perception was significantly better on the control than on the inattention trial, $t(12) = 2.38$, $p < .05$. Since recognition choices were not offered for color, guessing correctly by chance would be rather unlikely. As to location, guessing by chance would lead to 25% correct (four quadrants), so that the 9 of 13 correct on the inattention trial yields a significant $\chi^2(1) = 13.6$, $p < .01$.

Five subjects (28%) in the inattention trial reported not seeing anything in addition to the cross. When forced to choose, the correct shape and quadrant were chosen once and the correct color was chosen twice.

As a final manipulation, we probed for shape perception *immediately after* the critical trials in case subjects were perceiving but quickly forgetting the shape of the test stimulus. In other words, they were not required to report on the line-length task on the critical trials.

Part 5

Line judgments were not obtained on any of the critical trials, and due to accurate reporting of color and location without attention in all the previous variations, subjects were no longer probed for these attributes of the stimulus. Subjects were only given the recognition test for the shape of the test stimulus. The masks used were the same as those in Part 1; otherwise, the design was the same as Part 4 except as described below.

Method

Subjects. There were 13 subjects, 5 females and 8 males, ranging in age from 18 to 39. The median age was 20.

Procedure. Immediately after each of the three critical trials the subjects were told to think of the shape of the additional object, if any, that was presented and then shown the recognition screen after a brief pause of about 2 s. The pause prevented the recognition screen from overriding a subject's perception or serving as an unwanted mask because of its abrupt presentation. Subjects identified which shape they thought they had seen or responded that they had seen no additional object. If they identified a shape, they were asked to give a confidence rating for that shape. If they reported seeing no object, they were asked to give a confidence rating that nothing else was presented.

Results and Discussion

Eleven of the 13 subjects (85%) reported seeing an object in the inattention trial, but of these only 2 (18%) correctly reported the shape. Again, for some reason, the mean confidence rating was relatively high, namely, 2.5. In the divided attention trial nine of 13 (69%) were correct, and in the control trial all 13 (100%) were correct. The mean confidence ratings here were 2.9 and 3.0, respectively. Performance on the control trial was significantly better than on the inattention trial, $t(10) = 6.8$, $p < .01$. Two subjects (15%) in the inattention trial reported not seeing anything in addition to the cross. The result makes it somewhat less likely that the poor performance in shape perception without attention is due to a memory loss in subjects waiting for the recognition test while reporting their line judgments. However, this experiment in itself does not rule out the possibility that the difficulty lies with memory rather than perception. We consider this question further in the discussion.

The fact is that all the variations of Experiment 4 produced the same pattern of results—shape perception is at a chance level in the inattention trial while color and location are quite accurately perceived. The results of all five variations of the experiment on the detection of shape are presented graphically in Fig. 5. This pattern of results, taken together with the results of previous research using very different methods (Rock

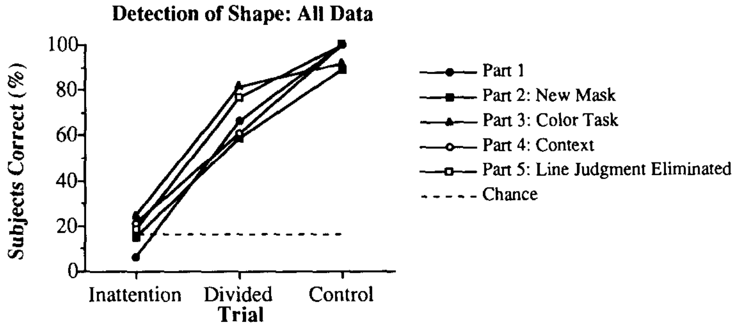

FIG. 5. The results for all variations of Experiment 4 on shape detection for the three critical trials and showing the chance level of 16.7% based on the fact that six choices were given in the recognition test.

& Gutman, 1981; Rock, Schauer, & Halper, 1976; Butler & McKelvie, 1985), strongly support the notion that shape perception requires attention.

It is of interest to consider the choices of shapes in the recognition test for the inattention trial. One can ask whether there is a different distribution of choices as a function of which of the three figures was presented. Suppose for example that subjects detected something about the shape, such as some feature, but not the overall shape itself. Then when shown the triangle one might expect more choices of the diamond and X as well as of the triangle because each of these has oblique contours. When shown the rectangle one might expect more choices of the cross and square as well as the rectangle because all three contain right angles as well as horizontal and vertical contours. The fact is, however, that overall the distribution of choices for the three figures is not significantly different than chance, $\chi^2(10) = 10.6$, $p > .05$.

Nonetheless, there are some indications that subjects' recognition choices are to some extent influenced by the test figure shown. For example, when the triangle was shown, four subjects selected a triangle, whereas none did when the rectangle or cross was shown. When the rectangle was shown, three subjects selected it whereas only one did when the triangle was shown and only one did when the cross was shown. Moreover, when the rectangle was shown, 18 subjects selected the square compared to 10 and 11 who did so when the triangle and cross, respectively, were shown. As can be seen by these values, there was a strong preference or response bias for the square in the recognition test regardless of what figure was shown, and the basis of this preference is not obvious. In any event there is some slight indication from these data that features of the test figures such as right angles or oblique contours were occasionally detected by the subjects.

GENERAL DISCUSSION

First, a further word is warranted about the line-judgment task. As can be seen in Fig. 2, subjects improve over the first few trials. This is understandable because it requires a few experiences with the brief, masked exposure of the display to fully appreciate the careful attention to the lines of the cross required in order to perform accurately. If anything, by the fourth trial, attention is even more focused to the line-judgment task than it is in the first trial. By the fourth trial the level of performance is about 80% and remains so for the remaining trials. The same overall trend occurs for the subjects in the control group who only perform the line-judgment task throughout. In fact the performance of the two groups was the same on the fourth trial.

So we have interpreted the steady performance on this task in the fourth trial to mean that there is no shifting of attention to the test stimulus. One difficulty with this interpretation is that there is also no decrement in the line-judgment task on the seventh trial and no difference between the experimental and control subjects on this trial. Therefore one might infer that attention is not shifted from the line-judgment task on this trial. Yet we consider it a divided-attention trial, not only because subjects now can and apparently do expect something other than the cross figure to appear but also because the data show that they now do in fact perform much differently, perceiving whatever is displayed, including shape, with considerable accuracy. So one might think that they must be dividing their attention which would lead to lower accuracy in the line-judgment task. At present we have no good explanation of this seeming contradiction.

It may be helpful now to summarize the data for the perception of the test stimuli introduced in the various experiments. Figure 6 presents the findings graphically in terms of percentage of correct reports for all cases where something is detected in each of the three critical trials. Location here refers to the quadrant in which the test stimulus is reported to be, whether that stimulus is a single blob, more than one blob (in one or several quadrants), or a colored (or black) shape. It is clear that when something is detected, its location is almost always perceived correctly. The same is true about color, although there is some slight loss of accuracy for color on the critical fourth trial. The comparison between performance for location and color on the one hand and shape on the other is striking in the inattention trial, as is the difference between performance for shape perception on the inattention trial and the other two critical trials.

One might argue that the results for color and shape are incommensurate because the tests for each are not comparable. For color the subject

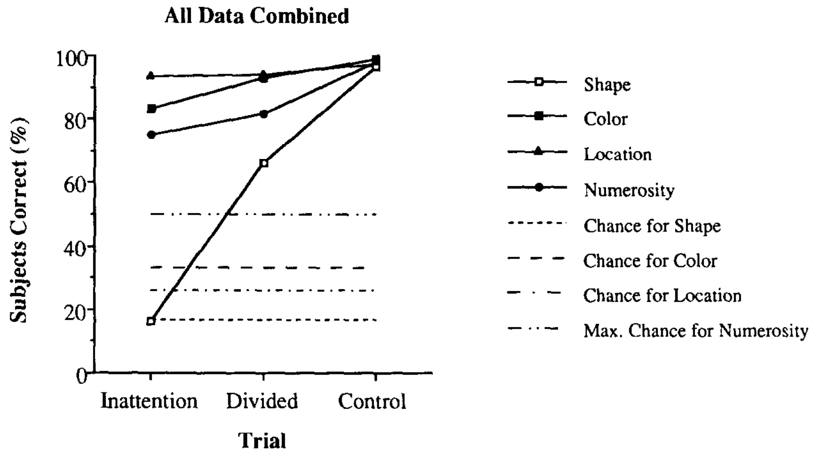

FIG. 6. The results of all experiments for the stimulus properties of shape, color, location, and number and showing the chance levels for each of these properties as well.

has only to identify it verbally whereas for shape a recognition test with six alternatives is used. Thus we do not know with what specificity the color has been perceived and encoded. Any nuance of a given hue would suffice for a correct answer. On the other hand, one might maintain that the recognition test for shape was difficult, i.e., required making a fine discrimination. We have no good metric for ranking shapes for similarity. But the fact is that we chose regular geometric shapes that are clearly very different from one another, i.e., rectangle, triangle, cross, etc. It is difficult to think of shapes that would be judged to be more different from one another. Therefore we are satisfied that our finding of failure to perceive shape is not an artifact of an exceptionally difficult recognition test requiring very fine discriminations.

The result for numerosity shown in Figure 6 warrants further comment. Those values are based on the approximate criterion of plus or minus one step among the six choices offered to subjects in Experiment 3 on numerosity. It is worth noting that since 77% of the subjects were correct by this criterion on the inattention trial there is not that much improvement on the divided attention and control trials. The results for the three critical trials using the criterion of exactly correct (not shown in Fig. 6) are also not too different since 35% were correct on the inattention trial and only 53% were correct on the control trial.

The point we wish to make about the numerosity results is that the subjects do fairly well without attention, at least in comparison with how they do on the task with attention. It has been known with a reasonable degree of certainty since 1871 that when numerosity perception is investigated under normal conditions of attention, but with brief exposure so as to exclude counting, perfect accuracy is only to be expected up to around four items (Jevons, 1871; Saltzman & Garner, 1948; Kaufman, Lord, Reese, & Volkmann, 1949; Glanville & Dallenbach, 1929; Jensen, Reese, & Reese, 1950; Klahr, 1974; Taves, 1941; Atkinson et al., 1976). Beyond that, estimating or, given enough time, counting occurs. These facts suggest that were it not for our six-choice recognition test in which gross, not fine, discrimination of number is required beyond four items, performance beyond four items would have been much poorer than it was. In fact, our subjects tended to underestimate the number of items both in the inattention and attention trials.

However, our subjects were far from perfect in their number reports even when four or fewer items were presented, the level of exact accuracy for these cases being 43% for the inattention trial. Whether or not this is the result of an effect of inattention on acuity we cannot say. It is interesting to note that subjects do better in Experiment 2, in which they also report the number of blobs perceived up to four, albeit in different quadrants, even though this was not considered an experiment on numerosity. The percentage correct here on the inattention trial was 69. Perhaps the greater spacing of the blobs apart from one another in separate quadrants accounts for the superior performance in that experiment compared to Experiment 3. It is known that there are adverse interference effects between elements in eccentric vision (Andriessen & Bouma, 1976).

In any event our interest here is not so much in the perception of numerosity per se but in the question of whether multiple elements are perceived and localized correctly. The answer to the first part of the question is clearly "yes" but the answer to the question of localization will have to await the development of a method of more precise testing than was employed in Experiment 3.

We now consider possible criticisms of our method. It might be said that our method is really not new. In certain respects it is similar to the dichotic listening paradigm (Cherry, 1953) and, to the extent that this is true, is not a new method. The similarity is that in dichotic listening there is also only one "trial" albeit an extended one over the period of the entire message, during which the subjects are obliged to attend exclusively to the message they shadow and may not know they will be questioned about the unshadowed message. Another similarity concerns the results. Certain sensory aspects of the unattended message such as quality of voice are experienced just as we find that a feature such as color is experienced. Nonetheless the differences are great enough to distinguish the two methods in important respects. There is first of all the difference in sense modalities studied. Then there is the difference in the duration of the exposure to the unattended material. In dichotic listening there is ample opportunity to switch attention from attended to unattended message whereas in our method there is far less likelihood for this to occur. The final test in the dichotic listening paradigm necessarily entails memory for whatever was encoded of the extended message in the unattended channel whereas in our method only short-term memory of a single test stimulus is required. In some experiments on dichotic listening, unlike in our experiments on the inattention trial, the subjects are given some task concerning the unshadowed message so they can divide their attention to some extent. In all experiments in dichotic listening the subjects are obviously aware that there *is* an unattended message, whereas as we have seen in our method, approximately 25% of the subjects are unaware that anything other than the cross has been presented.

It might be argued that we have not eliminated the possibility of eye movements on the critical trials. While it is true that on the average it requires at least 200 ms to initiate and carry out eye movements, there are no doubt some subjects who can do so in less time. Thus some subjects might conceivably have succeeded in fixating the test stimulus. Of course, to do so implies detection of the object, so this argument is somewhat circular. However, it is possible that something is detected in the periphery and fixation allows more precise perception of the object. Another possibility is that despite instructions some subjects may not be fixating the point where the center of the cross figure will appear and thus the test stimulus may occasionally fall on the foveal region when it is exposed. While we cannot rule out this possibility, the fact is that there is no advanced knowledge of the quadrant in which the test stimulus will appear. So it seems likely that this would occur only very rarely, if ever.

A further difficulty with this criticism is that it does not explain the specific findings. For example, if foveal vision were to explain the perception of a single blob in Experiment 1, it could not explain the perception of more than one blob in more than one quadrant in Experiment 2, nor could it explain failure to perceive shape in Experiment 4. Finally we must point out that the issue here is not one of the retinal location of the test stimulus. We chose to present it somewhat off the fovea only because we thought that it might be difficult for subjects not to attend to an object on the fovea despite the assigned task and absence of expectation of the test stimulus. And note that the entire test stimulus was always within 2.3° of the fixation point. We have now begun to investigate shape perception under conditions in which the center of the cross figure is peripheral and the test stimulus foveal. So far the results indicate that shape is now sometimes perceived, but in a surprising number of cases either no object is perceived at all (inattentional blindness despite foveal stimulation!) or, if it is, the shape is not correctly perceived. Moreover, in our research on the role of attention in grouping, we have conducted experiments in which the pattern extended across the entire visible field centered on the fixation point and cross and found that, with attention to the line-judgment task, this central location of the pattern still does not lead to grouping (Mack et al., 1992).

A related criticism is that while it is true that the subject is not attending to the test stimulus at the moment it appears, since it is not at all expected, once it appears, it draws attention. If so, our method does not succeed in eliminating attention to the test stimulus. There are a number of answers to this argument. First, as in the case of possible eye movement to the test stimulus, for something to draw attention it must be detected prior to attention. The argument then would have to be that once attention is drawn to the test stimulus, the perception of it is better than the mere detection of it prior to such drawing of attention. But as we have seen, our results on shape suggest that what is perceived is a shapeless blob in a certain location and that hardly seems to be superior as a percept to whatever is detected that draws attention. Second, if attention were indeed drawn to and thus allocated to the test stimulus, one would think that there would be some loss in the accuracy of the line judgments on the critical fourth trial. As was illustrated in Fig. 2, however, this does not appear to be the case. Moreover, Fig. 2 also shows that performance on the line-judgment task is no better on a fourth trial when no test stimulus is presented at all. Third, if attention is drawn to the stimulus object, why do our subjects fail to perceive it adequately when it is a shape? Fourth, in Experiment 2, in which blobs are presented in two, three, or four quadrants, subjects perceive them fairly accurately. So one would have to argue that attention can be simultaneously drawn in several different directions. Fifth, if attention is drawn to a test stimulus, why do approximately 25% of the subjects fail to see it at all? This finding makes more sense as one of the possible consequences of complete inattention. There is also the matter of timing. However rapid a shift of attention may be, it surely requires some finite period of time and that period could only begin after the perception and decision about the line-judgment task has been made. So the question arises as to whether or not this still leaves time for possible processing of the test stimulus with attention before the mask appears. Then there is the question of whether as small an element as the test blob used in Experiments 1 and 2 is obtrusive enough to draw attention. The appearance of the test stimulus should not be regarded as an onset of a stimulus since it and the cross come on and go off simultaneously. Only if the test stimulus comes on while viewing the cross would it have the character of an onset (see Yantis & Jonides, 1990; Yantis & Johnson, 1990). For these various reasons then we are inclined to reject this criticism.

Another criticism might be that a recognition test is not the most sensitive measure of a prior perception or prior processing known to cognitive psychology. Priming is now considered to be more sensitive. Had we used a priming measure we might have discovered evidence for processing of shape. This is a legitimate criticism but we cannot use the traditional response time (RT) measure of priming for the simple reason that our method allows only one critical trial. Without averaging RT over many trials and comparing average control and experimental RTs, no reliable data would be available. There is the possibility, however, of employing some other priming paradigm in which RT is not the dependent variable and such a method may be uncovered for future research. However, even if some such priming method can be found and reveals evidence that shape is indeed detected, registered, or processed, the fact remains that our recognition test data indicate that shape is not *consciously* perceived without attention. Our research is directed at the question of what is and what is not perceived without attention and not at the question of whether or not certain information might be registered about a stimulus object or whether certain processing might occur below the level of conscious awareness. Still, it would be important to know if such information about, or processing of, shape might be present preattentively and unconsciously.[4]

One final criticism that might be made of our method is that our data bear more on memory than perception and this is a matter that we take very seriously. Where subjects fail to identify the test stimulus in our recognition test it may be because they did perceive it but have not retained it by the time of the test some seconds later. Of course when subjects succeed in recognition they must have perceived the object and retained it in memory. Since subjects do succeed in perceiving and remembering blobs, their locations, number, and color, the argument would have to maintain that they perceive shape as well as these other properties but for some reason only fail to remember shape. Our shapes were familiar ones, easily encodable once perceived. So although we are inclined to discount this criticism too, we have begun to investigate it.

A brief comment about our method of focusing attention in relation to location is warranted. Posner (1978, 1980) has demonstrated strong effects of the expected locations of stimuli on perception. In our method it is plausible to say that the subjects were attending to the locations of the

[4] It would now appear that shape is detected when not consciously experienced. DeSchepper and Treisman (1991) have found a negative priming effect—such as was demonstrated by Tipper (1985) who used meaningful overlapping figures—for overlapping novel shapes such as were used by Rock and Gutman (1981). The unattended shape in the overlapping pair on one trial increased response time when it was the same as a subsequent relevant shape in an overlapping pair in a same–different matching task.

cross lines rather than any other locations and there are several ways in which this might be carried out. They could try to focus on the anticipated approximate locations of the lines' end points or on the lengths of each line in their entireties before going on to compare the two. In either case, though, attention is to or on the line regions rather than to or on the spaces within the quadrant regions. Since we sought to eliminate attention from the region(s) in which the stimulus or stimuli would be presented, such locationally based attention serves our purposes admirably.

However, we cannot say with certainty whether or not a locational aspect of attention is really playing a causal role in our method. One might instead say that what matters in our method is the fact that the subject is attending to a task and simply does not expect any stimulus other than the cross to appear. The task may simply entail the utilization of spatially independent processing resources. From this perspective it would not matter if the critical stimulus appeared directly in the locus of the cross, i.e., directly on one of the lines. The results might be much the same. It is of interest to note that the methods employed in the previously cited research on the effect of inattention on shape perception (Rock et al., 1976; Rock & Gutman, 1981) were such that the object appeared in a location to which attention was directed but the unattended object's shape was nonetheless not subsequently recognized. See also the related experiment by Neisser and Becklen (1975) on the perception of unattended meaningful events.[5] Should it prove to be the case that it is irrelevant where the critical stimulus appears in relation to the cross, then we have succeeded in diverting attention from the test stimulus in a manner different from that of diverting spatial attention.

So much for objections to the conclusions we have drawn from our new method. The findings seem to bear out our working hypothesis that the kind of organization that is achieved preattentively, perhaps the only kind, is one in which uniform elements of which all regions are connected

[5] Recent experiments by Epstein and his associates seem to contradict our findings about form perception (Epstein & Babler, 1989, 1990; Epstein & Lovitts, 1985). The focus of these experiments was the question of whether or not constancy of shape occurs under conditions of inattention. The subjects were given a distracting task but at the same time a novel two-dimensional shape tilted about its vertical axis was presented. Under ordinary conditions of attention, the shape would be perceived veridically despite its compressed retinal image. Without attention, the rotated object apparently was perceived as a shape in accordance with the compressed proximal stimulus. Although perception was not veridical, there *was* perception of projective shape, which thus seems to contradict our finding of failure to perceive shape of any kind. There were, however, many differences in procedure. In Epstein and Lovitts' experiment, the shape appeared in central vision for 1 s. Moreover, many shapes were presented under their attention-withdrawn condition before the test was given. Despite these investigators' attempts to eliminate attention to the shape therefore, we are inclined to regard their procedure as one of divided attention.

tend to be perceived as units (see Palmer & Rock, in preparation). Such units are also correctly localized without attention and certain properties belonging to them such as color are also given without attention. Whereas according to our research on the grouping of such elements with one another by virtue of Gestalt laws such as proximity and similarity, such grouping does not occur without attention (Mack et al., 1992).

Why, though, is it the case that the shape of such elements is not perceived without attention? Several explanations are possible. One that has been advanced by Treisman and her associates (Treisman, 1988; Treisman & Gelade, 1980) is that shapes consist of separate features and that the perception of shape thus requires the conjoining or integrating of these features. Feature integration is held to require attention. However, an alternative explanation is that shape perception is based on a structural description, propositional in nature, and such a description requires attention (See Rock, 1983, Chapter 3, for the evidence and logic behind this thesis).

To what extent can we generalize our findings about the perception of shape? There are many factors that might be relevant, such as type of figure, retinal locus, and visual angle. As to type of figure, we feel that those we tested are as representative as any one might choose. These are well-known prototypical geometric shapes and certainly differ enough from one another as not to be confused. Our figures were solid regions rather than outline. Some new, preliminary research we have conducted suggests that outline figures may be easier to discriminate from one another than solid figures—possibly because they are processed by higher spatial-frequency channels—but on the other hand, few objects in the environment are outline.

As to retinal locus, as noted our figures are entirely within 2.3° from the fixation point. Consequently the resolution was still quite good despite their location outside the fovea. Some new, preliminary research we have conducted using the same method seems to indicate that shapes presented at the fixation point are perceived without attention at least some of the time, but we are inclined to interpret this finding as the result of some attention diverted to whatever stimulates the fovea. This is why we have used non-foveal loci in the experiments reported here. While it is known that attention can be directed to a non-foveal stimulus, it does not necessarily follow that all attention can be *eliminated* from a foveal stimulus. However, our preliminary findings indicate that inattentional blindness does occur for foveally presented stimuli and that when the stimulus *is* seen, its exact shape is by no means always perceived.

As to the visual angle of the critical stimulus, we can only guess that, had we used larger stimuli in the periphery, they would have been detected more often and their shape sometimes perceived rather than not perceived at all. Such an outcome however might be the result of an attention-drawing tendency of more extensive object stimuli.

One surprising result consistently obtained in all of our experiments was that roughly 25% of subjects are completely unaware of the stimulus object on the inattention trial. Forcing these subjects to choose a quadrant, color, or shape (depending upon the particular experiment) does not lead to beyond-chance performance. Nor does the nature of the test stimulus seem to matter, so that while one might intuitively understand why an observer could fail to detect a small blob as in Experiment 1, it is quite surprising that either a larger stimulus object such as one of the shapes we used in Experiment 4 or an array of blobs either in one or many quadrants could also remain totally undetected. One might expect that subjects would be more certain than their ratings suggest if indeed they have not seen anything but the cross figure. The mean rating for such trials for all experiments combined was 1.8. However, we have already commented on why such ratings might not reflect a subject's degree of certainty in these cases. In interviewing subjects after the experiment, and from their data, it seemed clear to us that such reports were genuine. A similar result of about the same percentage of such failures of detection was found in some preliminary experiments on grouping by Arien Mack in which the stimulus configuration was entirely within one quadrant but was even larger in visual angle than our shapes. Even motion is not always detected under conditions of inattention, when it always is in the control condition that allows attention (Mack, Tang, Rock, Stone, Linnett, & Ro, 1991). This failure to perceive anything on the inattention trial can be contrasted with the finding that on the final control trial there were never any such failures. Thus the effect cannot be attributed to the brief exposure, peripheral location, or masking of the stimulus per se. We regard this finding of inattentional blindness, consistently obtained in many experiments using our method in two different laboratories, as one of the most important to come out of this research.

We cannot say whether this effect is based on individual differences or on some other factor that will lead to such failure of detection a certain percent of the time by any subject, because we have only the one critical trial per subject. In other words, to consider one possibly relevant factor, the degree of focused attention to the required task, it is possible that some observers focus more than others but it is equally plausible that the same observer might focus differently at different times. In any event one might regard this finding as reflecting the kind of effect that does seem to occur occasionally in daily life. We often feel that we have had no awareness whatsoever of some object or event by virtue of attending to something else. Our experiments seem to demonstrate such an effect in a form more striking than that shown by other published research because here nothing at all about the stimulus is experienced consciously whereas in other research, such as on dichotic listening (Cherry, 1953; Moray, 1959) or overlapping forms (Rock & Gutman, 1981), the presence of the unattended stimuli and certain of their properties *is* perceived.

Finally, we come back to a question we raised at the outset, namely, whether our method concerns the elimination of *attention* or the elimination of *expectation*. If the latter, does the absence of expectation lead to the elimination of the *intention* to perceive the test figure? These are difficult questions which we can hardly resolve at this stage of our research. Our method does seem to entail two separable features, namely, attention to the line-judgment task *and* the absence of expectation of the test stimulus. In the seventh, or divided-attention, trial there is still attention to the line task but no longer the absence of expectation of the test stimulus. The results of this trial in which by and large the perception of the test stimulus is good, suggest that expectation may be a factor. However in some pilot experiments testing this question, we have created a condition of no expectation, without focusing attention on another task, and this does not lead to failure of perception. The two findings suggest that our method may entail an *interaction* of two factors, attention to a different task and lack of expectation. As to a role of lack of intention created by the absence of expectation, we are inclined to believe that intention plays a role only when there is a task to perform. That is, we doubt that intention is necessary merely to perceive something. In any event research is needed to disentangle these states of mind and their possible effects on perception.

What is clear is that our results support our guiding hypothesis that individual elements would be perceived without attention. Features of these elements such as their location and color are also perceived preattentively. Thus initial perceptual organization appears to generate discrete elements based on connected regions of uniform stimulation, and these elements become candidates for later attentional processing.

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