Perceptual Grouping Produced by Changes in Orientation and Shape

Abstract. *The relative effectiveness of changes in orientation and shape in producing perceptual grouping has been studied using a method based on threshold judgments. Statistical analyses of the threshold values show that rotating some of the figures in a field from a vertical position to a slant of 45° facilitates segregating the field into separate perceptual groups. In contrast, changes in the shape or orientation of these figures, which leave their component lines vertical and horizontal, do not reliably aid grouping. The results also suggest that the similarity of the figures composing the field is not a good predictor of the degree to which the figures will cohere to form distinct perceptual groups.*

Since Wertheimer (*1*) pointed out that patterns composed of element shapes break up into relatively segregated units based on the similarity of their elements, a basic problem has been to specify the decisive properties that produce grouping. Demonstrations (*2*) of perceptual grouping provide information that not all properties equally facilitate grouping. However, the relative effect of variables in producing grouping can only be indirectly inferred because of a confounding of stimulus variables. In these experiments a method based on threshold measurements was used to test the effectiveness of changes in shape and orientation in producing perceptual grouping.

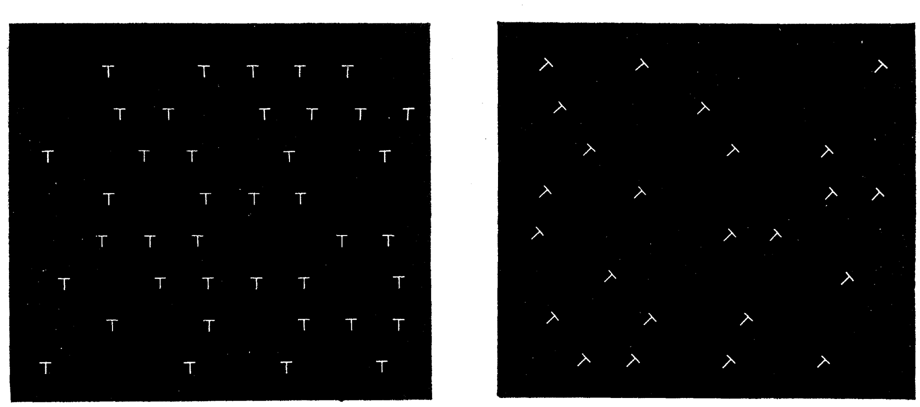
There are two patterns of *T*'s in Fig. 1: in pattern A, the *T*'s are upright, while in pattern B the *T*'s are slanted 45°. When these two patterns are combined to obtain a single equally spaced field of upright and slanted *T*'s there is no separation of the field into upright and slanted *T*'s. However, if the brightness of the upright *T*'s is reduced the perceptual field separates into two groups—less bright upright *T*'s and brighter slanted *T*'s. Measurements of the amount by which the brightness of the upright *T*'s in pattern A has to be reduced for the figures in patterns A and B to segregate into two perceptual groups permit an evaluation of shape and orientation changes. If the changes of shape and orientation of the elements of pattern B facilitate the emergence of separate groups, the amount by which the light in pattern A needs to be reduced for grouping to occur will be less than if these changes did not facilitate grouping.

Three experiments were conducted; the general procedure was the same for each experiment. The patterns employed consisted of two-line figures cut on 22.5- by 35-cm plastic sheets. When the sides of a plastic sheet are illuminated, the light is transmitted through the sheet in a series of reflections from surface to surface. If, however, cuts are made on the plastic sheet, the light is emitted at these points causing the cuts to appear luminous.

The apparatus was designed to accommodate two superimposed plastic sheets, one in front of the other, containing the standard and comparison patterns (A and B of Fig. 1, respectively). Each sheet was placed in a specially constructed wooden frame. The plastic sheet containing the standard pattern was always placed in the front frame, while the plastic sheet containing the comparison pattern was always placed in the back frame. The cut surfaces were always away from the observer. The sheets were illuminated by 40-watt lumiline lamps kept in boxes located to the right and left sides of each frame. These boxes contained long, narrow slits into which the sides of the plastic sheets were inserted. The lamps were connected to variacs so that the brightness of the front and back patterns could be varied independently. When the patterns were equally illuminated, an observer saw a single rectangular field made up of two types of luminous shapes against a black background. Around this rectangular area, black paper was attached which concealed the light sources as well as the apparatus.

The experiments were run in a darkroom in which there was no light other than that coming from the luminous shapes. Observers sat at 165 cm from the targets and viewed them monocularly; no chin rest was employed. They were instructed to lower the brightness of the standard pattern by rotating the knob of the variac until two separate groups were seen. They were cautioned to reduce the brightness gradually so as not to overshoot by any degree. Near the threshold, however, fine adjustments were allowed. Before each judgment, the experimenter set the standard and comparison patterns at equal brightness. After the observer's judgment was recorded by the experimenter, the next comparison target was presented. (The comparison targets were shown in a random order.) The observers were able to develop a stable criterion and to give consistent judgments during a preliminary session during which time no data were collected. The observers were undergraduate students at Harvard University who were paid to participate in the experiments. They were unaware of the purpose of the experiments. Each of the observers made ten judgments on each target during the course of two 1-hour experimental sessions.

Luminance measures were taken with a Spectra Pritchard Photometer employing a 30-minute arc field. The meter was placed at the same distance from the display as was the observer (165 cm), and subtended a circular



A **B**

Fig. 1. (A) Pattern of upright *T*'s employed as the standard in experiments 1 and 2. (B) Pattern of *T*'s slanted at 45°, one of a larger number of comparison patterns used in experiments 1 and 2. When these two patterns are combined so that a single equally spaced field of upright and slanted *T*'s is obtained, there is no separation of the field into two groups.

field of approximately 14 mm in diameter. All luminance measures refer to the luminance of the individual element averaged over this aperture (*3*). The raw data of the experiments were numbers taken directly from the variac settings determined by the observers. The intensity in foot-lamberts (1 ft-lam = 1.076 mlam) corresponding to these numbers was determined from a graph in which foot-lamberts were plotted against variac settings.

In the first experiment, the standard pattern consisted of 41 upright *T*'s (Fig. 1A), and the comparison patterns consisted of 23 elements (Fig. 1B). Seven comparison patterns of various shapes were used (Fig. 2). They consisted of: (i) an upright *T* having a 2-mm gap between the vertical and horizontal line; (ii) an upright *T* identical to the standard; (iii) an upright *T* whose vertical line is equal to the length of the vertical line plus the length of the gap of target i; (iv) a backward *L*; (v) a *T* on its side, the two lines having the same vertical and horizontal position as the standard; (vi) a *T* slanted at 45°; and (vii) the *L* shape rotated to form a *V*. With the exception of target iii, the two lines making up the figures were equal (5 mm) in length, and were always at right angles to one another. The mean luminance of the elements on the standard and comparison patterns was always set at 0.114 ft-lam. When the standard and comparison patterns were superimposed, the total field was 17 by 15.5 cm. The separation between elements in the combined field was 2 cm. (Five observers served in the experiment.)

The results of the experiment are shown in Fig. 2. The first figure in the pairs of figures shown in the top row illustrates the shape of the standard pattern, the second one the shape of the comparison pattern. The mean luminance setting of the standard pattern at which the field was seen to segregate into two separate groups is presented for each of the comparison patterns averaged over the five observers. The larger luminance values indicate that the standard pattern had to be reduced less in order to achieve a segregation of the field. The comparison patterns have been arranged so that they go from the largest to the smallest threshold. A Tukey test (*4*) of multiple comparisons was used to compare the means. The results show

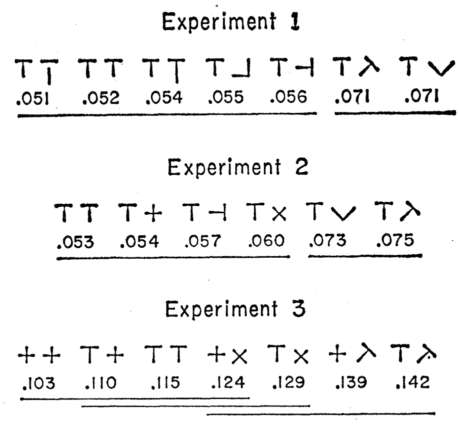


Fig. 2. The mean luminance setting of the standard pattern at which the field was seen to segregate into two separate groups is presented for each of the comparison patterns averaged over the five observers. The first figure in the pairs of figures shown illustrates the shape on the standard pattern; the second one, the shape on the comparison pattern. The larger luminance values indicate that the standard pattern had to be reduced less in order to achieve a segregation of the field. The comparison patterns have been arranged from the largest to the smallest threshold. A Tukey test of multiple comparisons was used to compare the means. Those means which did not differ significantly from each other at the .01 level are underscored by the same line.

that *T V*, and *T* and slanted *T* differ significantly at the .01 level from the other stimuli, but not between themselves. At the .01 and .05 levels of significance, the remaining stimuli did not differ significantly with respect to each other. The means that do not differ significantly from each other are underscored by the same line. The results show that changes in the shape and orientation of the figures without changes in the orientation of the component lines do not as readily facilitate the separation of the field into distinct perceptual groups. For example, a *T* on its side and a backward *L* involve changes in the orientation of the element and in the shape of the element, but leave the component lines vertical and horizontal. The patterns *T V*, and *T* and slanted *T* involve changes in orientation and shape in which the component lines are tilted, rather than vertical and horizontal. The results also show that a small gap, or the slight increase in the size of the vertical bar of the *T*, does not introduce enough of a difference to affect grouping.

A second experiment was conducted in which four of the stimuli were the same as those used in the first experiment. Two new stimuli were added: a +, and a + tilted at 45° to form an ×. The arrangement of the elements, the apparatus, and the procedure were identical to the first experiment. The same five observers who served in the first experiment served in the second experiment; approximately 2 weeks elapsed between the two experiments.

The results obtained were highly similar to the results obtained for the first experiment. It can be seen that *T V*, and *T* and slanted *T* again required the smallest decrease in the brightness of the standard field in order to be seen as a distinct group. A Tukey analysis indicates again that the stimuli fall into two groups; *T V*, and *T* and slanted *T* differ from the remaining stimuli at the .01 level, but do not differ between themselves. The remaining stimuli again do not differ among themselves at either the .01 or .05 level. Surprisingly, the result of the experiment is that crossing the lines does not facilitate the segregation of the field into two perceptual units. The comparison target of ×'s did not separate as readily as the comparison target of slanted *T*'s or *V*'s. In fact the ×'s did not yield significantly different results from the comparison pattern consisting of upright *T*'s identical to the standard. It should be noted, however, that the comparison target consisting of ×'s did give the third smallest threshold, following the slanted *T*'s and *V*'s. If we take *T T* as a standard and compare each of the remaining conditions with the standard, *T* and slanted *T* and *T V* differ significantly at the .005 level, *T* × at the .05 level, and *T* and *T* on its side and *T* + fail to differ significantly (*5*).

In the third experiment, the arrangement and number of elements on the standard and comparison patterns were altered radically. Each plastic sheet contained 144 shapes randomly arranged, but placed so there was no overlap when the two sheets were superimposed. There were two standards in this experiment, a *T* and a +, and four comparison targets, a +, an ×, a slanted *T*, and a *T*. Seven stimuli were presented: *T T*, *T* +, *T* ×, *T* and slanted *T*, + +, + ×, and + and slanted *T*. All lines composing the elements measured 6 mm. The mean luminance of the individual elements on the patterns was set at 0.29 ft-lam.

There were four observers, three of whom had served in the earlier experiments. The procedure was modified so that the brightness of the comparison targets (rather than that of the standard pattern) was reduced. With the exception of the noted modifications, the apparatus and procedure were the same as in the previous experiments.

The results of this study confirm the findings of the previous experiments, although the patterns vary radically in number, separation, and arrangement of elements. The results of a Tukey analysis of the data are shown in Fig. 2. As can be seen, fields containing slanted *T*'s are segregated most readily, while those containing only vertical and horizontal lines require a much greater lowering of the brightness for two separate groups of elements to be seen. The × pattern again forms a bridge between these two extremes; + × and *T* × do not differ significantly from *T* and slanted *T* or + and slanted *T*, but on the other hand, they do not differ significantly from *T* + and *T* *T* either. Whether the standard pattern contained a *T* or a + only slightly affected the thresholds.

The main conclusions to be drawn from these experiments are that when elements are composed of two lines of equal length, changes in orientation or shape which maintain the vertical and horizontal lines in the element do not strongly affect grouping. If the orientation of the lines is changed to 45° and 135°, however, perceptual grouping relative to a vertical-horizontal pattern will be facilitated.

Two comments should be made about this conclusion. First, the fact that no significant differences were found in the thresholds with changes in shape does not mean that changes in the arrangement of the lines without changing their orientation has no effect whatsoever. The statistical tests employed are conservative with respect to the type 1 error. If we had not taken an error rate based on the whole experiment, more of the differences would have been significant. In fact, it is important to point out that the results indicate that there are variables other than the orientation of the lines which affect the tendency to group. This is illustrated by the fact that the × has the same slant as the slanted *T* and *V*, yet it groups less readily. All we wish to conclude at the present time is that changes which alter the direction of the component lines from vertical or horizontal to diagonal, proved to be more effective in facilitating grouping than changes which left the component lines in the same direction.

It should be noted that the similarity of the figures does not appear to be a good predictor of grouping. In an independent study, ten observers judged the slanted *T* as more similar to the upright *T* than either a backward *L* or a *V*. The threshold for segregation of the slanted *T*'s, however, is more similar to the threshold of the *V*, while the threshold of the backward *L* is more similar to the threshold of an upright *T*. This suggests that an analysis of grouping in terms of the similarity of the figures is not feasible. It should be noted in this connection that informational analysis of grouping based on redundancy of figures (*6*) cannot be used to explain the results, as there are always two kinds of elements whose position and number remain constant.

The results of the experiments indicate that it is necessary to examine the specific properties involved in accounting for segregation. Of the variables studied in the present experiments, the orientation of the lines proved to be the most powerful. Gibson (*7*) has suggested that the direction of a line is a basic element in the perception of a pattern. It is suggestive in this connection, that Hubel and Wiesel (*8*) found specific receptors for line orientation when studying the cortical neurons in area 17. This would suggest that relatively simple pattern properties are the most powerful in pattern segregation. However, since changes in orientation change the horizontal and vertical dimensions of the figures, the result of the experiments could also be interpreted in terms of these variables. Further experimentation is necessary to separate the effects of orientation from the dimensions of the figures.

It should be noted that the most effective variable appears to be brightness. It has been found that a number of different shapes in a number of different displays could be presented which would not segregate into groups as long as the brightness was equal for the elements in both patterns. Again, the overall similarity was not a reliable predictor of their tendency to segregate into groups. This suggests that the judged similarity of two figures is based on properties of the shapes which do not necessarily influence their separation into groups. Demonstrations which have shown the importance of more complex properties (such as shape similarity) in perceptual grouping, should be considered carefully, as they often involve changes in orientation and size of the lines composing the figures.

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References and Notes

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3. Although an attempt was made to equate the brightness of the two lines composing a figure, they were not always identical. That the results were not due to this fact was shown by a further study in which the lines for all elements were equated. The results obtained confirm the present findings.
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9. Supported by NSF grant GB-2901 and a grant from the Carnegie Corporation.

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Underwater Vocalization by Sea Lions: Social and Mirror Stimuli

Abstract. *Underwater vocal response of three sea lions* (Zalophus californianus) *increased under conditions of social interaction. When confronted by their mirror images, two animals increased their number of vocalizations, which included "whinny" sounds, barks, buzzing, and varying patterns of click trains. Click vocalizations showed habituation and recovery when the animals were in the presence of the mirror stimulus.*

Vocalization by an animal often appears related to alertness or increased activity; presumably during activated states, physiologic arousal is great (*1*). Among seals and sea lions, vocalizations in air (sounds often having a pulsed structure) are valuable in communication and are frequently associated with stress, social play, fighting or sparring, increased sexual activity, and disturbance from a resting state (*2*). It has been suggested (*3*) that