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Dominance of configural properties in visual form perception

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Perceptual relations between configural and component properties were examined in three experiments. The pattern of performance in discrimination and classification tasks with a set of four lines that varied in curvature (Experiment 1) was compared with the pattern of performance in these tasks with sets of configuration defined on spatial relations among these lines. The configurations in the latter sets varied in their component properties ("curvature") as well as in their configural properties ("closure" in Experiment 2 and "parallelism" in Experiment 3). The results indicated that discrimination and classification performance with the configurations was dominated by their configural properties, regardless of the discriminability of their component properties. The implications of these results for the role of configural properties in form perception are discussed.

The question of whether perception is analytic or wholistic is an enduring issue in the psychology of perception. The notion of wholistic processing, which is considered to be in the spirit of the Gestalt theory, refers to the hypothesis that the initial information-processing step in identification, discrimination, or classification of objects involves the processing of wholistic properties rather than of component properties. One of the attempts to test this hypothesis is the global/local paradigm proposed by Navon (1977). The merits and the limits of this paradigm are discussed elsewhere (see Kimchi, 1992, for a review). Another attempt to test the hypothesis about the perceptual primacy of wholistic properties concerns the role of configural properties in object perception. The essential characteristic of configural properties is that they do not inhere in the components but depend instead on the interrelations among components (e.g., Garner, 1978; Rock, 1986). The Gestaltist claim that the whole is different from the sum of its parts (e.g., Wertheimer, 1967) can perhaps be captured by configural properties such as closure, symmetry, and certain other spatial relations among components.

Several findings seem to suggest the perceptual dominance of configural properties. One such finding is the "configural-superiority effect" reported by Pomerantz, Sager, and Stoever (1977). Pomerantz et al. found that ( ) and ((were more easily discriminated from one another than) and (, and that ⊿ and ⊻ were more discriminable from each other than were ⁄ and ╲ . Pomerantz and Pristach (1989) attempted to provide diagnostic criteria for configural properties using attentional measures. They constructed visual configurations by the orthogonal combination of line segments, and reasoned that if the line segments had been grouped into configural dimensions, spreading attention among them would be easy and selective attention to the individual segments would be difficult. They found, however, that their diagnostics were not foolproof indicators of configural interaction among the line segments, because the performance characteristics of configural interaction do not surface unless the configural properties are distributed among the stimuli in a way that makes them useful for the assigned tasks.

A different approach, which involves a comparison between component and configural properties, was proposed by Lasaga (1989). The logic underlying this approach is as follows: A pattern of performance in discrimination and classification tasks with a set of four stimuli varying in simple property is obtained. The discrimination performance reveals the degree of perceived interstimulus similarity between the stimuli in the set. The classification performance reveals which grouping maximizes perceived intragroup similarity and minimizes perceived intergroup similarity. These simple stimuli are then spatially combined to construct a set of four new stimuli. These new stimuli have component properties and configural properties, and they are similar/dissimilar to each other in these two kinds of properties. A pattern of performance in discrimination and classification tasks with the new set of stimuli is obtained. A comparison between the pattern of performance obtained with the simple stimuli and the pattern of performance obtained with the configurations constructed from these simple stimuli allows for an evaluation of the relative perceptual dominance of the two types of properties. If the discrimination between stimuli that have dissimilar configural properties is always easier than discrimination between stimuli that have similar config-

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ural properties, irrespective of the discriminability of their component properties, and if classification according to configural properties is the easiest one, then perceptual dominance of the configural properties can be inferred.

Using this logic, Kimchi (1994) found that performance based on configurations was faster and more accurate than performance based on their components, regardless of the discriminability of the components. For example, discrimination and classification performance with a set of four lines that varied in orientation showed that discrimination between two oblique lines was more difficult than discrimination between an oblique line and a vertical or a horizontal line, and that the easiest classification involved grouping of the two oblique lines together and the vertical and the horizontal lines together. The pattern of performance with a set of four configurations that were constructed by spatial arrangements of these lines (a square, a diamond, a +, and an X) showed that discrimination between a pair of two "closed" stimuli (a diamond and a square) and discrimination between the two "open" stimuli (an X and a +) were more difficult than discrimination between any other pair of stimuli (whether or not they shared the same component lines), and that the easiest classification involved grouping of the diamond and the square together and the + and the X together. The same pattern of results was obtained with both connected configurations (Lasaga, 1989) and disconnected ones (Kimchi, 1994). Kimchi interpreted these results in terms of the perceptual dominance of the configural property of "closure." Another possible interpretation of these results may be made in terms of rotational subsets. In the sets of the stimuli used by Kimchi (1994), the configurations that had a similar configural property were simple rotations of each other (e.g., a square and a diamond, each being a 45º rotation of the other). The same holds true for the stimulus sets used by Lasaga (1989) and Pomerantz and Pristach (1989). Note that even if discrimination and classification performance was controlled by subsets generated by simple rotations, a wholistic view is still supported because such transformations operate on the stimulus as a whole. However, the notion of the configural properties presented here assumes that stimuli may have similar configural properties without being simple rotations of each other.

The purpose of the present study was twofold: (1) to further examine the perceptual dominance of the configural property of "closure" using configurations that shared this property but did not form rotational subsets, and (2) to generalize the previous results by employing a different component property ("curvature") and a different configural property ("parallelism").

The logic underlying the present experiments is the same as that employed by Kimchi (1994). Experiment 1 was designed to examine discrimination and classification performance of simple lines that varied in curvature (straight vs. curved lines). Certain visual search studies suggest that curvature is an elementary property for the perceptual system (Treisman & Gormican, 1988; Wolfe, Yee, & Friedman-Hill, 1992). The stimuli used in Experiment 1 were then grouped to form the set of stimuli used in Experiment 2 and the set of stimuli used in Experiment 3. The stimuli in both sets were similar/dissimilar to each other in terms of their component properties (i.e., lines and curvature) and in their configural properties "closure" in Experiment 2 and "parallelism" in Experiment 3. The patterns of performance in discrimination and classification tasks obtained with the configurations (Experiments 2 and 3) were compared with the pattern of performance obtained with the line components (Experiment 1), and the relative perceptual dominance of the component and configural properties was evaluated.

EXPERIMENT 1

Method

Subjects. Eighteen students from the University of Haifa, 12 women and 6 men between 20 and 34 years of age, volunteered for the experiment and were paid for their participation. All had normal vision.

Apparatus. The experiment, including stimulus presentation and reaction-time recording, was controlled by a Silicongraphics Indigo-II workstation connected to a flat, 17-in. Silicongraphics monitor.

Stimuli. The stimuli were four lines varied in terms of curvature: two curved lines and two straight lines. The lines were aligned diagonally (45º and −45º rotations from the vertical; see Figure 1A). Each curved line consisted of a 66.8º arc taken from a circle of 18.2-mm radius. The subjects sat approximately 180 cm from the screen. From this position, each stimulus subtended 0.48º of visual angle for length. The stimuli were drawn in black on a white background.

Design and Procedure. The stimuli were presented one at a time and the subject was required to make a two-choice speeded response by pressing one of two buttons on a mouse. For this, the subject was instructed to use the index and middle fingers of his/her dominant hand. In the discrimination tasks, only two stimuli were used in each task and the two stimuli were assigned to different response buttons. In the classification tasks, all four stimuli were used and two of the stimuli were assigned to each of the two response buttons. There were six discrimination tasks (according to the six possible ways of pairing four stimuli) and three classification tasks. Each task was administered in a separate block of 52 trials preceded by 16 practice trials, with each stimulus in the subset occurring on an equal number of trials. The response assignment for the stimuli and the order of the tasks were counterbalanced across subjects.

Each experimental trial began with a fixation dot visible for 500 msec. After an interval of 500 msec, the stimulus appeared at the center of the screen and stayed on until the subject responded or for a maximum of 2,000 msec. The subjects were informed about the relevant stimulus set and the response assignment at the beginning of each task, and were instructed to respond as quickly and as accurately as possible. The sessions were conducted in a dimly white-illuminated room and each lasted about 45 min.

Results and Discussion

All data summaries and analyses are based on the subjects' median reaction times (RTs) for correct responses and on the percentage of error rates (PEs). Mean correct RTs and PEs are presented in Table 1. Separate analyses of variance (ANOVAs) were performed for the discrimination and classification tasks.

The one-factor repeated-measures ANOVA performed on the discrimination data yielded no significant effect of task either for RTs [$F(5,85) = 1.68, p > .14$] or for PEs [$F(5,85) = 1.34, p > .25$].

The ANOVA performed on the classification RTs indicated a significant effect of task [$F(2,34) = 18.95, p <$

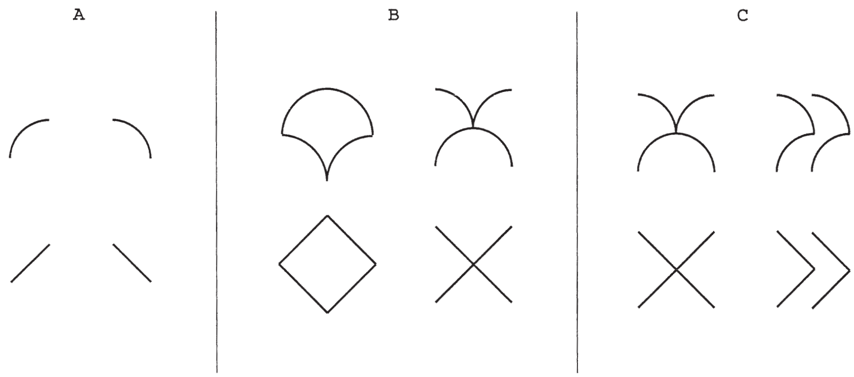

Figure 1. The stimulus sets used in Experiment 1 (A), Experiment 2 (B), and Experiment 3 (C).

.0001]. Post hoc comparisons using Duncan's procedure showed that grouping of the two curved lines together and of the two straight lines together did not differ significantly from grouping of the two right-diagonal lines together and the two left-diagonal lines together (533 and 498 msec, respectively). These two ways of grouping, one based on curvature and the other based on orientation, were significantly faster than the grouping of the left-diagonal curved line and the right-diagonal straight line together and the right-diagonal curved line and the left-diagonal straight line together (612 msec). The pattern of the error-rate data was similar to that of the RTs, but the effect of task just approached significance [$F(2,34) = 2.88$, $p < .07$].

Although both curvature and orientation were equally available for classification, the latter is of no further concern here because it did not play a role in the construction of the configurations used in the next two experiments.

EXPERIMENT 2

Method

Subjects. Eighteen students from the University of Haifa, 10 women and 8 men between 20 and 26 years of age, volunteered for the experiment and were paid for their participation. All had normal vision.

Stimuli. The simple stimuli used in Experiment 1 were grouped to form the set of four stimuli used in Experiment 2. The relevant groupings were those that produced stimuli that differed in discriminable component properties (i.e., curved vs. straight lines) but shared a configural property (e.g., closure) and those that produced stimuli that shared a component property (e.g., curved lines) but differed in configural properties (i.e., closure vs. nonclosure). The stimuli are presented in Figure 1B. Each stimulus subtended 0.94º of visual angle.

The configural properties involved in the present set of stimuli are much like those involved in the sets of stimuli employed by Kimchi (1994, Experiments 2 and 4) and by Lasaga (1989). The present configurations, however, do not form any rotational subsets.

Apparatus, Design, and Procedure. The apparatus, design, and procedure were the same as those in Experiment 1.

Table 1
Mean Reaction Times (RT, in Milliseconds), Percentage of Error Rates (PE), and Standard Deviations (*SD*) for the Discrimination and Classification Tasks in Experiment 1

Task	RT	*SD*	PE	*SD*
	Discrimination Tasks			
	509	64.0	1.53	2.37
	492	79.9	1.29	2.78
	490	54.3	1.03	1.68
	482	66.1	1.03	1.68
	474	58.8	1.01	2.05
	473	66.7	0.31	1.04
	Classification Tasks			
	612	113.1	6.71	10.15
	533	87.3	2.85	6.71
	498	66.3	2.30	4.27

Results and Discussion

Mean correct RTs and PEs for the different tasks are presented in Table 2. The ANOVA performed on the discrimination data indicated a significant effect of task [$F(5,85) = 14.79$, $p < .0001$] for RTs only ($F < 1$ for PEs). Duncan's post hoc comparisons revealed that the two slowest discriminations were between the two "closed" figures and between the two "open" figures (483 and 493 msec, respectively). All of the other discriminations were equally fast.

The ANOVA performed on the classification data indicated a significant effect of task [$F(2,34) = 70.60$, $p < .0001$] for RTs only ($F < 1$ for PEs). Duncan's post hoc comparisons revealed significant differences between the three tasks. The fastest classification involved the groupings of the two "closed" figures together and of the two "open" figures together. The next fastest classification involved the grouping of the two figures consisting of straight lines together and the two figures consisting of curved lines together. These two classifications were significantly faster than the classification that involved grouping of the curved-line "closed" figure and the straight-line "open" figure together and the straight-line "closed" figure and the curved-line "open" figure together.

EXPERIMENT 3

Method

Subjects. Eighteen students from the University of Haifa, 12 women and 6 men between 18 and 25 years of age, volunteered for the experiment and were paid for their participation. All had normal vision.

Table 2
Mean Reaction Times (RT, in Milliseconds), Percentage of Error Rates (PE), and Standard Deviations (*SD*) for the Discrimination and Classification Tasks in Experiment 2

Task	RT	*SD*	PE	*SD*
Discrimination Tasks				
	493	74.0	1.70	3.00
	483	50.3	1.49	2.90
	450	57.5	1.39	2.77
	448	65.9	1.22	2.13
	444	71.0	1.21	2.40
	438	63.0	1.11	2.25
Classification Tasks				
	606	67.5	2.55	5.08
	527	85.9	2.16	3.83
	460	69.2	1.65	3.56

Stimuli. The simple stimuli used in Experiment 1 were grouped in another way to form the set of four stimuli that was used in Experiment 3 (see Figure 1C). Once again, the grouping produced stimuli that had similar components (e.g., curved lines) but differed in configural properties (i.e., "parallelism" vs. "nonparallelism") and stimuli that differed in their components (i.e., straight vs. curved lines) but had a similar configural property (e.g., "parallelism"). Each stimulus subtended 0.94º of visual angle.

Apparatus, Design, and Procedure. The apparatus, design, and procedure were the same as those used in Experiment 1.

Results and Discussion

Mean correct RTs and PEs for the different tasks are presented in Table 3. The ANOVA performed on the discrimination data indicated a significant effect of task [$F(5,85) = 5.01, p < .0005$] for RTs only ($F < 1$ for PEs). Duncan's post hoc comparisons revealed that the discrimination between the two figures with "parallelism" was slower than all other discriminations, which did not differ among themselves.

The ANOVA performed on the classification data indicated a significant effect of task both for RTs [$F(2,34) = 40.90, p < .0001$] and for PEs [$F(2,34) = 9.43, p < .001$]. Duncan's post hoc comparisons for the RT data revealed significant differences between all three tasks in speed of classification. The fastest classification involved the grouping of the two figures with "parallelism" together and the two figures with "nonparallelism" together. The next fastest classification involved grouping of the two figures with curved lines together and the two figures with straight lines together. The slowest classification involved the grouping of the straight-line figure with "parallelism" and the curved-line figure with "nonparallelism" together and the curved-line figure with "parallelism" and the straight-line figure with "nonparallelism" together. Post hoc comparisons for the PE data revealed that the slowest classification was also significantly less accurate than the two other classifications.

GENERAL DISCUSSION

The patterns of performance obtained in Experiments 2 and 3 were not predicted by the pattern of performance obtained in Experiment 1. The classification performance in Experiment 1 showed that the classification that involved grouping of the two curved lines together and the two straight lines together was significantly faster than the classification that involved a mixture of curved and straight lines (given that orientation varied orthogonally to curvature). Assuming that classification performance is a function of intragroup similarity and intergroup dissimilarity, the classification performance in Experiment 1 predicted that a discrimination between a stimulus consisting of curved lines and a stimulus consisting of straight lines should be easier than a discrimination between a pair of stimuli that have similar component lines (either curved or straight lines), and that a classification that involves grouping of the two stimuli consisting of curved lines together and the two stimuli consisting of straight lines together should be easier than a classification that involves grouping together stimuli that differ in their component lines.

Contrary to this prediction, the two most difficult discriminations in Experiment 2 and the two most difficult discriminations in Experiment 3 involved a discrimination between a stimulus consisting of curved lines and a stimulus consisting of straight lines. The two stimuli in each of these pairs differed in component lines but had similar configural property ("closure" in Experiment 2; "parallelism" in Experiment 3).

Moreover, the discrimination between a pair of stimuli that differed in the configural property was equally easy whether or not they differed in component lines. For example, the discrimination between a "closed" figure and an "open" figure, both consisting of curved lines, was as fast as the discrimination between a "closed" figure consisting of straight lines and an "open" figure consisting of curved lines (444 and 448 msec, respectively; see Table 2, discrimination RTs). Similarly, the discrimination between a figure with "parallelism" and a figure with "nonparallelism," both consisting of straight lines, was made as quickly as the discrimination between a figure with "parallelism" and straight lines and a figure with "nonparallelism" and curved lines (487 and 486 msec, respectively; see Table 3, discrimination RTs).

The classification performance obtained in Experiments 2 and 3 also did not follow the prediction derived from the pattern of performance obtained in Experiment 1. Two classifications in Experiment 2 involved the same mixture of curved and straight lines, but they differed in difficulty: one was the easiest classification and one was the most difficult. This held true for the classification performance in Experiment 3. The easiest classification was presumably based on configural properties ("closure" in Experiment 2, "parallelism" in Experiment 3). The classification based on configural properties was significantly easier than the classification that involved the grouping together of stimuli consisting of similar line components.

The present results show clearly that when both configural and component properties are present in the stimuli and can be used for the tasks at hand, discrimination and classification performance is dominated by configural properties, regardless of the discriminability of the component properties. When configural properties are not effective for the task at hand, discrimination and classification can be based on component properties, but there is a significant cost in time relative to performance based on configural properties. Note that the present configurations, unlike those used previously by Kimchi (1994) and Lasaga (1989), do not form any rotational subsets. The present findings, however, con-

Table 3
Mean Reaction Times (RT, in Milliseconds), Percentage of Error Rates (PE), and Standard Deviations (*SD*) for the Discrimination and Classification Tasks in Experiment 3

Task	RT	*SD*	PE	*SD*
Discrimination Tasks				
	528	64.6	3.61	4.87
	502	60.5	3.21	4.28
	492	62.3	3.08	4.60
	487	63.1	3.06	4.04
	486	49.0	2.48	3.86
	479	66.0	2.28	3.54
Classification Tasks				
	625	80.4	7.42	10.25
	546	63.4	4.00	6.43
	504	67.0	2.54	5.30

verge with these previous findings, and thus are seen to support an interpretation in terms of the configural properties involved.

The finding of the perceptual dominance of configural properties is seen to suggest that the human perceptual system may be more sensitive to configural than to component properties. As noted earlier, configural properties are defined as relations among the more elementary components. It is quite possible that the interrelations between the components are more salient to the perceptual system than are the components themselves, and that therefore configural properties are available sooner than component properties (see also Pomerantz & Pristach, 1989).

Classification and discrimination tasks do not necessarily tap earlier representations. Nevertheless, the present results seem to converge with other findings that suggest the availability of higher order and configural properties in early stages of perceptual processing. Recent findings within the visual search paradigm have shown that certain scene-based properties (e.g., Enns & Rensink, 1990; Kleffner & Ramachandran, 1992), part-whole information (Wolfe, Friedman-Hill, & Bilsky, 1994), and configural properties (Kolinsky & Morais, 1986; Treisman & Paterson, 1984) are available to rapid search. Highly relevant to the present study is the recent work of Rensink and Enns (1995), which demonstrated that visual search for Müller-Lyer stimuli was based on the configurations rather than on the component segments that are easily detected in isolation. Rensink and Enns suggested that low-level rapid grouping could account for the formation of units that are accessed by rapid search. It is yet to be determined whether the same processes also account for the configural effects reported here, but the similarity between these effects and those reported by Rensink and Enns is quite striking.

Taken together, these findings seem to suggest that certain configural properties not only dominate performance in information processing tasks, but may also play an important role early in perception.

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