Journal of Experimental Psychology:
Human Perception and Performance

VOL. 11, NO. 6 DECEMBER 1985

Separability and Integrality of Global and Local Levels of Hierarchical Patterns

Ruth Kimchi
University of California, San Diego

Stephen E. Palmer
University of California, Berkeley

We used a constrained classification task to examine the perceptual relations between global and local levels in hierarchical patterns composed of many, relatively small elements and those composed of few, relatively large elements. In Experiments 1 and 3 subjects were asked to make classifications based on "form" or "texture." In Experiments 2 and 4 they were asked to classify according to the "shape" of the configuration or the elements. The results indicate that configural and elemental levels are perceptually separable for many-element patterns when processed as form and texture: Subjects could attend to either level without being affected by variation along the irrelevant dimension. However, when the same many-element patterns were processed for global and local shape, subjects could not selectively attend to either level. For few-element patterns, global configuration and local elements appeared to be perceptually integral dimensions. These results are relevant to two issues: the global precedence hypothesis and the explanations of integral and separable dimensions.

A basic tenet of the Gestalt view of perception is that the whole is different from the sum of its parts and, moreover, that the whole is perceived prior to its parts (Kohler, 1930/1971; Wertheimer, 1925/1950). One aspect of the part–whole relation concerns the perception of global versus local features. Recently it has been proposed that perceptual processing proceeds from global structuring toward analysis of more local detail (Broadbent, 1977; Navon, 1977, 1981).

This global-to-local hypothesis has been tested experimentally by studying the perception of hierarchical patterns in which larger figures are constructed by suitable arrangement of smaller figures. Two levels of pattern structure can be identified in such stimuli: "Local elements" refers to the smaller figures that make up the pattern, and "global configuration" refers to the larger figure constructed from the local elements.

Using a set of converging operations, Navon (1977) demonstrated the perceptual priority of global configurations. The main finding was that conflicting information between the global and the local levels (e.g., a large *H* made up of small *S*s) had an inhibitory influence on responding to the local letter in a Stroop-like interference task, but not to the global letter. Navon and others (e.g., Broadbent, 1977) interpreted these findings as evidence for the

This article is based in part on the doctoral dissertation of the first author at the University of California, Berkeley. The research was supported in part by Grant MH-33103 to the second author and in part by Contract N00014-79-C-0323, NR 667-437 with the Personnel and Training Research Programs of the Office of Naval Research and by a grant from the System Development Foundation to Donald A. Norman and David E. Rumelhart.

We would like to thank Wendell R. Garner, James Cutting, William Banks, and an anonymous reviewer for helpful comments on an earlier version of this article.

Requests for reprints should be sent to Ruth Kimchi, who is now at the Faculty of Industrial Engineering and Management, Technion—Israel Institute of Technology, Technion City, Haifa 32000, Israel.

inevitability of global precedence in visual perception.

Other researchers have questioned the generality of Navon's claim (e.g., Hoffman, 1980; Kinchla & Wolfe, 1979; Martin, 1979; McClean, 1979; Miller, 1981; Pomerantz & Sager, 1975), demonstrating important boundary conditions of the phenomenon and pointing out some variables that can affect global versus local superiority. However, all of these researchers seem to share two assumptions with Navon: (a) There are two perceptual levels corresponding directly to the global configuration and local elements, and (b) the critical question is which level gets processed first.

The validity of the first assumption was examined in our previous work (Kimchi, 1983; Kimchi & Palmer, 1982). We used the terms *global configuration* and *local elements* to refer to distinct levels of *geometrical structure in the stimulus domain.* Whenever hierarchical patterns are constructed, these two geometrical levels are present, regardless of the number or relative size of the elements. In the psychological domain, however, this may not be true. In particular, we suggested that the *perceptual* entities of "form," "texture," and "figural parts," bear a complex relation to the *stimulus* dimensions of "global" and "local" levels of structure as defined above.

Previous studies with patterns composed of different numbers and relative sizes of local elements (Goldmeier, 1936/1972; Kimchi, 1983; Kimchi & Palmer, 1982) suggest that the mapping of geometrical levels in the stimulus domain into perceptual levels of the psychological domain differs for patterns composed of many small elements and those composed of a few large elements in the following way: When many small elements comprise a pattern, the local elements are processed as texture and the global configuration as form. However, when few large elements comprise a pattern, both the local and the global levels are processed as form. The elements in such patterns are perceived as figural parts of the overall form. We hypothesized that the difference between these two cases lies in the relative perceptual *separation* between the two levels of pattern structure. For instance, the global configuration and the local elements of patterns composed of many and/or relatively small elements seem to be phenomenologically separable in the following sense: Replacing the elements of such patterns by other elements does not affect the perception of its global form. This phenomenal separation does not seem to exist in patterns composed of a few relatively large elements: Replacing the elements of such patterns by other elements does seem to affect the perception of its form. This suggests that these two types of patterns—those containing many small elements and those containing a few large ones—might differ in their dimensional integrality/separability as defined by Garner (1974).

Garner (1974) used several converging experimental operations to distinguish between integral and separable dimensions. Stimuli varying along integral dimensions are perceived as unitary entities, whereas those varying along separable dimensions are perceived in terms of distinct dimensions or attributes. One critical method used to differentiate between the two kinds of dimensional relations is the constrained classification paradigm (Garner, 1974, 1978). Subjects are required to classify stimuli according to one stimulus dimension. Performance on conditions in which the irrelevant dimension varies is compared to the control condition in which only the relevant dimension varies in order to examine the facilitative and interfering effects of variation on the irrelevant dimension. Integral dimensions are those that produce an increase in speed of discrimination and an improvement in accuracy when combined redundantly, and a decrease in speed of discrimination and an impairment in accuracy when combined orthogonally. One such pair would be the height and width of rectangles. Separable dimensions are those that produce no facilitation when combined redundantly and no interference when combined orthogonally. Such a pair would be form and color. The present experiments were designed to test the perceptual integrality/separability of the configural and elemental levels when the number and the relative size of the elements vary. Our previous conclusions lead us to predict that the perceptual levels of form and texture will be separable—like form and color—when there are many small elements, but not when there are few large elements.

Understanding the perceptual interactions between the global and local levels of pattern structure has two important implications. The first concerns the global precedence hypothesis. As Navon (1977, 1981) pointed out, global precedence cannot be tested unless the perceptual units are known. To answer the question of whether a local element constitutes a perceptual unit of the compound pattern, Navon appealed to "our common sense reinforced by our knowledge of Gestalt laws of organization" (Navon, 1981 p. 27). Because the local elements in hierarchical patterns clearly can be perceived as separate entities, they qualify, according to Navon, as perceptual constituents as well. However, both Goldmeier's (1930/1972) studies and ours (Kimchi, 1983; Kimchi & Palmer, 1982) strongly suggest that the perceptual role of the local element in many-element patterns is different from its role in few-element patterns, although Navon's criterion applies equally to both cases. The present experiments are designed to test the hypothesis that the configural and elemental levels bear different perceptual relations to each other when there are many small versus a few large constituents. Indeed, it may be argued that the relations between the configural and elemental levels play a role in defining the nature of the perceptual units in a compound stimulus.

The second implication concerns the relative explanatory power of stimulus structure versus the internal processing of that structure in accounting for performance on the classification task. Garner (1974) emphasized the importance of stimulus structure. When his stimulus theory is applied to the present case, hierarchical patterns have stimulus structure with a clear logical asymmetry, because "an element can exist in isolation without configuration, but any configuration must by definition be constructed from elements" (Pomerantz & Sager, 1975, p. 461). These logical relations hold for both few- and many-element patterns, and they predict a unidirectional interaction between the global and the local levels. Thus any difference in the interaction between the two levels due to number and relative size of the elements will require an explanation in terms of perceptual processing rather than dimensional structure in the stimulus per se.

Experiment 1

A speeded classification paradigm with a discrete reaction time procedure was employed for two types of patterns: those composed of a few relatively large elements and those composed of many relatively small elements. Subjects were instructed to discriminate the patterns in terms of the dimensions of form and texture. If the global configuration and the local elements of many-element patterns are separable when processed as form and texture, there should be no improvement in discrimination speed when the two are combined redundantly, and no loss in discrimination speed when they are combined orthogonally. On the other hand, if the global configuration and the local elements of patterns composed of a few relatively large elements are not separable when processed as form and texture, they should produce a redundancy gain when the two are combined in a correlated manner, and interference when they are combined orthogonally.

Method

Subjects. Eight females and 4 males from 18 to 35 years old with normal vision served as subjects.

Stimuli. Two sets of four patterns each were created by orthogonally combining two types of global configurations (square and rectangle) with two types of local elements (black-and-white squares and black-and-white rectangles). The two sets differed with respect to the number and relative size of the elements in the pattern. One set—the *many-element set*—consisted of patterns made up of 15, 29, 81, and 85 elements. The square elements were arranged in a checkerboard design; the rectangle elements were arranged in a grating design. The other set—the *few-element set*—consisted of patterns made up of 3, 4, 5, and 7 relatively large elements arranged in a similar way, so that they can be viewed as magnification of a small area of the patterns in the many-element set. The stimuli in the two sets are presented in Figure 1. The drawings were made into slides and back-projected to subjects seated about 60 cm from the screen. From this position the global square subtended 2.09° of visual angle in the many-element patterns, and 2.79° in the few-element patterns. The global rectangle subtended 3.97° in width and 1.04° in height in the many-element patterns, and 3.97° in width and 1.33° in height in the few-element patterns. Each individual square element subtended 0.23° in the many-element pattern, and 1.33° in the few-element pattern. Each individual rectangle element subtended 0.17° in width in the many-element patterns, and 0.57° in width in the few-element patterns. (The height of the individual rectangle was equal to the height of the global configuration in which it was embedded.) The stimuli were presented to the subjects one at a time.

Design. The experiment employed a completely within-subjects, three-factor design: pattern type (few-element and many-element), criterial dimension (form and texture), and task. All factors were combined orthogonally. The tasks included two single-dimension tasks, two correlated-dimensions tasks, and one orthogonal-dimensions task. The *single-dimension task* required speeded discrimination between just two stimuli that varied on only one dimension, while the other (irrelevant) dimension was held constant at each of its two levels. When form was the relevant dimension, one single-dimension task involved the Stimulus Subsets a and b, and the second single-dimension task involved the Stimulus Subsets c and d. When texture was the relevant dimension, one single-dimension task used the Stimulus Subsets a and c, and the second single-dimension task used the Subsets b and d. The *correlated-dimensions task* required discrimination between just two stimuli that varied on both dimensions in a correlated fashion. One correlated-dimensions task involved the Stimulus Subsets a and d, and the second correlated-dimensions task involved the Stimulus Subsets b and c. In the *orthogonal-dimensions task* the two dimensions varied independently. This task required discrimination among all four stimuli in the set on the basis of the relevant dimension, ignoring the irrelevant one.

Each task consisted of one block of 32 trials, with each stimulus in the subset occurring an equal number of trials. Because the orthogonal condition involved four stimuli, whereas the other conditions involved two, there were two blocks of orthogonal-dimensions tasks differing only in the random ordering of trials within each block.

All tasks occurred in a different random order for each criterial dimension and for each subject. Half of the subjects were presented first with the few-element set and then with the many-element set; the other half of the subjects received the reverse order. The criterial dimensions were administered in different sessions within each set. The order of the criterial dimensions was counterbalanced across subjects.

Procedure. Subjects were presented with the stimuli, and the two dimensions were defined: global form and its two levels—"square" and "rectangle"—and texture and its two levels—"checkerboard" and "grating." Subjects were instructed to attend to one dimension while ignoring the other, and to decide which of its two levels was present in the stimulus. Responses were made by pressing the leftmost key (for square and checkerboard) or the rightmost key (for rectangle and grating) on a six-key response panel. Subjects were to respond with the index finger of their left and right hands as quickly as possible while making as few errors as possible. Feedback about the correct response was provided by presenting a light briefly over the appropriate key as soon as the subject responded. Error trials for each block were retaken at the end of that block.

The sequence of events for each trial was as follows. First, a fixation dot appeared at the center of the screen for 500 ms. After a 500-ms interval, the stimulus appeared and stayed on until the subject responded. At this time a feedback light came on above the correct key for 1,500 ms. The next trial began with the appearance of the fixation dot 3 s after the previous response.

At the start of each criterial dimension session, subjects received 12 practice trials composed of three occurrences of each stimulus in the set of patterns. In addition, 12 practice trials were given at the start of each task block, so that subjects could familiarize themselves with the particular subset of stimuli to be used in this block. There was

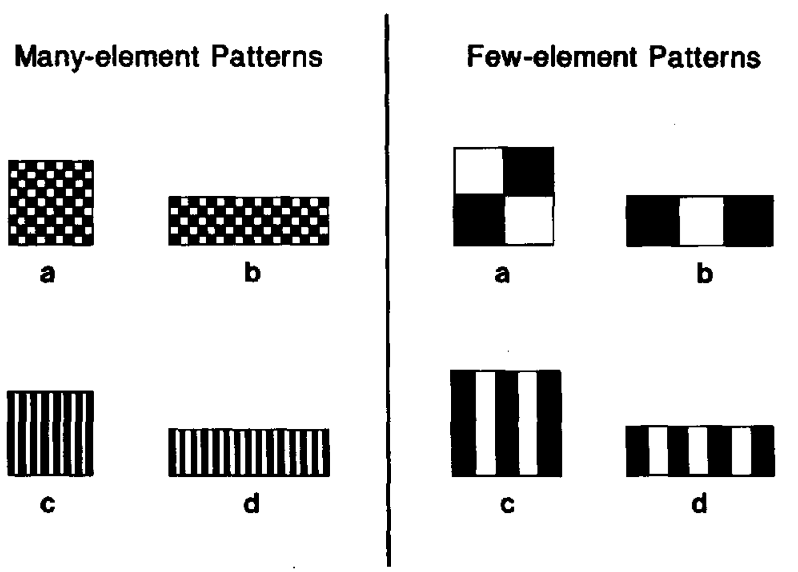

Figure 1: The two sets of patterns used in Experiments 1 and 2: The few-element set and the many-element set.

a rest period of 5 min between the two session within a set, and a 10-min break between the two sets. Altogether the experiment lasted about 2 hr.

Results and Discussion

Mean reaction times and percentage errors for the different tasks for the two sets are presented in Table 1. Reaction times and percentage errors for the two single-dimension tasks have been pooled within each criterial dimension because the two were formally equivalent. Reaction times and percentage errors for the two correlated-dimension tasks also have been pooled within each criterial dimension for the same reason.

The reaction time data were first analyzed by a three-factor repeated measures analysis of variance (ANOVA). The three factors were type of pattern, criterial dimension, and task. The analysis indicated a significant effect of task, $F(2, 22) = 12.052$, $p < .001$. There was no significant difference between few- and many-element patterns ($F < 1$) and no significant difference between the two dimensions, $F(1, 11) = 2.663$, $p > .10$. The interaction between pattern types and tasks was significant $F(2, 22) = 4.096$, $p < .04$. The interaction between pattern types and dimensions ($F < 1$), the interaction between dimensions and tasks, $F(2, 22) = 2.259$, $p > .10$, and the three-way interaction between patterns, dimensions, and tasks ($F < 1$) were not significant. Because the interaction between types of patterns and tasks was significant, the few-element patterns data and the many-element patterns data were analyzed separately.

Few-element patterns. A two-factor repeated measures ANOVA (Dimension × Task) showed a significant effect of task, $F(2, 22) = 14.509$, $p < .001$. There was no significant effect of dimension ($F < 1$) and no significant interaction between dimensions and tasks, $F(2, 22) = 2.281$, $p > .10$.

Form discrimination and texture discrimination did not differ significantly when each dimension was used alone (i.e., in the single-dimension task) ($F < 1$). Thus, the dimensions of form and texture were equally discriminable. The single-dimension tasks provided a baseline performance for each of the two dimensions. A set of two planned comparisons was performed: Performance on the correlated-dimensions task was compared to that on the single-dimension task to see whether the redundancy provided by the irrelevant dimension increased the speed of discrimination. Performance on the orthogonal-dimensions task was compared to that on the single-dimension task to see whether irrelevant variation decreased the speed of discrimination. These comparisons were assessed by F tests, using the Comparison × Subject interaction as the error term (see Keppel, 1973).

The results of the planned comparisons showed that when form and texture were combined redundantly, there was a significant gain in speed of discrimination, averaging 12 ms, $F(1, 11) = 9.026$, $p < .02$. When form and texture were combined orthogonally, there was a significant loss in speed of discrimination, averaging 20 ms, $F(1, 11) = 11.169$, $p < .01$.

Many-element patterns. The results of the ANOVA showed no significant effect of task ($F <$

Table 1
Mean Reaction Times (in ms) and Percentage Errors (PE) in Experiment 1

Criterial dimension	Task dimension: Single	PE	Correlated	PE	Orthogonal	PE
			Many-element			
Form	389	5.33	397	4.43	399	5.72
Texture	407	4.29	396	4.70	409	4.81
			Few-element			
Form	395	4.68	386	2.99	410	5.59
Texture	399	3.12	385	3.39	424	4.03

1), no significant effect of dimension ($F < 1$), and no significant interaction between dimensions and tasks, $F(2, 22) = 1.370$, $p > .25$. Once again, form and texture did not differ significantly in discriminability, $F(1, 11) = 3.141$, $p > .10$. None of the planned comparisons yielded a significant result: There was no significant gain in speed of discrimination when form and texture were combined redundantly ($F < 1$) and no significant loss in speed of discrimination when form and texture were combined orthogonally ($F < 1$). Thus, it is the difference in the facilitation and interference effects between few- and many-element patterns that accounts for the significant interaction between pattern types and tasks noted above.

Error analysis. The error rates data showed similar effects to those of the reaction time (RT) effects, but the error rates differences were less reliable, and none of them reached statistical significance. However, they do suggest no speed–accuracy trade-off.

Thus, few-element and many-element patterns yielded reliably different patterns of results. Form and texture of many-element patterns seem to be separable dimensions by Garner's (1974) criteria: They permit selective attention to either dimension without interference from variation on the other, and showed no improvement in discrimination speed when there was a correlated variation along the irrelevant dimension. This is perhaps not too surprising in light of the fact that form and color are separable; texture seems to play much the same role as color when there are sufficiently many small local elements. On the other hand, form and texture of few-element patterns showed both interference and facilitation effects: Form and texture were discriminated more slowly when there was orthogonal variation along the other, irrelevant dimension, and they were discriminated more quickly when there was correlated variation along the irrelevant dimension. Thus, form and texture of few-element patterns seem to be perceptually integral dimensions. The integrality of form and texture appears to be slightly asymmetrical: The amount of redundancy gain was larger by 5 ms in texture discrimination than in form discrimination, and the amount of orthogonal interference was larger by 10 ms in texture discrimination than in form discrimination. However, none of these asymmetrical effects reached significance ($F < 1$, $p > .25$, respectively).

A secondary but interesting issue concerns the effect of congruity of identity (or content) between the configural and elemental levels. Two of the four stimuli in a set contain the same shape at both configural and elemental levels (Stimuli a and d; note, however, that it is more so for Stimulus a than for Stimulus d, where the global and the local shapes differ in orientation), whereas the other two contain different shapes (Stimuli b and c). Although the dimensional instructions did not call for shape identification on both levels, Stimuli a and d can be considered as congruent and Stimuli b and c as incongruent with respect to the identity at the two levels. Incongruity between the two levels might produce Stroop-type interference. To examine the effect of incongruity on performance, two analyses were performed. One was concerned with the difference between the performance on the two correlated-dimensions tasks because one of the correlated-dimensions task involved only congruent stimuli, whereas the other one involved only incongruent stimuli. (Mean latencies are presented in the middle column of Table 2.) A three-factor repeated measures ANOVA (Pattern × Dimension × Task) showed no significant difference between the two tasks, $F(1, 11) = 4.200$, $p > .05$; no significant interaction between patterns and tasks ($F < 1$); no significant interaction between dimensions and tasks ($F < 1$); and no significant three-way interaction between patterns, dimensions, and tasks ($F < 1$). Thus, the congruity/incongruity of identity between the two levels did not seem to affect performance on these two tasks.

In the second analysis, RT data of the single-dimension and the orthogonal-dimensions tasks were analyzed for responses to congruent and conflicting stimuli (the mean reaction times are presented in Table 2). A four-factor repeated measures ANOVA (Pattern × Dimension × Task × Congruity) showed no significant effect of congruity ($F < 1$). The only significant interaction was the Pattern × Dimension × Congruity interaction, $F(1, 11) = 6.327$, $p < .05$, which is accounted for by some small and nonsignificant amount of interference from incongruent textural elements in the orthogonal-dimensions task with the many-ele-

Table 2
Mean Reaction Times (in ms) to Congruent (CG) and Conflicting (CF) Stimuli in Experiment 1

Criterial dimension	Task dimension					
	Single		Correlated		Orthogonal	
	CG	CF	CG	CF	CG	CF
Many-element						
Form	390	389	396	398	393	404
Texture	410	404	390	402	411	407
Few-element						
Form	396	393	383	389	414	406
Texture	401	398	376	395	422	426

ment patterns, whereas there was no incongruity interference with the few-element patterns in either dimension ($F < 1$). Taken together, these results suggest that incongruity of identity (or content) between the configural and elemental levels did not have a significant interference effect on performance.

Note that according to previous analysis of hierarchical patterns (Goldmeier, 1936/1972; Kimchi, 1983; Kimchi & Palmer, 1982), the structure of many-element patterns is perceived in terms of form and texture. The local elements of such patterns are processed in aggregation as texture, although it is possible, of course, to process them separately for their shape. On the other hand, patterns composed of a few, relatively large elements are perceived in terms of form and figural parts. That is, the elements of such patterns are perceived as individuated parts of the global form that are not independent of it. Thus, we would claim that the few-element patterns in the present experiment do not really have "texture" per se, because many small elements seem to be required for separability of form and texture. The instructions were given in terms of texture in order to eliminate any instructional differences between the two sets of patterns. Therefore, the results for the few-element patterns can be restated as follows: *Global form* and *local elements* of few-element patterns seem to be integral dimensions.

Experiment 2

The previous analysis suggests that changing the task so that it will require identification of the local shape will not affect the pattern of results for the few-element stimuli. However, it might affect the pattern of results for the many-element stimuli, because we assume that the local elements of many-element stimuli are "naturally" processed as texture. Demanding that the local elements be processed in terms of their shape might require refocusing attentional mechanisms and thereby affect the interaction between the configural and elemental levels. The present experiment was designed to study the effect of this different task demand on the integrality/separability of these two levels.

Method

Subjects. Four females and 8 males from 18 to 34 years of age with normal vision served as subjects.

Stimuli. The stimuli were the same as in the previous experiment except for their sizes. Subjects were seated about 110 cm from the screen. From this position the global square subtended 1.40° of visual angle in the many-element patterns, and 1.77° in the few-element patterns. The global rectangle subtended 2.60° in width and 0.78° in height in the many-element patterns, and 2.60° in width and 0.94° in height in the few-element patterns. Each individual square element subtended 0.16° in the many-element patterns, and 0.94° in the few-element patterns. Each individual rectangle subtended 0.10° in width in the many-element patterns, and 0.42° in width in the few-element patterns. The height of the individual rectangle was equal to the height of the global configuration in which it was embedded. (Notice that although the present stimuli were only about two thirds as large as those in Experiment 1, they are all well within the range that others have used to study global versus local processing questions with no variable effect of size.)

Design and procedure. The design and procedure were the same as in the previous experiment. The only difference was that in the present experiment subjects were instructed to discriminate the criterial dimensions of the shape of global configuration with square and rectangle as its two levels, and the shape of local elements with square and rectangle as its two levels.

Results and Discussion

Dimensional interaction. Mean reaction times and error rates for the different tasks for the two sets are presented in Table 3.

A three-factor repeated measures ANOVA (Pattern × Dimension × Task) was performed on the reaction time data. The analysis showed a significant effect of task, $F(2, 22) = 11.625$, $p < .001$. There was no significant effect of dimension, $F(1, 11) = 1.543$, $p > .20$, and no significant effect of pattern ($F < 1$). None of the interactions reached significance: Pattern ×

Table 3
Mean Reaction Times (in ms) and Percentage Errors (PE) in Experiment 2

Criterial dimension	Task dimension					
	Single	PE	Correlated	PE	Orthogonal	PE
			Many-element			
Configuration	402	3.64	408	4.16	418	4.29
Elements	400	3.51	402	4.55	422	4.81
			Few-element			
Configuration	409	3.64	401	3.58	421	3.90
Elements	396	4.29	386	4.03	416	5.59

Dimension interaction, $F < 1$; Pattern × Task interaction, $F(2, 22) = 2.495$, $p > .10$; Dimension × Task interaction, $F(2, 22) = 1.201$, $p > .30$; and Pattern × Dimension × Task interaction ($F < 1$).

The global and the local shape of the few-element patterns did not differ significantly in discriminability, $F(1, 11) = 3.055$, $p > .10$. The results of the planned comparisons indicated a significant gain in speed of discrimination, averaging 9 ms, when the dimensions were combined redundantly, $F(1, 11) = 13.620$, $p < .005$, and a significant loss in speed of discrimination, averaging 16 ms, when the dimensions were combined orthogonally, $F(1, 11) = 17.714$, $p < .001$. There was a slight, though nonsignificant, asymmetry in the dimensional interaction: The amount of orthogonal interference was larger by 8 ms in elements discrimination than in configuration discrimination.

The global and local shape of the many-element patterns were also equally discriminable ($F < 1$). The results of the planned comparisons indicated no increase in speed of discrimination when global configuration and local elements were combined redundantly ($F < 1$). When global configuration and local elements were combined orthogonally, there was a significant loss in speed of discrimination, averaging 19 ms, $F(1, 11) = 6.023$, $p < .04$.

Error analysis. As in the previous experiment, the error rates data showed similar effects to those of the reaction time effects, but none of the error rates differences reached statistical significance. Once again, however, they suggest no speed–accuracy trade-off.

The results of few-element patterns in the present experiment replicated those of the previous experiment, suggesting that the processing of these patterns was not affected by the dimensions defined by the experimenter. The global configuration and the local elements of the few-element patterns seem to be perceptually integral dimensions. These results are consistent with the hypothesis that few-element patterns are processed in terms of their overall form and its figural parts.

The demand to discriminate local shape rather than texture affected the pattern of results for the many-element patterns. Although the results of the previous experiment suggested complete perceptual separability between the global configuration and the local elements when the latter are processed as texture, the present results suggest some interaction between the two when the elements are processed as individual shapes. Neither the global shape nor the local shape could be selectively attended without interference from variation along the other, irrelevant dimension. Note, however, that the global configuration and local elements are not integral dimensions because they fail to produce redundancy gain in the correlated-dimensions conditions.

Incongruity effect. The task in the previous experiment did not call for shape identification on the two levels, and the results indicated no incongruity effects. On the other hand, the task in the present experiment called for identifying the shapes on both levels and thus for a potential conflict between implicit responses.

A three-factor repeated measures ANOVA (Pattern × Dimension × Task) was performed on the RT data of the two correlated-dimensions tasks (mean latencies are presented in

Table 4). The analysis showed no significant difference between the two tasks ($F < 1$), and none of the interactions reached significance: The Pattern × Type interaction ($F < 1$); the Dimension × Task interaction, $F(1, 11) = 3.059$, $p > .10$; and the Pattern × Dimension × Task interaction $F(1, 11) = 2.593$, $p > .10$.

The mean reaction time to congruent and incongruent stimuli in the single-dimension and in the orthogonal-dimensions tasks are presented in Table 4. A four-factor repeated measures ANOVA (Pattern × Dimension × Task × Congruity) showed no significant effect of congruity ($F < 1$). The Pattern × Congruity interaction, and the Task × Congruity interaction did not reach significance, $F(1, 11) = 4.082$, $p > .05$, and $F(1, 11) = 4.703$, $p > .05$, respectively. The three-way interaction Pattern × Task × Congruity was significant, $F(1, 11) = 6.463$, $p < .05$, and therefore the few-element patterns and the many-element patterns data were analyzed separately. Analysis of the few-element patterns data showed no significant effect of congruity, $F(1, 11) = 2.547$, $p > .10$; no significant interaction between dimensions and congruity ($F < 1$); no significant interaction between tasks and congruity ($F < 1$); and no significant Dimension × Task × Congruity interaction, ($F < 1$). The analysis of the many-element patterns data showed no significant effect of congruity, $F(1, 11) = 2.905$, $p > .10$, but a significant interaction between tasks and congruity, $F(1, 11) \times 8.626$, $p < .020$. There was a significant difference between response times to congruent and conflicting stimuli, averaging 13 ms, in the orthogonal-dimensions task only, $F(1, 11) = 8.573$, $p < .025$.

Thus, the results with the few-element patterns clearly indicate the presence of dimensional interaction, but the absence of incongruity effects: *Variation* along the irrelevant dimension was hard to ignore, but the specific *identity* of the irrelevant dimension did not seem to affect processing of the relevant dimension. On the other hand, the results with the many-element patterns indicate that both variation along the irrelevant dimension and the identity of the irrelevant dimension were hard to ignore and seem to affect processing of the relevant dimension. These results agree with those of Pomerantz (1983, Experiment 2). Using compound letters as stimuli and presenting them with positional certainty, Pomerantz found significant orthogonal interference, significant Stroop-type interference, and no significant asymmetry in both interference effects.

Table 4
Mean Reaction Times (in ms) to Congruent (CG) and Conflicting (CF) Stimuli in Experiment 2

Criterial dimension	Task dimension: Single CG	Single CF	Correlated CG	Correlated CF	Orthogonal CG	Orthogonal CF
Many-element						
Configuration	403	401	396	420	415	420
Elements	404	397	406	398	412	432
Few-element						
Configuration	409	409	396	406	424	418
Elements	398	394	386	386	417	415

Experiments 3 and 4

The goal of Experiments 3 and 4 is to determine the generalizability over stimuli of the separability/integrality of the global and local dimensions of many- and few-element patterns. This is of particular importance because the results of Experiments 1 and 2 yielded statistically reliable but small effects. Thus the next two experiments attempted to replicate the previous results with a different set of stimuli.

Method: Experiment 3

Subjects. Five females and 7 males from 18 to 33 years of age with normal vision served as subjects.

Stimuli. Two sets of four patterns each were created by orthogonally combining two types of global configuration (square and rectangle) with two types of local elements (squares and rectangles). The many-element set consisted of patterns made up of 16 elements, and the few-element set consisted of patterns made up of 4 elements. The stimuli in the two sets are presented in Figure 2. The drawings were made into slides and back-projected to subjects seated about 110 cm from the screen. From this position the global square subtended 1.20° of visual angle, and the global rectangle subtended 2.39° in width and 0.55° in height. Each individual square element subtended 0.25° in the many-element patterns, and 0.50° in the few-element patterns. Each individual rectangle element subtended 0.55° in width and 0.10° in height in the many-element patterns, and 1.20° in width and 0.20° in height in the few-element patterns.

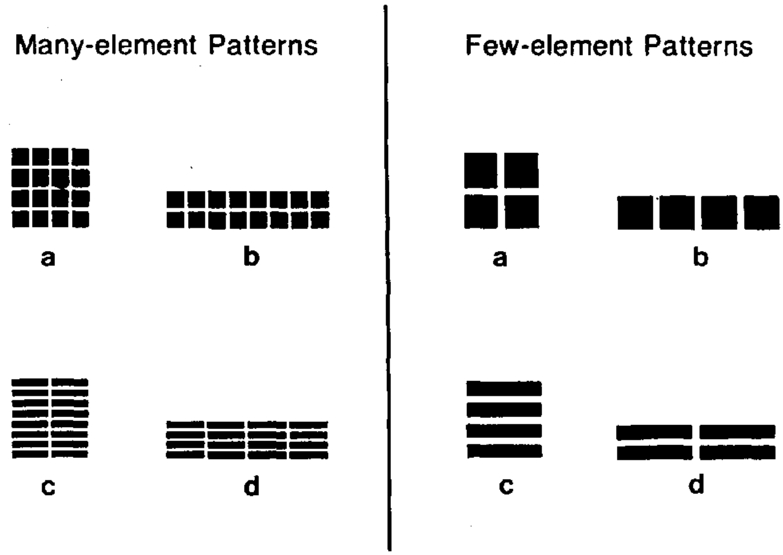

Figure 2: The two sets of patterns used in Experiments 3 and 4.

Design and procedure. The design and procedure were the same as in Experiment 1. The two levels of the texture dimension were defined as "regular" (the square element texture) and "elongated" (the rectangular element texture).

Results: Experiment 3

Dimensional interaction. Mean reaction times and percentage errors for the different tasks for the two sets are presented in Table 5. A three-factor repeated measures ANOVA indicated a significant difference between few-element and many-element patterns, $F(1, 11) = 8.660$, $p < .02$, and a significant difference among the three tasks, $F(2, 22) = 21.454$, $p < .001$. There was no significant difference between the two criterial dimensions, ($F < 1$). The interaction between pattern types and tasks was significant, $F(2, 22) = 3.44$, $p < .05$. The Pattern × Dimension interaction and the Dimension × Task interaction were not significant, $F(1, 11) = 2.192$, $p > .10$, and $F < 1$, respectively. The three-way interaction Pattern × Dimension × Task was also not significant, $F(2, 22) = 2.532$, $p > .10$. Because the interaction between types of patterns and tasks was significant (as in Experiment 1), the few-element patterns data and the many-element patterns data were analyzed separately.

The analysis of the few-element patterns showed a main effect of task, $F(2, 22) = 13.158$, $p < .001$, no significant effect of dimension ($F < 1$), and no significant interaction

Table 5
Mean Reaction Times (in ms) and Percentage Errors (PE) in Experiment 3

Criterial dimension	Task dimension					
	Single	PE	Correlated	PE	Orthogonal	PE
			Many-element			
Form	409	4.42	416	3.51	412	4.03
Texture	421	4.29	414	4.16	430	6.64
			Few-element			
Form	395	4.03	389	3.64	420	3.38
Texture	386	3.90	384	2.99	403	4.03

between tasks and dimensions ($F < 1$). Form and texture were equally discriminable ($F < 1$). The planned comparisons indicated that when form and texture were combined orthogonally, there was a significant loss in speed of discrimination, averaging 21 ms, $F(1, 11) = 26.277, p < .001$. There was no significant gain in speed of discrimination when the two dimensions were combined redundantly ($F < 1$). However, a closer examination of the data showed that there was a significant gain in speed of discrimination, averaging 24 ms, in the "positively" correlated-dimensions task, $F(1, 11) = 5.849, p < .05$, but not in the "negatively" correlated-dimensions task, $F(1, 11) = 1.503, p > .20$. These results suggest the presence of two factors in the present experiment: Dimensional interaction and incongruity effect. The analysis of the latter is reported below.

The analysis of the many-element patterns showed no significant effect of task, $F(2, 22) = 1.283, p > .10$; no significant effect of dimension, $F(1, 11) = 2.241, p > .10$; and no significant interaction between dimensions and tasks, $F(2, 22) = 2.342, p > .10$. Form and texture were equally discriminable, $F(1, 11) = 1.405, p > .25$. The results of the planned comparisons showed no reliable redundancy gain in the correlated-dimensions task, $F < 1$, neither in the positively correlated-dimensions task, $F(1, 11) = 7.942, p < .05$. The error rate negatively correlated-dimensions task, $F(1, 11) = 1.421, p > .25$, and no reliable orthogonal interference, $F(1, 11) = 1.656, p > .20$. These results indicate once again the separability of form and texture in many-element patterns.

Error analysis. The error rate data showed similar effects to those of the RT effects, although not all error differences reached statistical significance. There was a significant effect of tasks in the few-element patterns, $F(3, 33) = 5.918, p < .01$, and the planned comparisons indicated a significant improvement in accuracy in the positively correlated-dimensions task, $F(1, 11) = 7.942, p < .05$. The error rate data for the many-element patterns did not show a significant effect of task, $F(3, 33) = 1.639, p > .15$, and none of the planned comparisons yielded a significant result.

Incongruity effect. The response times to congruent and conflicting stimuli in the three tasks are presented in Table 6. The four-factor

Table 6
Mean Reaction Times (in ms) to Congruent (CG) and Conflicting (CF) Stimuli in Experiment 3

	Task dimension					
	Single		Correlated		Orthogonal	
Criterial dimension	CG	CF	CG	CF	CG	CF
	Many-element					
Form	404	415	408	426	405	419
Texture	429	412	406	424	417	442
	Few-element					
Form	390	401	370	408	413	427
Texture	391	381	380	388	401	405

repeated measures ANOVA, testing the incongruity effect in the single-dimension task and in the orthogonal-dimensions task, showed a significant effect of incongruity, $F(1, 11) = 5.065, p < .05$; a significant interaction between dimensions and incongruity, $F(1, 11) = 14.227, p < .005$; a significant interaction between tasks and incongruity, $F(1, 11) = 9.140, p < .020$; and a significant Dimension × Task × Incongruity interaction. $F(1, 11) = 11.084, p < .005$. The results of the few-elements patterns showed a significant interaction between dimensions and incongruity, $F(1, 11) = 12.042, p < .005$. The effect of inconsistency between the configural and elemental level was inhibitory on the response to form, averaging 13 ms, $F(1, 11) = 15.243, p < .005$, but not to texture ($F < 1$). With the many-element patterns there was a significant incongruity effect, $F(1, 11) = 5.794, p < .05$; a significant Task × Incongruity interaction, $F(1, 11) = 12.133, p < .005$; and a significant Dimension × Task × Incongruity interaction, $F(1, 11) = 7.376, p < .020$. There was a mutual inhibitory effect in the orthogonal-dimensions task, averaging 20 ms, $F(1, 11) = 13.913, p < .005$. Incongruity in the single-dimension task had a small inhibitory effect on the response to form, but a facilitatory effect on the response to texture (*ns*).

The three-factor repeated measures ANOVA, testing the difference between the positively correlated-dimensions task and the negatively correlated-dimensions task, showed a significant difference between the two tasks, (averaging 23 ms in the few-element set and 18 ms

Table 7
Mean Reaction Times (in ms) and Percentage Errors (PE) in Experiment 4

Criterial dimension	Task dimension					
	Single	PE	Correlated	PE	Orthogonal	PE
			Many-element			
Configuration	431	2.14	439	2.34	450	2.92
Elements	437	3.51	440	2.83	456	1.95
			Few-element			
Configuration	431	3.32	420	1.95	455	2.14
Elements	433	2.52	429	2.48	443	1.75

in the many-element set) $F(1, 11) = 7.637$, $p < .02$. There was no significant interaction between dimensions and tasks, $F(1, 11) = 1.311$, $p > .30$, and no significant Pattern × Dimension × Task interaction, $F(1, 11) = 2.213$, $p > .15$.

Method: Experiment 4

Subjects. Eight females and 8 males from 18 to 33 years of age with normal vision were paid to serve as subjects.

Stimuli. The stimuli were the same as in Experiment 3 except for their sizes. Subjects were seated about 60 cm from the screen. From this position the global square subtended 1.81° of visual angle and the global rectangle subtended 3.81° in width and 0.81° in height. Each individual square element subtended 0.76° and 0.38° in the few-element and the many-element patterns, respectively. Each individual rectangle element subtended 1.81° in width and 0.29° in height in the few-element patterns, and 0.86° in width and 0.17° in height in the many-element patterns.

Design and procedure. The design and procedure, including dimensional instructions, were the same as in Experiment 2.

Results: Experiment 4

Dimensional interaction. Mean reaction times and percentage errors for the different tasks for the two sets are presented in Table 7. The ANOVA performed on the RT data showed a significant effect of task, $F(2, 30) = 13.459$, $p < .001$. There was no significant effect of pattern ($F < 1$), and no significant effect of dimension ($F < 1$). None of the two-way interactions was significant: Pattern × Task interaction, $F(2, 30) = 1.720$, $p > .15$; Dimension × Task interaction, $F < 1$; Pattern × Dimension interaction, $F < 1$. The Pattern × Dimension × Task interaction was also not significant, $F(2, 30) = 1.209$, $p > .30$.

The global and the local shape of the few-element patterns was equally discriminable ($F < 1$). The results of the planned comparisons indicated a significant amount of orthogonal interference, averaging 17 ms, $F(1, 15) = 12.919$, $p < .005$, and a significant amount of redundancy gain, averaging 8 ms, $F(1, 15) = 6.127$, $p < .05$. These results suggest once again that the global configuration and the local elements of the few-element patterns are integral dimensions.

The global and the local shape of the many-element patterns also did not differ in discriminability ($F < 1$). The results of the planned comparisons indicated a significant amount of orthogonal interference, averaging 19 ms, $F(1, 15) = 6.886$, $p < .020$. There was no gain in speed of discrimination when global configuration and local elements were combined redundantly ($F < 1$).

Error analysis. As in the previous experiments, the error rate data showed similar effects to those of the RT effects, but most of the error differences did not reach statistical significance. There was a significant improvement in accuracy in the positively correlated-dimension task with the few-element patterns, $F(1, 15) = 5.461$, $p < .05$. There was no significant improvement or impairment in accuracy with the many-element patterns.

Incongruity effect. Mean reaction times to congruent and conflicting stimuli in the three tasks are presented in Table 8. The four-factor ANOVA, testing the incongruity effect in the single-dimension and the orthogonal-dimensions tasks, showed a significant effect of incongruity, $F(1, 15) = 5.147$, $p < .05$, and a significant interaction between tasks and in-

Table 8
Mean Reaction Times (in ms) to Congruent (CG) and Conflicting (CF) Stimuli in Experiment 4

Criterial dimension	Task dimension					
	Single		Correlated		Orthogonal	
	CG	CF	CG	CF	CG	CF
Many-element						
Configuration	430	432	433	445	437	463
Elements	437	437	441	439	438	462
Few-element						
Configuration	433	429	412	428	441	469
Elements	423	442	427	431	425	460

congruity, $F(1, 15) = 13.872$, $p < .01$. Conflicting identity between the configural and the elemental levels had a mutual inhibitory effect, averaging 31 ms, in the orthogonal-dimensions tasks only with the few-element patterns, $F(1, 15) = 17.311$, $p < .001$, and a mutual inhibitory effect, averaging 25 ms, in the orthogonal-dimensions task with the many-element patterns, $F(1, 15) = 11.956$, $p < .01$.

The three-factor ANOVA, testing the difference between the positively correlated-dimensions task and the negatively correlated-dimensions task, showed no significant difference between the two tasks, $F(1, 15) = 2.839$, $p > .10$; no significant interaction between dimensions and tasks, $F(1, 15) = 1.823$, $p > .15$; and no significant Pattern × Dimension × Task interaction ($F < 1$).

Discussion: Experiments 3 and 4

Dimensional interaction. The results of the present experiments replicated those of the previous experiments. Form and texture of many-element patterns appeared to be separable dimensions: Variation along the irrelevant dimension had no effect on responses to the relevant dimension (see Experiment 3). Only when the task involved shape identification on both levels did irrelevant variation interfere with responses to the relevant dimension (see Experiment 4).[1] On the other hand, global configuration and local elements of few-element patterns appeared to be integral dimensions: Subjects had difficulty in ignoring irrelevant variation on both dimensions, and correlated variation improved performance. (See Experiments 3 and 4. Note that in Experiment 3 redundancy gain was found only in the positively correlated-dimensions condition, due apparently to the presence of incongruity effects as well.)

Incongruity effects. In the present experiments incongruity effects were found with the many-element patterns and with the few-element patterns. Thus, Stroop-type interference was present both when the global and local dimensions appeared to be separable and when the global and local dimensions appeared to be integral.

Perceptually separable dimensions can produce Stroop-type interference if they are to be analyzed by the same processing mechanism, such as shape identification. Indeed, Stroop-type interference was obtained when the task explicitly involved shape identification on both the configural and elemental levels of many-element patterns (see Experiment 4). The presence of Stroop-type interference when the many-element patterns were processed in terms of form and texture (see Experiment 3) suggests that in addition to the processing of the textural aspect of the local dimension, processing of the individual local forms was going on as well.

Stimuli that vary along integral dimensions are not expected to produce Stroop-type interference because they are perceived as unitary entities rather than in terms of distinct dimensions. What, then, can be the possible source of the Stroop-type interference with the few-element patterns in the present experiments? One possible source is the process of decomposition of such stimuli to the component dimensions (see also Ward, 1983). Once decomposed, the component dimensions can elicit conflicting responses. Another possibility is that the difference between the congruent and incongruent stimuli is due not to response

[1] Note that the change to a task requiring element identification had the same effect in the present experiments (where the size of the stimuli in Experiment 4 increased relative to their size in Experiment 3) as in the previous ones (where the size of the stimuli in Experiment 2 decreased relative to their size in Experiment 1), suggesting that indeed these minor changes in the size of the stimuli (due to changes in laboratory set-up) did not have any effects.

competition (explicit or implicit), but rather to overall figural goodness. That is, the patterns with congruency between the configural and elemental levels might have higher degree of figural goodness than the patterns with incongruency between the two levels. Unfortunately, it is impossible to differentiate between these two alternatives in the present experiments.

General Discussion

The present experiments demonstrate that the perceptual relations between the configural and elemental levels of hierarchical patterns depend on the number and the relative size of the local elements. Furthermore, the interaction between the two levels in many-element patterns depends somewhat on dimensional instructions.

When many-element patterns were processed in terms of form and texture (Experiments 1 and 3), the global and the local levels were perceptually separable: There was no facilitation in performance when form and texture were combined redundantly, and selective attention was successful when the two were combined orthogonally. There was, however, a failure of selective attention, indicated both by orthogonal interference and Stroop-type interference, when the processing of the local shape rather than the textural aspect of the local level was involved (Experiments 2 and 4). These findings agree with current views of form and texture perception. There is already quite a lot of evidence that different aspects of the stimulus are extracted for form perception and for texture perception (e.g., Beck, 1982; Julesz, 1981a, 1981b; Pomerantz, 1981), suggesting the involvement of different processes. Julesz (1975) and Beck (1982) have suggested that form and texture perception of many small elements are mediated by different attentional modes: Form perception of the elements requires focused attention, whereas texture perception can be accomplished by a distributed attentional system. Whatever the exact mechanisms are, the global configuration and the local elements are processed differently as a discrete form and as texture, respectively. On the other hand, the global form and the individual local form are likely to be analyzed by the same processing mechanisms and thus might interfere with each other. It is possible that at least with some stimuli, form and texture processing of the local elements is going on at about the same time, as the results of Experiment 3 suggest.

The processing of few-element patterns did not seem to be affected by dimensional instructions, suggesting that subjects were actually processing the same aspects of the stimuli in both cases. The global configuration and the local elements of these patterns seem to be perceptually integral by Garner's (1974) criteria: They produced an increase in speed of processing when the two were combined redundantly, and a failure of selective attention when the two were combined orthogonally. The integrality of global configuration and local elements suggests that indeed the few-element patterns are processed in terms of form and figural parts. With the stimulus set used in Experiments 3 and 4, incongruity effects were found as well. The possible locus of the Stroop-type interference was discussed previously.

The present experiments show clearly that the same physical properties, namely, the global configuration and local elements, are not treated dimensionally the same by the subjects in the many-element and in the few-element patterns. Thus, the local elements constitute a physical dimension of hierarchical patterns. However, the perceived dimension is either texture or figural parts, depending on the number and the relative size of the local elements. These findings point to the importance of defining dimensions psychophysically rather than just physically (see also Garner, 1974).

One formulation of the global precedence hypothesis is that the features of the higher level of structure are prior to those of the lower level, and the choice of many-element patterns for testing this hypothesis seems to be well motivated (Navon, 1981). However, the finding that the global configuration of many-element patterns interacts differently with texture and with local form points to the need to specify which features or aspects of the global and local dimensions are considered when testing the global precedence hypothesis. Most of the experiments designed to test the global precedence hypothesis have used many-element patterns with tasks that demand shape identification (e.g., Hoffman, 1980; Martin, 1979; Navon, 1977), and thus they have tested the hypothesis that the global form is prior to the local form (rather than the more general hypothesis about the priority of the global level over the local one). The separability of form and texture of many-element patterns in the present experiments indicates clearly that in this case neither the global configuration nor the local elements is prior to the other. Even when the two levels interfered with each other (i.e., when shape identification at both levels was involved), no indication of priority of either level was obtained. Rather, the interference effect tended to be mutual: Neither level could be effectively ignored, suggesting that some local shape information was available at the same time as global shape information (see also Miller, 1981; Pomerantz, 1983). Another possible version of the global precedence hypothesis is closer to the Gestalt notion of the priority of wholes over their parts. Patterns composed of a few, relatively large elements seem to be better candidates for testing this hypothesis because the local elements of such patterns are indeed the figural parts of the overall form. With the few-element patterns used in Experiments 1 and 2 there was a slight asymmetry, though nonsignificant, in favor of the global configurations. The only significant asymmetrical interference effect was obtained in Experiment 3, where incongruent elements interfered more than incongruent global configuration. However, this local-to-global interference effect failed to be replicated in Experiment 4, which involved the same stimulus set. Thus, it seems fair to conclude that at least with the few-element patterns in the present experiments, neither significant global precedence nor significant local precedence was the case.

The present results also bear upon the issue of the explanatory adequacy of stimulus structure versus the internal processing of that structure. Hierarchical patterns are a case of a clear asymmetry in the logical and physical structure of the stimuli, as given by the necessary relations between the two dimensions; local elements can exist without a global configuration, but a global configuration cannot exist without local elements. This asymmetry in the logical structure holds both for few- and many-element patterns, and it predicts that the experimental results for all patterns will be asymmetrical with local elements having priority. However, the argument in terms of logical structure fails to account for the present results for three reasons. First and foremost, the present results indicate that the configural and the elemental levels bear different perceptual relations to each other when there are few versus many constituents. The logical structure hypothesis cannot account for this fact without redefining the "logically-given" dimensions, and this calls into question the very nature of such an explanation. Second, although hierarchical stimuli have a clear logical asymmetry, the experimental results did not show equivalent asymmetry. A similar conclusion has been reached recently by Garner (1983). Third, the interaction between the two levels can be manipulated by task demands, at least for the many-element patterns. All of these findings, therefore, *require* an explanation that includes the operation of processing mechanisms in order to account for performance in the present experiments.

Some of these processes are likely to take place early in the perceptual or even the sensory system. For instance, the differences in the results for few- and many-element patterns may be due in part to the extent to which the global and local levels are processed in overlapping versus independent spatial frequency channels (e.g., Campbell & Robson, 1968; De Valois & De Valois, 1980). Other relevant processes are probably attentional in nature. For instance, the difference between the pattern of results for many-element patterns when element-shape versus element-texture instructions were used may be due to the effects of attentional "zooming" transformations from low to high spatial frequencies (e.g., Broadbent, 1977). Some part of these differences might also result from still later processes concerned with decisions and response compatibility, particularly Stroop-type interference effects (e.g., Miller, 1981; Posner, 1978).

We do not yet know exactly how these internal processing mechanisms operate and interact to produce the precise pattern of results we found here. However, it is clear that our understanding of performance on tasks involving hierarchical stimuli will depend heavily on theories about such internal processes. A careful analysis of stimulus qualities may be *necessary* for success in such an enterprise, but it certainly is not *sufficient*.

References

Beck, J. (1982). Textural segmentation. In J. Beck (Ed.), *Organization and representation in perception* (pp. 285–315). Hillsdale, NJ: Erlbaum.

Broadbent, D. E. (1977). The hidden preattentive processes. *American Psychologist, 32,* 109–118.

Campbell, F. W., & Robson, J. G. (1968). Application of Fourier analysis to the visibility of gratings. *Journal of Physiology, 197,* 551–556.

De Valois, R. L., & De Valois, K. K. (1980). Spatial vision. *Annual Review of Psychology, 31,* 309–341.

Garner, W. R. (1974). *The processing of information and structure.* Hillsdale, NJ: Erlbaum.

Garner, W. R. (1978). Selective attention to attributes and to stimuli. *Journal of Experimental Psychology: General, 107,* 287–308.

Garner, W. R. (1983). Asymmetric interactions of stimulus dimensions in perceptual information processing. In T. J. Tighe, & B. E. Shepp (Eds.), *Perception, cognition, and development: Interactional analyses* (pp. 1–37). Hillsdale, NJ: Erlbaum.

Goldmeier, E. (1972). Similarity in visually perceived forms. *Psychological Issues, 8* (1, Whole No. 29). (Originally published 1936.)

Hoffman, J. E. (1980). Interaction between global and local levels of a form. *Journal of Experimental Psychology: Human Perception and Performance, 6,* 222–234.

Julesz, B. (1975). Experiments in the visual perception of texture. *Scientific American, 232(4),* 34–43.

Julesz, B. (1981a). Figure and ground perception in briefly presented isodipole textures. In M. Kubovy & J. R. Pomerantz (Eds.), *Perceptual organization* (pp. 27–51). Hillsdale, NJ: Erlbaum.

Julesz, B. (1981b). Textons, the elements of texture perception, and their interaction. *Nature, 290,* 91–97.

Keppel, G. (1973). *Design and analysis: A researcher's handbook.* Englewood Cliffs, NJ: Prentice-Hall.

Kimchi, R. (1983). *Perceptual organization of visual patterns.* (Doctoral Dissertation, University of California, Berkeley, 1982). *Dissertation Abstracts International, 44,* 345B.

Kimchi, R. & Palmer, S. E. (1982). Form and texture in hierarchically constructed patterns. *Journal of Experimental Psychology: Human Perception and Performance, 8,* 521–535.

Kinchla, R. A., & Wolfe, J. M. (1979). The order of visual processing: "Top-down", "bottom-up" or "middle-out." *Perception & Psychophysics, 25,* 225–231.

Kohler, W. (1971). Human perception. In M. Henle (Ed. and trans.), *The selected papers of Wolfgang Kohler,* (pp. 142–167). New York: Liveright. (Originally published in French, 1930.)

Martin, M. (1979). Local and global processing: The role of sparsity. *Memory & Cognition, 7,* 476–484.

McClean, J. D. (1979). *Perspectives on the forest and trees: The precedence of parts and whole in visual processing.* (Doctoral dissertation, University of Oregon, 1978). *Dissertation Abstracts International, 39,* 6162B–6163B. (University of Michigan Microfilms No. 79-12574).

Miller, J. (1981). Global precedence in attention and decision. *Journal of Experimental Psychology: Human Perception and Performance, 6,* 1161–1174.

Navon, D. (1977). Forest before trees: The precedence of global features in visual perception. *Cognitive Psychology, 9,* 353–383.

Navon, D. (1981). The forest revisited: More on global precedence. *Psychological Research, 43,* 1–32.

Pomerantz, J. R. (1981). Perceptual organization in information processing. In M. Kubovy & J. R. Pomerantz (Eds.), *Perceptual organization* (pp. 141–179). Hillsdale, NJ: Erlbaum.

Pomerantz, J. R. (1983). Global and local precedence: Selective attention in form and motion perception. *Journal of Experimental Psychology: General, 112,* 516–540.

Pomerantz, J. R. & Sager, I. C. (1975). Asymmetric integrality with dimensions of visual pattern. *Perception & Psychopysics, 18,* 460–466.

Posner, M. I. (1978). *Chronometric explorations of mind.* Hillsdale, NJ: Erlbaum.

Ward, L. M. (1983). On processing dominance: Comment on Pomerantz. *Journal of Experimental Psychology: General, 112,* 541–546.

Wertheimer, M. (1950). Gestalt theory. In W. D. Ellis (Ed.), *A source book of Gestalt psychology,* London: Routledge & Kegan Paul. (Originally published in German, 1925.)

Received July 25, 1984
Revision received July 22, 1985 ■