Percepts, Concepts and Categories
B. Burns (Editor)

Structure and Process in Perceptual Organization

RUTH KIMCHI
MORRIS GOLDSMITH
University of Haifa, Israel

I. INTRODUCTION

A particularly stubborn and enduring issue in the psychology of perception concerns the way in which perception might be organized -- the primacy of "wholes" versus "parts." Two basic positions on this topic can be traced back to the controversy between two schools of perceptual thought: Structuralism and Gestalt.

The Structuralists (e.g., Wundt, 1874; Titchener, 1909), were rooted firmly in British empiricism with its emphasis on atomism and associative mechanisms, and were also influenced by nineteenth-century physiology. They held that the basic units of perception are independent local sensations and their physiological counterparts -- specific nerve energies. In their view, every sensory whole must be built up from a conglomerate of elementary sensations, and the perception of segregated, organized units corresponding to objects in the physical world is achieved only by associations learned through experience.

The Gestaltists (e.g., Kohler, 1929, 1930/1971; Koffka, 1935/1963; Wertheimer, 1923/1955), on the other hand, argued against both atomism and learning in perception, asserting the primacy of extended units and organization in the percept. A basic tenet of the Gestalt view is that a specific sensory whole is qualitatively different from the complex that one might predict by considering only its parts. The whole quality is not just one more added element or factor as was proposed by Ehrenfels' (1890) Gestaltqualitat, nor does it arise "as a secondary process from the sum of the pieces as such. Instead, what takes place in each single part already depends upon what the whole is" (Wertheimer, 1923/1955, p.5). That is, the quality of a part is determined by the whole in which that part is integrated. According to the Gestalt theory, the perception of distinct organized units is not the product of sensory elements tied together by associative learning, but is, instead, a direct result of electrical field processes in the brain responding to the entire pattern of stimulation.

While the Gestalt view eventually lost favor, perhaps largely due to its implausible physiological aspects (Pomerantz & Kubovy, 1986), the modern psychology of perception has continued to grapple with the problem of perceptual organization. On the one hand, the basic flavor of the structuralist approach has been retained in most current models of perception, especially models of pattern and object recognition (see Treisman, 1986, for an extensive review). Such "analytic" models assume that objects are identified, recognized, and classified by detecting combinations of elementary features, parts, or components. At the same time, in the last 15 years or so, perceptual organization and the Gestalt view of perception (excluding their physiological theory) have recaptured the interest of cognitive psychologists (e.g., Kubovy & Pomerantz, 1981; Beck, 1982; Boff, Kaufman, & Thomas, 1986, Vol. 2; Gopher & Kimchi, 1989; Shepp & Ballesteros, 1989). This revival includes work on such issues as perceptual grouping, part-whole relationships, processing of global and local aspects of visual patterns, object-superiority effects, configural-superiority effects, texture discrimination, and event perception. It is also expressed in the growing usage of the term "wholistic" rather than "analytic" to describe perception (e.g., Uttal, 1988).

Unfortunately, a clear understanding of the current work on "wholistic" perception may be hampered by the looseness with which the term is used in the literature, often without a clear theoretical or operational definition. There are, in fact, at least two different usages of the term "wholistic" with regard to perception. The first, and more common usage, is considered to be in the spirit of Gestalt theory, and refers to the primacy of *wholistic properties* in perception. In this usage, the terms "wholistic" and "global" are often used interchangeably to express the hypothesis that the initial information-processing step in the identification, discrimination, or classification of objects involves processing of global properties, rather than local or component properties (e.g., Navon, 1977, 1981; Uttal, 1988).

The other usage of "wholistic" perception is quite distinct. It refers to the notion that the *unitary whole*, rather than its properties (whether wholistic or component), is the primary unit for processing. In its strong version, such a notion seems to entail that at some level of processing, "properties" as such have no immediate psychological reality. This usage is most common among investigators working on dimensional interaction (e.g., Shepp & Ballesteros, 1989). Note that from this point of view, the primacy of wholistic properties suggested by the other usage would be equated with "analytic" processing, because properties (though wholistic ones) would have a definite psychological reality. A very thoughtful discussion of this notion of wholistic processing can be found in Kemler Nelson (1989).

We do not intend to propose that one conceptualization of wholistic processing is in any sense "better" than the other. Both, when clearly presented, may be entertained as viable hypotheses regarding characteristics of the human information-processing system, although for the sake of clarity it would be helpful if the two were termed differently. However, even within these two usages there remains a lack of conceptual clarity which we suggest may be remedied using the concepts of psychological stimulus structure and mode of processing. It seems that the former notion of wholistic processing, which refers to the primacy of wholistic properties, often fails to take into account the psychological structure of the stimulus. The "unitary whole" conceptualization, on the other hand, being developed within a framework which emphasized stimulus structure, does take it into account, but then it is sometimes unclear what remains to be accounted for by wholistic processing which is not already accounted for by the stimulus structure itself. Some attempts to explicate this latter usage in terms of structure and process can be found in a number of chapters in a recent book edited by Shepp and Ballesteros (1989), and the interested reader is referred to that book for more information.

In this chapter we will focus on the former usage of wholistic perception which refers to the primacy of wholistic or global properties. We will attempt to show how research within the dominant paradigm used to investigate this notion (the "global/local" paradigm) could be bolstered by a more careful analysis in terms of structure and process. In order to do so, we will begin with a metatheoretical discussion on the utility of a structure/process distinction, and to anticipate, support a distinction drawn largely from Garner's (1974) work on dimensional interaction. We will then go on to use this distinction in order to elucidate some basic conceptual problems having to do with stimulus structure within the "global/local" paradigm, and thereby hope to further clarify the utility of the structure/process distinction itself.

II. STRUCTURE AND PROCESS

A. Basic Concepts

A prominent conceptual distinction between structure and process in the cognitive psychology literature stems from the work of Garner, presented in his seminal book *The Processing of Information and Structure* (1974). Broadly speaking, this distinction refers to *stimulus structure* on the one hand, and to various *modes of processing* available to the perceiving organism on the other. Structure is tied to the stimulus, while process is tied to the perceiver. However, considering structure to be a stimulus concept does not necessarily mean that it is the physical structure which is being referred to. Rather, stimulus structure refers to those stimulus aspects which have human information processing consequences, and as such, it is *psychological* stimulus structure, defined *psychophysically*.

Consider, for example, Garner's identification of "integral" and "separable" stimulus structure on the one hand, and a possible processing mechanism such as "selective" processing on the other. Phenomenologically, certain stimuli which vary along what Garner termed integral dimensions (e.g., hue, brightness, and saturation) are perceived unitarily (e.g., as a single color), and a change in any one dimension appears to produce a qualitatively different stimulus (e.g., a different color). In contrast, stimuli varying along separable dimensions (e.g., size of circle and angle of a radial line inside it) are perceived as having distinct dimensions or attributes.

Garner (1974) used several converging operations to distinguish these two types of stimulus structure operationally. Integral dimensions: (a) show facilitation when the dimensions are correlated and interference when combined orthogonally in speeded classification, (b) produce a Euclidean metric in direct similarity scaling, and (c) are classified on the basis of overall similarity relations. Separable dimensions: (a) show neither facilitation nor interference in speeded classification, (b) produce a city-block metric in direct similarity scaling, and (c) are classified on the basis of separate dimensions.

Having identified integrality and separability as aspects of stimulus structure, Garner could then address how such structure might impose constraints on available processing mechanisms. He pointed out that selective processing is impossible for stimuli composed of truly integral dimensions, but it is optional, or may even be primary, for stimuli composed of separable dimensions.

While this example may serve to illustrate Garner's approach, we run the risk of overlooking its complexity. Thus several points should be emphasized: First, as we mentioned earlier, although Garner asserted that there is structure in the stimulus which can be described independently of the perceiver, it is still a psychophysical structure that he referred to. Second, although he emphasized the role of stimulus structure in constraining possible modes of processing, he at the same time recognized the flexibility of human information processing, as expressed in his notions of primary and secondary processes (Garner, 1974), and mandatory and optional processing (Garner, 1976). Third, he also recognized the mutual constraints that stimulus properties impose on processing and vice versa (e.g., Garner, 1978).

B. Arguments For and Against a Structure/Process Distinction

From the preceding discussion, we see that the structure/process distinction can be used to capture the relatively invariant constraints imposed upon human information processing by the relevant psychological properties of the stimulus on the one hand, and the relatively flexible modes of processing given structural constraints on the other. Many investigators who share the basic spirit of Garner's approach have followed his lead and emphasized the importance of psychological stimulus structure and modes of processing in understanding adult human information processing, as well as developmental trends in perception and cognition (see, e.g., Shepp & Ballesteros, 1989).

Nonetheless, in metatheoretical discussions regarding issues of representation, the very meaningfulness of a structure/process distinction has been called into question (e.g., Anderson, 1978). Several theorists have pointed out the necessary interdependence of cognitive representations (or data structures) and the processes which operate upon them, emphasizing the fact that any number of equivalent processing models may be derived for any psychological task. Different processing models may simulate human cognition equally well, because differences in representational structure may be compensated for by complementary differences in processing operations and vice versa (see, e.g., Palmer 1978; Rumelhart & Norman, 1988). This has led some theorists to the conclusion that the "true" allocation of structure and process in otherwise equivalent models is in principle undecidable, and therefore such efforts would best be directed elsewhere (Anderson, 1978).

Why have so many researchers in perception and cognition, then, maintained their faith in the utility of a structure/process distinction, despite such a fundamental objection? We suggest that the basic reason stems from the fact that "structure" and "process" as used by Garner and others have somewhat different meanings than when the same terms are used to refer to aspects of perceptual/cognitive *representational systems* (although the different senses are sometimes confused).

In one sense, the structure/process distinction following Garner is a conceptual distinction which provides a framework for studying the perceptual/cognitive system in its relation to the real world. It serves to highlight the mutual constraints between the structure of the stimulus to be processed on the one hand, and the different modes of processing available to the perceiving organism on the other.

In a different sense, however, representations (or data structures) and processes (or operations), as aspects of cognitive representational systems, are *functional entities* in information processing theories or "process models." Information processing theories attempt to describe what is actually going on inside the head when the organism is engaged in various perceptual and cognitive activities. The very general claim is that what is taking place is the processing of information, which is characterized in terms of cognitive representations and the processes which operate upon them (e.g., see Palmer & Kimchi, 1986). Thus, a fundamental issue for the information processing theorist is the nature of the internal representations and processes, and how to represent them in psychological theory.

Historically, the basic objection to the structure/process distinction was raised within the context of the "mental imagery debate" (see Block, 1981; Kosslyn, 1986), between proponents of "analog" versus "propositional" representations for modeling mental images. It is probably no coincidence that the debate involved researchers whose work was clearly tied to computer simulation modeling. At the detailed algorithmic level at which a "sufficient" computer simulation model is developed, decisions about the nature of data structures and the operations which access and modify them cannot be ignored (though they may be designated as "irrelevant" to the essence of the model).

The central issue with regard to structure and process in cognitive representational systems is whether the nature of internal representations and processes can be resolved by behavioral data (e.g., Anderson, 1978; Pylyshyn, 1979). Most cognitive psychologists do have faith in such an enterprise, at least at some level of description. We propose that it is precisely in undertaking this endeavor, at the appropriate level of description, that the conceptual distinction between structure and process presented earlier can be useful. Here psychological stimulus structure and mode of processing are theoretical *concepts* or explanatory constructs. As such, they are not embodied in the system itself, but rather in the theorist's understanding of the system. This conceptual distinction is useful in delineating those stimulus and organismic aspects which must be taken into account by any complete theory of human information processing, providing a working *framework* in which specific process models can be developed.

The relationship between the "conceptual" structure/process distinction and process models can be described as follows: Both stimulus structure and processing aspects, as well as their mutual interaction, need to be represented in any complete information processing model of the perceptual/cognitive system. That is, analysis guided by the conceptual distinction between structure and process provides useful constraints on *what* aspects of human information processing must be embodied in the process model. However, it need not predetermine *how* those aspects are to be represented in the model. How stimulus and processing aspects are actually represented in cognitive representational systems, in terms of data structures and operations, is a separate issue which pertains to specific process models.[1]

[1]We have confined our discussion of representational systems to fit those of "traditional" processing models, since historically the objection to the structure/process distinction was raised within this framework. More recently, however, the connectionist approach to modeling information processing has also been pointed to as having "dissolved"

There remains an issue, however, as to whether even at the conceptual level the distinction between structure and process might not be so much excess baggage. It could be argued that structure and process are simply two overlapping views of the performance characteristics of the perceptual/cognitive system. For instance, if stimulus structure is described in terms of all the information relevant to the perceiver, then such a description may be considered to be an adequate description of the perceptual system (e.g., Gibson, 1966, 1979). Alternatively, a description of the perceptual system might be given solely in terms of all the possible modes of processing by which an organism can process stimuli.

Most cognitive psychologists are not comfortable with either approach, for several good reasons: A description solely in terms of psychological stimulus structure, while it may constitute a higher-level mapping theory of perception, is concerned entirely with what the mapping is to the exclusion of how this mapping might be achieved (see Palmer & Kimchi, 1986). Also, many cognitive psychologists are unhappy about having to include in the stimulus structure (albeit perceived structure) properties that seem to require some organismic knowledge system (e.g., Rosch, 1978). On the other hand, a description completely in terms of processing fails to enhance our understanding of the structural constraints relevant to the human information processing system. Therefore, including both stimulus structure and process in psychological theory would seem to be desirable.

Perhaps the most important reason to maintain the structure/process distinction, however, is its relation to process models, as discussed above. We emphasized that while the analysis of human performance in terms of structure and process at a conceptual level need not constrain the allocation between representations and operations in possible process models, it does provide a different and important constraint -- what must be included in the model (regardless of how). Thus, the distinction between structure and process can provide a practical framework for the actual work of the cognitive psychologist, both in directing research, and in the interpretation of experimental results.

the distinction between structure and process, for different reasons. It is enough to say here that the issue of whether or not the structure/process distinction is meaningful in connectionist models, as in traditional process models, is an issue regarding representational systems. As such, it too has no bearing on the "conceptual" structure/process distinction to which we subscribe in this chapter.

C. A Methodological Criterion for Identifying Structure and Process

To avoid vagueness, there is still a need for a criterion on which to base the structure/process distinction. We suggest that such a criterion is available, at least as a first approximation. By tying structure to the stimulus and process to organismic mode of processing, converging operations can then be used to support the distinction. On the one hand, stimulus structure can be identified by the convergence of performance characteristics across information processing tasks with given stimuli. The set of converging operations for identifying integral and separable dimensions provided by Garner (1974) is a good example.

Conversely, mode of processing can be identified by the convergence of performance characteristics across stimuli for given information processing tasks. For example, a "wholistic" mode of processing in high speed classification tasks has been inferred from classification performance based on overall similarity across both integral and separable stimuli (J.D. Smith & Kemler Nelson, 1984). Further, as a means of dealing with the inherent mutual interaction between structure and process, it is possible to use a "boot-strapping" strategy to differentiate modes of processing once there exist well-defined operational criteria for distinguishing between different stimulus structures. A good example can be found in the work of L.B. Smith and Kemler (1978), Foard and Kemler Nelson (1984), and Kemler Nelson (1989). These workers initially abstracted a criterion of "privileged axes" from the well-defined converging operations for dimensional integrality and separability. They could then use this criterion to infer modes of processing (analytic or wholistic) across stimuli (separable and integral) in several different kinds of tasks.

III. STRUCTURE AND PROCESS IN WHOLISTIC PERCEPTION

A. The Primacy of Wholistic Properties

A visual object, viewed as a whole, has both wholistic properties and component parts.[2] Wholistic properties are properties that depend on the interrelation between the component parts. The Gestaltists' claim that the whole

[2]A thorough discussion of the various ways of analyzing a stimulus into properties, parts, features, dimensions, etc. is beyond the scope of this chapter. Comprehensive treatments may be found in Garner (1978) and Treisman (1986).

is more or at least different from the sum of its parts can perhaps be captured by the notion of wholistic properties such as closure, symmetry, and certain other spatial relations between the component parts. As we have mentioned earlier, one sense of "wholistic" perception is embodied in the claim that processing of wholistic properties precedes processing of component properties. Within this conceptualization, the *global precedence hypothesis*, put forward by Navon (1977), is considered by many cognitive psychologists to be a modern version of the Gestaltists' claim about the primacy of wholistic or global processing in perception (e,g., Pomerantz, 1981; Kimchi, 1982; Treisman, 1986; Robertson, 1986; Uttal, 1988). This hypothesis has generated a wealth of empirical research which has nonetheless left the issue still unsettled and somewhat confused.

We will first present the hypothesis along with the framework in which it was formulated, and the experimental paradigm used to test it. We will then critically analyze some basic assumptions underlying much of the research within this paradigm in terms of structure and process, and support this analysis with experimental evidence. Our analysis will then allow us to examine the extent to which this line of research has been able to shed light on the primacy of wholistic vs. component properties.

B. The Global Precedence Hypothesis

Posing the question "Is the perceptual whole literally constructed out of the percepts of its elements?" Navon (1977) proposed that "perceptual processes are temporally organized so that they proceed from global structuring towards more and more fine-grained analysis. In other words, a scene is decomposed rather than built up" (Navon, 1977, p. 354).

The global precedence hypothesis was formulated within a framework in which a visual scene is viewed as a hierarchical network of subscenes interrelated by spatial relationships (e.g., Winston, 1975; Palmer, 1977). The globality of a visual feature corresponds to the place it occupies in the hierarchy: features at the top of the hierarchy are more global than those at the bottom, which in turn are more local. Consider for example the structure of a human face. The face as a whole has global features (e.g., shape, expression, etc.) as well as a set of local features or component parts (e.g., eyes, nose, dimples, etc.). In turn, the component parts when considered as wholes also have global features and a further set of local features or component parts. The global precedence hypothesis claims that the processing of a scene is global-to-local. That is, global

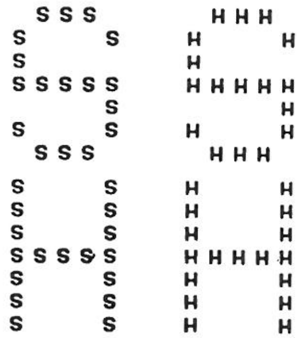

Figure 3.1. Example of the compound letters used in the global/local paradigm. (Adapted from Pomerantz, Pristach, & Carson, 1990.)

features of a visual object are processed first, followed by analysis of local features.

This hypothesis has been tested experimentally by studying the perception of hierarchically constructed patterns, in which larger figures are constructed by suitable arrangement of smaller figures. An example is a set of large letters constructed from the same set of smaller letters (see Figure 3.1). Within the framework discussed above, the large letter is considered a higher-level unit and the small letters are lower-level units. Both levels have a set of global and local features. However, the features of a higher level unit (either global or local) are considered to be more global than features of lower level units by virtue of their position in the hierarchy. Thus, the modifier "more" should precede local and global (see also Ward, 1982).

The choice of hierarchical patterns for testing the global-to-local hypothesis is seemingly well motivated, and the rationale is as follows: The global configuration and the local elements can be equally complex, recognizable, and codable, and one level cannot be predicted from the identity of the other (Navon, 1977, 1981). Once the global configuration and the local elements are equated, except for their level of globality, performance measures such as relative speed of identification, and/or asymmetric interference can be used in order to infer the precedence of one level or the other.[3]

[3]Whether the paradigm properly allows the inference of temporal *precedence* from findings of perceptual *dominance* is an interesting issue in itself. We will hereafter use "precedence" when referring to the original formulation of the theoretical hypothesis, but

Note however, that the local elements of hierarchical patterns are not the local features of the global figure in the same way as eyes, nose, and mouth are the local features of a face, or in the way that vertical and horizontal lines are the local features of the letter H. Thus, the global-to-local hypothesis that is in fact tested by hierarchical patterns is the following: The features of a high-level unit (e.g., the shape of the larger figure) are processed first, followed by analysis of the features of the lower-level units (e.g., the shape of the small figure) (Navon, 1981; Kimchi, 1982).

By a set of converging operations, Navon (1977) demonstrated the perceptual dominance of global configurations. In one experiment (Navon, 1977, Experiment 2), he asked subjects to respond to an auditorily presented name of a letter while looking at a hierarchical letter. The subject's auditory discrimination responses were affected (interfered or facilitated) by the global level of the visual stimuli but not by the local one. In another experiment (Navon, 1977, Experiment 3), Navon employed a Stroop-like interference paradigm and found that conflicting information between the local and the global levels (e.g., a large H made up of small S's) had an inhibitory influence on identification of the local letter but not on the identification of the global letter. Navon and others (e.g., Broadbent, 1977) interpreted these findings as evidence for the inevitability of global precedence in visual perception.

Other researchers have used similar stimuli (i.e., hierarchical letters composed of many small letters) and employed identical or similar experimental tasks (e.g., Stroop-like interference, target search, speeded classification) to explore the generality of global precedence in what we refer to here as the "global/local paradigm." These studies demonstrated important boundary conditions of the phenomenon and pointed out certain variables that can affect global versus local dominance. Such variables include overall stimulus size (e.g., Kinchla & Wolfe, 1979), sparsity of the local letters (e.g., Martin, 1979), "clarity" or "goodness" of form (e.g., Hoffman, 1980; Sebrechts & Fragala, 1985), retinal location (e.g., Pomerantz, 1983; Grice, Canham, & Boroughs, 1983; Kimchi, 1988), spatial uncertainty (e.g., Lamb & Robertson, 1988; Kimchi, Gopher, Rubin, & Raij, in press), and exposure duration (e.g., Paquet & Merikle, 1984). Several studies also have examined the locus of the phenomenon -- perceptual, attentional, or preattentive (e.g., Miller, 1981; Boer & Keuss, 1982; Paquet & Merikle, 1988).

will use the term "dominance" to refer to empirical findings.

C. The Structure of Hierarchical Patterns

Our present goal is not to evaluate or interpret the experimental results obtained within the global/local paradigm, but rather to question some basic assumptions underlying much of the research with hierarchical patterns. A basic presupposition seems to be that there are two distinct perceptual levels corresponding directly to the global figure and local elements, and that the critical question is which level gets processed first. We suggest that the supposed correspondence between perceptual and experimenter-defined levels of pattern structure may hold in some cases and not in others; therefore a clear notion of how hierarchical patterns are structured perceptually is an important prerequisite for asking meaningful questions about how such structure may be processed.

Experimenters have characterized hierarchical patterns as having two distinct levels of pattern structure: global configuration and local elements. (We use the term "pattern" to refer to the entire stimulus, i.e., to both levels at once.) In the perceptual domain, however, three phenomenal aspects can be identified: overall form, figural parts, and texture. Whenever small figures are positioned near each other in such a way that their positions form the pattern of a larger figure, the two experimenter-defined levels of pattern structure (i.e., the global configuration and the local elements) are present regardless of the number and/or the relative size of the elements. However, Kimchi (1982; Kimchi & Palmer, 1982) has claimed that the mapping from the two levels of pattern structure in the *stimulus* domain into meaningful levels in the *perceptual* domain depends critically on the number and the relative size of the elements.

Phenomenologically, patterns composed of many relatively small elements (many-element patterns) are perceived as overall form associated with texture. Patterns composed of few relatively large elements (few-element patterns) are perceived as overall form and figural parts. The local elements of many-element patterns lose their function as individual parts of the form and are relegated to the role of "material" (Goldmeier, 1936/1972) or "texture" (Kimchi, 1982; Kimchi & Palmer, 1982), and do not interact with the form of the pattern. That is, the global form and the local elements of many-element patterns are phenomenally independent: Replacing the elements of the patterns by other elements does not affect the perception of its overall form. On the other hand, the local elements

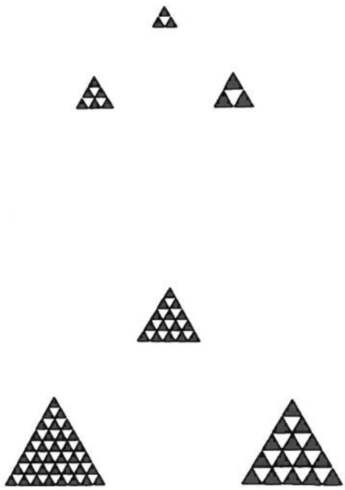

Figure 3.2. Example of the stimulus triads used in Kimchi & Palmer's (1982) study (Experiment 1) with adults, and in Kimchi's (1990) study (Experiment 1) with children. (Adapted from Kimchi, 1982.)

of few-element patterns are perceived as figural parts of the overall form.[4]

Kimchi (1982; Kimchi & Palmer, 1982, 1985; Kimchi, 1988, 1990) used several converging operations to support this distinction operationally. In a forced-choice similarity judgment task subjects were presented with stimulus triads composed of a standard pattern and two comparison patterns. One comparison pattern was a proportional enlargement of the standard pattern (i.e., an enlargement in which the size of both the global configuration and the local elements are increased by uniform dilation). The other comparison pattern was a particular sort of unproportional enlargement in which the global configuration is enlarged but the measurements of the elements are unchanged (see Figure 3.2). Few-element patterns were judged to be more similar to their proportional enlargements which preserved both the global and the local structures as well as the relationships between them. Many-element patterns, on the other hand, were

[4]A similar phenomenal distinction between two types of patterns was proposed independently by Pomerantz (1981, 1983). In what Pomerantz termed "Type P" patterns, only the position of the local elements matters for the overall form. In "Type N" patterns both the position and the nature of the local elements matter.

judged to be more similar to their unproportional enlargements which preserved the global form as well as the texture of the pattern (Goldmeier, 1936/1972; Kimchi & Palmer, 1982, Experiment 1; Kimchi, 1990, Experiment 1).

The relative salience of the local element in few- and many-element patterns was examined using a similarity judgment task involving stimulus triads in which the global configuration was pitted against the local elements (see Figure 3.3). Few-element patterns were judged to be more similar to a same-element pattern in which the same elements are arranged to form a different configuration than to a same-configuration pattern (i.e., a pattern in which different elements are arranged to form the same configuration), while many-element patterns were judged to be more similar to a same-configuration pattern than to a same-element pattern (Kimchi & Palmer, 1982, Experiment 2; Kimchi, 1990, Experiment 2). Subjects' preferences for verbal descriptions of the patterns were also consistent with the similarity judgments. When presented with descriptions in which the global configuration was the grammatical subject and the local elements were the grammatical object (e.g., "A triangle made of triangles") and descriptions in which the global configuration and the local elements had a reversed role (e.g., "Triangles arranged to form a triangle"), subjects preferred the former kind of descriptions for many-element patterns, and the latter kind of description for few-element patterns (Kimchi & Palmer, 1982, Experiment 4).

In a parametric study using the two similarity judgment tasks described above, the number of elements and their relative size was varied systematically. The results showed that the critical number of elements for which the switch in the similarity judgments occurred was 7 ± 2, both for adults (Kimchi, 1982; Kimchi & Palmer, 1982), and for children as young as three years of age (Kimchi, 1990).

Converging evidence was then obtained for the perceptual separation/nonseparation of global and local levels in hierarchical patterns as a function of the number of elements in the pattern. In a speeded classification task involving a set of four patterns created by orthogonally combining two types of global configuration and two types of local elements (see Figure 3.4), subjects were required to classify the patterns according to either global form or texture. Few-element patterns showed a pattern of results which is typical of integral dimensions: Facilitation was obtained when the global configuration and the local elements were combined redundantly, and interference was obtained when they were combined orthogonally. Many-element patterns, on the other hand, showed a pattern of results typical of separable dimensions: No facilitation was obtained when the global configuration and the local elements were combined redundantly,

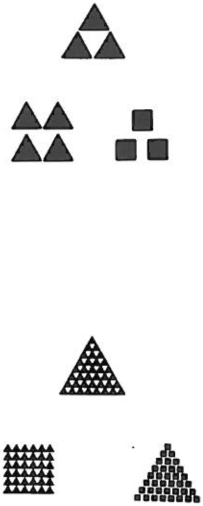

Figure 3.3. Example of the stimulus triads used in Kimchi & Palmer's (1982) study (Experiment 2) with adults, and in Kimchi's (1990) study (Experiment 2) with children. (Adapted from Kimchi, 1982.)

and no interference was obtained when they were combined orthogonally (Kimchi & Palmer, 1985, Experiments 1 and 3).

Few-element and many-element patterns also produced reliably different patterns of results in a simultaneous comparison task in which subjects were required to determine whether two simultaneously presented patterns were the same or different at the global or at the local level (Kimchi, 1988), and in an identification task employing a Stroop-like interference paradigm (Kimchi & Merhav, in press), using the same stimuli as in the speeded classification task. It is interesting that the requirement to classify the same patterns according to global and local forms (rather then in terms of global form and texture) did not affect the pattern of results obtained with the few-element patterns, both with the speeded classification task (Kimchi & Palmer, 1985, Experiments 2 and 4), and with the simultaneous comparison task (Kimchi, 1988). This could be expected from the relation between number of pattern elements and the "appearance" of texture. Inasmuch as a critical number of elements (around 7 + 2) is required for texture perception, there is simply no perceived texture in few-element patterns. For many-element patterns, on the other hand, there is a difference between texture and local form. While global form and texture of many-element patterns

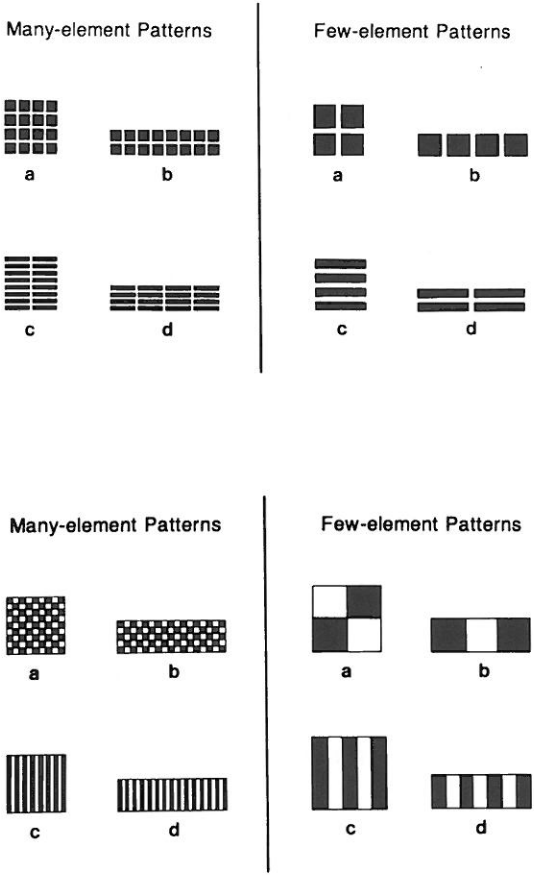

Figure 3.4. The four sets of stimuli used in Kimchi & Palmer's (1985) study, and in Kimchi & Merhav's (1990) study. The stimulus pairs used in Kimchi's (1988) study were created from the two upper sets. (Adapted from Kimchi & Palmer, 1985.)

were found to be perceptually separable, the requirement to classify such patterns in terms of global and local forms did result in interference between the levels (Kimchi & Palmer, 1985, Experiments 2 and 4; Kimchi, 1988; Kimchi & Merhav, in press).

Further evidence for perceptual separation/nonseparation between the global and local levels of many- and few-element patterns respectively, has been obtained with similarity judgments and speeded classification using different stimuli (Klein & Barresi, 1985).

In sum, this body of evidence suggests that there is good reason to distinguish the perceptual structure of patterns composed of many, relatively small elements, from that of patterns composed of few, relatively large elements. The two types of stimuli show clearly distinguishable performance characteristics across different tasks, and across subjects (adults and children). In particular, the local elements of few-element patterns are perceived as figural parts of the overall form, and the global and local levels are perceptually integral. On the other hand, the local elements of many-element patterns are perceived as textural molecules, and the overall form and the texture of such patterns are perceptually separable.

The specific perceptual mechanisms underlying these two types of perceptual structure have yet to be determined (but see Kimchi & Palmer, 1985, for some suggestions), and the research findings reported here do not dictate how such mechanisms should be modeled. Nonetheless, we see here a good example of how the empirical identification of perceptual stimulus structure provides constraints for any cognitive/perceptual model which must then allow for such structure. We propose that the converging evidence for the difference in the perceptual stimulus structure of few- and many-element patterns has several important implications for the global/local paradigm, and for the issue of structure and process in general. We first discuss the implications for the global/local paradigm.

D. Implications for the Global/Local Paradigm

The choice of hierarchical patterns for testing the global precedence hypothesis was guided by the assumption that the global configuration and the local elements comprise two distinct structural levels which are statistically independent, and that each constitutes a stimulus in its own right. The global configuration and the local elements could then be equated, except for their level of globality, and the perceptual precedence of one level or the other inferred from performance measures such as relative speed of identification and/or asymmetric interference. However, the finding that the perceptual separation of configural and elemental levels of hierarchical patterns depends on the number and relative size of the elements -- that local elements are sometimes perceived as distinctive parts of the overall form, and at other times, as textural molecules -- challenges the validity of this assumption, and has implications for interpretation of the experimental findings obtained in the global/local paradigm.

First, the asymmetric interference effects used to infer global or local precedence may depend on the relative perceptual separation of the global and the local levels. To the extent that the local elements are perceptually separable from the global configuration, local-to-global interference is much less likely than when the two levels are perceptually integral. As we have seen, the relative perceptual separation depends at least in part upon the number and relative size of the local elements. It follows, then, that positing precedence of the global level of structure (as operationalized in this paradigm) as a rigid perceptual law is hardly tenable.

Second, even if we were to find that global dominance is uniformly observed with *many-element* patterns, what could we infer from this with regard to the global precedence hypothesis? If the local elements of many-element patterns serve to define texture, then they may not be represented as individual figural units at all. Therefore it is not clear whether a faster identification of the global configuration should be accounted for by its level of globality, or rather, by a qualitative difference between figural unit and textural molecule.

There is also a further implication which stems from the characterization of the local level in many-element patterns as texture. It is frequently claimed that texture segregation occurs early in perceptual processing; it organizes the visual field and defines the units for further processing. Experimental evidence suggests that texture segregation depends on local properties of the texture molecules (e.g., Julesz, 1981; Beck, 1982; Treisman, 1985). This, in turn, would suggest that properties of the local elements in many-element hierarchical patterns are extracted prior to those of the global configuration, even though they do not seem to affect the speed of response to identify the global configuration.

Also, in view of the confounding between relative size and number of elements in many-element patterns, it may be that relative size alone could account for observed global dominance. That is, a local element may be processed more slowly simply because it is relatively small, rather than because of its level of globality (Navon & Norman, 1983; Kimchi et al., 1990).

Finally, in a more fundamental sense it can be argued that if the global precedence hypothesis is interpreted as positing the perceptual primacy of wholistic properties versus component properties, then patterns composed of few, relatively large elements should be better suited to test the hypothesis. That is because the local elements of such patterns seem to have psychological reality as component parts of the overall form, while the local elements of many-element patterns do not.

E. Implications Regarding Structure and Process

We now turn to the structure/process distinction. We feel that the study of few- and many-element patterns has several important implications for this issue.

First, it demonstrates the importance of defining properties *psychophysically* rather than just physically. The findings presented above clearly show that the same stimulus properties as defined by the experimenter (i.e., global configuration and local elements), are not treated equivalently by subjects, for few- and many-element patterns. The local elements are physically present in hierarchical patterns, and they have the same logical status, regardless of the number of elements. However, the *perceptual* property is either texture or figural part, depending on the number and relative size of the local elements.

Navon pointed out, and rightly so, that "strictly speaking, global precedence cannot be tested unless it is known what the perceptual units are" (1981, p. 27), and in the absence of such precise knowledge, Navon suggested that "we have to rely on our common sense reinforced by our knowledge of Gestalt laws of organization" (p. 27). Yet, it has been demonstrated above that such informal criteria may still allow for a discrepancy between the effective perceptual units as defined by the experimenter, and those having psychological reality in the perceptual system. Clearly, such a discrepancy can cause the experimenter to commit an inferential error regarding the proper characterization of perceptual processing. For this reason, the stimulus structure used to test a processing hypothesis has to be carefully analyzed and supported in psychophysical terms.

A second point concerns the fact that logical relations in the stimulus structure should not predetermine processing hypotheses, because the logical structure of the stimulus does not necessarily predict processing consequences (see Garner, 1983; Kimchi & Palmer, 1985). Hierarchical patterns provide a clear case of asymmetry in the logical structure of the stimuli: Local elements can exist without a global configuration, but a global configuration cannot exist without local elements (e.g., Pomerantz & Sager, 1975), and this asymmetry holds both for few- and many-element patterns. However, the findings presented above serve to emphasize the danger of predicting performance or making processing assumptions on the basis of logical relations in the stimulus domain alone.

The danger in tying processing assumptions to logical stimulus structure may be further illustrated with regard to the notion of "emergent properties". Wholistic properties such as closure and symmetry are often termed "emergent

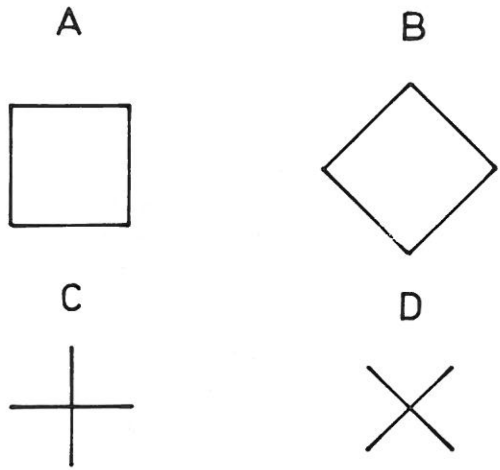

Figure 3.5. Example of a set of stimuli that share either wholistic or component properties: The pair A,B and the pair C,D share wholistic properties (closure and intersection, respectively). The pair A,C and the pair B,D share component properties (horizontal/vertical lines, and oblique lines, respectively). (Adapted from Lasaga, 1990.)

properties"(e.g., Garner, 1978; Pomerantz, 1981) because they do not inhere in component properties but rather they "emerge" from the interrelations between the components themselves (see Figure 3.5). Despite the semantic connotation of the term "emergent," however, there is no actual necessity for emergent properties to be perceptually *derived*. Emergent properties might be computed from relevant component properties, but it is also possible that they are directly detected by the perceptual system (i.e., without the component properties having a psychological reality of their own). The description of wholistic or configural properties as "emergent" is only supported as a description in the *stimulus* domain. In other words, both component and wholistic properties (whether "emergent" or not) must be treated as stimulus aspects. Whether wholistic properties then dominate component properties at a certain level of processing, or whether they are extracted earlier than component properties, are empirical questions in the *processing* domain. At present, there is some evidence that such "emergent properties" do indeed dominate component properties in discrimination and classification tasks (e.g., Pomerantz, Sager, & Stoever, 1977; Lasaga, 1989), and that they may be extracted at early stages of perceptual processing (e.g., Treisman & Paterson, 1984; Kolinsky & Morais, 1986).

F. More about Global Precedence

In the foregoing discussion of the global precedence hypothesis and the global/local paradigm used to test it, we focused on issues of stimulus structure. There are also *processing* issues related to this paradigm which include, for example, the distinction between processing dominance and temporal order of processing (e.g., Ward, 1983), serial processing versus relative speed of processing (e.g., Navon, 1981, Lasaga, 1989), and the possible difference in the underlying modes of processing reflected in speed of processing versus interference (e.g., Navon & Norman, 1983; Lamb & Robertson, 1988). We chose to focus on the structure issues because they bear heavily on the assumptions underlying the paradigm, and yet have been neglected by much of the research. Further, although structure and processing issues are to some extent independent of each other -- and this is a strength of the structure/process distinction -- we feel that structure issues are in some sense primary, since questions regarding processing can only empirically be decided once we have a clear idea of the stimulus structure which is being processed.

Another aspect to be considered when testing a processing hypothesis is the nature of the task. Any information processing activity involves processes at different stages of processing, and different experimental tasks can tap different stages of processing. For example, Kimchi & Palmer (1985) found, using a speeded classification task, that the dimensions of form and texture of many-element patterns were separable. However, in a simultaneous comparison task, asymmetric interference was observed when a potential conflicting output between these dimensions was present (Kimchi, 1988). Other similar findings have been reported demonstrating that with separable dimensions selective attention can be possible in one task, but not in another, depending on the likelihood of dimensional output conflict (e.g., Santee & Egeth, 1980). Stated more generally, dimensional analysis is a necessary but not sufficient condition for successful selective attention to a stimulus dimension. In a similar vein, local properties may be extracted prior to the stage of complete identification of the global configuration, depending on task demands and stimulus structure. However, it does not rule out the possibility that in early stages of perceptual processing, wholistic properties are available prior to the component properties.

At this point we would like to emphasize what may have been overlooked. Our analysis does not have any implication for the tenability of the global precedence hypothesis. As we understand it, the global precedence hypothesis postulates that wholistic properties such as closure, symmetry, and other spatial relations between component parts are available in the percept prior to component properties. This is an interesting and viable hypothesis that should continue to be examined. The arguments we presented in this chapter are relevant to the assumptions underlying the global/local paradigm and to the operationalization of globality. Essentially, we pointed out the importance of making a clear and careful analysis of stimulus structure before going on to make inferences about processing.

In view of the evidence that local elements of many-element patterns do not have a psychological reality as local or component properties, the choice of such patterns for testing the global precedence hypothesis seems to be unfortunate, despite its elegance in controlling for many intervening variables. Furthermore, as mentioned earlier, relative size alone may provide a reasonable account for obtained global dominance with many-element patterns (Navon & Norman, 1983; Kimchi et al., 1990). To the extent that globality is inherently confounded with relative size, the finding that "larger" properties are available earlier than relatively "smaller" properties (provided that eccentricity is held constant) would be informative. But certainly more than this is claimed by the global precedence hypothesis. The interesting and essential difference between wholistic and component properties is not their relative size.

Consider for example the stimuli in Figure 3.5. To distinguish the wholistic property of closure from the component vertical and horizontal lines on the basis of their relative sizes would seem to miss the point. Rather, the essential characteristic of wholistic properties, as we have mentioned before, is that they do not inhere in the components, but depend instead on the interrelations between them. We suggest that the ultimate precedence of wholistic versus component properties should be tested with stimuli whose structure does not allow for the most essential aspect of globality to be confounded with other, less central aspects. This is not an easy challenge.

IV. CONCLUDING REMARKS

In this chapter we have tried to show how the theoretical concepts of structure and process can help to further our understanding of the perceptual/cognitive system. We began with a discussion of the structure/process distinction in general, and then continued with an analysis of the global/local paradigm, which we hope served to illustrate more concretely the benefits of carefully considering both structure and process together.

The global precedence hypothesis is a processing hypothesis, and the major import of our analysis was to demonstrate that a clear notion of the perceptual structure of the stimulus is an important prerequisite for asking meaningful questions about processing. A basic assumption underlying the global/local paradigm is that the two levels of hierarchical patterns, the global configuration and the local elements, map directly into distinct perceptual units that differ only in their level of globality. However, we presented evidence that the local elements map into different perceptual units, and that the configural and elemental levels bear different perceptual relations to each other, in few- and many-element patterns. Such evidence severely weakens the plausibility of the forementioned assumption, and was shown to have important implications for the interpretation of obtained experimental findings. As a general rule, it is important to consider the perceptual structure of the stimuli used to test any processing hypothesis.

At the same time, the studies of few- and many-element patterns reported here serve to demonstrate that although a careful analysis of stimulus aspects per se may be necessary for understanding performance on a psychological task, it is not sufficient. Consider performance on a task involving hierarchical patterns. As discussed earlier, from strictly a stimulus point of view, the logical structure of such patterns predicts processing asymmetry. Yet it was found that the perceptual relations between configural and elemental levels of such patterns depend on the number of elements embedded in the patterns. The logical structure cannot account for this fact without redefining the "logically-given" relations. On the other hand, from strictly a processing point of view, it might be argued that the very fact that local elements of many-element patterns are perceived as "textural molecules" is precisely due to global precedence itself (e.g., Navon, 1981). This argument, however, has difficulty explaining why, in contrast to many-element patterns, the local elements of few-element patterns are perceived as figural parts. Here too, it seems that the processing hypothesis of global precedence alone cannot account for the different perceptual status of the local elements in few- and many-element patterns without redefining its notion of global precedence.

Clearly, then, stimulus structure and organismic mode of processing must be considered together if we are to understand performance on a psychological task. Further, recall that we refer to stimulus structure defined psychophysically, and as such it depends not only on the properties of the stimulus per se, but on characteristics of the perceptual system as well. For this reason, identification of psychologically relevant properties in the stimulus domain may also further our understanding of the processing mechanisms underlying stimulus structure. For instance, differences between few- and many-element patterns in terms of stimulus properties such as number and relative size of local elements can give us some clues as to the operation of possible mechanisms that may account for the differences in the perceptual structure of these two types of hierarchical patterns.

This leads us to one final important point. If perceptual stimulus structure constrains processing, but at the same time depends on processing, where does that leave us with regard to the distinction between structure and process? We might say that a more complete understanding of human information processing would require a distinction between three aspects: (a) the stimulus structure, (b) the processing of that structure, and (c) the processing mechanism accounting for that structure. The inclusion of stimulus structure in our psychological explanations allows for the mechanism accounting for such structure to be dealt with as a problem separate from how that structure may be processed in different psychological tasks. Thus, any complete process model for hierarchical patterns will have to account for the relative perceptual separation of configural and elemental levels when the number and the relative size of the elements vary. But as long as such effects are taken into account as stimulus structure, global precedence and other similar processing hypotheses can be tested using appropriate stimuli, notwithstanding temporary ignorance regarding the specific mechanisms underlying such structure.

In the long run, differentiating relatively invariant stimulus structure from relatively flexible modes of processing offers the far-reaching promise of guiding us towards the built-in structural constraints of the perceptual/cognitive system itself. Admittedly, it is no easy task to determine what in human performance should be accounted for by stimulus structure, and what by mode of processing. However, such an enterprise, difficult though it may be, is not without its rewards.

ACKNOWLEDGMENTS

The preparation of this chapter was partially supported by a grant from The Israeli Academy of Sciences and Humanities to the first author, and by a National Science Foundation Graduate Fellowship to the second author. It also benefitted from the facilities of the Institute of Information Processing and Decision Making, University of Haifa.

REFERENCES

Anderson, J. R. (1978). Arguments concerning representations for mental imagery. Psychological Review, 85, 249-277.

Beck, J. (1982). Textural segmentation. In J. Beck (Ed.), Organization and representation in perception (pp 285-317). Hillsdale, NJ: Erlbaum.

Block, N. (Ed.) (1981). Imagery. Cambridge, MA: The MIT Press.

Boer, L. C., & Keuss, P. J. G. (1982). Global precedence as a postperceptual effect: An analysis of speed-accuracy tradeoff functions. Perception & Psychophysics, 31, 358-366.

Boff, K. R., Kaufman, L., & Thomas, J. P. (1986). Handbook of perception and performance, Vol. 2. New York: Wiley.

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

Ehrenfels, C. von. (1890). Uber Gestaltqualitaten. Vierteljahrschrift fuer Wissenchaftliche Philosophie, 14, 249-292.

Foard, C. F. & Kemler Nelson, D. G. (1984). Holistic and analytic modes of processing: The multiple determinants of perceptual analysis. Journal of Experimental Psychology: General, 113, 94-111.

Garner, W. R. (1974). The Processing of Information and Structure. Hillsdale, N.J.: Erlbaum.

Garner, W. R. (1976). Interaction of stimulus dimensions in concept and choice processes. Cognitive Psychology, 8, 98-123.

Garner, W. R. (1978). Aspects of a stimulus: Features, dimensions, and configurations. In E. Rosch & B. B. Lloyd (Eds.), Cognition and categorization. Hillsdale, NJ: Erlbaum.

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 analysis (pp. 1-38). Hillsdale, NJ: Erlbaum.

Gibson, J. J. (1966). The senses considered as perceptual systems. Boston: Houghton-Mifflin.

Gibson, J. J. (1979). The ecological approach to visual perception. Boston: Houghton-Mifflin.

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

Gopher, D., & Kimchi, R. (1989). Engineering psychology. Annual Review of Psychology, 40, 431-455.

Grice, G. R., Canham, L., & Boroughs, J. M. (1983). Forest before trees? It depends where you look. Perception & Psychophysics, 33, 121-128.

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. (1981). Textons, the elements of texture perception and their interactions. Nature, 290, 91-97.

Kemler Nelson, D. G. (1989). The nature and occurrence of holistic processing. In B. Shepp & S. Ballesteros (Eds.), Object perception: Structure & Process. Hillsdale, NJ: Erlbaum. pp. 357-386.

Kimchi, R. (1982). Perceptual organization of visual patterns. Doctoral Dissertation, University of California, Berkeley.

Kimchi, R. (1988). Selective attention to global and local levels in the comparison of hierarchical patterns. Perception & Psychophysics, 43, 189-198.

Kimchi, R. (1990). Children's perceptual organization of hierarchical patterns. European Journal of Cognitive Psychology.

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

Kimchi, R., Palmer, S. E. (1985). Separability and integrality of global and local levels of hierarchical patterns. Journal of Experimental Psychology: Human Perception and Performance, 11, 673-688.

Kimchi, R., & Merhav, I. (1991). Hemispheric processing of global form, local form, and texture. Acta Psychologica, 76, 133-147.

Kimchi, R., Gopher, D., Rubin, Y., & Raij, D. (in press). Dichoptic and binocular viewing: Effects of attention and task requirements. Human Factors.

Kinchla, R. A., Wolfe, J. M. (1979). The order of visual processing: "Top down," "bottom up" or "middle-out". Perception & Psychophysics, 25, 225-31.

Klein, R. M., & Barresi, J. (1985). Perceptual salience of form versus material as a function of variations in spacing and number of elements. Perception & Psychophysics, 37, 440-446.

Koffka, K. (1963). Principles of Gestalt Psychology. New York: Harcourt, Brace & World. (Originally published, 1935.)

Kohler, W. (1929). Gestalt Psychology. New York: Liveright.

Kohler, W. (1971). Human perception. In M. Henle (Ed. and trans.) The Selected Papers of Wolfgang Kohler. New York: Liveright. (Originally published in French, 1930.)

Kolinsky, R., & Morais, J. (1986). Evidence for early extraction of emergent properties in visual perception: A replication. Perceptual and Motor Skills, 63, 171-174.

Kosslyn, S. M. (1986). Toward a computational neurophysiology of high-level vision. In T. J. Knapp & L. C. Robertson (Eds.), Approaches to Cognition: Contrasts and Controversies (pp. 223-242). Hillsdale, N.J.: Erlbaum.

Kubovy, M., Pomerantz, J. R. (Eds.) (1981). Perceptual Organization. Hillsdale, NJ: Erlbaum.

Lamb, M. R., & Robertson, L. C. (1988). The processing of hierarchical stimuli: Effects of retinal locus, locational uncertainty, and stimulus identity. Perception & Psychophysics, 44, 172-181.

Lasaga, M. I. (1989). Gestalt and their components: Nature of information-precedence. In B. Shepp & S. Ballesteros (Eds.), Object perception: Structure & Process (pp. 165-202). Hillsdale, NJ: Erlbaum.

Martin, M. (1979). Local and global processing: the role of sparsity. Memory and Cognition, 7, 476-484.

Miller, J. 1981. Global precedence in attention and decision. Journal of Experimental Psychology: Human Perception and Performance, 7, 1161-74.

Navon, D. (1977). Forest before trees: The precedence of global features in visual perception. Cognitive Psychology, 9, 353-83.

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

Navon, D. & Norman, J. (1983). Does global precedence really depend on visual angle? Journal of Experimental Psychology: Human Perception and Performance, 9, 955-965.

Palmer, S. E. (1977). Hierarchical structure in perceptual representation. Cognitive Psychology, 9, 441-474.

Palmer, S. E. (1978). Fundamental aspects of cognitive representation. In E. Rosch & B. B. Lloyd (Eds.), Cognition and Categorization (pp. 259-303). Hillsdale, NJ: Erlbaum.

Palmer, S. E. & Kimchi, R. (1986). The information processing approach to cognition. In T. J. Knapp & L. C. Robertson (Eds.), Approaches to Cognition: Contrasts and Controversies (pp. 37-77). Hillsdale, NJ: Erlbaum.

Paquet, L. & Merikle, P. M. (1988). Global precedence in attended and nonattended objects. Journal of Experimental Psychology: Human Perception and Performance, 14, 89-100.

Paquet, L. & Merikle, P. M. (1984). Global precedence: The effect of exposure duration. Canadian Journal of Psychology, 38, 45-53.

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, 511-535.

Pomerantz, J. R., Sager, L. C., & Stoever, R. J. (1977). Perception of wholes and their component parts: Some configural superiority effects. Journal of Experimental Psychology: Human Perception & Performance, 3, 422-435.

Pomerantz, J. R., & Kubovy, M. (1986). Theoretical approaches to perceptual organization. In K. R. Boff, L. Kaufman, & . P. Thomas (1986). Handbook of perception and performance, Vol. 2 (pp 36:1-46). New York: Wiley.

Pylyshyn, Z. W. (1979). Validating computational models: A critique of Anderson's indeterminacy of representation claim. Psychological Review, 86, 383-394.

Robertson, L. C. (1986). From Gestalt to Neo-Gestalt. In T. J. Knapp & L. C. Robertson (Eds.), Approaches to Cognition: Contrasts and Controversies (pp. 159-188). Hillsdale, NJ: Erlbaum.

Rosch, E. (1978). Principles of categorization. In E. Rosch & B. B. Lloyd (Eds.), Cognition and categorization (pp. 27-48). Hillsdale, NJ: Erlbaum.

Rumelhart, D. E. & Norman, D. A. (1988). Representation in memory. In R. C. Atkinson, R. J. Herrnstein, G. Lindzey, R. D. Luce, (Eds.), Handbook of Experimental Psychology. New York: Wiley.

Santee, J. L. & Egeth, H. E. (1980). Selective attention in the speeded classification and comparison of multidimensional stimuli. Perception & Psychophysics, 28, 191-204.

Sebrechts, M. M. & Fragala, J. J. (1985). Variation on parts and wholes: Information precedence vs. global precedence. Proceedings of the Seventh Annual Conference of the Cognitive Science Society, 11-18.

Shepp, B. E., & Ballesteros, S. (Eds.) (1989). Object perception: Structure & Process. Hillsdale, NJ: Erlbaum.

Smith, J.D., & Kemler Nelson, D.G. (1984). Overall similarity in adults classification: The child in all of us. Journal of Experimental Psychology: General, 113, 137-159.

Smith, L. B., & Kemler, D. G. (1978). Levels of experienced dimensionality in children and adults. Cognitive Psychology, 10, 502-532.

Titchener, E. (1909). Experimental psychology of the thought process. New York: MacMillan.

Treisman, A. (1985). Preattentive processing in vision. Computer Vision, Graphics, and Image Processing, 31, 156-177.

Treisman, A. (1986). Properties, parts, and objects. In K. R. Boff, L. Kaufman, & . P. Thomas (1986). Handbook of perception and performance, Vol. 2 (pp 35:1-70). New York: Wiley.

Treisman, A., & Paterson, R. (1984). Emergent features, attention, and object perception. Journal of Experimental Psychology: Human Perception and Performance, 10, 12-31.

Uttal, W. R. (1988). On seeing forms. Hillsdale: N.J.: Erlbaum.

Ward, L. M. (1982). Determinants of attention to local and global features of visual forms. Journal of Experimental Psychology: Human Perception and Performance, 8, 562-581.

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

Wertheimer, M. (1955). Gestalt theory. In W. D. Ellis (Ed.), A source book of Gestalt psychology (pp. 1-16). London: Routhedge & Kegan Paul. (Originally published in German, 1923.)

Winston, P. H. (1975). Learning structural descriptions from examples. In P. H. Winston, (Ed.), The psychology of computer vision. New York: McGraw-Hill.

Wundt, W. (1874). Grundzuge der physiologischen psychologie. Leipzig: Engelmann.

Commentary

Structure and Process in Perceptual Organization, R. Kimchi & M. Goldsmith

JAMES T. ENNS
University of British Columbia

A Martian vision researcher, on a first visit to earth, would not be able to miss the fascination that Earthling researchers hold for a peculiar sort of stimulus. It consists of a large shape--often a letter of the English alphabet--made up of many smaller shapes--often also letters of the alphabet. Although the present popularity of this stimulus might at first suggest to the Martian that it was a recent innovation, careful reading of older Earthling articles would soon reveal its distinguished history as a behavioral probe into the hidden workings of the human visual system.

Since its recent re-introduction by Navon (1977), this stimulus has played an important role in several areas of visual perception, including work on attention, the time course of perception, multiple spatial frequency channels, the relative importance of parts and wholes in determining a final percept, interactions among processing streams, hemispheric differences in pattern perception, and the development of perception in children. Its wide popularity has sprung largely from the assumption that this stimulus permits the separation of perceptual processing into "local" and "global" streams. Although the theoretical concepts of *local* and *global* have varied from area to area, the operational definition has been clear--*local* refers to the small letters and *global* to the large one.

Kimchi and Goldsmith force all researchers to reconsider this assumption. Does this stimulus, in fact, separate the local from the global information? The empirical and logical evidence amassed argues for a strong "No." The authors show that it all depends on the number and size of the little elements (letters or shapes) that make up the big form (letter or shape). With a small number of elements, the local level is seen as an integral part of the global level. This subjective impression is supported by performance measures of similarity judgment, speeded classification, and speeded comparison. With a large number of elements, the local level is seen as a separable, or interchangeable, aspect of the global form. As such, the small elements do not have a perceptual status equal to the large form. The unmistakable conclusion is that the structure of these popular stimuli cannot be predicted on purely logical or physical grounds, as has been assumed for so long. The *psychological* structure depends on the visual system's interpretation--the elements can be either *form* (integral parts of the larger whole) or *material* (interchangeable placeholders with a characteristic texture).

What are the consequences of this result for future research and theory? Kimchi and Goldsmith spell out several, including the importance of defining stimulus structure psychophysically, the danger of predicting how a stimulus will be processed from its logical structure, and the inherent ambiguity of the conventional test for so-called global precedence. I would like to focus briefly on what I see to be an even more subversive implication--subversive even to the view espoused by Kimchi and Goldsmith. It concerns an assumption that is operative throughout this chapter, namely, that there is *one* stimulus structure to be uncovered by careful psychophysical testing.

Kimchi et al.'s results show that the interpretation of the identical local elements will change as a function of the surrounding context (i.e., the number and size of other local elements). Surely the representation of the same element has not changed at the level of the retina. However, and this seems equally clear, *some* representation has changed in order to produce the obtained behavioral data. To me, this argues for a view in which the phrase *stimulus structure* refers to nothing more (or less) than the representation available to the processing mechanism which governs the response. In other words, its meaning is inherently relative. In theory, the physical structure of the stimulus can be contrasted with its structure at the ganglion level, this structure can be compared with that at the striate cortex, an even more complex representation may be available to conscious awareness. Ultimately, it will be important to know *which* structure is responsible for a particular psychophysical outcome or for the percept that is experienced phenomenologically.

At this stage in the history of vision science, it is asking too much of any psychophysicist to know the correct mapping between behavioral tasks and level of processing (see Spillman & Werner, 1990, for chapters addressing this issue). However, some first approximations already exist and are hinted at by Kimchi and Goldsmith. For example, measures of preattentive vision such as "pop out" visual search and "immediate" texture segmentation allow stimulus structure to be examined prior to the onset of attentive processing mechanisms. The psychophysical technique of selective adaptation can also be used to study representations that may not be available for conscious inspection. The challenge, of course, will be to develop a series of such tools for probing vision at a large number of different levels.

The important contribution of Kimchi and Goldsmith toward this endeavor has been to show the importance of defining stimulus structure with converging psychophysical tests. What remains for future research is the design of tests that isolate the *multiple* stimulus structures in the visual system.

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

Spillman, L., & Werner, J.S. (1990). Visual perception: The neurophysiological foundations. Academic Press.