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9

Relative Dominance of Holistic and Component Properties in the Perceptual Organization of Visual Objects

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The perceptual relations between wholes and their component parts have been a controversial issue for psychologists and philosophers before them. The question is whether processing of the overall structure precedes and determines the processing of the component parts or properties, or whether the component properties are registered first and are then synthesized to form the objects of our awareness. There have been two opposite approaches to this issue: the early feature-analysis view and the holistic primacy view. According to the prevailing early feature-analysis view, perceptual processing begins with the analysis of simple features and elements that are later integrated into coherent objects. In this chapter, I present empirical findings that challenge this view, showing holistic primacy in different perceptual tasks and early in the course of perceptual processing.

There has been much confusion regarding the notion of holistic perception, owing in part to the looseness with which the term is used in the literature, often without a clear theoretical or operational definition. I use the term "holistic primacy" to refer to the view that holistic properties are primary in perception. A visual object, viewed as a whole, has both holistic properties and component properties or parts. Holistic properties are properties that depend on the interrelations between the component parts. In this context the terms "holistic," "global," and "configural processing" are often used interchangeably to express the hypothesis that holistic properties, rather than component properties, dominate perceptual processing.

I begin with a very brief review of the early feature-analysis view and empirical evidence that supports it. Next, I present the holistic primacy view. I then review and discuss in detail behavioral findings that demonstrate the relative dominance of holistic versus component properties in the discrimination, identification, and classification of visual objects. The following section focuses on recent experiments that have studied the microgenesis of the perceptual organization of visual objects. This microgenetic analysis is particularly revealing because it provides information about the relative dominance of holistic and component properties during the evolution of the percept. I then discuss the implications of all these findings for the longstanding dichotomy between analytic versus holistic perception, arguing that recent developments in the psychological and physiological research on visual perception weaken this dichotomy. The research on visual perception provides increasing evidence for a highly interactive perceptual system in which both simple properties and holistic properties play a role in the early organization of visual objects.

Early Feature Analysis

The early feature-analysis viewpoint, which has its roots in the Structuralist school of thought (e.g., Titchener, 1909), holds that objects are initially decomposed into simple features and components. Perceptual wholes are constructed by integrating these features and components. A modern representative of this viewpoint is the computational approach to vision by Marr (1982) that claims that the visual primitives are local geometric properties of simple form components such as sloped line segments. Similarly, the feature-integration theory (e.g., Treisman, 1986; Treisman & Gormican, 1988) assumes that simple features and components are analyzed at early stages of perceptual processing. Focused attention is then needed to establish spatial relations between components and to integrate them into coherent objects.

The early feature-analysis approach has been supported by many experimental findings, both physiological and psychological, and has dominated cognitive psychology for several decades. I review very briefly some of the evidence for early feature analysis. An extensive review can be found in Treisman (1986).

Physiological Evidence

Physiological studies using single-cell recording and autoradiographic techniques have shown that the cortical areas most directly connected to visual input (V1 and V2) contain cells that are sensitive to distinct visual properties such as orientation, luminance, color, motion, and spatial frequency (Hubel & Wiesel, 1962, 1977; Schiller, 1986; Zeki, 1978, 1993). The outputs of these cells often form retinotopic maps that preserve retinal topography. These findings have suggested that the visual system analyzes visual objects into separate simple properties, each of which is organized by position.

Psychological Evidence

A major source of support for the early feature-analysis view comes from psychophysical studies that have focused on the determinants of effortless texture segmentation and visual search (e.g., Beck, 1982; Julesz, 1984; Treisman, 1988).

In visual search the task is to detect as quickly and as accurately as possible the presence or absence of a target among other items (distractors) in the display. The number of distractors varies. Correct reaction times (RTs) to the target are examined as a function of the total number of items (target and distractors) in the display, and the slope of the RT function over number of items indicates search rate. If the time to detect the target is independent, or nearly independent, of the number of items in the display and the target seems to pop out (as for example, a diagonal line among vertical ones, see figure 9.1), then target search is considered fast and efficient, and target detection occurs under widely spread attention. If the time to detect a target increases as the number of other items in the display increases, then search is considered difficult and inefficient, and target detection requires focused attention (e.g., Duncan & Humphreys, 1989; Enns & Kingstone, 1995; Treisman & Gormican, 1988). Note that a continuum of search rates exists with search efficiency increasing the more discriminable from each other are the target and distractors.

In a typical texture discrimination task an array composed of two groups of elements (either side by side or one embedded into the other) is presented very briefly (for less than 150 ms). Texture segregation is considered effortless if it can be done without scrutiny, namely, if it occurs under these very brief exposure durations (e.g., Julesz, 1981).

Given the widespread view that early perceptual processes are rapid,

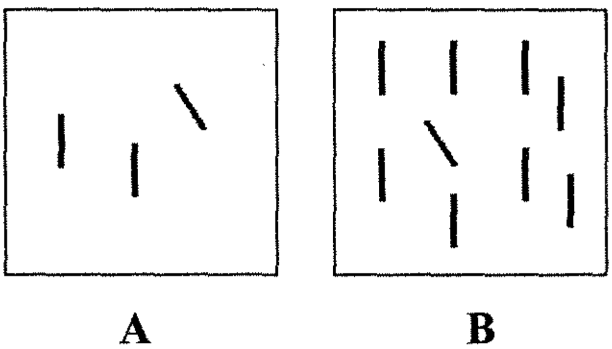

FIGURE 9.1 A pop-out of a diagonal line among vertical lines: the diagonal line is detected as easily in a nine-item display as in a three-item display.

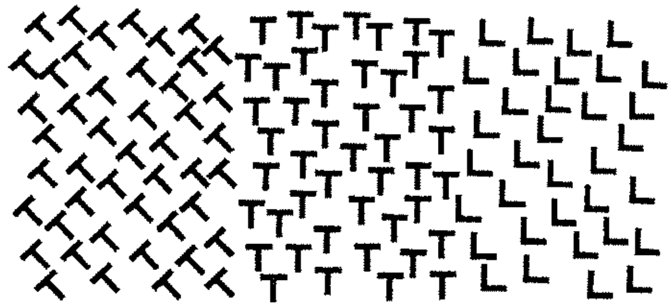

FIGURE 9.2. A group of tilted Ts is easily segregated from a group of upright Ts (disparity of line orientation), whereas a group of upright Ls (disparity of line arrangement) is not. After Beck (1982).

spatially parallel, and effortless whereas later processes are more effortful, time-consuming, and attention demanding (e.g., Neisser, 1967; Treisman, 1982), visual pop-out and effortless texture segmentation for a given feature have been interpreted as evidence that it is extracted by early perceptual processes and is included in the set of visual primitives (e.g., Julesz, 1984; Treisman, 1982; Treisman & Gelade, 1980).

Visual pop-out was found for targets that differ from distractors in simple properties such as orientation, color, size, and curvature. An example of pop-out owing to orientation disparity is presented in figure 9.1. These simple properties were also found to mediate effortless texture segregation (e.g., Julesz, 1981, 1984; Treisman, 1982). For example, as illustrated in figure 9.2, disparity of line orientation (as between an upright T and a tilted T) enables easy segregation between groups of elements, whereas differences in the spatial relationships between features (as between an upright T and an upright L) do not (e.g., Beck, 1966, 1967). Likewise, a single tilted T pops out among upright Ts, but a single L does not (e.g., Ambler, Keel, & Phelps, 1978). These and similar findings of efficient and effortless detection for simple properties have been taken as evidence for the early feature-analysis view.

The Primacy of Holistic Properties

In contrast to the atomistic view of the Structuralist school of thought, the Gestaltists (e.g., Koffka, 1935; Kohler, 1947; Wertheimer, 1955) argued for the primacy of whole units and organization in the percept. A basic tenet of the Gestalt view is that a whole is qualitatively different from the complex that one might predict by considering only its parts. The Gestaltists' notion of perceptual organization implies that wholes are organized prior to perceptual analysis of their properties and components.

Despite the prevalence of the early feature-analysis approach, students of perception have continued to grapple with the problem of perceptual organization originally recognized by Gestalt psychology (e.g., Kubovy & Pomerantz, 1981; Palmer & Rock, 1994; Pomerantz & Kubovy, 1986). A modern version of the Gestalt approach is the view that holistic properties are primary in perception (e.g., Chen, 1982; Kimchi, 1992; Navon, 1977; Uttal, 1988). The Gestaltists' claim that the whole is different from the sum of its parts can perhaps be captured by holistic properties such as closure, symmetry, and certain other spatial relations between the component parts. Such properties do not inhere in the component parts, and cannot be predicted by considering only the component parts (e.g., Garner, 1978; Kimchi, 1994; Navon, 1977; Rock, 1986). In the last two decades or so, work on issues such as perceptual grouping, part-whole relationships, perception of global and local aspects of visual patterns, and context effects in object perception have yielded findings that challenge the early feature-analysis view.

In the next two sections I review in detail studies that demonstrate perceptual dominance of holistic/configural properties. The first section focuses on the role of holistic properties in the identification, discrimination, and classification of visual objects. The second section focuses on the relative dominance of holistic properties during the evolution of the percept.

Dominance of Holistic Properties in Identification and Discrimination of Visual Objects

The Global Advantage Effect

In the spirit of the Gestalt psychology, Navon (1977) proposed that perceptual processing proceeds from global structuring toward more fine-grained analysis. This *global precedence hypothesis* has been tested by studying the perception of hierarchical 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 having either the same identity as the larger letter or a different identity (see figure 9.3). The larger letter is considered a higher level unit relative to the smaller letters, which are, in turn, lower level units. Properties of the higher level unit are considered to be more global than properties of the lower level units by virtue of their position in the hierarchical structure. In a typical experiment, observers are presented with such stimuli and are required to identify the larger (global) or the smaller (local) letter in separate blocks of trials. All else being equal, *global advantage* is observed: the global letter is identified faster than the local letter, and conflicting information between the global and the local levels exerts asymmetrical global-to-local interference (e.g., Navon, 1977).

Several studies have demonstrated important boundary conditions of global advantage, pointing out certain variables that can modulate the ef-

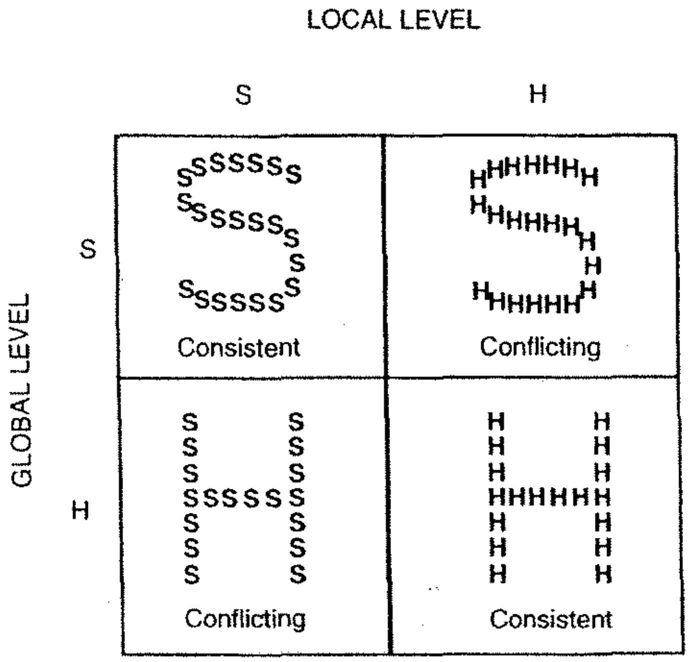

FIGURE 9.3. An example of Navon's type hierarchical stimuli: large Hs and Ss are composed of small Hs and Ss. After Navon (1977).

fect. Global advantage is less likely to occur when the overall visual angle of the hierarchical stimulus exceeds 7°–10° (e.g., Kinchla & Wolfe, 1979), with foveal than peripheral presentation (e.g., Pomerantz, 1983), with spatial certainty than spatial uncertainty (e.g., Lamb & Robertson, 1988), with sparse than dense elements (e.g., Martin, 1979), with few relatively large elements than many relatively small elements (e.g., Kimchi, 1988; Yovel, Yovel, & Levy, 2001), with long than short exposure duration (e.g., Luna, 1993; Paquet & Merikle, 1984), and when the goodness of the local forms is superior to that of the global form (e.g., LaGasse, 1994; Sebrechts & Fragala, 1985).

The mechanisms underlying the global advantage effect or its locus are still disputed. Several investigators interpreted global advantage as reflecting the priority of global properties at early perceptual processing (e.g., Broadbent, 1977; Han, Fan, Chen, & Zhuo, 1997; Navon, 1977, 1991; Paquet & Merikle, 1988), possibly as a result of early perceptual-organizational processes (Behrmann & Kimchi, in press). Other investigators suggested that global advantage arises in some postperceptual process (e.g., Boer & Keuss, 1982; Miller, 1981a, 1981b; Ward, 1982). It has also been claimed that global advantage is mediated by low-spatial frequency channels (e.g., Ivry & Robertson, 1998; Shulman & Wilson, 1987).

Notwithstanding the lack of consensus regarding the mechanisms underlying the effect, global advantage is normally observed with the typical stimuli used in the global/local paradigm (i.e., larger figures made up of many, relatively small figures), to the limits of visibility and visual acuity (see Kimchi, 1992, for an extensive review).

Kimchi (1992) has raised several concerns about the interpretation of global advantage as evidence for the primacy of holistic properties. The primacy of holistic properties implies that a property that is defined as a function of the interrelations among components would dominate the component properties. This is what was intended to be tested in the global/local paradigm with the hierarchical stimuli: whatever the components are, spatial relationships between the components would have perceptual priority. The nature of the components and their perceptual status in relation to the global configuration was actually ignored. However, as I have argued elsewhere (Kimchi, 1992, 1994), the local elements of the hierarchical letters (see figure 9.3) are not the component properties of the larger letter. The local properties of the letter H, for example, are, among others, vertical and horizontal lines. Furthermore, the nature of the components and their perceptual status in relation to the global configuration may have consequences for the interpretation of experimental findings obtained in the global/local task. For example, Kimchi and Palmer (1982, 1985) have shown that many-element patterns, like those typically used in the global/local paradigm, are perceived as global form associated with texture, and the form and texture are perceptually separable. Patterns composed of few, relatively large elements, on the other hand, are perceived as a global form and figural parts. A similar distinction between patterns in which only the position of the elements matters for the global form, and patterns in which both the position and the nature of the elements matter, was proposed independently by Pomerantz (1981, 1983). If the local elements of many-element patterns serve to define texture or are mere placeholders, 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, thus suggesting global precedence, or rather, by a qualitative difference between identification of a figural unit versus a textural molecule.

Another issue is that the difference between global and local properties, as operationally defined in the global/local paradigm, may be captured in terms of relative size, and relative size alone rather than level of globality, may provide a reasonable account for obtained global advantage with hierarchical patterns (Navon & Norman, 1983). Yet the difference between holistic and component properties is not necessarily their relative size. To distinguish, for example, the closedness of a square (a holistic/configural property) from its component vertical and horizontal lines on the basis of their relative sizes would seem to miss the point. Rather, as noted earlier, the essential characteristic of holistic properties is that they do not inhere in the components, but depend instead on the interrelations among them. Lasaga (1989) and Kimchi (1994; Kimchi & Bloch, 1998) attempted to compare directly between component properties and properties that are defined on the spatial relationships between the components. It has even been demonstrated that configural properties need not be necessarily global. These studies are discussed later.

Pop-out Search and Effortless Texture Segregation for Higher Level Properties

Although earlier visual search studies showed visual pop-out for simple features, more recent studies have shown fast and efficient search also for certain higher level properties such as three-dimensional orientation, lighting direction, and surface slant (Enns & Rensink, 1990, 1991; Kleffner & Ramachandran, 1992), for part-whole information (Wolfe, Friedman-Hill, & Bilsky, 1994), and for global configuration (Kimchi, 1998; Rensink & Enns, 1995; Saarinen, 1995).

For example, Enns and Rensink (1990) found pop-out among items defined by the spatial relations between lines when the items correspond to three-dimensional objects that differ in spatial orientation (figure 9.4A); however, search was slow and inefficient for similar items that appear two-dimensional (figure 9.4B). These findings suggest sensitivity to three-dimensional structure in early perceptual processing.

Configural effects in visual search were demonstrated by Rensink and Enns (1995). Targets and distractors were Mueller-Lyer configurations differing in wing arrangements (wings-in versus wings-out; see figure 9.5). Two critical conditions were the different-overall condition (figure 9.5A) in which the target central line is the same as the distractor central lines, but the overall length of the target and distractor configurations is different, and the different-segment condition (figure 9.5B) in which the target item differs from the distractor items only in the physical length of the central

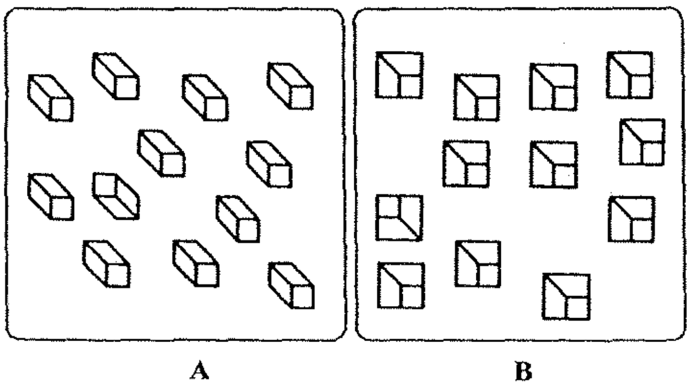

FIGURE 9.4. (A) Visual pop-out among items that correspond to three-dimensional objects that differ in spatial orientation. (B) No pop-out is observed for similar items that appear two-dimensional. Reprinted from Enns, J. T., & Rensink, R. A., A model for the rapid interpretation of line drawings in early vision, *Vision Search 2*, (Gale, Carr & Brogan, Eds.), (Fig. 4.2, p. 76). Copyright 1992, with permission from Taylor & Francis Group, UK.

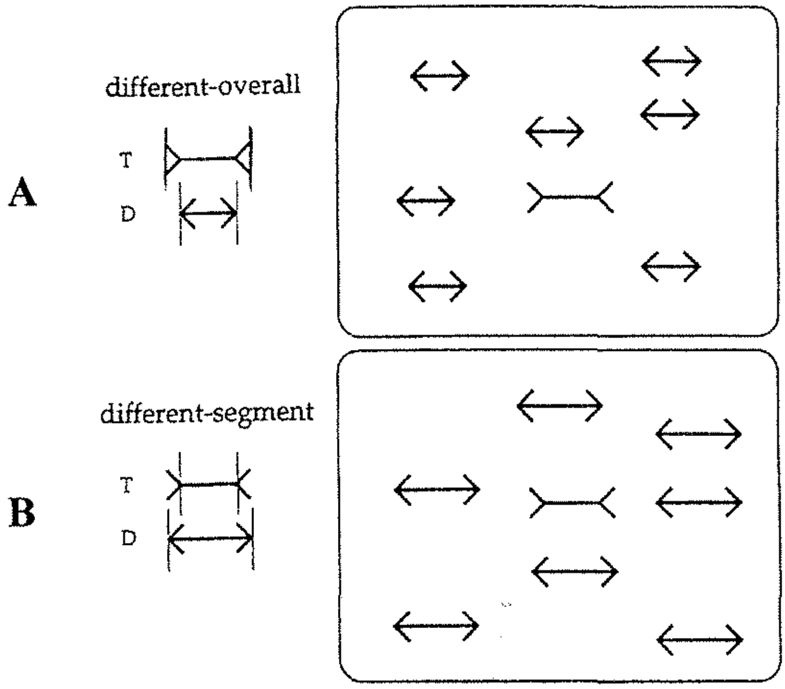

FIGURE 9.5. An example of the stimuli in Rensink and Enns (1995) visual search experiment. (A) Target (T) that has the same central line as the distractors (D) but differs from the distractors in overall length pops out. (B) Search for target that differs from the distractors in the length of the central line but has a similar overall length is difficult. Adapted from Rensink & Enns (1995), with permission.

line. Line length is known to support visual pop-out for isolated line segments (e.g., Treisman & Gormican, 1988). The question is whether visual search is governed by the segment length or by the overall length. If search were based on the component segments, then search would be faster in the different-segment condition than in the different-overall condition. The results, however, showed high-speed pop-out search for the latter but not for the former condition, indicating that visual search was based on complete configurations rather than on the component line segments.

Studying visual search for global configuration and local elements of hierarchically constructed patterns, Kimchi (1998) showed visual pop-out for the global configuration of many-element stimuli. In separate blocks, participants were required to detect the presence or absence of a global target or a local target. In the global search, the target differed from the distractors only in the global shape (figure 9.6A and C); in the local search, the target differed from the distractors only in the local elements (figure 9.6B and D). When target and distractors were many-element patterns, the results showed high-speed pop-out search for the global targets, whereas

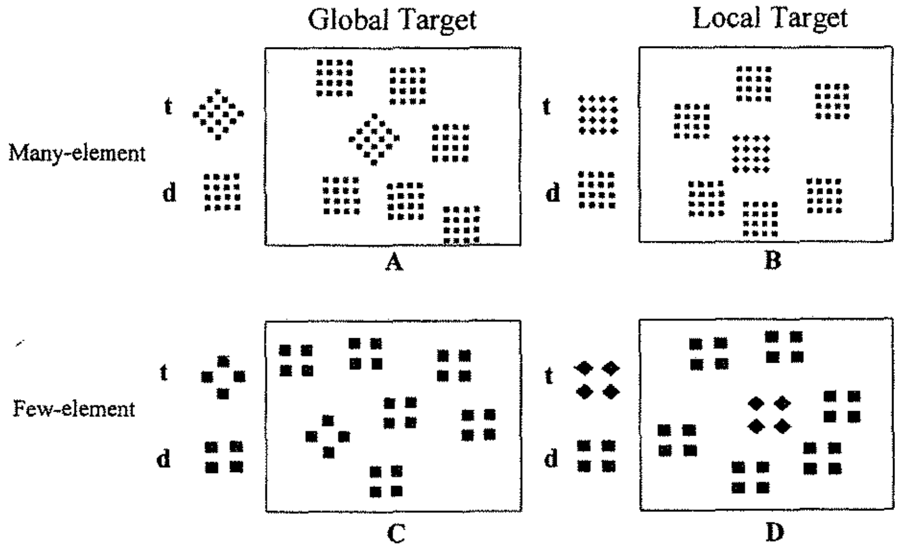

FIGURE 9.6. The targets (t) and distractors (d) in Kimchi's (1998) visual search experiment. Global diamond configuration of many-element pattern pops out among global square configurations even though target and distractors have the same local elements (A), and local diamonds of few-element stimuli pop-out among local squares even though target and distractors have the same global configurations (D). Search for local diamond elements in a display of many-element patterns composed of squares (B), and search for global diamond configuration in a display of few-element square configurations (C) are more difficult.

search for the local targets was slow and inefficient. For the few-element patterns, on the other hand, search for local targets was faster than search for global targets (see also Enns & Kingstone, 1995), demonstrating the effect of number and relative size of elements on global superiority. I will return to this point later. The slow search rate for the local targets in the many-element condition cannot be accounted for by discrimination difficulty owing to their small size because previous results with similar patterns, in different and similar paradigms, suggest that the relevant factor is the relative rather than the absolute size of the elements (e.g., Kimchi & Palmer, 1982; Kimchi & Peled, 1999).

Texture-segregation experiments have shown that a group of triangles pops out in a field of arrows, and a group of pluses is effortlessly detectable in a field of Ls (e.g., Williams, 1992). These easy, effortless texture segregations are presumably mediated by closure and intersection, respectively. Interestingly, the effectiveness of line orientation for texture segregation is reduced when the elements in the array have similar properties such as intersection and closure (e.g., a group of Xs is not as easily detectable in a field of pluses as is a group of diagonal lines in a field of vertical lines, Beck, 1982). It seems that similarity in configural properties overrides differences in simple properties (even differences that produce better segregation in single-line element array), but not vice versa (e.g., pluses and Ls).

These findings indicate that features that are much more complex than simple geometric features can be extracted very rapidly from a visual array, and therefore are presumably available in early perceptual processing.

Perceptual Context Effects: Object and Configural Superiority

OBJECT SUPERIORITY EFFECT

Other investigations of the holistic primacy issue have examined performance with lines presented in a context. For example, Weisstein and Harris (1974) required participants to determine which of four possible diagonals is present in a briefly flashed visual array. The diagonal lines were presented either alone or in the context of vertical and horizontal lines that carried no task-relevant information in terms of task requirements. The context lines were either configured to suggest three-dimensional objects or arranged to appear two-dimensional, lacking figural unity. Examples of the stimuli used by Weisstein and Harris are presented in figure 9.7. This and other studies have shown that a barely visible, briefly flashed line segment can be identified more accurately when it is part of a pattern that

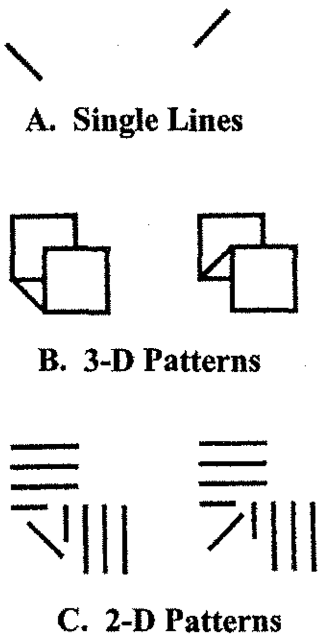

FIGURE 9.7. The object superiority effect: the discrimination between the two oriented lines (A) is easier when the lines are embedded in a three-dimensional context (B) than in a flatter context (C). After Weisstein & Harris (1974).

looks unified and three dimensional than when it is part of a flatter pattern (e.g., Enns & Prinzmetal, 1984; Weisstein & Harris, 1974) or when presented alone (e.g., McClelland, 1978; Williams & Weisstein, 1978). The former facilitatory effect (three-dimensional vs. flat context) has been called the *object superiority effect*, and the latter (three-dimensional context vs. no context) the *object line effect*. Hereafter, I use the term "object superiority" to refer to these two effects because the results have been attributed to properties of the object level.

Research concerned with object superiority focused on stimulus properties that can account for the effect. In addition to three-dimensionality (e.g., Lanze, Weisstein, & Harris, 1982), these include connectedness (e.g., Chen, 1982) and structural relevance (e.g., McClelland & Miller, 1979; Weisstein, Williams, & Harris, 1982). Line masking (e.g., Klein, 1978), and the amount of line detail located on and about the fixation (e.g., Earhard, 1980; Earhard & Armitage, 1980) impair context effectiveness.

CONFIGURAL SUPERIORITY EFFECT

Further experiments have shown that identification or discrimination of line segments and other simple stimuli can be improved by the addition of a context that creates a configuration that is clearly only two dimensional in appearance (e.g., Pomerantz, Sager, & Stoever, 1977; Williams & Weisstein, 1978). Pomerantz et al. (1977) presented participants with four stimuli arranged in a square, three of which were identical to one another, whereas the fourth was always different. Participants were required to locate the odd stimulus, which was randomly located at one of the four corners of the square. In one condition, the stimuli were single diagonal lines (figure 9.8A). In another condition, the same context (a right

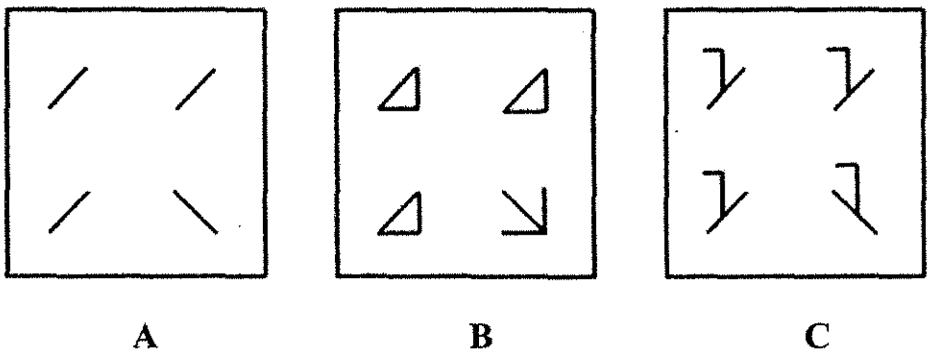

FIGURE 9.8. The configural superiority effect: the discrimination between diagonal lines (A) is improved when a context of a right angle is added to each diagonal line that converts the stimuli into triangles and arrows (B). Discrimination becomes more difficult when context converts the diagonal lines into the configurations in (C). After Pomerantz (1981).

angle) was added to each diagonal line that converted the stimuli into triangles and arrows (figure 9.8B). Reaction times to locate the odd stimulus were much faster for the configurations than for the lines. This and similar findings of improvement have been called *configural superiority effect* (e.g., Pomerantz, 1981; Pomerantz et al., 1977). It has been suggested that configural superiority is due to emergent properties that are possessed by perceptual wholes and do not inhere in their component parts, and are salient to the human perceptual system (e.g., Pomerantz, 1981; Pomerantz & Pristach, 1989).

It is important to note that context can also impede performance (e.g., Pomerantz, 1981). For example, adding a context to the diagonal lines presented in figure 9.8A that converts them into the configurations in (B) improves discrimination, but adding a context that converts them into the configurations in (C) actually impedes discrimination. These findings clearly indicate that performance with configurations cannot be predicted from performance with their components in isolation (as in the whole is different from the sum of its parts), but they also raise several issues regarding the interpretation of the configural superiority effect.

One potential problem is relative discriminability. It may be argued that configural superiority reflects an advantage that would be observed with any two stimuli that differed in discriminability, rather than an indication that performance is dominated by configural properties. For example, open versus closed figures may be more discriminable than right versus left diagonal lines, and it is this difference in discriminability that accounts for the faster performance with the triangles and arrow than with the diagonal lines. Attempts to circumvent this issue (Kimchi, 1994; Kimchi & Bloch, 1998; Lasaga, 1989) are discussed in the next section.

Another issue is that configural properties may not surface if they are not correlated with response categories. Pomerantz and Pristach (1989) attempted to provide diagnostic criteria for configural properties using attentional measures. They constructed visual configurations by the orthogonal combination of line segments, and reasoned that if the line segments have been grouped into configurations, spreading attention among them should be easy, and selective attention to the individual segments should be difficult. They found, however, that their selective and divided attention tasks may fail to diagnose configural interaction among the line segments because configural properties can go undetected if they are not correlated with response categories in a useful way.

Relative Dominance of Configural Versus Component Properties

Lasaga (1989) and Kimchi (1994; Kimchi & Bloch, 1998) used a different approach to evaluate the relative dominance of component and configural properties that circumvents the issues discussed above. They obtained in-

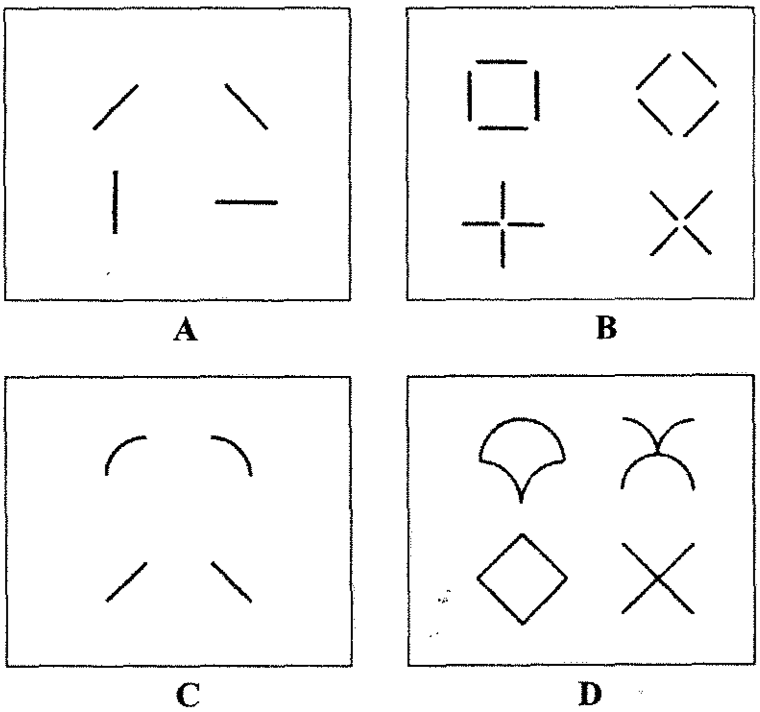

FIGURE 9.9. Examples of the stimulus sets in Kimchi's (1994) and Kimchi and Bloch's (1998) discrimination and classification experiments. Four simple lines that vary in orientation (A) are configured into the stimuli in (B). Four simple lines that vary in curvature (C) are configured into the stimuli in (D). Note that for the stimuli in (D), configurations that share configural properties are not, unlike those in (B), simple rotation of one another. Figures A and B are reprinted from Kimchi (1994), with permission from Pion Ltd., London. Figures C and D are reprinted from Kimchi (1998), with permission from Psychonomic Society Publications.

formation about the relative discriminability of the components and then examined whether discriminability of the components had an effect on performance with the configurations. They reasoned that if the discrimination between stimuli that have dissimilar configural properties is always easier than discrimination between stimuli that have similar configural properties, irrespective of the discriminability of their component properties, and if classification according to configural properties is the easiest one, then perceptual dominance of the configural properties can be inferred.

To follow the logic underlying this approach, consider the stimulus sets presented in figure 9.9. Discrimination and classification performance with the four simple lines that vary in orientation (A) showed that discrimination between the two diagonal lines is more difficult than between any other pair of lines, and the classification that involves grouping of the horizontal and vertical lines together and the two diagonal lines together is significantly faster and more accurate than the two other possible groupings (Kimchi, 1994; Lasaga & Garner, 1983). These simple stimuli were then grouped to form a new set of four stimuli (B). The relevant groupings were those that produced stimuli that differed in highly discriminable component properties (e.g., diagonal vs. vertical lines), but shared a configural property (e.g., closure), and those producing stimuli that shared a component property (e.g., diagonal lines), but differed in configural property (closed vs. open).

The pattern of performance with the simple lines predicts that a discrimination between a stimulus consisting of vertical and horizontal lines and a stimulus consisting of diagonal lines (e.g., a square vs. a diamond) would be easier than a discrimination between a pair of stimuli that have similar component lines (e.g., a diamond vs. an X), and that the easiest classification would be the one that involves grouping of the square and plus together and the diamond and X together. Contrary to this prediction, the two most difficult discriminations were square versus diamond, and plus versus X—that is, between stimuli that had dissimilar component properties but similar configural properties (closure in the first pair and intersection in the second). Therefore, the difficulty in the discrimination may be attributed solely to the similarity of the configural property in each of these pairs. Moreover, the discrimination between a pair of stimuli that differs in a configural property was equally easy, whether or not they differed in component properties. For example, the discrimination between square and plus was as easy as the discrimination between square and X, despite the fact that the first pair shares component properties and the second pair does not. The easiest classification performance was the one that was presumably based on configural properties, and the next easiest classification was the one that was presumably based on component properties (Kimchi, 1994).

Similar results were also observed for other connected and disconnected configurations (Kimchi & Bloch, 1998; Lasaga, 1989). Furthermore, similar results were also observed with stimulus sets in which stimuli that shared a configural property, were not, unlike those in (B), a simple rotation of each other (Kimchi & Bloch, 1998). An example is four lines that varied in curvature (C) and were configured into the new stimuli presented in (D).

These findings show clearly that when both configural and component properties are present in the stimuli and can be used for the task at hand, performance is dominated by configural properties, regardless of the discriminability of the component properties. When configural properties are not effective for the task at hand, discrimination and classification can be based on component properties, but there is a significant cost of time relative to performance based on configural properties.

Global Versus Configural Properties

Although the terms "global" and "configural" are often used interchangeably, recent research indicates that configural properties need not be global. As noted earlier, the difference between global and local properties (as operationally defined in the global/local paradigm) may be captured in terms of relative size. Yet, the critical difference between holistic/configural and component properties is not their relative size.

Kimchi (1994) reasoned that in order to examine whether the distinction between global and configural has a psychological reality, it is necessary to orthogonally manipulate level of globality (global vs. local) and type of property (configural vs. simple), and to study the processing consequences of this manipulation. With hierarchical stimuli, it is possible to construct stimuli in which different types of properties are present at the global and the local levels of the stimulus. Accordingly, Kimchi employed hierarchical stimuli that varied in configural (closure) and simple (line orientation) properties at the global or the local levels. The orthogonal combination of type of property and level of structure produced four sets of four stimuli each, presented in figure 9.10. The two congruent sets (A and D) consisted of stimuli in which the same type of property (closure in A and line orientation in D) was present at the global and the local levels. The two incongruent sets (B and C) consisted of stimuli in which a different type of property was present at the global and at the local level (closure on the global level and orientation at the local level in C, and orientation at the global level and closure at local level in B). Participants were required to classify a set of four stimuli on the basis of either the variability present at the global level (the global classification task) or the variability present at the local level of the stimuli (the local classification task).

The results showed that global classification based on closure was as fast as local classification based on closure, whereas global classification based on line orientation was faster than local classification based on line orientation. Performance with the different stimulus sets showed that global and local classifications were equally fast for stimulus set A and for stimulus set B, both of which had closure at the local level. Global classification was faster than local classification for stimulus set C and for stimulus set D, both of which had line orientation at the local level. These results indicate that global advantage depended on the type of property involved in local discrimination. Global advantage was observed when local discrimination involved a simple property (line orientation), but not when it involved a configural property (closure).

Han, Humphreys, and Chen (1999) used different stimuli (arrows and triangles) and the typical global/local task. One set of stimuli consisted of larger arrows made of smaller arrows that varied in the orientation of the arrows (down left or down right). The orientation of the local arrows was

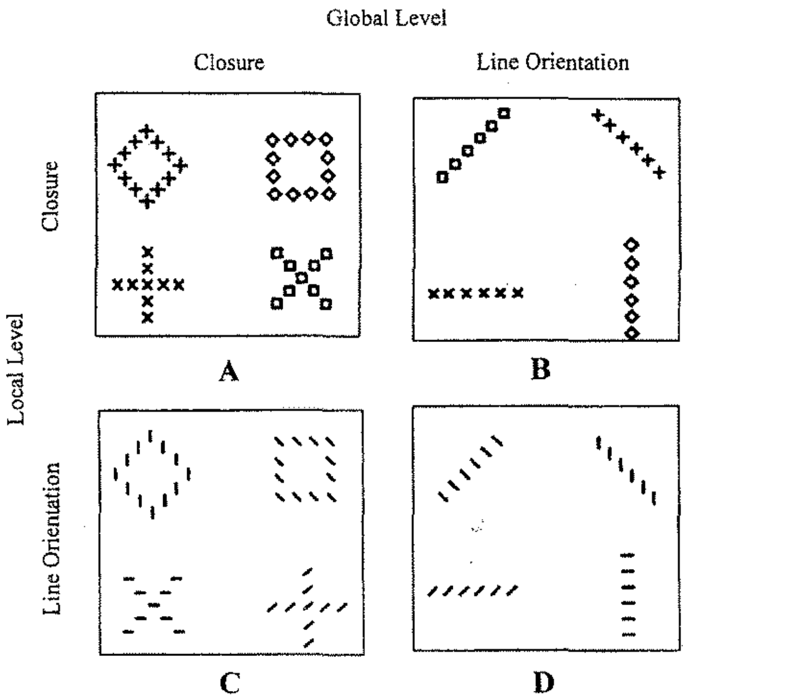

FIGURE 9.10. The stimulus sets in Kimchi's (1994, Experiment 5) global/local classification experiment. The stimuli are produced by orthogonal combination of type of property (closure—closed/open, line orientation) and hierarchical level (global, local). Reprinted from Kimchi (1994), with permission from Pion Ltd., London.

either consistent or inconsistent with that of the global arrow. Another set of stimuli consisted of larger arrows or triangles made up of arrows or triangles. The shapes at the global and the local levels were consistent or inconsistent. Han et al. found a global advantage (i.e., faster reaction times for global than for local identification and global-to-local interference) for both orientation discrimination and closure discrimination, but the global advantage was much weaker for the closure discrimination task than for the orientation discrimination task. Under divided-attention conditions, there was a global advantage for orientation but not for closure discrimination tasks. Interestingly, when participants responded to the orientation of line segments in closed shapes, global advantage was observed as in the case of orientation discrimination in open shapes, suggesting that it is the relevance of the property to task rather than its mere presence that matters.

Thus, both Kimchi's (1994) and Han et al.'s (1999) results indicate that relative global or local advantage for many-element patterns depends on whether discrimination at each level involves configural or simple properties. When local discrimination involves a configural property like closure, the global advantage markedly decreases or even disappears relative to the case in which discrimination at that level involves a simple property like orientation.

These findings converge with the findings reviewed earlier that show a relative perceptual dominance of configural properties. They also suggest that configural properties are not necessarily global or larger. Leeuwenberg and van der Helm (1991) also claim that holistic properties that dominate classification and discrimination of visual forms are not always global. According to the descriptive minimum principle approach proposed by Leeuwenberg and van der Helm, the specification of dominant properties can be derived from the simplest pattern representations, and it is the highest hierarchical level in the simplest pattern representation, the "superstructure," that dominates classification and discrimination of visual forms. The "superstructure" is not necessarily global or larger.

Dominance of Holistic Properties During the Microgenesis of the Percept

The findings discussed so far indicate that certain holistic/configural properties dominate discrimination and classification performance, and are accessible to rapid search. These findings, however, do not necessarily imply that holistic properties are available in early perceptual processing. This is especially the case with discrimination and classification performance because it can be based on later rather than earlier representations.

A different, perhaps more direct way to examine the availability of holistic properties in early perception is to study the time course of the development of the percept, namely the microgenesis of the percept. This microgenetic analysis would reveal information about the relative dominance of holistic and component properties during the evolution of the percept.

Kimchi (1998, 2000) used primed matching to study the microgenesis of the perceptual organization of hierarchical stimuli and line configurations. The basic procedure (Beller, 1971) is as follows. Participants view a priming stimulus followed immediately by a pair of test figures, and they must judge, as rapidly as possible, whether the two test figures are the same as each other or different from one another. The speed of *same* responses to the test figures depends on the representational similarity between the prime and the test figures: responses are faster when the test figures are similar to the prime than when they are dissimilar to it. Thus, primed matching enables us to assess implicitly the participant's perceptual representations. By varying the duration of the prime, we can tap earlier and later representations (Kimchi, 1998, 2000; Sekuler & Palmer, 1992). The logic underlying these experiments is as follows. At a short prime duration only the early representation of the priming stimulus is available and can act as a prime. Therefore, responses to test figures that are similar to the early representation of the priming stimulus should be facilitated.

Later representations are available only at longer prime durations, facilitating positive responses to test figures that are similar to these representations. Thus, if we construct test figures that are similar to the prime in configural or in component properties, then responses to such test pairs at different prime durations should reveal which properties are available in earlier and later representations of the priming stimulus.

Microgenesis of the Perceptual Organization of Hierarchical Stimuli

Kimchi (1998) studied the microgenesis of the perceptual organization of hierarchical stimuli that vary in number and relative size of their elements. The priming stimuli were few- and many-element patterns presented for various durations (from 40 ms to 690 ms). The test stimuli consisted of two hierarchical patterns each. There were two types of same-response test pairs defined by the similarity relation between the test figures and the prime. In the element-similarity test pair, the figures were similar to the prime in their elements but differed in their configurations. In the configuration-similarity test pair, the test figures were similar to the prime in their global configurations but differed in their elements. In addition, an X was presented as a neutral prime, and served as a baseline condition for the two types of test pairs. An example of priming stimuli and their respective same- and different-response test pairs is presented in figure 9.11A.

If the local elements are initially represented and the global configuration is constructed only later, then at short prime durations correct "same" responses to the element—similarity test figures are expected to be faster than responses to the configuration-similarity test figures. The opposite pattern of results is expected if the global configuration is initially represented. In that case, at short prime durations correct "same" responses to the configuration-similarity test figures are expected to be faster than responses to the test figures having the same elements as the prime. Given that prime-test similarity in elements entails dissimilarity in configuration, and vice versa (see figure 9.11A), two possible effects may contribute to differences between configuration-similarity and element-similarity test pairs: a facilitation owing to prime-test similarity, and an interference due to prime-test dissimilarity. Facilitation and inhibition are assessed in comparison to the neutral condition. At longer prime durations, the differences between the two types of test pairs are expected to disappear because presumably both the global configuration and the elements are represented by then.

The results for the few-element stimuli, presented in figure 9.11B, showed an early representation of the local elements: prime-test similarity in elements produced faster responses than similarity in configuration at the shorter prime durations (40, 90, and 190 ms). This difference was mainly due to interference produced by dissimilarity in elements. The ab-

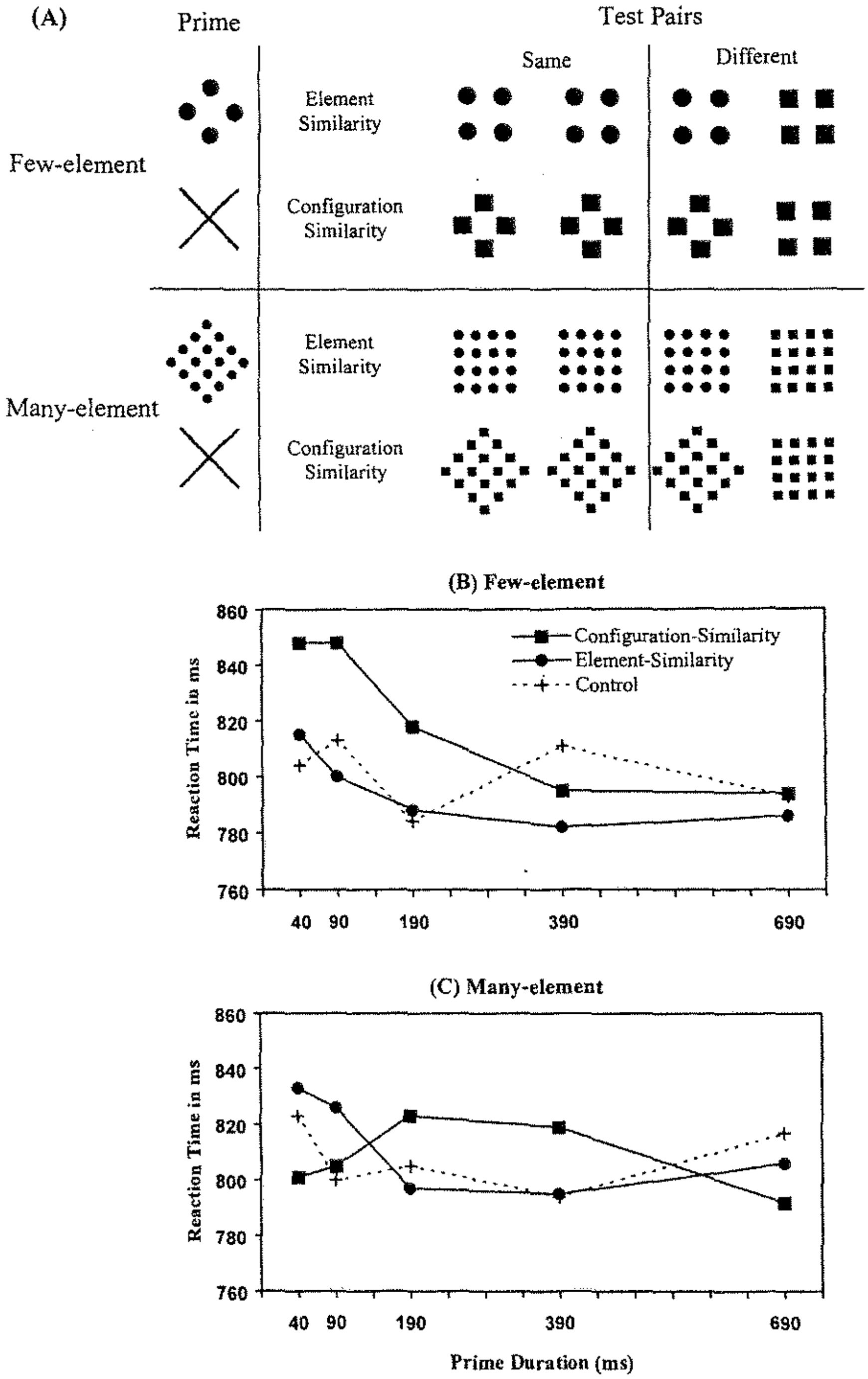

FIGURE 9.11. (A) Examples of the priming stimuli and the same- and different-response test pairs for few-element and many-element patterns in Kimchi's (1998) primed-matching experiment with hierarchical stimuli. (B) Mean correct same RTs for each prime-test similarity (element-similarity, configuration-similarity, and neutral) as a function of prime duration, for the few-element primes, and (C) for the many-element primes. Adapted with permission from Kimchi 1998.

sence of facilitation for the element-similarity condition suggests an early representation of the configuration, albeit a weak one. No significant differences between element and configuration similarity, and no significant facilitation or inhibition, were observed at the longer prime durations of 390 and 690 ms, suggesting that by then elements and configuration were equally available for priming.

The results for the many-element stimuli (figure 9.11C) showed an early representation of the configuration: prime-test similarity in configuration produced faster responses than similarity in elements at the shorter prime durations (40 and 90 ms). Both facilitation owing to configuration similarity and inhibition owing to configuration dissimilarity contributed to this difference. The pattern of reaction time seemed to reverse at the longer prime duration of 190 and 390 ms: element similarity actually produced significantly faster responses than similarity in configuration. No priming effects were observed at the 690 ms prime duration.

Taken together, these results indicate that the relative dominance of global configuration and elements in the course of the organization of hierarchical stimuli depends on the number and relative size of the elements. A pattern composed of a few, relatively large elements is represented initially in terms of both its individual elements and its global configuration, but the representation of the global configuration is weaker than that of the elements. The global configuration consolidates with time and becomes equally available for priming as the elements at around 400 ms. On the other hand, the initial representation of a pattern composed of many, relatively small elements is its global configuration, without individuation of the elements. The individuation of the elements occurs later in time: the elements are available for priming at about 200 ms, and for a while they seem to be somewhat more readily available for priming than the global configuration. By 700 ms, the global configuration and the elements of the many-element patterns seem to be equally available for priming.

The finding of early representation of the global configuration of many-element stimuli is compatible with the global advantage effects under short exposure durations (e.g., Navon, 1977; Paquet & Merikle, 1984), and the availability of the global configuration to rapid search (Kimchi, 1998), observed for similar many-element stimuli. Furthermore, the findings from visual search discussed earlier indicate that the individuation of the local elements of many-element patterns not only consumes time but also demands focused attention. These results also suggest that the consolidation of the global configuration of few-element patterns demands attention.

Microgenesis of the Perceptual Organization of Line Configurations

Configural dominance in discrimination and classification tasks was observed both for connected line configurations (e.g., Kimchi & Bloch, 1998;

Lasaga, 1989) and for disconnected ones (e.g., Kimchi, 1994). Kimchi (2000) studied the relative dominance of the configurations and the component lines during the microgenesis of such stimuli, again using primed matching. In one experiment (Kimchi, 2000, Experiment 1), the priming stimuli were a diamond and a cross that varied in the connectedness between their line components (no gap, small gap, and large gap), and were presented at various durations (from 40 to 390 ms). The figures in the configuration-similarity test pair were similar to the prime in both configuration and line components, whereas the figures in the component-similarity test pair were similar to the prime in lines but dissimilar in configuration. A random array of dots was used as a neutral prime and served as a control condition for the assessment of facilitation and inhibition effects. The priming stimuli and the same- and different-response test pairs are presented in figure 9.12. For this set of stimuli, priming effects of the configuration would manifest in facilitation for the configuration-similarity condition, and possibly interference for the component-similarity condition (owing to dissimilarity in configuration). Priming effects of the line components would manifest in facilitation for both similarity conditions (because both types of test pairs are similar to the prime in components).

The results (see figure 9.13) showed early availability of the configuration, manifested in facilitation for the configuration-similarity test pairs and inhibition for the component-similarity test pairs observed under the shortest exposure duration of 40 ms. These effects were more pronounced for the no-gap (A) and the small-gap (B) conditions than for the large-gap condition (C), suggesting that proximity between the line segments has an effect on the early availability of global configuration and components.

In a second experiment, with the stimuli presented in figure 9.14A, no effect of proximity was found (Kimchi, 2000, Experiment 2). In this experiment, the primes were square configurations that varied in proximity between the components (small gap, large gap). The figures in the configuration-similarity test pair were similar to the prime in configuration but dissimilar in components, whereas the figures in the component-similarity test pair were similar to the prime in components but dissimilar in configuration. For this set of stimuli, priming effects of the configuration would manifest in facilitation for the configuration similarity condition and possibly interference for the component similarity condition (owing to dissimilarity in configuration). Priming effects of the line components would manifest in facilitation for component similarity conditions and possibly interference for the configuration similarity condition (owing to dissimilarity in components).

The results, presented in figure 9.14B and C, showed priming effects of the configuration (i.e., facilitation for configuration-similarity and inhibition for component-similarity) that were equally strong and equally

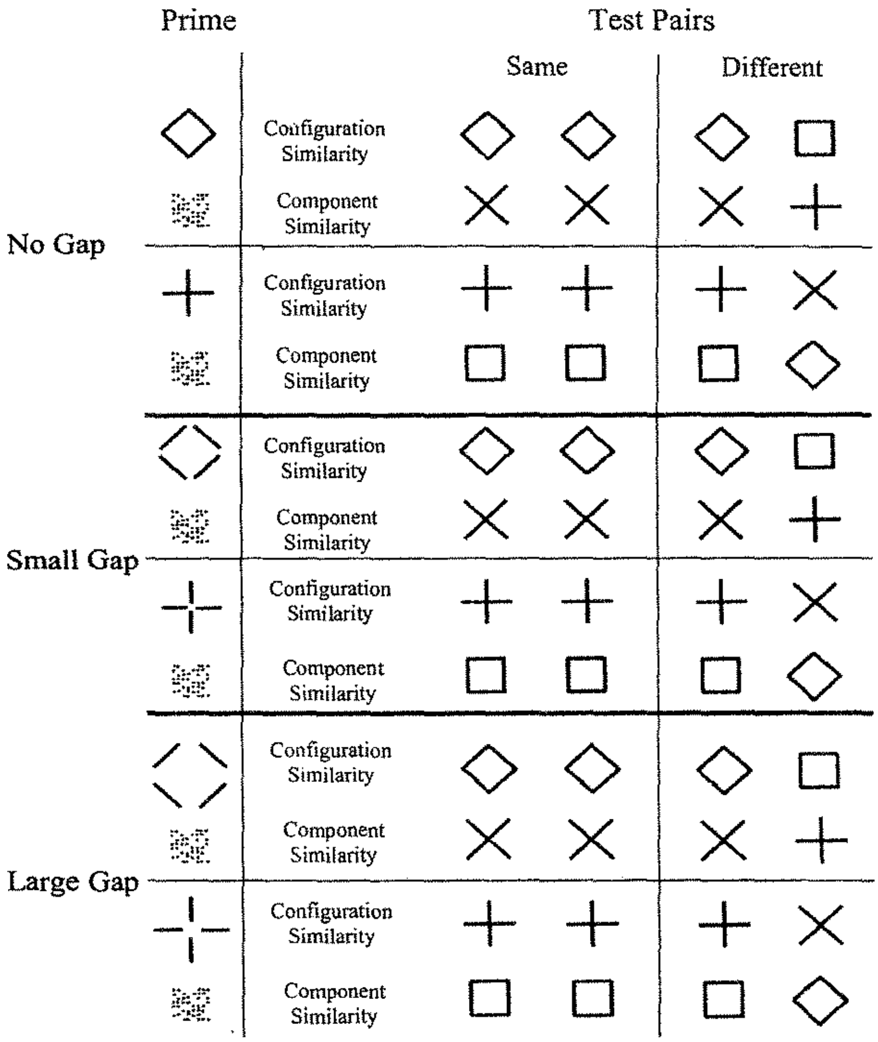

FIGURE 9.12. The priming stimuli and the same- and different-response test pairs for the no gap, small gap, and large gap conditions, in Kimchi's (2000, Experiment 1) primed-matching experiment with line configurations. Adapted with permission from Kimchi (2000).

early (observed under 40 ms prime duration) for strong proximity/small gap (B) and weak proximity/large gap (C). The results of these two experiments suggest that proximity between components seems to have a larger effect on the relative dominance of the global configuration when only closure (as in the diamond prime) or only collinearity (as in the cross prime) is present in the stimulus than when closure and collinearity are combined (as in the latter square primes).

A recent study by Kimchi and Hadad (2002) showed early priming

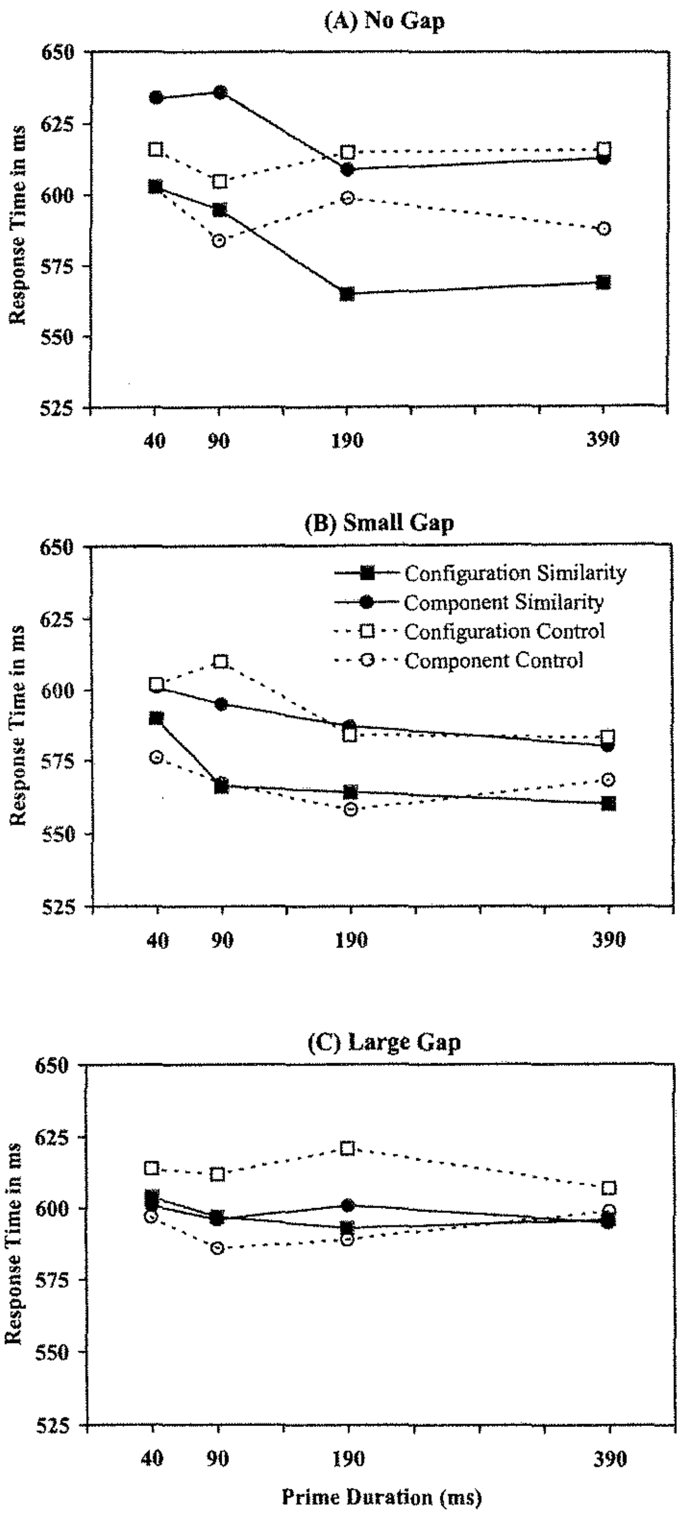

FIGURE 9.13. Mean correct same RTs for each prime-test similarity as a function of prime duration (collapsed across prime type) for each gap condition in the primed-matching experiment with line configurations. Reprinted from Kimchi (2000) with permission from Elsevier Science.

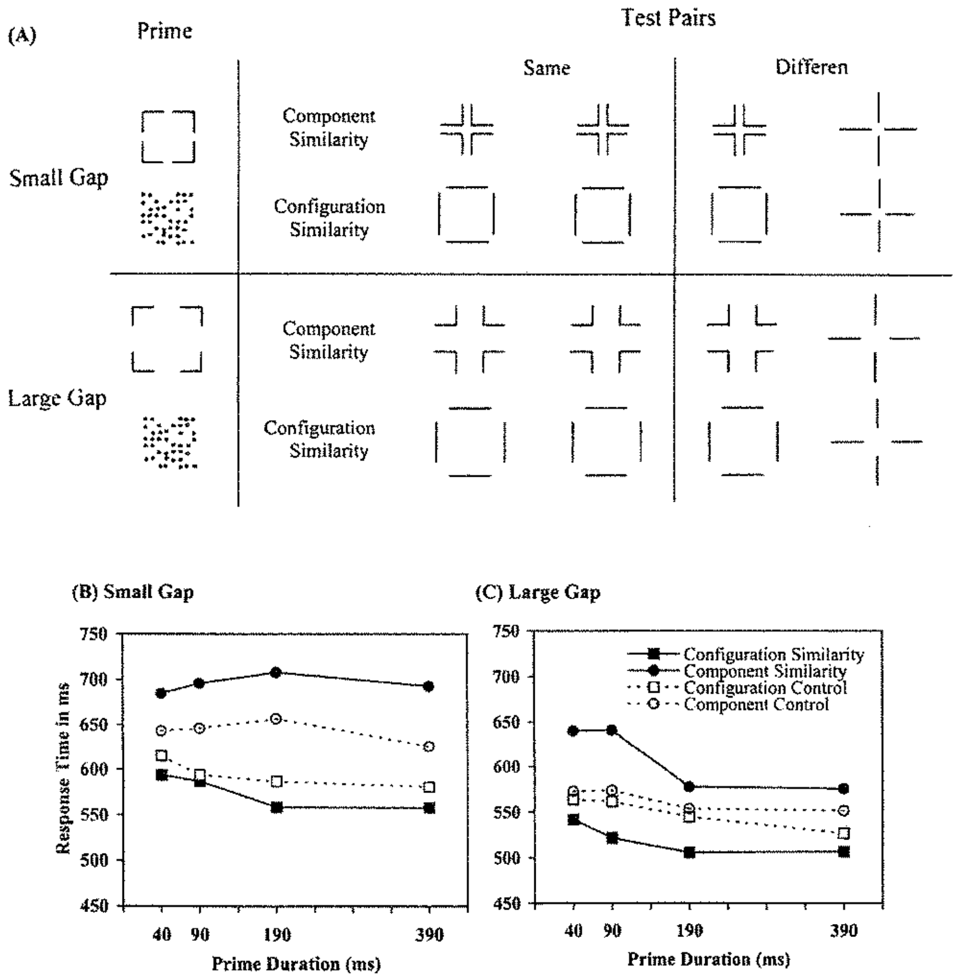

FIGURE 9.14. (A) The priming stimuli and the same- and different-response test pairs for the small gap and large gap conditions in Kimchi's (2000, Experiment 2) primed-matching experiment with square configurations. (B) Mean correct "same" RTs for each prime-test similarity as a function of prime duration for small gap, and (C) for large gap. Reprinted from Kimchi (2000) with permission from Elsevier Science.

effects of the configuration even in the absence of collinearity or closure when the disconnected primes were familiar (upright letters). The configuration of similar disconnected unfamiliar primes (inverted letters) was available only later in time.

Taken together, the microgenetic analysis revealed relative dominance of global configuration or elements at different times along the progressive development of the percept, depending on the number of elements and their relative size (for hierarchical stimuli), and an early configural organization of line segments, the strength of which depends on proximity, collinearity, closure, and familiarity.

Analytic Versus Holistic Perception Revisited

The conventional early feature-analysis view holds that early perceptual processing is characterized by rapid processes that extract simple features in parallel over space and register them in independent spatiotopic maps. Whole objects are constructed by integration of these simple features via serial and time-consuming processes (e.g., Treisman, 1986, 1991).

The findings reviewed in this chapter clearly challenge this view. Holistic properties, namely properties that are defined as a function of interrelations among components, have been found to dominate discrimination and classification performance (e.g., Kimchi, 1994), to be accessible to rapid search (e.g., Rensink & Enns, 1995), and to be available for priming even under very short exposure durations (Kimchi, 1998, 2000). These findings provide converging evidence for early representation of holistic properties. In light of this evidence, a view that holds that only simple features are available in early perceptual processing and that these features are integrated later to produce perceptual wholes is hardly tenable. However, several findings suggest that positing holistic primacy as a rigid perceptual law is hardly tenable, either. Early relative dominance of either global structure or of components has been found, depending on certain stimulus factors (Kimchi, 1998, 2000). Configural dominance has been found with certain configurations but not with others (e.g., Pomerantz, 1981), and the relative dominance of configural properties versus component properties has been found to depend on its relevance to the task at hand (e.g., Han et al., 1999; Pomerantz & Pristach, 1989).

It is possible, then, that the resolution of the controversy between early feature-analysis and holistic primacy will not rest on one or the other side of the analytic versus holistic dichotomy. The results of the microgenetic analysis (Kimchi, 1998, 2000) are particularly instructive because they show that the relative dominance of configural and component properties varies during the evolution of the percept. The most important implication of the microgenetic results is that early perceptual processing involves organization, presumably grouping and segregation processes as proposed by Gestalt psychology. These processes rely on a host of cues, such as proximity, connectedness, collinearity, closure, and symmetry. Recent research has shown that input from higher level object representations also contributes to rapid grouping and segmentation (e.g., Kimchi & Hadad, 2002; Peterson, 1994, chapter 10 this volume; Peterson & Gibson, 1994; Vecera & Farah, 1997).

This view of early organizational processes implies that early perceptual processing involves interactions among components, and in this sense it can be considered holistic or global. However, organizational processes do not necessarily render the dominance of the global or the configural aspects. Grouping can produce weak or strong configurations, a mere aggregation of elements, or configurations that preempt the components. Furthermore, it is suggested that organization is flexible to a degree; it may change during the microgenesis of the percept, and may even be somewhat modulated by task requirements. An important empirical issue is to determine the conditions and the cues that support strong versus weak grouping. For example, recent findings indicate that closure is a powerful grouping cue (Han et al., 1999; Kimchi, 1994; Kovacs & Julesz, 1994). Further research is required to address this issue.

The popularity of the early feature-analysis view has been in part due to the logical relations between components and configurations: components can exist without a global configuration, but a global configuration cannot exist without components, therefore components need to be prior to the configuration. Similarly, if holistic/configural properties do not inhere in the component properties but rather emerge from the interrelations among components, then logic dictates the priority of the components. However, the logical structure of the stimulus does not necessarily predict processing consequences (see Garner, 1983; Kimchi, 1992; Kimchi & Palmer, 1985). Consider, for example, hierarchical patterns like the ones presented in figures 9.3 and 9.11. Such patterns provide a clear case of asymmetry in the logical structure of the stimuli, and this asymmetry holds both for few- and many-element patterns. Yet, few- and many-element patterns differ from one another in their perceived organization (Kimchi & Palmer, 1982), in the perceptual relations between elements and configuration (Kimchi & Palmer, 1985; Klein & Barresi, 1985), and in the microgenesis of their organization (Kimchi, 1998). These findings demonstrate that processing assumptions cannot be made on the basis of logical relations in the stimulus domain alone.

In the same vein, the description of holistic or configural properties as "emergent" is only supported as a description of the stimulus. There is no actual necessity for emergent properties to be perceptually derived. Configural 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). Thus, both component and holistic properties (whether "emergent" or not) must be treated as stimulus aspects. Whether holistic properties dominate component properties at a certain level of processing or whether they are extracted earlier than component properties are empirical questions.

Another major contributor to the popularity of the early feature-analysis view has been influence from physiology. Earlier work on the physiology of vision, most notably the work of Hubel and Wiesel (e.g., 1959, 1968), has fostered the idea of specific feature detectors that extract simple stimulus features, and the feed-forward view. The flow of neural information from the retina to the higher level cortical areas has been characterized as proceeding from responses to simple features in small receptive fields to responses to more complex stimulus configurations in larger receptive fields, in a strictly feed-forward way.

Serious concerns have been raised, however, about using physiological evidence to draw conclusions about perceptual experience (e.g., Uttal, 1997), as the relations between neural events and perceptual experience are not straightforward. But even within a physiological framework, recent findings, in the cortex, of horizontal interactions and massive back projections from higher to lower centers of the visual system (see Spillmann, 1999, for a review) challenge the classical feed-forward view and suggest a highly interactive system. For example, responses of neurons in the primary visual cortex (V1) to stimuli inside the classical receptive fields can be modulated by contextual stimuli outside the receptive field, (e.g., Lamme, Super, & Spekreijse, 1998; Zipser, Lamme, & Schiller, 1996), suggesting that even the earliest stage of visual cortical processing is involved in complex visual perception. These and similar findings suggest that certain holistic perceptual phenomena such as configural superiority are not unfeasible from a physiological point of view, as has been widely assumed.

Concluding Remarks

Both psychological and physiological evidence suggest that early perceptual processing provides more sophisticated structures than has been assumed by the early feature-analysis view. Psychological studies have provided converging evidence (much of which has been reviewed in this chapter) for perceptual primacy of certain holistic properties, suggesting that perceptual wholes are not perceived by independent processing of components. Physiological studies indicate that organization (i.e., grouping and segregation) takes place as early as the primary visual cortex (e.g., Westheimer, 1999). These recent developments in psychological and physiological research on visual perception make the controversy between analytic and holistic perception seem too simplistic. Given that the goal of the perceptual system is identification and recognition of objects, scenes, and events in the environment, it is possible that the human perceptual system is more sensitive to configural properties because they are environmentally relevant. But no sequential model, either a model in which component properties are extracted first, followed by the extraction of configural properties, or one in which configural properties precede component properties, is compatible with recent findings. There is now increasing evidence that suggests a highly interactive perceptual system in which both simple properties and holistic/configural properties are represented in the early organization of a visual object.

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