4 Visual Perceptual Organization: A Microgenetic Analysis

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INTRODUCTION

The visual world consciously perceived is very different from the retinal mosaic of intensities and colors that arises from external objects. We perceive an organized visual world consisting of discrete objects, such as people, houses, and trees, that are coherently arranged in space. Some internal processes of organization must be responsible for this achievement.

The Gestalt school of psychology was the first to study the problem of perceptual organization. According to the Gestaltists, organization is composed of grouping and segregation processes (Koffka, 1935; Kohler, 1929/1947). The well-known principles of grouping proposed by Max Wertheimer (1923/1955) identify certain stimulus factors that determine organization. These factors include proximity, similarity, good continuation, common fate, and closure.

Although the Gestalt work on perceptual organization has been widely accepted as identifying crucial phenomena of perception and their demonstrations of grouping appear in almost every textbook on perception, there has been, until the last decade or so, little theoretical and empirical emphasis on perceptual organization. This may be, in part, because perceptual organization is so deeply ingrained in visual experience that it is often hard to appreciate the difficulties involved in achieving it.

Another reason for the paucity of attention to the problem of perceptual organization is that cognitive psychology has been dominated for several decades by the "early feature-analysis" view, according to which early perceptual processes analyze simple features and elements (e.g., sloped line segments) that are integrated later, presumably by attention demanding processes, into coherent objects (e.g., Marr, 1982; Treisman, 1986; Treisman & Gormican, 1988). A major contributor to the popularity of the "early feature-analysis" view has been earlier work on the physiology of vision, most notably the work of Hubel and Wiesel (e.g., 1959, 1968), that has fostered the idea of a hierarchical system that proceeds from extracting simple properties to extracting more complex stimulus configurations in a strictly feedforward way.

Thus, traditional theories of perception have treated organization only briefly. To the extent that they did address organization, they assumed that it occurs early, preattentively, and in a bottom-up fashion to represent units to which attention is deployed for later, more elaborated processing (e.g., Treisman, 1986).

In the last decade or so, there has been a growing body of research on perceptual organization. Clear progress has been made, but there still remain many open questions and controversial issues. In this chapter, I review recent work by my colleagues and I, using mainly (but not exclusively) a microgenetic approach in an attempt to shed light on several of these open issues.

One issue concerns the structures provided by early perceptual processing. The question is whether early perceptual processing provides only simple properties or elements, as assumed by traditional theories of perception, or complex stimulus configurations as implied by the Gestaltists' notion of perceptual organization.

A second issue concerns the order of organizational processing and its time course. First, there is the question of where in visual processing grouping occurs. Some researchers have argued that Gestalt grouping does not occur at such an early stage of vision as has been widely assumed (Palmer, this volume; Palmer & Rock 1994a; Palmer, Neff, & Beck, 1996; Rock & Brosgole, 1964; Rock, Nijhawan, Plamer, & Tudor, 1992). Palmer and Rock (1994a, 1994b; Palmer, this volume) have further argued for a more basic organizational principle, the principle of uniform connectedness, that precedes all other forms of grouping and according to which a connected region of uniform visual property (such as color, texture, and motion) is perceived initially as a single perceptual unit. Other investigators, however, have argued that uniform connectedness does not have a privileged status in perceptual organization (e.g., Han, Humphreys, & Chen, 1999; Kimchi, 1998; Peterson, 1994). A second question concerns the time course of grouping. Several studies have suggested that various grouping processes may vary in their time course, showing, for example, an earlier impact of grouping by proximity than grouping by good continuation or by similarity of shape (e.g., Ben-Av & Sagi, 1995; Han & Humphreys, 1999; Han et al., 1999; Kurylo, 1997).

A third issue concerns the stimulus factors that engage the mechanism of organization. New grouping factors have been added to the list of classical principles of grouping (Palmer, 1992, this volume; Palmer & Rock, 1994a), and others are yet to be determined. There are also the questions of how several grouping factors are integrated and what the strength of their combined influence is. The Gestalt grouping principles, as well as the new ones, can predict the outcome of grouping with certainty only when there is no other grouping factor influencing the outcome, but they cannot predict the outcome of a combination of factors. The visual system, however, clearly integrates over many grouping factors.

A fourth issue concerns the role of past experience in perceptual organization. The question is whether past experience influences the products of organization, as assumed by the traditional view, or whether it has a direct influence on organization, as suggested by recent findings demonstrating that knowledge of specific object shapes affects figure-ground segregation (e.g., Peterson, this volume; Peterson & Gibson, 1994), image segmentation (Vecera & Farah, 1997), and grouping (Kimchi & Hadad, 2002).

Finally, a fifth issue concerns the role of attention in organization. The question is whether organization occurs preattentively, as has been widely assumed, or whether it involves focused attention. Some studies have suggested that grouping requires attention (Mack, Tang, Tuma, Kahn, & Rock, 1992; Rock, Linnet, Grant, & Mack, 1992), though other findings have demonstrated that certain grouping occurs under conditions of inattention (e.g., Moore & Egeth, 1997).

In the remainder of this chapter, I present findings that address these issues. I begin with a general description of the major approach we have taken to study perceptual organization—the microgenetic approach—and the paradigm we have used to study microgenesis—the primed matching paradigm. I then present studies that have examined the microgenesis of the perceptual organization of hierarchical stimuli and line configurations, demonstrating relative dominance of global structures or elements at different times along the progressive development of organization, depending on certain stimulus factors and their combinations. Next, I describe evidence for the role of past experience in perceptual grouping. Then, I describe recent experiments that we have done to examine the role of attention in different types of organization and the time course of these organizations. I present preliminary results suggesting that not all groupings are created equal in terms of time course and attentional demands. I close by considering the implications of all these findings to the five issues raised above.

MICROGENETIC ANALYSIS AND THE PRIMED MATCHING PARADIGM

One of the major ways we have used to address issues of perceptual organization has been to study the microgenesis of organization, namely, the time course of the development of the representation of visual objects. This microgenetic analysis is important for understanding the processes underlying organization, rather than just the final product of these processes.

To study the microgenesis of organization we used the primed matching paradigm. 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.

This paradigm also enables us to explore the time course of organization (e.g., Kimchi, 1998, 2000; Sekuler & Palmer, 1992). If we assume that the internal representation of a visual stimulus develops over time, then only the early representation of the priming stimulus would be available for priming at short prime duration. Therefore, responses to test figures that are similar to the early representation of the prime 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 vary the duration of the prime, and construct test figures that are similar to different aspects of the prime (e.g., components or global configuration), then responses to such test pairs at different prime durations would reveal which structures are available in earlier and later representations of the priming stimulus. Note that both findings of representational change and findings of no representational change during the microgenesis of the percept would be informative.

PERCEPTUAL ORGANIZATION OF HIERARCHICAL STIMULI: MICROGENESIS AND STIMULUS FACTORS

Hierarchical Stimuli and the Global Advantage Effect

Since the seminal work of Navon (1977), hierarchical stimuli, in which larger figures are constructed by suitable arrangement of smaller figures, have been extensively used in investigations of global versus local perception. In a typical experiment in the global/local paradigm, the stimuli consist of a set of large letters constructed from the same set of smaller letters having either the same or different identity as the larger letter. The observers are presented with one hierarchical stimulus at a time and are required to identify the larger (global) or the smaller (local) letter in separate blocks of trials. All else being equal, a global advantage is observed: The global letter is identified faster than is the local letter, and conflicting information between the global and the local levels exerts asymmetrical global-to-local interference (e.g., Navon, 1977).

Although the phenomenon seems to be robust (to the limits of visibility and visual acuity) and has been observed under various exposure durations, including short ones (e.g., Navon, 1977; Paquet & Merikle, 1988), the mechanisms underlying the global advantage effect or its locus are still disputed (see Kimchi, 1992, in press, for a review). Whereas several investigators interpreted the global advantage as reflecting the priority of global structures at early perceptual processing (e.g., Broadbent, 1977; Han, Fan, Chen, & Zhuo, 1997; Navon, 1977, 1991; Paquet & Merikle, 1988), other investigators suggested that the global advantage arises in some postperceptual process (e.g., Boer & Keuss, 1982; Miller, 1981a, 1981b; Ward, 1982).

A more direct way to examine whether early perceptual processing provides global structures is to study the microgenesis of the organization of hierarchical stimuli. In addition, previous work by Goldmeier (1972) and Kimchi (1988, 1990; Kimchi & Palmer, 1982, 1985) suggests that the relative dominance of the global and local structures of hierarchical stimuli may depend on the number and relative size of the elements. They found that patterns composed of a few, relatively large elements are perceived in terms of global form and figural parts. The elements are perceptually salient and interact with the global form. On the other hand, patterns composed of many, relatively small elements (like the ones typically used in the global/local paradigm) are perceived in terms of global form and texture, and the two are perceptually separable.

Microgenesis of the Perceptual Organization of Hierarchical Stimuli

To examine the relative dominance of the global configuration versus the local elements during the evolution of the percept, I studied the microgenesis of the perceptual organization of hierarchical stimuli that vary in number and relative size of their elements (Kimchi, 1998, Experiment 1). The priming stimuli were few- and many-element patterns presented for various durations (40, 90, 190, 390, or 690 ms). Each trial included a prime followed immediately by a pair of test figures. 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 global 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 Fig. 4.1, part A.

If the local elements are represented early and the global configuration is constructed only later, then at short prime durations correct same responses to the element-similarity test figures would 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 would be faster than

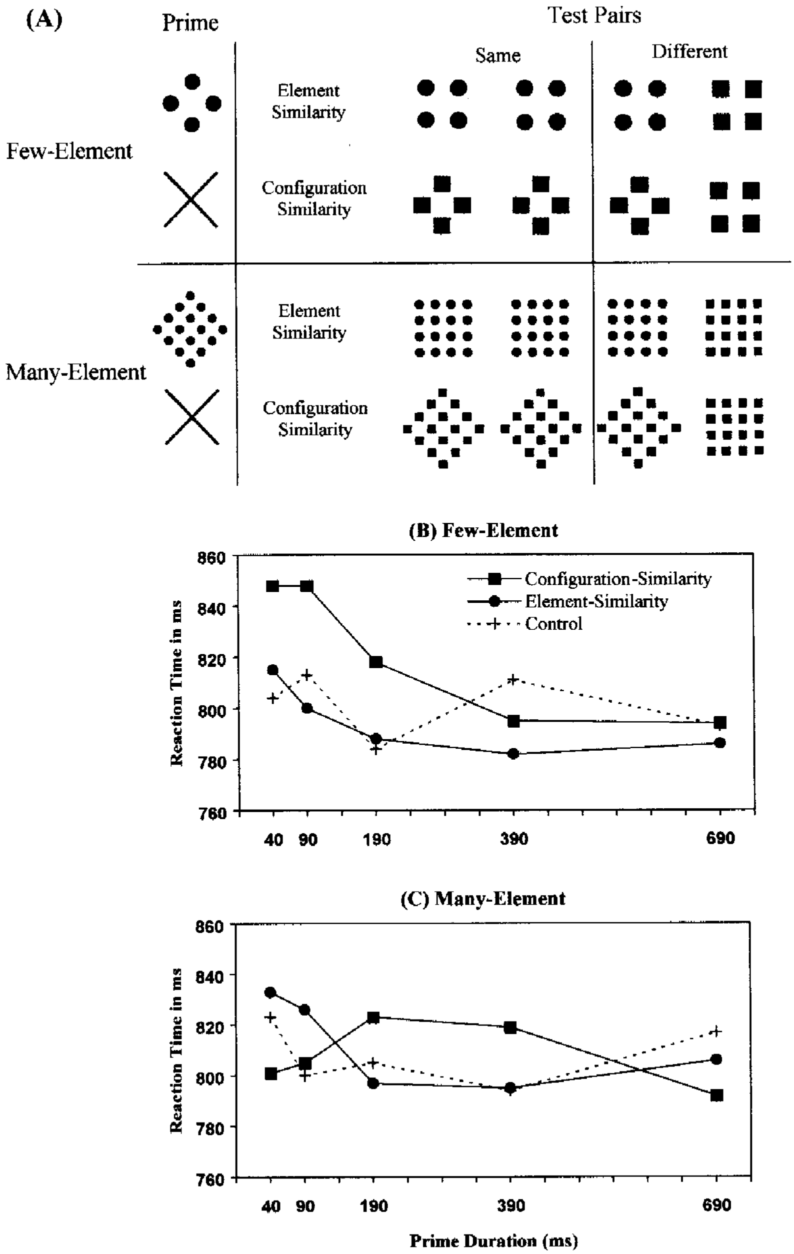

FIG. 4.1. (A) Examples of the priming stimuli and the same- and different-response test pairs for few-element and many-element patterns in Kimchi's (1998) primed-matching experiment with

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 Fig. 4.1, part A), two possible effects may contribute to differences between configuration-similarity and element-similarity test pairs: a facilitation due to prime-test similarity and an interference due to prime-test dissimilarity. Facilitation and inhibition are assessed in comparison with 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 are presented in Fig. 4.1, parts B and C. The results for the few-element stimuli (Fig. 4.1B) 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). A comparison with the control condition reveals that this difference was mainly due to interference produced by dissimilarity in elements. The absence of facilitation for the element-similarity condition under the earlier prime durations suggests an early representation of the configuration, albeit a weak one. The early representation of the configuration was not strong enough to cancel interference due to dissimilarity in elements. No significant difference 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 that point, elements and configuration were equally available for priming.

The results for the many-element stimuli (Fig. 4.1C) 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 due to similarity in configuration and inhibition due to dissimilarity in configuration contributed to this difference. The pattern of reaction time (RT) seemed to reverse at the longer prime duration of 190 and 390 ms: Similarity in elements actually produced significantly faster responses than similarity in configuration. No priming effects were observed at the 690-ms prime duration.

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 both in terms of its individual elements

FIG. 4.1. *(continued)* 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. From "Uniform Connectedness and Grouping in the Perceptual Organization of Hierarchical Patterns," by R. Kimchi, 1998, *Journal of Experimental Psychology: Human Perception and Performance, 24,* p. 1107, 1108. Copyright 1998 by APA. Reprinted with permission.

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 around 700 ms, the global configuration and the elements of the many-element patterns seem to be equally available for priming.

Accessibility of Global Configurations and Local Elements to Rapid Search

Further support for the difference in the early representations of few- and many-element patterns (elements for the former and global configuration for the latter) has come from visual search, which is another way to address the question regarding the structures that are provided by early perceptual processing.

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 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, 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).

Given the widespread view that early perceptual processes are rapid and effortless—whereas later processes are more effortful, time-consuming and attention demanding (e.g., Neisser, 1967; Treisman & Schmidt, 1982)—visual pop-out for a given property has been interpreted as evidence that it is extracted by early perceptual processes (e.g., Enns & Rensink, 1990; Treisman & Schmidt, 1982).

To examine whether the global configuration or the local elements of few- and many-element stimuli are accessible to rapid search, participants were required, in separate blocks, to detect the presence or absence of a global target or a local target (Kimchi, 1998, Experiment 3). In the global search, the target differed from the distractors only in the global shape; in the local search, the target differed from the distractors only in the local elements. The number of items in the display was 2, 6, or 10. An example of the stimulus displays for the two types of search in few- and many-element conditions is presented in Fig. 4.2, for a display size of 6.

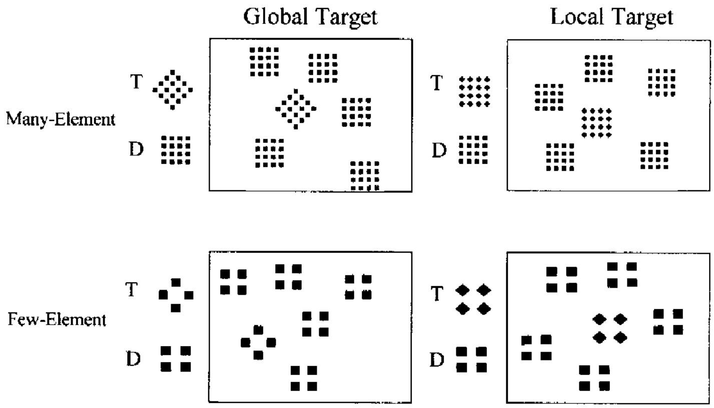

FIG. 4.2. The targets (T) and distractors (D) in Kimchi's (1998) visual search experiment (see text for details).

The microgenetic analysis for hierarchical stimuli predicts that the global configuration of many-element stimuli is more likely to be accessible to rapid search than the local elements because the global configuration is represented prior to the individuation of the elements. For the few-element patterns, on the other hand, the local elements are more likely to be accessible to rapid search than is the global configuration because the microgenetic findings indicate that the local elements of few-element patterns are represented prior to the full consolidation of the global configuration.

The results of the visual search converged with the microgenetic findings. When target and distractors were many-element patterns, the results showed high-speed pop-out search for the global targets (mean search rate 1.29 ms/item for target-present trials and 5.97 ms/item for target-absent trials), indicating the accessibility of the global configuration to rapid search. Search for the local targets of many-element patterns was slow and inefficient (mean search rates 33.88 ms/item for the target-present and 78.06 ms/item for target-absent trials), suggesting that the detection of the local targets involved focused attention. For the few-element patterns, on the other hand, a high-speed pop-out search was observed for local targets (mean search rates 2.90 ms/item for target-present and 14.26 ms/item for target-absent trials), indicating the accessibility of the local elements to rapid search. Search for global targets of the few-element patterns was slower (mean search rates 13.27 ms/item for the target-present and 28.76 ms/item for target-absent trials), suggesting the involvement of focused attention. Note that although search for the global target in the few-element condition was slower than search for the local targets, it was not as slow as search for the local elements in the many-element condition. These results provide further evidence for some early representation of the global configuration of the few-element patterns and for no early individuation of the local elements of the many-element patterns.

Summary

Taken together, the microgenetic and the visual search results suggest that the elements of few-element stimuli are represented early along with a weak representation of the global configuration. The grouping of few, relatively large elements into global configuration consumes time and requires focused attention. On the other hand, the global configuration of many-element stimuli is represented early, and the individuation of the local elements occurs later in time and requires focused attention. The early, rapid organization of many, relatively small elements into global configurations seems to be mandatory because search for local targets appeared inefficient despite the local search and global search being administered in separate blocks.

PERCEPTUAL ORGANIZATION OF LINE CONFIGURATIONS: MICROGENESIS AND STIMULUS FACTORS

To obtain further insights into the processes of perceptual organization and the stimulus factors that engage the mechanism of organization, I have studied the time course of the organization of line segments into configurations. Previous work with line configurations demonstrated configural dominance in discrimination and classification tasks both for connected line configurations (e.g., Kimchi & Bloch, 1998; Lasaga, 1989) and for disconnected ones (e.g., Kimchi, 1994; Pomerantz, Sager, & Stoever, 1977). These findings, however, do not necessarily imply that the global configuration of line segments is available in early perceptual processing because discrimination and classification performance can be based on later rather than earlier representations.

In a series of experiments I examined the relative dominance of configuration and components during the microgenesis of the organization of line configurations, using primed matching once again. The priming stimuli varied in the grouping factors present in the image (connectedness, proximity, collinearity, closure, and collinearity and closure combined).

Grouping Line Segments by Connectedness, Collinearity, and Closure

In the first experiment (Kimchi, 2000, Experiment 1), the priming stimuli were a diamond and a cross configurations that varied in the connectedness between their line components (no gap, small gap, and large gap) and were presented for various durations (40, 90, 190, and 390 ms). Connectedness was manipulated between subjects. The gaps between the component lines subtended 0.29° each in the small gap condition, and 1° each in the large gap condition. There were two types of same-response test pairs. 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 Fig. 4.3. The line segments of the cross are likely to be grouped by collinearity, whereas the line segments of the diamond are more likely to be grouped by closure. The relatability theory (Kellman, this volume; Kellman & Shipley, 1991; Shipley & Kellman, 1992), which formalizes the Gestalt principle of good continuation, suggests that the visual system connects two noncontiguous edges that are relatable so that the likelihood of seeing a completed figure increases systematically with the size of the angle that must be interpolated, with the 50% threshold occurring at around 90°. According to this criterion, the cross configuration is characterized by high relatability (an angle of 180°—collinearity), and diamond configuration is characterized by low relatability (an angle of 90°). The diamond configuration, however, possesses closure, whereas the cross does not.

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 (due 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 Fig. 4.4) showed early availability of the configuration that was manifested in facilitation for the configuration-similarity test pairs and inhibition for the component-similarity test pairs. These priming effects were observed under the shortest exposure duration of 40 ms and did not vary with prime duration. These effects were more pronounced for the no-gap (Fig. 4.4, part A) and the small-gap (Fig. 4.4, part B) conditions than for the large-gap condition (Fig. 4.4, part C), suggesting that proximity between the line segments has an effect on the early availability of global configuration. Note, however, that no facilitation due to component similarity alone was observed, even for the large-gap condition.

The early availability of configural organization observed in this experiment may have been overestimated for three reasons. One, there was an asymmetry between the two same-response test pairs with respect to their similarity relation to the prime: The configuration-similarity test pair was similar to the prime in both lines and configuration, whereas the component-similarity test pair was similar in lines but dissimilar in configuration. This asymmetry could have biased the participants in overreacting to configuration dissimilarity in the component-similarity condition. Two, the participants may have been biased toward complete configurations because all the test figures were connected configurations. Three, the figures in each of the two different-response test pairs differed from one another in both components and configuration so that participants could adopt a strategy of relying only on configural information in making their same/different judgments, thus

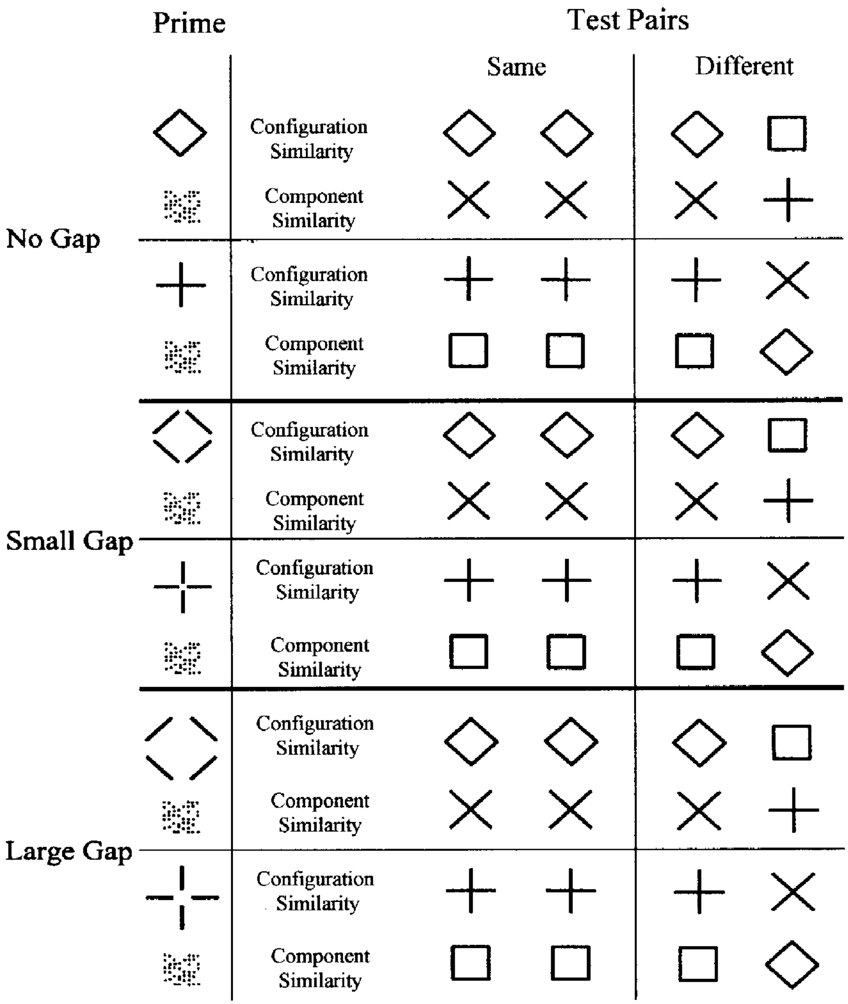

FIG. 4.3. The priming stimuli and the same- and different-response test pairs for the no-gap, small-gap, and large-gap conditions in Kimchi's (2000, Experiment 1) primed-matching experiment with line configurations. From "The Perceptual Organization of Visual Objects: A Microgenetic Analysis," by R. Kimchi, 2000, *Vision Research, 40,* p. 1336. Copyright 2000 by Elsevier Science Ltd. Reprinted with permission.

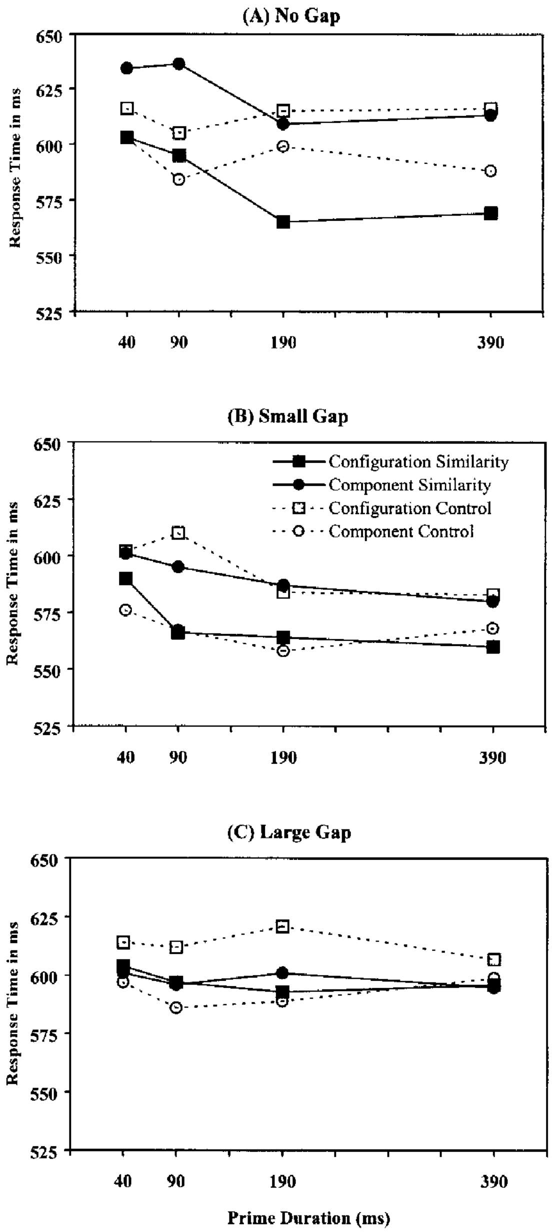

FIG. 4.4. Mean correct same RTs for each prime-test similarity as a function of prime duration (collapsed across prime type) for each gap condition in Kimchi's (2000, Experiment 1) primed-matching experiment with line configurations. From "The Perceptual Organization of Visual Objects: A Microgenetic Analysis," by R. Kimchi, 2000, *Vision Research, 40,* p. 1338. Copyright 2000 by Elsevier Science Ltd. Reprinted with permission.

biasing them toward the configuration.[1] These potential biases are controlled for in the experiment described next, which was conducted with the stimuli presented in Fig. 4.5, part A.

Collinearity and Closure Combined

In this experiment (Kimchi, 2000, Experiment 2) the primes were square configurations that varied in proximity between the components (small gap, large gap). For these stimuli, the components are likely to be grouped into a configuration by the combination of collinearity and closure. 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 (see Fig. 4.5, part A). 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 (due to dissimilarity in configuration). Priming effects of the line components would manifest in facilitation for the component similarity conditions and possibly interference for the configuration similarity condition (due to dissimilarity in components).

The results (see Fig. 4.5, parts B and C) showed clear priming effects of the configuration, namely, facilitation for configuration similarity and inhibition for component similarity. These priming effects were observed under the earliest prime duration of 40 ms and did not vary significantly with prime duration. These results converged with the previous ones, indicating an early representation of the global configuration. Because there was no bias toward the configuration in this experiment, this convergence indicates that the early availability of the configuration observed in the previous experiment is not likely to be due to any bias.

With this set of stimuli, however, no effect of proximity was observed: The priming effects of the configuration were equally strong and equally early (observed under 40-ms prime duration) for strong proximity/small gap (Fig. 4.5, part B) and for weak proximity/large gap (Fig. 4.5, part C). This difference in the effect of proximity suggests that proximity between components has a larger effect on the early availability of the global configuration when only closure (as in the diamond prime, Fig. 4.3) or only collinearity (as in the cross prime, Fig. 4.3) is present in the stimulus than when closure and collinearity are combined (as in the square prime,

[1]The results of this experiment were completely replicated in an experiment in which the figures in the component-similarity test pairs were single lines rather than a connected configuration. This replication weakens the arguments concerning potential biases due to connected test figures for a configuration-based same/different judgment. But this experiment introduced another problem, namely, that the test figures in the component similarity condition differed from the prime also in number of lines (whereas each of the test figures in the configuration-similarity condition included four lines as did the prime).

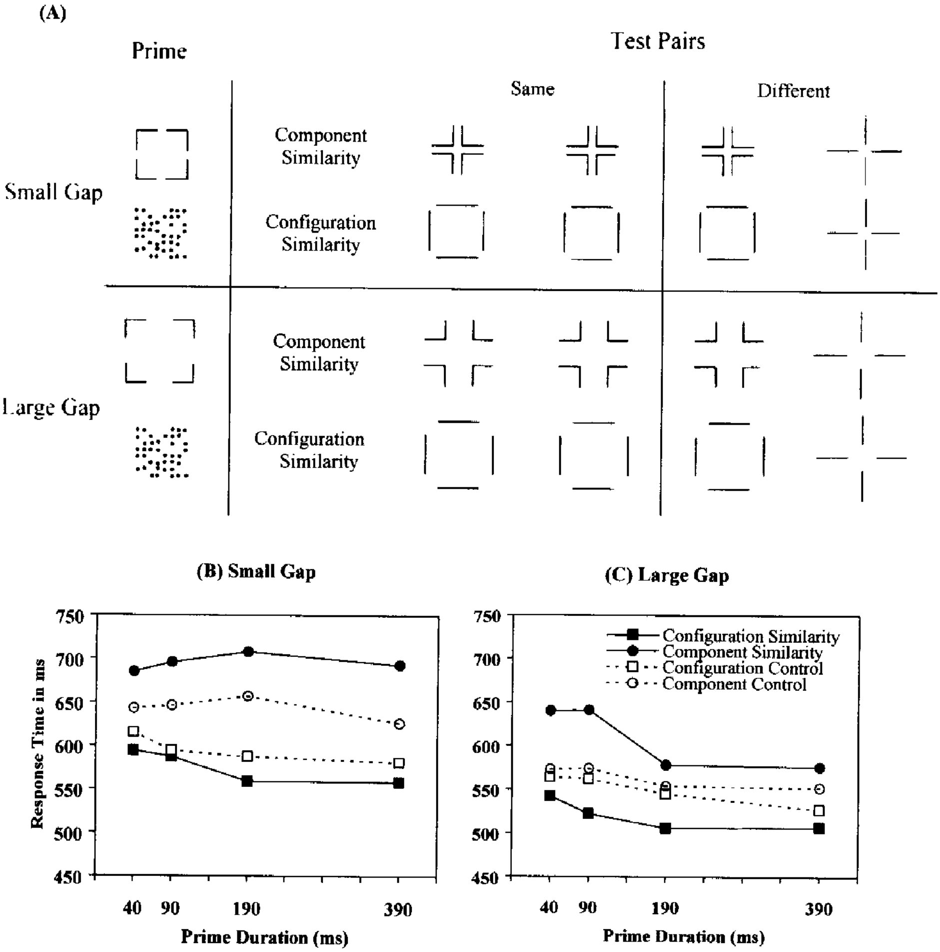

FIG. 4.5. (A) The priming stimuli and the same- and different-response test pairs for the small-gap and large-gap conditions in Kimchi's (2000, Experiment 2) primed-matching experiment with square configurations. (B) Mean correct same RTs for each prime-test similarity as a function of prime duration for the small-gap condition, and (C) for the large-gap condition. From "The Perceptual Organization of Visual Objects: A Microgenetic Analysis," by R. Kimchi, 2000, *Vision Research, 40,* p. 1340, 1341. Copyright 2000 by Elsevier Science Ltd. Reprinted with permission.

Fig. 4.5). Some evidence for the potential power of the combination of closure and collinearity comes also from the work of Donnelly, Humphreys and Riddoch (1991), which demonstrated that the combination of closure and collinearity results in an efficient visual search, much more so than in the presence of closure alone.

Open-Ended Line Segments Versus Closed Figural Elements

A comparison of the microgenetic findings for the line configurations and those for the hierarchical stimuli raises an interesting discrepancy. The findings for the hierarchical stimuli showed an early representation of the components for stimuli composed of four relatively large elements, whereas the findings for stimuli composed of four line segments showed an early representation of the configuration. This apparent discrepancy might be due to a difference in the salience of the components (greater for the solid circles and squares in the hierarchical stimuli than for the line segments) or, alternatively, to a difference in the nature of the components (open-ended lines vs. closed shapes). To rule out a simple salience account, I studied the microgenesis of organization for patterns composed of four outline shapes (see Fig. 4.6) for which the difference in salience in comparison to the line segments was minimized (Kimchi, 2000, Experiment 3). The results converged with the results for the few-element hierarchical stimuli, showing an early relative dominance of the elements. This finding rules out a simple salience account; rather, the early grouping of the local elements, or, alternatively, the early individuation of the local elements, seems to depend not only on the number and the relative size of the elements but also on their properties, with closure at the local level presumably being important for element individuation.

Summary

Taken together, these microgenetic findings demonstrate that open-ended line segments are rapidly organized into configurations provided the presence of collinearity, closure, or both. These results also yield information about the relationship between the grouping factors of closure, collinearity, and proximity. Proximity between line components facilitates grouping by either closure (as in the diamond prime) or collinearity (as in the cross prime), but the combination of closure and collinearity (as in the square primes) dominates proximity in early perceptual grouping. In contrast to open-ended line segments, closed figural elements are individuated early and are grouped into configurations over time.

In addition, the finding that the configural organization of disconnected line segments was available under the same short duration (i.e., 40 ms) as the configuration of the connected line segments suggests that uniform connectedness (UC) may not have a privileged role in perceptual organization, as claimed by Palmer

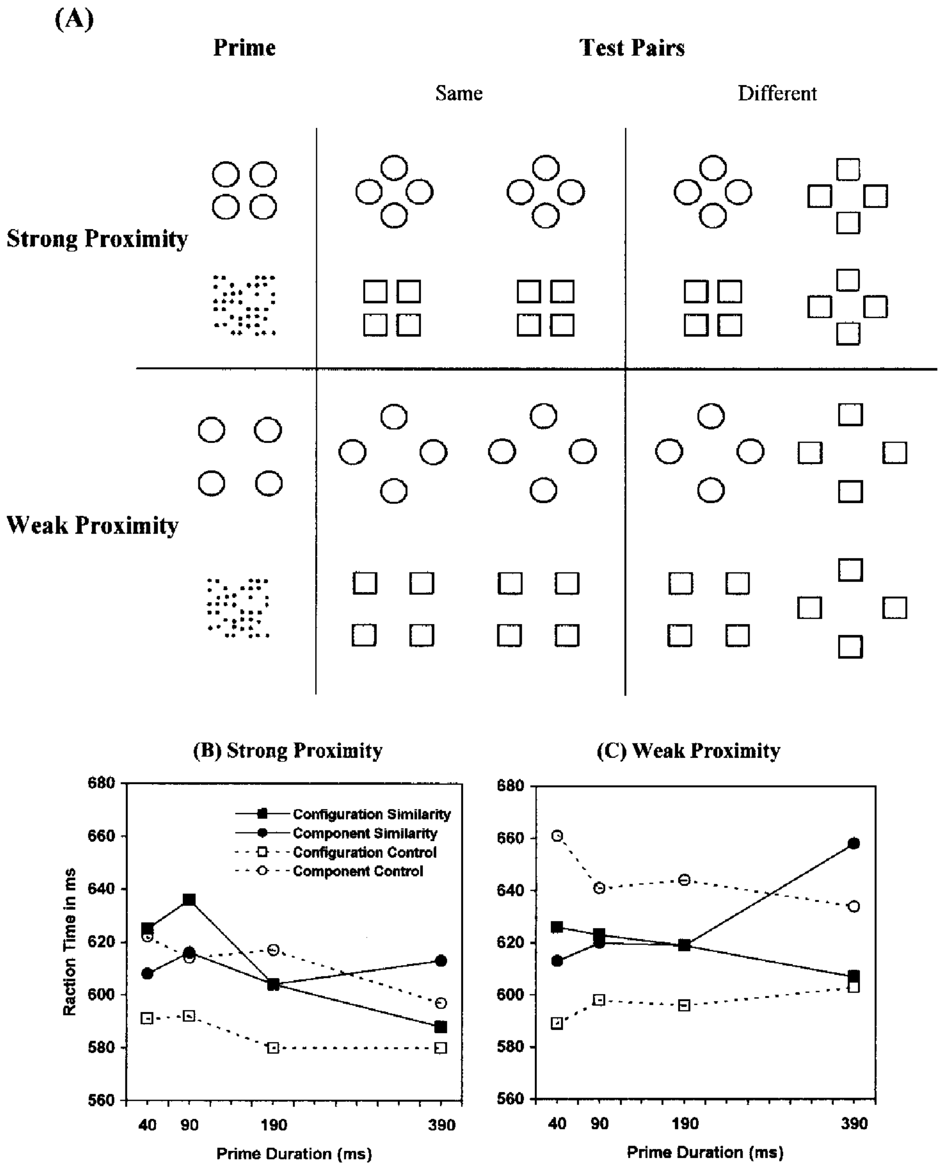

FIG. 4.6. (A) The priming stimuli and the same- and different-response test pairs for the two proximity conditions in Kimchi's (2000, Experiment 3) primed-matching experiment with the few-element stimuli. (B) Mean correct "same" RTs for each prime-test similarity as a function of prime duration for strong proximity, and (C) for weak proximity among the elements. From "The Perceptual Organization of Visual Objects: A Microgenetic Analysis," by R. Kimchi, 2000, *Vision Research, 40,* p. 1340, 1341. Copyright 2000 by Elsevier Science Ltd. Reprinted with permission.

and Rock (1994a, 1994b). Palmer and Rock's theory predicts that the early representation of the primes in Fig. 4.3 in the no-gap condition would be the complete diamond and cross configurations, by virtue of UC. Parsing processes can then divide the uniformly connected diamond or cross into four component lines at the interior concave discontinuities. On the other hand, the theory predicts that the early representations of the primes in the small-gap and large-gap conditions are the component lines because each of the lines forms a UC region. Grouping processes can then group the four lines into a diamond or a cross configuration. The results, however, showed early priming of the configuration for both connected and disconnected configurations.

THE ROLE OF PAST EXPERIENCE IN PERCEPTUAL ORGANIZATION

Phenomenologically, a very fragmented image is perceived initially as a random array of pieces, but, once recognized, it is perceived as an organized picture. The question is whether past experience (in particular, object memories) has a direct influence on perceptual organization, or only on the output of organizational processes. The traditional and widely held view has been that organization must precede object recognition because it requires a candidate object on which to work (e.g., Marr, 1982; Neisser, 1967; Treisman, 1986). In this view, perceptual organization is accomplished on the basis of low-level, bottom-up cues, without access to object representations in memory.

To examine whether past experience exerts an influence on perceptual grouping, Hadad and I used primed matching and manipulated the familiarity of the prime and its connectedness (Kimchi & Hadad, 2002). To manipulate familiarity we used as primes Hebrew letters, presented upright (familiar) or inverted (unfamiliar). This manipulation of familiarity allowed us to equate the familiar and the unfamiliar stimuli in their bottom-up grouping factors (e.g., connectedness, collinearity, proximity). The disconnected primes were formed by dividing each letter into four line segments at the interior concave discontinuities (Hoffman & Richards, 1984) and introducing small or large gaps between the line segments. A neutral prime, consisted of a random array of dots, served as a baseline condition. The primes were presented for various durations (40, 90, 190, 390, and 690 ms). The priming stimulus was followed immediately by a pair of test figures. We used two types of same-response test pairs: The figures in the similarity test pair were similar to the prime, and the figures in the orientation-dissimilarity test pair were 180° rotational transforms of the prime. An example of upright and inverted primes and their respective same- and different-response test pairs in the three gap conditions (no gap, small gap, and large gap) is presented in Fig. 4.7. Familiarity was manipulated within subjects and connectedness between subjects. For the sake of simplicity, I refer hereafter only to the similarity test pairs. For

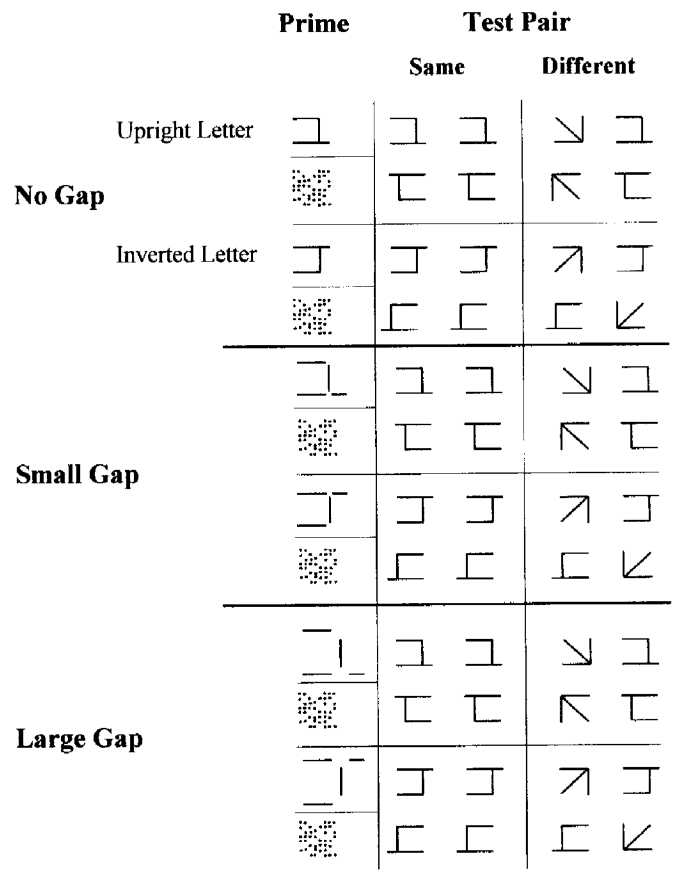

FIG. 4.7. Examples of upright and inverted primes and the *same*- and *different*-response test pairs in the no-gap, small-gap, and large-gap conditions. For each prime, the similarity test pair is the upper pair and the orientation-dissimilarity test pair is the lower pair. The random array of dots serves as a neutral prime, providing a baseline (control) for each of the test-pair types. From "Influence of Past Experience on Perceptual Grouping," by R. Kimchi and B. Hadad, 2002, *Psychological Science, 13*, p. 44. Copyright 2002 by APS. Reprinted with permission from Blackwell Publishers.

these test pairs, priming effects of the configuration would manifest themselves in facilitation.

The traditional view predicts additive effects of connectedness and familiarity on priming. According to this view, the primes (whether upright or inverted) get organized only on the basis of bottom-up cues, without any influence from object memories. Consequently, connectedness would affect the organization of the primes. Upright primes are then recognized faster than inverted primes because they are more likely to activate object representations and thereby speed responses to similar figures. This would result in additive effects of connectedness and familiarity on priming. An advantage of familiar relative to unfamiliar primes would indicate an influence of past experience on the output of organization rather than on organization itself. However, if familiarity interacts with connectedness so that the effect of disconnectedness on priming is more detrimental for unfamiliar than for familiar primes, this would indicate that object memories contribute to the grouping of the line segments into a configuration. The microgenetic analysis enables us to determine how early in time the effect of familiarity is exerted relative to that of connectedness.

The results for the similarity condition are presented in Fig. 4.8, parts A (upright primes) and B (inverted primes). These results show that familiarity interacted with connectedness in their effect on priming: Connectedness had no effect on the priming of familiar primes, whereas the priming effects of unfamiliar primes varied as a function of connectedness. For the upright primes, both connected and disconnected primes produced equal amounts of facilitation that was observed under the earliest duration of 40 ms and did not vary with prime duration (Fig. 4.8, part A). The results for inverted primes were quite different, showing that priming effects were affected by connectedness and by prime duration (Fig. 4.8, part B). Inverted connected primes produced facilitation that was as strong and as early as the facilitation produced by upright primes. Disconnectedness, however, had a detrimental effect on priming. The facilitation observed in the small-gap condition was significantly smaller than the one in the no-gap condition, and for the large-gap condition facilitation was observed only later in time.

These findings suggest an influence of past experience on the rapid grouping of line segments into a configuration. The effect of past experience manifested itself at the same time as the effect of connectedness, as indicated by the finding that the configuration of connected upright letter, the configuration of disconnected upright letter, and the configuration of connected inverted letter all were available under exposure duration of 40 ms. In the absence of familiarity and connectedness (as with the disconnected inverted primes), the grouping of the disconnected line segments into a configuration occurred later in time.

An alternative account for the observed priming effects of the configuration for the upright letters may be similarity in identity between the prime and the test figures, without any prior organization, rather than effects of familiarity on grouping. According to this alternative account the upright primes activate object representations, get identified, and facilitate responses to test figures with the same identity. Previous findings, however, indicate that partial information or stimulus degradation affects identification speed (e.g., Everett, Hochhaus, & Brown, 1985; Snodgrass & Corwin, 1988). Therefore, an effect of connectedness would be expected for the upright primes, but no such effect was found (see Fig. 4.8, upright primes). Thus, although we cannot rule out completely some effect of identity, the results are more compatible with the grouping account.

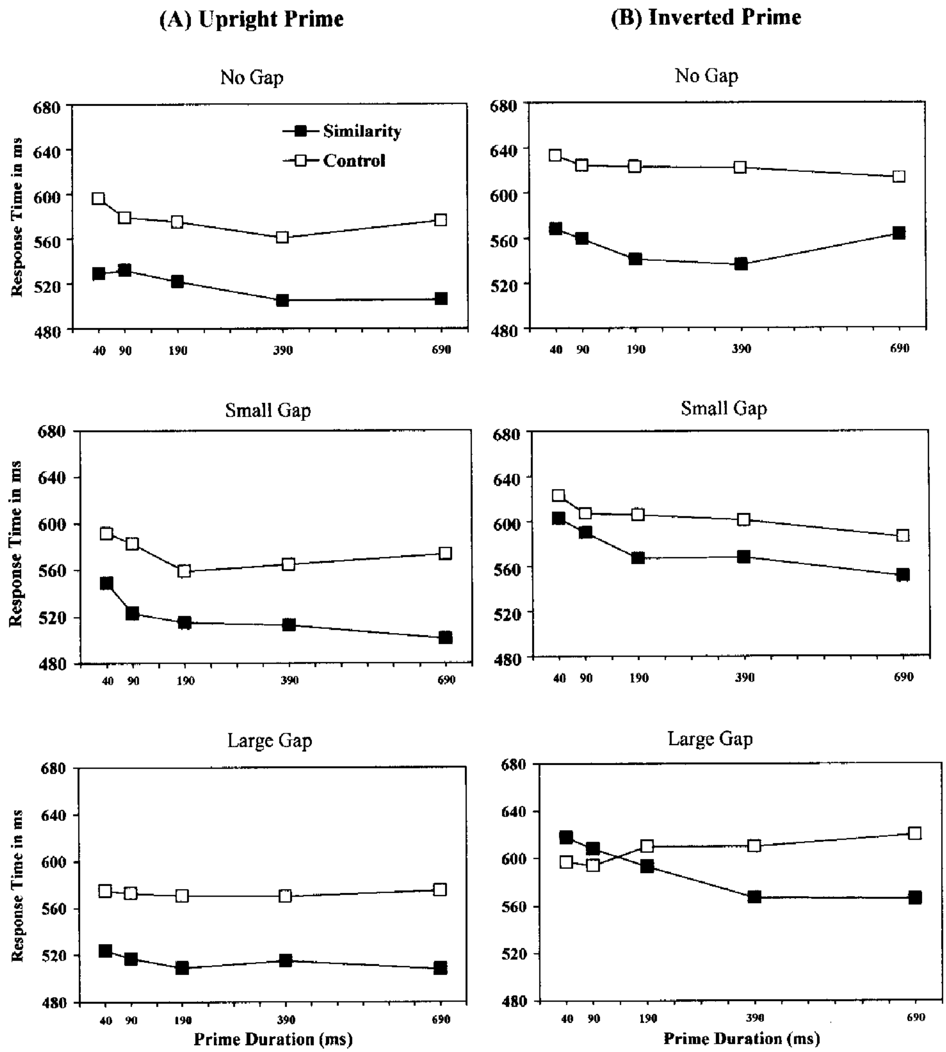

FIG. 4.8. Mean correct same RTs for the similarity and the control conditions as a function of prime duration for each gap condition for (A) upright primes and (B) inverted primes.

These results converge with the previous ones in demonstrating that uniform connectedness does not have a special role in perceptual organization. This is not to say that connectedness does not play a role in organization. The strength of connectedness manifested itself with the connected inverted primes. But connectedness is one of a number of cues that determine perceptual organization. We have shown that input from object memories is also among these cues.

SIMPLE SPATIAL FILTERING MECHANISMS OR SOPHISTICATED GROUPING PROCESSES?

One may argue that the results concerning the early representations of the hierarchical stimuli and the line configurations are due to spatial filters based on spatial-frequency channels operating at early visual processing (e.g., Ginsburg, 1986). Several investigators have already suggested that the global advantage observed with many-element hierarchical stimuli is mediated by low-spatial-frequency channels (e.g., Badcock, Whitworth, Badcock, & Lovegrove, 1990; Hughes, Fendrich, & Reuter-Lorenz, 1990; Lamb & Yund, 1993; Shulman, Sullivan, Gish, & Sakoda, 1986; Shulman & Wilson, 1987). Thus, blurring by large-scale, low-resolution filters at early stages of visual processing may account for the early representation of the global structures of the many-element patterns. Such blurring may also account for the early representation of the large elements of the few-element patterns due to their large absolute size.

Similarly, it can be argued that due to blurring by low-spatial-frequency channels, the existence of small gaps between line segments should not greatly affect priming, thus yielding a similar priming effect of the global configuration for connected and disconnected line segments.

Several findings, however, are not compatible with this account. First, it has been found that relative size of the elements (i.e., the size of the elements relative to the configuration in which they are embedded) rather than their absolute size is critical for the early organization of hierarchical stimuli. For example, Peled and I (Kimchi & Peled, 1999) examined whether absolute or relative size of elements governs priming effects for few-element patterns by using patterns in which the element number was held constant at four and the elements size varied in three conditions: (1) absolutely large, relatively large elements; (2) absolutely small, relatively large elements; and (3) absolutely small, relatively small elements. The first two conditions produced a similar pattern of results, indicating early priming effects of the elements. A different pattern of results was observed for the third condition. These results suggest that relative rather than absolute size of the elements is critical for determining early organization. Enns and Kingstone (1995) used visual search with few-element stimuli that varied in the absolute size of the elements (small vs. large), but the small and large elements had similar, large relative size. Search slopes for the local elements were shallow and did not differ for the small and large elements. Their results, then, demonstrate that few, relatively large elements, regardless of whether their absolute size is large or small, are accessible to rapid search.

The critical role of relative size suggests that simple spatial filtering mechanisms cannot fully account for the early organization of hierarchical stimuli. Ivry and Robertson's (1998) view that focuses on relative rather than absolute spatial frequencies in the image also cannot easily account for the early organization of hierarchical stimuli. According to Ivry and Robertson, the difference between global and local information is a difference along a continuum of spatial frequency. Therefore, the difference in the processing of few- and many-element stimuli is not compatible with their approach because the spatial frequency of the elements is relatively higher than that of the configuration for both types of stimuli (see also Behrmann & Kimchi, this volume).

Second, blurring by low spatial frequency channels cannot account for the finding, observed with the line configurations, that the effect of proximity on priming depended on the presence (or absence) of other grouping factors in the image (i.e., that proximity among the line segments facilitated grouping when either closure or collinearity was present but had no effect when closure and collinearity were combined). Nor can it account for the differential effect of connectedness on priming for familiar and unfamiliar stimuli, namely, that connectedness had no effect for familiar primes, but the priming effects for the unfamiliar primes varied as a function of connectedness. If the early priming of the global configuration of disconnected line segments were due to blurring by low-resolution filters, then connected and disconnected primes would have similar priming effects, regardless of whether other grouping factors are present or absent or whether the stimuli are familiar or unfamiliar.

Taken together, these findings suggest that early organization is unlikely to be due to simple spatial filtering at early perceptual processing. Rather, more sophisticated processes of grouping and individuation are likely to be involved in early organization. These processes rely on a host of cues, such as number and relative size of the elements, connectedness, collinearity, proximity, and familiarity.

THE ROLE OF ATTENTION IN PERCEPTUAL ORGANIZATION

Contrary to the assumptions of traditional theories of visual perception that perceptual organization occurs preattentively, Mack, Rock and their colleagues have claimed that no organization occurs without attention (Mack et al., 1992; Rock, Linnet et al., 1992). In their inattention paradigm, they used a relatively difficult primary task in which subjects had to determine whether the horizontal or vertical line of a briefly presented cross is longer. The display contained elements in the background of the cross for all of the initial trials. On the fourth, inattention trial the background elements were organized into rows (or columns) according to lightness or proximity, and the subjects were asked, after reporting which line of the cross was longer, about the background organization. Subjects could not report whether the background organization was vertical or horizontal. These kinds of findings led Rock and Mack to the conclusion that no Gestalt grouping takes place without attention. However, the poor knowledge of the subjects may reflect poor explicit memory rather than an indication of no organizational processing.

To circumvent the issue of explicit memory, Moore and Egeth (1997) used the inattention paradigm but devised indirect online measures of unattended processing. Their primary task was to determine which of two horizontal lines was longer. On the inattention trial the elements in the background were grouped by luminance into inducers biasing the horizontal line length by creating the Muller-Lyer or Ponzo illusion. Subjects were unable to report the background organization, but their line-length judgments were influenced by the illusions. These findings suggest that grouping by similarity in luminance does occur under conditions of inattention, albeit without subjects' awareness.

In addition, it has been suggested that grouping is not the unitary phenomenon referred to in much of the literature but rather involves two distinct processes: Clustering, or unit formation, which determines which elements belong together, and configuring, or shape formation, which determines how the grouped elements appear as a whole based on the interrelations of the elements (Koffka, 1935; Rock, 1986; Trick & Enns, 1997). This suggestion raises the possibility that different groupings may vary in their attentional demands, depending on the processes involved, with configuring being more demanding than just clustering.

Organization Without Attention

To examine whether organization can take place without attention, and whether different groupings vary in their attentional demands, Razpurker-Apfeld and I (Kimchi & Razpurker-Apfeld, 2001) used the method developed by Driver and his colleagues (cited in Driver, Davis, Russell, Turatto, & Freeman, 2001) to obtain online measures of unattended processing, and manipulated the grouping of the unattended elements. On each trial, subjects were presented with two successive displays, each appeared for 200 ms, and separated by 150 ms. Each display consisted of a central square matrix surrounded by background elements (see Fig. 4.9). The subject's task was to judge whether the two successive central target squares were the same or different. The organization of the background elements stayed the same or changed across successive displays, independently of whether the successive target squares were same or different. The colors of the elements always changed between the two successive displays to disentangle a change in color per se from a change in organization.

We employed three different background organizations (between subjects), examples of which are presented in Fig. 4.9 (in grayscale). One organization was the classical Gestalt grouping of elements into columns or rows by color similarity (Fig. 4.9, part A), similar to the one used by Driver et al. (2001). The second organization was grouping elements into a square or a cross by color similarity (Fig. 4.9, part B). These two types of organization involve grouping elements together into units on the basis of common color. We conjectured, however, that configuring is less demanding in the former, which requires determination of the orientation (vertical or horizontal) of the units, than in the latter, which requires

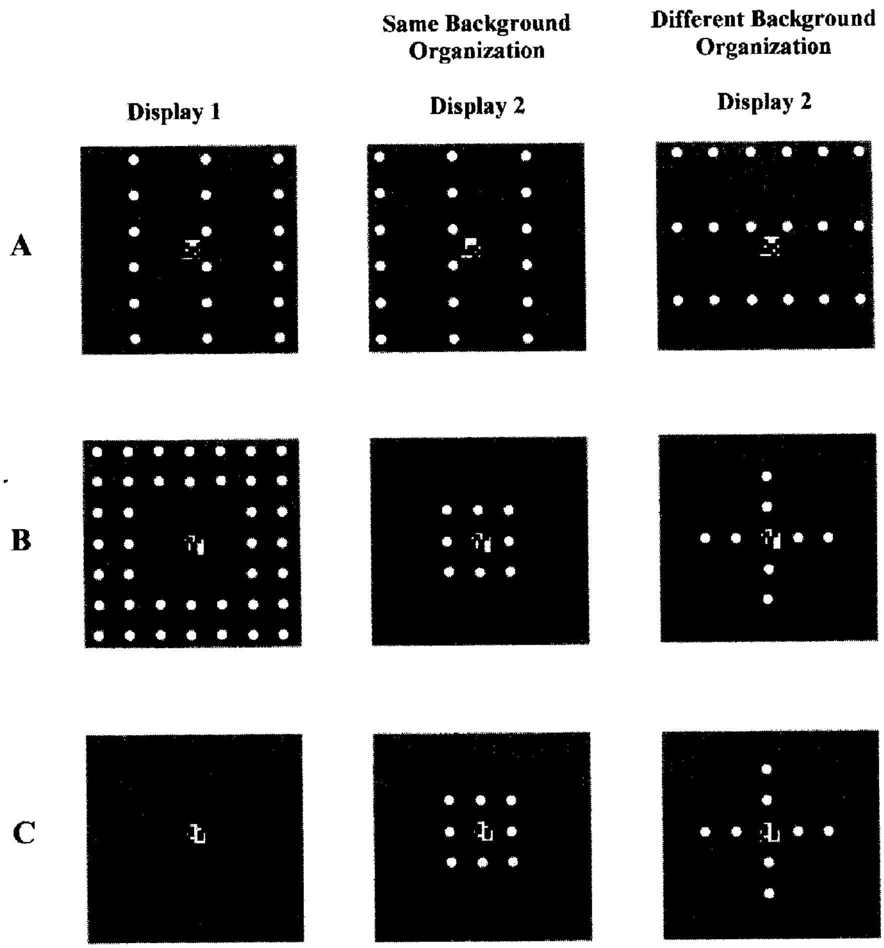

FIG. 4.9. Examples (in grayscale) of the displays for a single trial in the study of Kimchi and Razpurker-Apfeld (2001). The central target squares in Display 1 and Display 2 can be the same or different. The background elements can be grouped into columns/rows by color similarity (A), into square/cross by color similarity (B), or into square/cross (C). The background organization either stays the same across Display 1 and Display 2 or changes (independently of whether the central square changes or not). The colors of background elements always change between Display 1 and Display 2.

the formation of a distinctive shape. The third type of organization also required grouping elements into a square or a cross (Fig. 4.9, part C), but because this grouping is supported by several gestalt factors including proximity, similarity of color, similarity of luminance, and similarity of shape, and it does not involve segregation from other elements, it may be less demanding than the grouping into square/cross by color similarity.

If organization of the background elements occurs without attention, then target-same judgments would be faster and more accurate when the background organization stays the same than when it changes, and target-different judgments would be faster and more accurate when the background organization changes than when it stays the same.

The results are presented in Fig. 4.10. An influence of the background organization on the same-different judgments was observed for grouping elements into columns/rows by color similarity (Fig. 4.10, part A): Subjects were faster with their target-same judgments if the background organization stayed the same, and target-different judgments were faster if the background organization changed. In contrast, no effect of the background organization on subjects' performance was found for grouping elements into square/cross by color similarity (Fig. 4.10, part B). Yet, background organization clearly influenced subjects' judgments when grouping into a square or a cross did not involve segregation from other elements (Fig. 4.10, part C). For all three conditions, we found that the surprise questions at the end of the experiment replicated the results of Mack et al. (1992): Subjects were unable to report the background organization of the immediately preceding background displays.

We hypothesized that grouping elements into columns/rows by color similarity would be more attention demanding than grouping elements into square/cross by color similarity because configuring is simpler in the former than in the latter. We found, however, that under certain conditions (i.e., when no segregation from other elements is required), grouping into a shape can occur under inattention, suggesting that the process of shape formation per se cannot account for the difference between grouping into columns/rows and grouping into a shape by color similarity. Presumably, grouping that requires segregation from other elements is more attention demanding when it involves configuring into a shape than into a vertical or horizontal pattern because segregation in the former case also requires resolving figure-ground relations for the segregated units, whereas all units in the latter are designated as "figures."

Time Course of Organization

Interestingly, we found that differences in the time course of grouping parallel these differences in attentional demands. We used primed matching to explore the time course of three types of organization, similar to the ones manipulated in our inattention experiment. The priming stimuli and their respective same and different test pairs are presented in Fig. 4.11 (in grayscale; the actual elements in

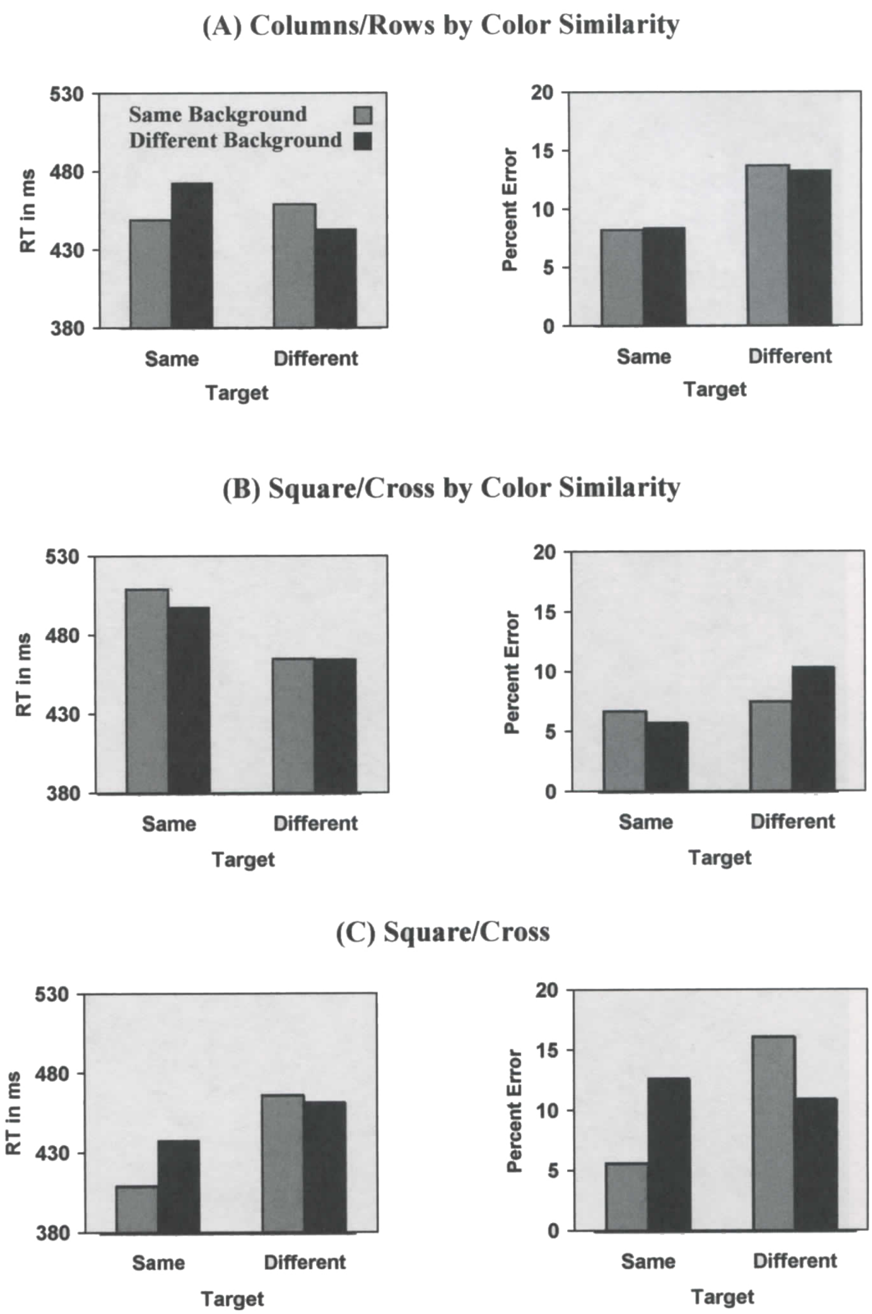

FIG. 4.10. Mean correct target-same and target-different RTs and percent error as a function of background (same or different) for the three background groupings in Kimchi and Razpurker-Apfeld's experiment (2001).

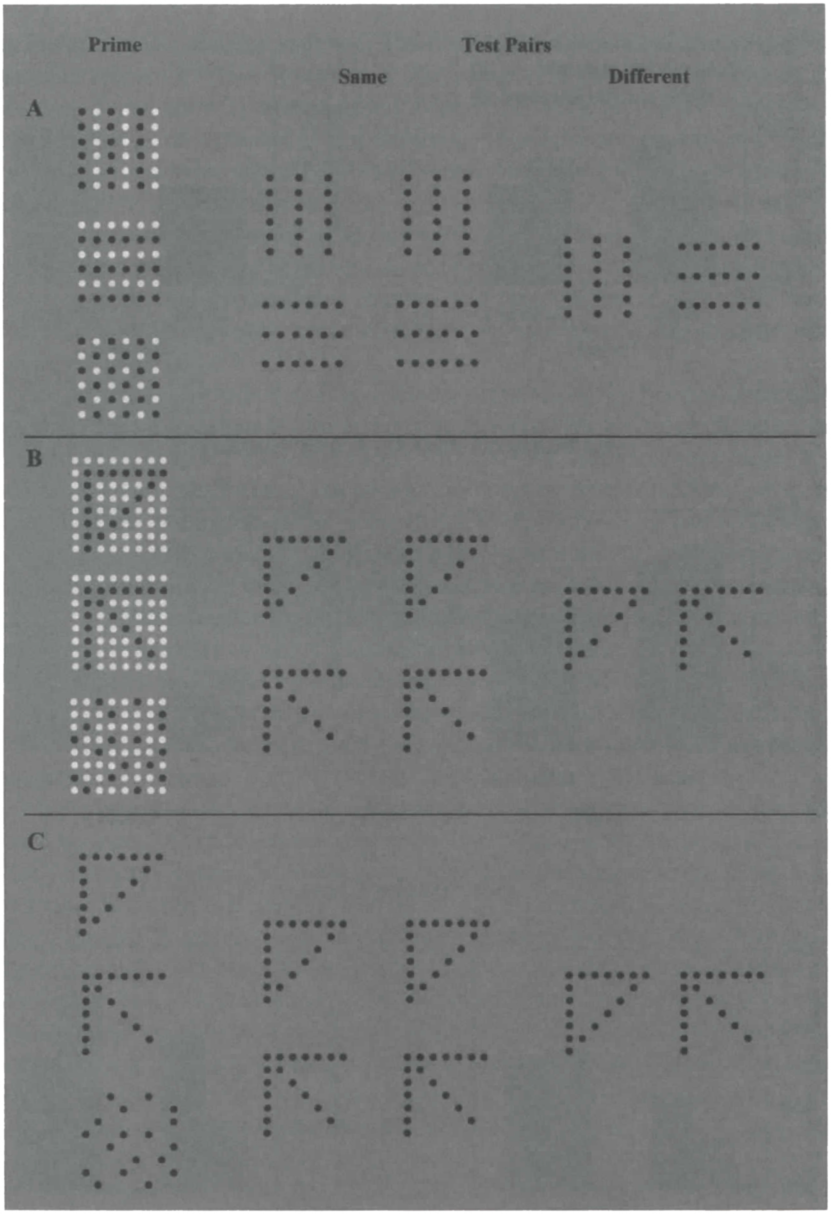

FIG. 4.11. Examples (in grayscale) of the priming stimuli and the same- and different-response test pairs in Kimchi and Razpurker-Apfeld's (2001) primed-matching experiment. The primes can be organized into columns/rows by color similarity (A), into triangle/arrow by color similarity (B), or into triangle/arrow (C). The color of the circle elements always changed between the prime and the test figures.

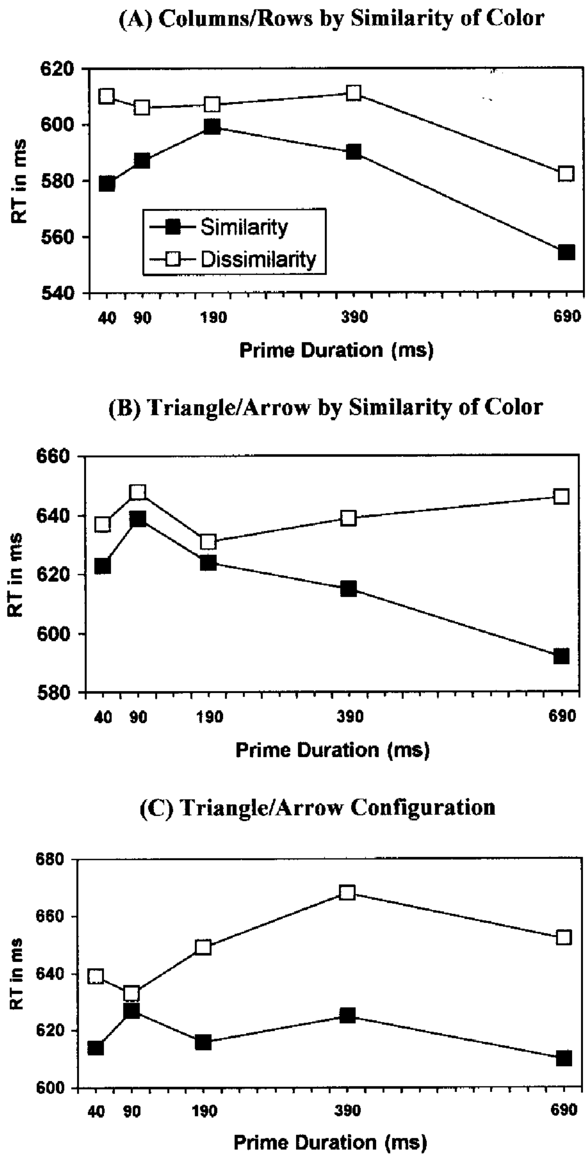

FIG. 4.12. Mean correct same RTs for the similarity and dissimilarity conditions as a function of prime duration (collapsed across prime type) for each of the three types of organization in Kimchi and Razpurker-Apfeld's (2001) primed-matching experiment.

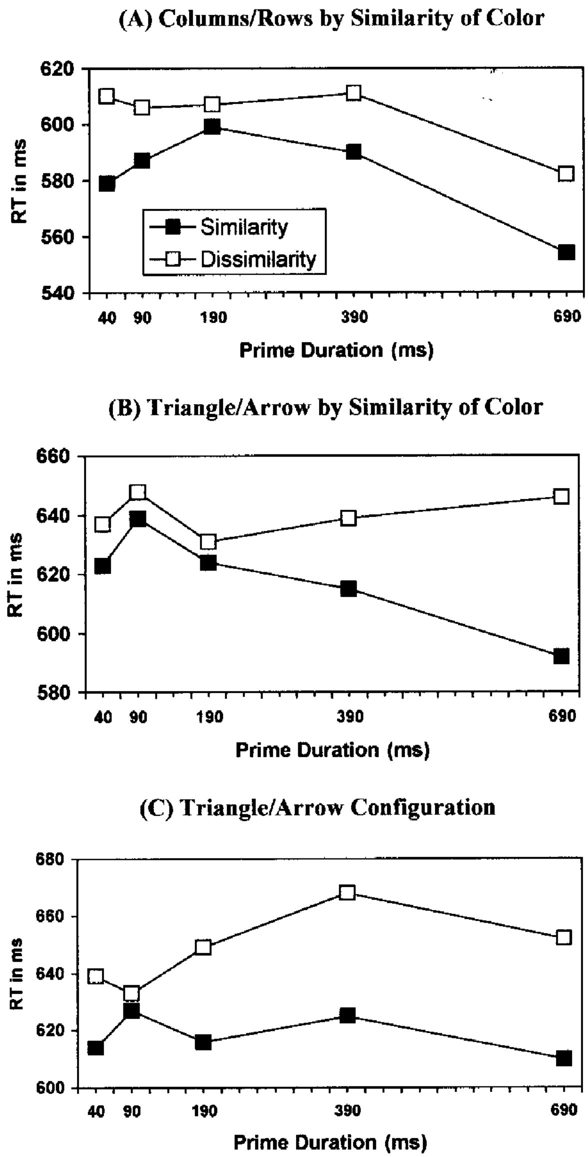

FIG. 4.12. Mean correct same RTs for the similarity and dissimilarity conditions as a function of prime duration (collapsed across prime type) for each of the three types of organization in Kimchi and Razpurker-Apfeld's (2001) primed-matching experiment.

the experiment were colored). In one condition the priming stimuli were colored elements that grouped into columns/rows by similarity of color (Fig. 4.11, part A). In a second condition the priming stimuli were colored elements grouped into a triangle or an arrow by color similarity (Fig. 4.11, part B). In the third condition, the priming stimuli were colored elements grouped into a triangle or an arrow, and no segregation from other elements was involved (Fig. 4.11, part C). Each of the test pairs was similar to one prime and dissimilar to the other. The color of the elements of the test figures was always different from that of the elements of the priming stimuli.

The results are presented in Fig. 4.12. Similarity between the prime and the test figures produced faster responses than dissimilarity under all prime durations, including the shortest duration of 40 ms, for organization into columns/rows by common color (Fig. 4.12, part A) and for organization into triangle/arrow when no segregation from other elements was required (Fig. 4.12, part C). For organization into triangle/arrow by common color, significant priming due to prime-test similarity was observed only under longer prime durations (Fig. 4.12, part B).

Summary

These results show that grouping elements into a vertical or a horizontal pattern by color similarity, and grouping elements into a shape (when no segregation from other elements is involved) occur rapidly and under conditions of inattention. Grouping elements into a shape by color similarity demands attention and consumes time. These findings suggest that quite an elaborated form of grouping can take place rapidly and without attention, albeit without subjects' awareness. Grouping into a shape that requires resolving figure-ground relations for segregated units appears to be time consuming and attention demanding. Further research is required to better understand the differences between attentional and inattentional grouping.

IMPLICATIONS TO ISSUES OF PERCEPTUAL ORGANIZATION

The findings reviewed in this chapter show that configural organization and global structures can be available early, presumably as a result of early rapid grouping, or can emerge later in time, as a result of late or slower attention demanding grouping, depending on the grouping operations, stimulus factors, and past experience. I turn now to the implications of these findings for the issues raised in the beginning of the chapter.

A first important implication is that early perceptual processing provides more complex structures than has been assumed by traditional theories of perception. The traditional theories, dominated by the early feature-analysis view, have assumed that early perceptual processes analyze only simple elements and properties. Contrary to this assumption, we found that global configurations, based on the interrelation among simple elements and line segments, are available for priming even under exposure durations as short as 40 ms, and are accessible to rapid search. Other investigators have reported similar results. Early levels of perceptual processing have been found to be sensitive to scene-based properties (e.g., Enns & Rensink, 1990; He & Nakayama, 1992; Kleffner & Ramachandran, 1992), to complete configurations rather than to components (e.g., Rensink & Enns, 1995), and to part-whole information (e.g., Wolfe, Friedman-Hill, & Bilsky, 1994). These findings provide converging evidence for early representation of complex configurations. In light of this evidence, a view that holds that only simple properties are available in early perceptual processing is hardly tenable.

A second implication is that both stimulus factors and past experience have an effect on perceptual organization. Some of the stimulus factors found to engage the mechanisms of early organization include number and relative size of elements, collinearity, proximity, connectedness, and closure (see also, for example, Kellman, this volume; Kovács & Julesz, 1994). Uniform connectedness (Palmer, this volume; Palmer & Rock, 1994a, 1994b), however, does not seem to have a privileged status in organization (see also Han et al., 1999; Peterson, 1994).

The importance of stimulus factors has been demonstrated in several of our findings. Thus, we have found that the priming effects of equally familiar stimuli depend on the grouping factors present in the image. For example, the priming effects of the global configuration of disconnected line segments with relatively weak proximity (large gap) between the line segments were stronger when both collinearity and closure were present in the image than when only collinearity or closure were present. In addition, familiar and unfamiliar primes produced similar priming effects of the configuration when connectedness was present in the image.

The influence of past experience on organization has been demonstrated in the findings of differential effects of priming of the global configuration for disconnected stimuli that were equated for the grouping factors present in the image but differed in familiarity (upright and inverted letters). The global configurations of upright letters were available for priming early, regardless of connectedness, whereas the configurations of disconnected inverted letters were not available until later. Our findings converge with other findings that have demonstrated the contribution of input from higher level object representations to figure assignment (e.g., Peterson, this volume; Peterson & Gibson, 1994) and image segmentation (Vecera & Farah, 1997).

These findings are incompatible with the traditional feedforward view that assumes perceptual organization is accomplished solely on the basis of bottom-up cues and is immune to influence from past experience (e.g., Marr, 1982). Rather, these findings are consistent with a hierarchical interactive model with temporally cascaded processing that includes feedforward and feedback mechanisms (e.g., McClelland & Rumelhart, 1981; Vecera & O'Reilly, 1998). They can also be accounted for by the parallel model proposed by Peterson (e.g., this volume) in which object recognition processes influence organization in parallel with lower level cues. Our finding that the effect of familiarity on the integration of the line segments manifested at the same time as the effect of connectedness suggests that at least some aspects of object representations in memory may be accessed in parallel with image-based cues. Presently, however, it is difficult to distinguish between the models (Peterson, 1999; Vecera & O'Reilly, 2000), and further research is needed to evaluate the relative adequacy of these models for perceptual organization.

A third implication is that not all groupings are created equal in terms of time course and attentional demands: Certain forms of grouping take place early, rapidly, and without attention, whereas other forms of grouping occur later, consume time, and require attention. Thus, for example, we found that grouping of elements into columns/rows by common color occurs rapidly and without attention. Grouping of many small elements into a shape also occurs rapidly and without focused attention, provided that no segregation from other elements is involved. On the other hand, grouping a few, relatively large closed elements into a configuration consumes time and requires focused attention. We also found that if the grouping of many elements into a configuration involves segregation of grouped elements into figure and ground, then it consumes time and cannot take place without attention.

Other studies reported in the literature also have demonstrated that different groupings vary in time course and attentional demands (e.g., Ben-Av & Sagi, 1995; Han & Humphreys, 1999; Han et al., 1999; Kurylo, 1997). Further support for the suggestion that not all groupings are created equal comes from the work Behrmann and I did with two agnosic patients (Behrmann & Kimchi, this volume). The patients had no problem grouping elements into columns/rows by proximity or by luminance, and grouping by collinearity. Nonetheless, they exhibited difficulties (and to different degrees) in grouping elements into configuration, even in the simpler case that does not involve segregation from other elements and in grouping by closure.

Clearly, our findings, along with other findings reported in the literature (e.g., Moore & Egeth, 1997), do not support the radical claim made by Mack and Rock (e.g., Mack et al., 1992) that no Gestalt grouping takes place without attention. Further research is required, however, to elucidate the different perceptual-organizational processes that differ in time course and attentional demands.

Recent neurophysiological findings are consistent with the behavioral findings reviewed in this chapter, indicating that grouping and segregation take place as early as the primary visual cortex, presumably as a result of horizontal interactions and back projections from higher to lower centers of the visual system (e.g., Lamme, Super, & Spekreijse, 1998; Spillmann, 1999; Westheimer, 1999). 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 et al., 1998; Sugita, 1999; Zipser, Lamme, & Schiller, 1996), suggesting that even the earliest stage of visual cortical processing is involved in complex visual perception such as grouping of image fragments. There is also evidence for mutual bottom-up and top-down reciprocity (e.g., Bullier & Nowak, 1995; Lee & Nguyen, 2001; Zhou, Friedman, & von der Heydt, 2000), suggesting that input from higher level representations can contribute to early organization.

CONCLUSIONS

The findings reviewed in this chapter indicate that early perceptual processing involves organizational processes of grouping and individuation, providing more complex structures than has been assumed by the traditional view. These processes rely on a host of cues, including lower level cues, such as connectedness and collinearity, and higher level cues, such as input from object representations. We have further shown that these organizational processes vary in their time course and attentional demands. These findings are part of recent developments in the psychological and physiological research on visual perception that provide converging evidence for a highly interactive perceptual system in which both image-based and object-based properties contribute to the early organization of visual objects.

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