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Research Article

INFLUENCE OF PAST EXPERIENCE ON PERCEPTUAL GROUPING

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Abstract—We used primed matching to examine the microgenesis of perceptual organization for familiar (upright letters) and unfamiliar (inverted letters) visual configurations that varied in the connectedness between their line components. The configurations of upright letters were available for priming as early as 40 ms, irrespective of connectedness between their line components. The configurations of connected inverted-letter primes were also available this early, but the configurations of disconnected inverted letters were not available until later. These results show that past experience contributes to the early grouping of disconnected line segments into configurations. These findings suggest an interactive model of perceptual organization in which both image-based properties (e.g., connectedness) and input from object memories contribute to perceptual organization.

The visual world consciously perceived is very different from the retinal mosaic of intensities and colors that arises from external objects. Humans perceive an organized visual world consisting of discrete objects that are coherently arranged in space. Some internal processes of organization must be responsible for this achievement. The Gestalt psychologists were 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). Grouping entails linking separated image fragments that correspond to the same object; figure-ground segregation entails the differentiation of the visual field into figures and grounds. The well-known grouping principles (Wertheimer, 1923/1955) identify stimulus factors that determine perceptual grouping. These factors include proximity, similarity, good continuation, common fate, and closure. Other factors, such as symmetry and relative area, have been suggested as determining figure-ground segregation (Rubin, 1915/1958).

Past experience also can have an effect on the perceived organization of visual stimuli: 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) exerts a direct influence on perceptual organization or only on the output of organizational processes. Wertheimer (1923/1955) suggested that past experience is one of the factors of perceptual organization, but because of the Gestaltists' strong anti-empiricist position, their work has been viewed as focused on the role of stimulus factors in organization (Kanizsa, 1979). The traditional and widely prevailing view has been that grouping and figure-ground segregation must precede object recognition because it requires a candidate object on which to work (e.g., Marr, 1982; Neisser, 1967). In this view, perceptual organization is accomplished on the basis of low-level, bottom-up cues without access to object representations in memory.

Recent results challenge this view, showing that knowledge of specific object shapes has an effect on figure-ground segregation and image segmentation (Peterson, 1994a; Peterson & Gibson, 1994a, 1994b; Vecera & Farah, 1997). For example, Peterson and her colleagues presented observers with stimuli comprising two adjacent regions sharing a common border, with a meaningful region along one side and a meaningless region along the other side. These stimuli were presented in both an upright and an inverted orientation. The observers were more likely to perceive the meaningful region as figure in upright than in inverted displays.

A few studies have investigated whether past experience influences perceptual grouping. Hock and Marcus (1976) examined same/different reaction times with pairs of intact and pairs of fragmented letters. Participants were slower responding to fragmented than to intact pairs, and the effect of fragmentation was larger for rotated than for upright letters. Wallach and Slaughter (1988) showed that familiarity influenced the perception of subjective contours. Vecera and Farah (1997) showed that when presented with two overlapping shapes and asked to determine whether two probed locations were on the same shape or on different shapes, participants were faster to respond when the shapes were upright letters than when they were rotated letters. The results of these studies seem to suggest that familiarity influences grouping and contour integration. It is not entirely clear, however, whether these results reflect the influence of familiarity on organization or on its outcome. For example, the advantage of upright letters observed by Vecera and Farah could have been due to faster recognition of upright than rotated letters. Vecera and Farah were aware of this possibility and performed an experiment (Experiment 4) in an attempt to rule it out. Unfortunately, the results of this experiment are not easily interpretable because, unlike in their other experiments, Vecera and Farah did not collect reaction times, only accuracy data, because of unreliable reaction times found in a pilot experiment. Also, the results of Hock and Marcus can be interpreted as indicating an effect of familiarity on discrimination of fragmented figures without resorting to perceptual organization: Presumably familiar fragmented figures are more likely than unfamiliar fragmented figures to activate object representations and thereby discrimination responses are faster to the former than to the latter.

In this article, we provide new evidence for the effect of past experience on perceptual grouping. We used primed matching to examine the microgenesis of perceptual organization for familiar and unfamiliar visual configurations that varied in the connectedness between their line components. 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. By varying the duration of the prime, we can tap earlier and later internal representations

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(Kimchi, 1998, 2000; Sekuler & Palmer, 1992). Thus, this paradigm enables us to assess implicitly the participant's perceptual representations and the time course of their organization. Microgenetic analysis is important for understanding the processes underlying perceptual organization rather than just the final outcome of these processes.

To examine whether past experience exerts an influence on perceptual grouping, we manipulated the familiarity of the prime (upright vs. inverted letters) and its connectedness (connected vs. disconnected). The primes were presented for various durations, and the test figures were always intact. 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. These two types of test pairs should be sensitive to priming from the configuration of the prime, but presumably in different directions. Priming effects of the configuration would manifest themselves in facilitation for the similarity condition, and possibly interference for the orientation-dissimilarity condition (because of dissimilarity in global orientation). With this set of primes and test figures, we expected to determine whether disconnected primes produce a pattern of priming similar to that of connected primes, and whether a difference between the priming of connected and disconnected primes, if any, depends on the familiarity of the prime. Because priming is a function of the representational similarity between the prime and the test figures, and the test figures were always intact, the configuration of the prime had to be available to produce priming. In contrast, in Hock and Marcus's (1976) study, no grouping of the fragmented letters was required for performing the discrimination task.

According to the traditional view, the primes get organized without any influence from object memories. 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 line segments into a configuration. Microgenetic analysis enabled us to examine how early in time the effect of familiarity is exerted, relative to that of connectedness.

METHOD

Participants

Forty-two students at the University of Haifa, Haifa, Israel, participated in this experiment (8 women and 6 men aged 20–26 years in the no-gap condition, 10 women and 4 men aged 20–25 years in the small-gap condition, and 8 women and 6 men aged 20–26 years in the large-gap condition). All participants had normal or corrected-to-normal vision.

Stimuli

Four Hebrew letters presented either upright or inverted served as primes. In addition, a neutral prime, consisting of a random array of dots, served as a baseline condition. Thus, each test type had its appropriate control. The complete set of the (connected) primes and the respective "same"- and "different"-response test pairs are presented in Figure 1.

The disconnected letters were formed by dividing each letter into four line segments at the interior concave discontinuities (Hoffman & Richards, 1984) and introducing either small or large gaps between the line segments. Participants sat approximately 60 cm from the screen on which the stimuli were presented, with their heads resting on a chin rest. From this position, the connected letters subtended 2.20° to 2.39° in width and 1.43° to 1.53° in height. The gaps between the line segments subtended 0.29° each in the small-gap condition and 0.95° each in the large-gap condition. The neutral prime subtended about 2° × 2°. All the test figures were intact, and their size was identical to that of the connected primes. The distance between the centers of the two stimuli in a test pair was 7 cm. Examples of the stimuli in the three gap conditions are presented in Figure 2.

Design

The seven factors of the experiment were gap (no gap, small gap, large gap), priming condition (prime, control), letter (א, נ, ו, ז), orientation (upright, inverted), prime duration (40, 90, 190, 390, 690 ms), test-pair type (similarity, orientation dissimilarity), and response ("same," "different"). The gap factor was between subjects, and the other factors were within subjects. All the combinations of the within-subjects factors were randomized within block, with each combination occurring on an equal number of trials. The figures in the "different"-response test pairs appeared equally often in each of the two possible locations. For each gap condition, there were 960 experimental trials in six blocks of 160 trials each, preceded by a practice block of 32 trials. Two additional trials at the beginning of each block were warm-up trials and were not included in the analyses.

Procedure and Apparatus

Each trial consisted of the following sequence of events. First, a central fixation dot appeared for 250 ms. After a 250-ms interval, a priming stimulus (an upright or inverted letter, or an array of random dots) appeared for a variable duration, followed immediately by the test display, which stayed on until the participant responded.¹

As quickly and as accurately as possible, the participant made a same/different judgment about the two test figures by pressing one of two keys. Response times (RTs) were recorded by the computer. Feedback about an incorrect response was provided by an auditory tone presented as soon as the participant responded. Trials on which the response was incorrect were repeated at the end of the block. The screen was viewed through a circular aperture (14 cm in diameter) in a matte black cardboard sheet.

RESULTS

All RT summaries and analyses are based on participants' mean RTs for correct responses. Error rates were low (an overall mean of 2.28%) and did not vary significantly across conditions, and there was no indication of a speed-accuracy trade-off. Therefore, we do not discuss error rates further.

1. Although the procedure had the potential to produce apparent motion, there was no strong percept of apparent motion. Presumably, the conditions were not optimal for it. Furthermore, even if some had occurred, it still would not have changed the results, because there is no reason to assume that it would have a different effect on upright versus inverted primes.

Upright prime	Test Pairs		Inverted prime	Test Pairs	
	Same	Different		Same	Different

Fig. 1. The complete set of the primes (connected) and the “same”- and “different”-response test pairs used in the experiment. The upright primes were four upright Hebrew letters; the inverted primes were the same letters inverted. For each prime, the upper pair shown is the similarity test pair and the lower pair shown is the orientation-dissimilarity test pair. The random array of dots served as a neutral prime, providing a baseline (control condition) for each of the test-pair types.

Priming effects are indicated by the difference in mean RTs for correct “same” responses for test pairs in the prime condition versus the control condition. Figure 3 shows priming effects as a function of prime duration and connectedness for the similarity test pairs and for the orientation-dissimilarity test pairs, separately for upright and inverted primes. Facilitation is indicated by positive values and inhibition by negative values.

Preliminary analyses confirmed that, as in past studies (Beller, 1971; Kimchi, 1998, 2000; Sekuler & Palmer, 1992), there were no effects of priming for “different” responses. Also, no significant interactions that involved letter were obtained. The collapsed data for “same” RTs were submitted to a five-factor (Priming Condition \times Test-Pair Type \times Prime Duration \times Orientation \times Gap Condition) analysis of variance that treated gap as a between-subjects factor and the other factors as within-subjects factors. The analysis showed a significant effect of priming condition, $F(1, 39) = 26.48, p < .0001$, that interacted significantly with test-pair type, $F(1, 39) = 71.40, p < .0001$; orientation, $F(1, 39) = 12.96, p < .0009$; and prime duration, $F(4, 156) = 4.81, p < .01$. There was also a significant interaction among priming condition, test-pair type, orientation, and gap condition, $F(2, 39) = 3.99,$

$p < .05$. Planned specific comparisons were carried out to assess the priming effects for the similarity and the orientation-dissimilarity test pairs in the different gap conditions for upright and inverted primes.

As can be seen in Figures 3a and 3b, familiarity interacted with connectedness in their effect on priming for the similarity test pairs, $F(2, 39) = 3.90, p < .03$. For upright primes (Fig. 3a), mean RT was significantly faster in the prime condition (544 ms) than in the control condition (605 ms), $F(1, 39) = 66.20, p < .0001$, indicating a significant facilitation. The facilitation was observed as early as 40 ms, $F(1, 39) = 23.19, p < .0001$, and did not vary with prime duration, $F(4, 156) = 1.41, p > .23$. There was no effect of connectedness on the amount of facilitation or on its time course: Neither the interaction between priming condition and gap condition nor the interaction among priming condition, prime duration, and gap condition was significant, $F_s < 1$. These results suggest that the configuration of the upright prime was available for priming as early as 40 ms, regardless of the connectedness of the prime.

Priming effects for the inverted primes (Fig. 3b), in contrast, were affected by connectedness, $F(2, 39) = 7.70, p < .0015$, and by prime

	Prime	Test Pairs	
		Same	Different
No Gap	Upright		
	Inverted		
Small Gap	Upright		
	Inverted		
Large Gap	Upright		
	Inverted		

Fig. 2. Examples of the primes and the “same”- and “different”-response test pairs in the no-gap, small-gap, and large-gap conditions.

duration, $F(4, 156) = 2.78, p < .05$. For inverted connected primes (no-gap condition), mean RT was significantly faster in the prime condition (588 ms) than in the control condition (645 ms), $F(1, 13) = 35.80, p < .0001$, indicating a significant facilitation that did not vary with prime duration, $F < 1$. Actually, there was no difference between the priming effect of the connected inverted primes and that of the connected upright primes, $F < 1$; nor was there a difference in the time course of priming for these two conditions, $F(4, 52) = 1.4, p > .24$. Disconnectedness, however, had a detrimental effect on priming for the inverted primes. The difference between the prime condition (610 ms) and the control condition (634 ms) in the small-gap condition, though significant, $F(1, 13) = 6.36, p < .05$, was significantly smaller than the corresponding difference in the no-gap condition, $F(1, 13) = 6.27, p < .02$. For the large-gap condition, no significant difference between the prime (634 ms) and control (640 ms) conditions was observed, $F < 1$. Rather, priming condition interacted with prime duration, $F(4, 52) = 3.06, p < .025$: A tendency for inhibition at short durations turned into significant facilitation at the longer durations of 390 and 690 ms, $F(1, 13) = 14.12, p < .01$, and $F(1, 13) = 7.62, p < .02$, respectively.

When the test figures were dissimilar to the prime in orientation (Figs. 3c and 3d), the interaction among priming condition, familiar-

ity, and connectedness just approached significance, $F(2, 39) = 2.46, p < .09$. For upright primes (Fig. 3c), the difference in mean RT between the prime condition (630 ms) and control condition (619 ms) was not significant, $F(1, 39) = 2.44, p > .12$, indicating no priming effect, but there was a significant interaction between priming condition and prime duration, $F(4, 156) = 2.72, p < .05$, that did not vary with connectedness, $F < 1$. A tendency for some inhibition at short prime durations diminished with time.² Presumably, interference due to dissimilarity in orientation was compensated for by facilitation due to similarity in identity, resulting in a null main effect. We return to this point later.

For inverted primes (Fig. 3d), a significant priming effect, $F(1, 39) = 8.17, p < .01$, was qualified by a significant interaction with connectedness, $F(2, 39) = 5.89, p < .005$. For the connected primes (no gap), mean RT was significantly slower in the prime condition (655 ms) than in the control condition (614 ms), $F(1, 13) = 23.25, p < .001$, indicating a significant inhibition that was not affected by prime duration, $F < 1$. This result was different from the results for connected upright primes, $F(1, 13) = 5.38, p < .05$, for which no significant priming was observed. No significant difference in mean RT between the prime and control conditions was observed for the small-gap inverted primes (623 ms and 628 ms, respectively, $F < 1$) and for the large-gap inverted primes (630 ms and 618 ms, respectively), $F(1, 13) = 3.14, p > .10$, and the interaction between priming condition and prime duration was not significant in either condition, $F < 1$ and $F(4, 52) = 1.38, p > .25$, for the small-gap and the large-gap conditions, respectively. The absence of priming effects for the small- and large-gap conditions was presumably due to the fact that no strong configuration was formed.

DISCUSSION

These results show that connectedness had no effect on the priming of familiar primes, whereas the priming effects of unfamiliar primes varied as a function of connectedness. Both connected and disconnected upright primes produced facilitation as early as 40 ms as a function of prime-test similarity, and dissimilarity in orientation between the prime and the test figures produced some early weak inhibition that diminished with time. The results for inverted primes were quite different. In the similarity condition, inverted connected primes produced facilitation that was as strong and as early as the facilitation produced by upright primes. In the orientation-dissimilarity condition, inverted connected primes produced interference. For disconnected inverted primes, facilitation was observed only later in time in the similarity condition, and dissimilarity in orientation produced no priming.

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 a connected upright letter, the configuration of a disconnected upright letter, and the configuration of a connected inverted letter all were available at 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.

2. The only exception to this trend is the nonsignificant interference observed at 690 ms for the no-gap condition.

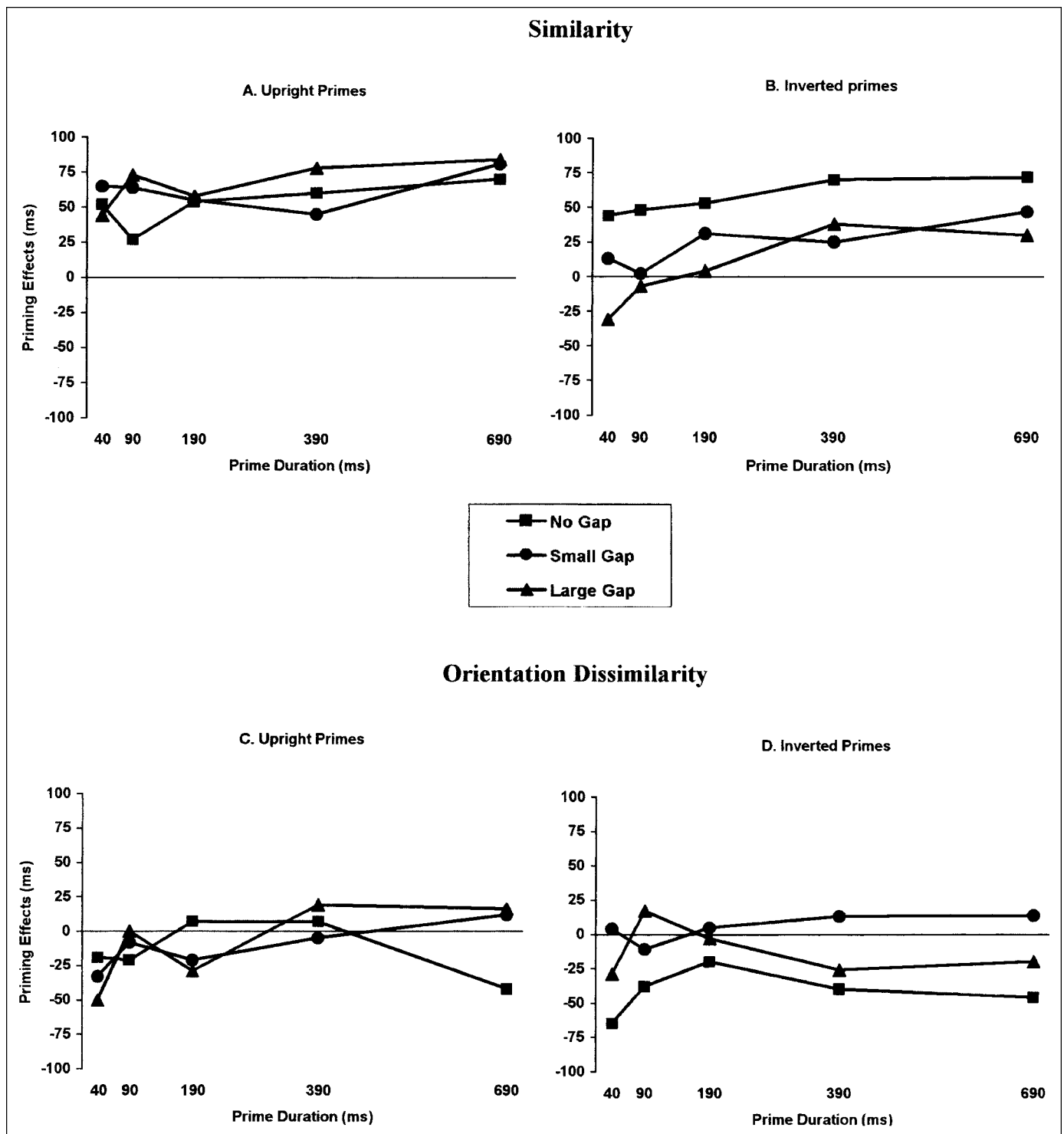


Fig. 3. Priming effects (difference between the prime and control conditions in mean correct response time for “same”-response test pairs) as a function of prime duration and connectedness. Results are shown separately for the similarity test pairs for (a) upright primes and (b) inverted primes and for the orientation-dissimilarity test pairs for (c) upright primes and (d) inverted primes. Facilitation is indicated by positive values and inhibition by negative values.

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We have assumed that priming depended on the similarity between the prime and the test figures, and therefore on organization of the prime into a well-formed configuration. An alternative account assumes that the observed priming effects are a function of similarity in identity between the prime and the test figures (without any prior organization). Presumably, the primes activate object representations, get identified, and facilitate responses to test figures with the same identity. This identity account also predicts that familiarity and connectedness interact in their effect on priming, but involves no assumption about grouping. Although this account may seem reasonable in the case of upright primes, it is much less plausible in the case of inverted primes. Inverted primes need to be rotated to upright in order to be identified, but the test figures on these trials were always either inverted or reflected.

Furthermore, some of the findings are not easily accounted for by the identity hypothesis. First, 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 also for upright primes, at least at short durations. Yet no effect of connectedness was found for the upright primes. Second, upright figures are identified faster than inverted ones (Jolicoeur, 1985, 1988; Tarr & Pinker, 1989), so there should be an advantage for upright primes relative to inverted primes even when connected. Yet the results showed the same amount of facilitation for connected upright and inverted primes in the similarity condition, and the facilitation in both cases occurred even with primes of the shortest duration. These results would be expected if priming were a function of the visual similarity between the prime and the test figures.

Alternatively, one may argue for dual-source priming, according to which either physical similarity (as with connected inverted primes) or similarity in identity (as with upright disconnected primes) suffices to produce priming; when neither is present (as with inverted disconnected primes), no priming occurs. The problem with this account is that it cannot easily explain the effect of similarity versus orientation dissimilarity in the case of upright primes, in particular, the disconnected ones. If priming for these primes is due to similarity in identity, then orientation dissimilarity between the prime and the test figures would be expected to produce priming similar to that found with orientation similarity, though perhaps smaller in magnitude or later in time. But the results show that the pattern of priming produced by similarity differed from the one produced by orientation dissimilarity: pronounced facilitation that did not vary with prime duration in the former, and early inhibition that diminished with time but did not turn into significant facilitation even at the longest duration in the latter.

Note, however, that comparing the results for the connected upright and inverted primes in the orientation-dissimilarity condition suggests some effect of similarity in identity. Dissimilarity in orientation between the prime and the test figures produced significant interference for inverted but not for upright primes. Because the test figures were rotational transforms of the primes, the degree of visual similarity between the prime and the test figures was the same for upright and inverted primes. Therefore, the differential effect of orientation dissimilarity cannot be attributed to a difference in visual similarity but rather must be attributed to a difference in similarity in identity. Indeed, the effect of orientation on letter identification is larger for unfamiliar than for familiar letters (Jolicoeur, Snow, & Murray, 1987; Koriart & Norman, 1985). Thus, the upright prime facilitated responses to its rotational transform by virtue of its identity, reducing somewhat the effect of orientation dissimilarity. The connected inverted prime,

although its configuration was available because of connectedness, apparently was not identified. Consequently, no similarity in identity was available to reduce the interference effect of orientation dissimilarity, resulting in a significant inhibition. Thus, similarity in identity played some role in priming, but, as the results for upright primes show, it occurred later in time, and was not strong enough to override the effect of visual dissimilarity even at longer durations.

Altogether, the results are more compatible with the grouping account than with either the identity or the dual-source account, suggesting that familiarity had an effect on the grouping of the disconnected primes.

Our results converge with other results (e.g., Peterson & Gibson, 1994a, 1994b; Vecera & Farah, 1997) in demonstrating effects of past experience on perceptual organization. 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 an interactive hierarchical model with temporally cascaded processing that includes feedforward and feedback mechanisms (e.g., McClelland & Rumelhart, 1981; Palmer & Rock, 1994a; Vecera & O'Reilly, 1998). The effect of past experience on grouping can be accounted for in such a model in the following way: Partial results of the image organization activate higher-level object representations that in turn feed back to facilitate and consolidate groupings that correspond to familiar objects. This activation may not initially be strong enough to support full identification, but when it is fed back, it suffices to influence grouping.

An alternative model was presented by Peterson (1994a, 1999; Peterson & Gibson, 1994a) to account for the influence of object knowledge on figure assignment. Peterson argued for the existence of a "pre-figural" recognition process that operates on both sides of each contour before figure-ground processing. The details of applying such a model to perceptual grouping need to be worked out, but the basic idea is that input from object recognition processes influences organization in parallel with lower-level cues. Further research is needed to evaluate the relative adequacy of these models in accounting for perceptual organization. Our finding that the effect of familiarity on the integration of the line segments occurred as early as the effect of connectedness suggests that at least some aspects of object representations in memory may be accessed in parallel with other, image-based cues.

The present results also converge with other results (Han, Humphreys, & Chen, 1999; Kimchi, 1998, 2000) demonstrating that uniform connectedness does not have a privileged role in perceptual organization, as claimed by Palmer and Rock (1994a, 1994b). 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 (Kimchi, 2000; Peterson, 1994b). The present findings show that input from object memories is also among these cues.

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