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Acta Psychologica 96 (1997) 193–206

acta psychologica

Hemispheric processing of form versus texture at the local level of hierarchical patterns

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Received 4 October 1996; revised form received 1 April 1997; accepted 2 April 1997

Abstract

Kimchi (Kimchi, R., 1992. Primacy of wholistic processing and global/local paradigm: A critical review. *Psychological Bulletin* 112, 24–38) proposed that the perception of hierarchical stimuli is dependent on the number of local elements. The local level of stimuli with smaller numbers of elements is perceived as discrete forms, and irrelevant form information at the global level affects processing of the local level; with larger numbers of local elements, however, the local level is seen as being comprised of a texture, and interlevel interaction is eliminated. The current study provides a test of Kimchi's hypothesis for left versus right cerebral hemispheric (LH vs. RH) processing, employing a stimulus set that sampled the critical range of a number of local elements more thoroughly than previous studies. Results indicate that (i) increasing the number of local elements reduces and eventually eliminates interlevel interference, (ii) the crossover point between perception of local elements as form vs. texture does not differ for LH vs. RH processing, and (iii) hemispheric differences in local–global processing of stimuli comprised of geometric shapes are not robust, although an LH advantage for local targets was obtained for stimuli with few local elements. © 1997 Elsevier Science B.V.

PsycINFO classification: 2323; 2520

Keywords: Visual perception; Laterality; Cerebral dominance; Local–global

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PII S0001-6918(97)00012-7

1. Introduction

Hierarchical stimuli, in which a large, global level form is built up of smaller, local forms, have proven to be a useful tool in examining such issues as cerebral hemispheric asymmetries in perceptual processing (e.g., Robertson and Lamb, 1991; Van Kleeck, 1989), the role of spatial frequency in visual processing (e.g., Shulman et al., 1986), the interaction between attentional and response processes (e.g., Miller, 1981), the role of selective attention in object perception (e.g., Pomerantz et al., 1989), upper–lower visual field anisotropies (e.g., Christman, 1993), and visual perception in infants (e.g., Ghim and Eimas, 1988). Studies employing local/global stimuli typically concentrate on two phenomena: (i) global precedence, in which aspects of global processing are begun and/or completed earlier than aspects of local processing and (ii) interlevel interference, in which irrelevant information at one level interferes with processing of the other level. This second phenomenon constitutes an explicit form of interaction between the two levels of local/global stimuli. Global precedence and interlevel interference represent the operation of distinct processes, as evidenced by behavioral and neurological dissociations between the two measures (Robertson and Lamb, 1991).

2. Integral versus separable processing of local and global levels

In an extensive series of papers, Kimchi and colleagues systematically examined the interaction between global and local dimensions of hierarchical stimuli (Kimchi, 1988, 1990, 1992; Kimchi and Merhav, 1991; Kimchi and Palmer, 1982, 1985). In particular, they have addressed the issue within Garner's framework (Garner, 1974) of integral versus separable dimensions. Stimuli comprised of separable dimensions show no improvement in the processing speed when the dimensions are correlated, nor interference when they are orthogonal; stimuli composed of integral dimensions, on the other hand, show an increase in the processing speed when the two dimensions are correlated, and interference when they are orthogonal. The aforementioned phenomenon of global interference suggests that local and global levels are often treated as integral dimensions.

Kimchi has argued that local and global dimensions are integral only under certain conditions. In particular, she suggested that when a pattern is comprised of small numbers of local elements, both the local and global levels are processed as form and the dimensions are integral. However, when a pattern is comprised of many local elements, local elements are processed as texture (in which case local elements lose their individual identity) and the global configuration is perceived as form. Once local elements are perceived as texture, they no longer interact with the global form of the figure, the local and global dimensions become separable, and interlevel interference is reduced or eliminated. In this regard, Kimchi and Palmer (1982) note the subitizing effect (Kaufman et al., 1949), whereby a brief presentation of up to six objects enables the viewer to report accurately the number of objects, but when more than eight objects are presented, performance rapidly declines.

Thus, when less than seven local elements are present, they are readily perceived as discrete forms; however, when more than seven elements are present, the inability to perceive them individually leads them to be seen as a composite texture.

Kimchi and Palmer (1982) found that, when four local elements were present, subjects perceived them as individual parts of an overall form that were perceptually salient, and normal patterns of global interference were obtained. However, when nine or more local elements were present, subjects treated them as homogenous texture, and global interference was eliminated. This effect has been replicated in adults (Kimchi, 1988) and in children (Kimchi, 1990).

3. Hemispheric asymmetries in local–global processing

Kimchi (1992), in summarizing the above results, stated that the critical number of local elements for the crossover between local elements being processed as individual forms versus texture as 7 ± 2. Given evidence for right versus left cerebral hemisphere superiority in the processing of global versus local levels, respectively (e.g., Van Kleeck, 1989), the question is raised as to whether the crossover point may vary for left versus right hemisphere (LH vs. RH) processing. For example, given the LH advantage for local processing, perhaps the LH is better at perceiving local elements as individual forms and consequently crosses over from local form to texture at a higher number of local elements.

The majority of studies examining hemispheric asymmetries in local/global processing have employed hierarchical letter stimuli of the sort originally developed by Navon (1977); such stimuli are not fully appropriate for testing Kimchi's model, as geometric elements lend themselves more readily to textural perception (e.g., checkerboard pattern) than alphabetic stimuli presumably do. However, a few laterality studies have used the geometric stimuli employed in Kimchi's studies. For example, Polich and Aguilar (1990) found hemispheric differences to be unrelated to local or global processing requirements. They did, however, report an overall trend towards an LH–RT advantage across processing conditions, as well as a hemisphere by shape interaction, with squares being processed faster in the LH relative to the RH, and rectangles being processed slightly slower than squares in both hemispheres. However, Kimchi and Merhav (1991) pointed out methodological limitations of the Polich and Aguilar (1990) study. First, Polich and Aguilar assessed interlevel interference by comparing consistent and inconsistent stimuli containing different numbers of local elements; given Kimchi's aforementioned arguments that interference is minimal for many element patterns, this renders ambiguous the nature of the interference reported by Polich and Aguilar. Similarly, the dimension of shape in their study was confounded with consistency and number of elements; e.g., their many element rectangles contained two local elements, while their few element squares contained four local elements.

Kimchi and Merhav (1991) also examined hemispheric differences in the processing of global form, local form, and local texture. Following the procedures of Kimchi and Palmer (1985), they found the typical LH versus RH advantages for processing the local versus global levels, respectively, when the local elements were labeled as forms; however, when the local elements were labeled as textures, no hemispheric differences were found. This suggests that the hemispheric differences found with local/global stimuli are dependent on the local level being perceived as individual forms.

The purpose of the present study is twofold: first, to provide a further test of the hypothesis that local elements are seen as a texture when the number of local elements is greater than 7 ± 2, and second, to examine potential hemispheric differences in the processing of local elements as form versus texture (e.g., whether the crossover from local form to local texture processing occurs at different points for the LH versus RH). This was accomplished by using lateralized presentation of a stimulus set that sampled the range from 4 to 16 local elements more fully. Previous studies have not thoroughly sampled the range from 5 to 9 local elements. For example, in Kimchi and Palmer's study (Kimchi and Palmer, 1985), the number of local elements ranged from 3 to 7, then jumped to fifteen. Similarly, experiment 1 by Kimchi and Merhav (1991) jumped from 4 to 16 local elements. While experiment 2 by Kimchi and Merhav employed stimuli with 3, 4, 5, 7, 15, 29, or 85 local elements, providing a better sampling of the critical range, their study was limited by the lack of equivalent consistent and inconsistent stimuli comprised of the same number of local elements.

4. Method

4.1. Subjects

Sixteen right-handed subjects with normal or corrected to normal vision served as subjects; 10 were female and 6 were male. These subjects were recruited from psychology courses, and received course credit for their participation. Handedness was assessed by use of a brief questionnaire.

4.2. Design

This experiment employed a five factor intra-subjects design. The factors were visual field (left and right), set type (few, crossover, and many element), target level (local and global), global shape (square and rectangle), and consistency (consistent and inconsistent). The three different sets crossed with the two different target levels were run in six separate blocks. Stimuli were presented randomly with the restriction that no more than four consecutive trials involved the same visual field or stimulus identity. Ordering of blocks was counterbalanced across subjects.

4.3. Apparatus and stimuli

Stimuli were created by orthogonally combining two types of global configuration (square and rectangle) with two types of local elements (black and white squares versus rectangles). Local elements for both sets were arranged in either a checkerboard pattern for squares or a grating pattern for rectangles. These stimuli were then categorized into one of three sets: few, crossover, and many element sets, and are shown in Fig. 1. The three sets differed in the number and relative size of the local elements in the pattern. The *few element set* consisted of patterns composed of four relatively large elements, the *crossover element set* consisted of patterns composed of 6–10 moderate sized elements, and the *many element set*, consisting of patterns composed of 16 relatively small elements.

In order to unambiguously measure the effects of number of local elements on interlevel interference, it is important that the consistent and inconsistent stimuli being compared consist of equal numbers of local elements. This constraint was not followed in the study by Polich and Aguilar (1990), where consistent and inconsistent stimuli always differed in the number of local elements (i.e., the inconsistent stimuli always had fewer elements than the consistent stimuli, possibly leading to an overestimation of interference). Conversely, the study by Kimchi and Merhav (1991) did use certain pairs of consistent and inconsistent stimuli with equal numbers of local elements; however, due to constraints in the nature of their stimuli, this restricted them to sampling only 4 versus 16 local elements.

Because consistent squares must be comprised of square numbers of local elements (e.g., 4, 9, 16, etc.), this creates problems for sampling the crossover range of 5–9 elements. To allow a broader sampling of this range, local interference was assessed by comparing (i) the global rectangle made from local rectangles with (ii) the global rectangle made from local squares. Conversely, global interference was assessed by comparing (i) the global rectangle made of local rectangles with

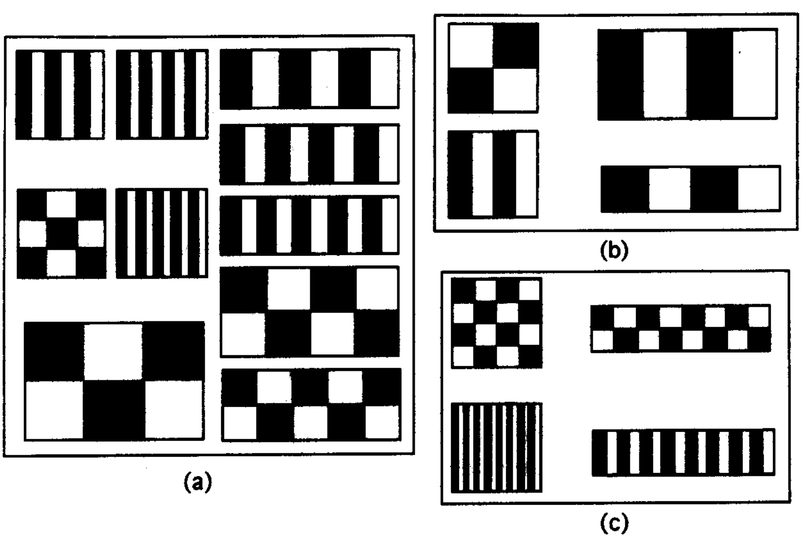

Fig. 1. Examples of stimuli: (a) crossover element set; (b) few element set; (c) many element set.

(ii) the global square made of local rectangles. Finally, because it is geometrically impossible to create a global rectangle from an odd number of local squares, the crossover element set contained only 6, 8, and 10 local elements for the global rectangle.

Stimuli were generated and presented on a Macintosh II computer. Stimulus presentation was controlled by MacLaboratory Reaction Time software (version 2.0.5), and was displayed on an AppleColor high-resolution RGB monitor from a viewing distance of 70 cm. The global square subtended 2.9° of visual angle in height and width for all element sets. The global rectangle subtended 5.9° in width and from 1.5° to 3.9° in height for all sets. For local rectangles, each local element subtended from 0.2° to 1.5° in width and shared the same height as the global figure they comprised. For local squares, individual elements subtended from 0.7° to 2.0° in width and height. Stimuli were presented with the inside edge of stimuli located 2.2° to the left or right of the central fixation point. Space averaged luminance of the display was 62.4 cd/m^2.

4.4. Procedure

Subjects were shown examples of all stimuli, and the two levels were defined: global form and its two configurations (square and rectangle) and local texture and its two types (checkerboard or grating). Subjects were instructed to attend to one level while ignoring the other, and to indicate the identity of the relevant configuration/form. Responses were made by pressing the "C" or "M" key using the index fingers of both hands. The response assignment of each key was counterbalanced inter-subjects. Subjects were told to respond as quickly and accurately as possible, and to remain focused on the center of the screen as indicated by a fixation point.

The sequence of events for each trial was as follows: a fixation point appeared in the center of the screen and remained for the entire block. Each trial began with a 100 ms duration warning tone. 500 ms after the offset of the tone, a stimulus appeared for 150 ms to either the left or right of fixation. Once the subject had responded, a 1.5 s inter-trial interval occurred. This was followed by the return of the warning tone indicating the start of the next trial. At the start of each block, subjects received 5–10 practice trials to familiarize themselves with the stimuli being used and the task at hand.

There were two blocks for each stimulus set, one corresponding to the local target task, and the other to the global target task. Each of the few and many element set blocks contained 80 trials, representing the factorial combination of four stimuli × 2 visual fields × 10 replications. The crossover element set blocks each contained 240 trials, again representing 10 replications of each of the 10 stimuli per visual field, with the exception of the 9 element consistent square which had 30 replications (this was done to ensure that squares and rectangles occurred equally often at the local and global levels). There were a total of 800 trials (160 for each of the few and many element sets, and 480 for the crossover set). The experiment consisted of two 30-min sessions. Each session contained one block from each set for a total of three blocks. Subjects were given short breaks between blocks.

5. Results

Six factor ANOVAs were performed on the RT and error data. RT analyses were based on subjects' median latencies for correct responses. Sex was an inter-subject variable, and intra-subject factors were visual field (left and right), set type (few, crossover, and many element), target level (local and global), global shape (square and rectangle), and consistency (consistent and inconsistent). The correlation between Ss' RTs and error rates was nonsignificant ($r =\ 0.19$, $p = 0.478$), indicating the absence of speed–accuracy tradeoffs. To address possible violations of the sphericity assumption, Geisser–Greenhouse corrections were applied to all effects involving the set type factor.

Analysis of the RT data revealed only one significant effect involving sex, an interaction between set type, target level, and sex, $F(2,30) = 5.54$, $p < 0.01$; this reflected the fact that males showed faster RTs to global targets for all set types, while females showed a global advantage for the few element set type and nominal local advantages for the cross-over and many element set types. Analysis of the error data revealed two interactions involving sex. A consistency × sex interaction, $F(2,30) = 5.95$, $p < 0.03$, reflected the fact that the males exhibited greater interference (Inconsistent minus Consistent) than females; a visual field × target × sex interaction, $F(2,30) = 5.97$, $p < 0.03$, reflected the fact that the males showed LVF versus RVF advantages in processing rectangles versus squares, respectively, while females showed the opposite pattern (albeit of smaller magnitude). Because none of these interactions involved more than one of the main variables of interest (i.e., set type, visual field and consistency) and are not readily interpretable, subsequent analyses were collapsed across sex.

There were main effects of set, $F(2,30) = 23.12$, $p < 0.001$, reflecting slower responding in the few element (520.3 ms) relative to the crossover (487.1 ms) and many element (466.9 ms) sets, and of visual field, $F(1,15) = 9.28$, $p < 0.01$, reflecting faster responding in the RVF (486.4 ms) relative to LVF (495.8 ms). There was a significant four-way interaction between set, target level, global shape, and consistency, $F(2,30) = 4.55$, $p < 0.025$, depicted in Fig. 2. A number of significant two- and three-way interactions involved various subsets of factors involved in the four-way interaction (set × target, $F(2,30) = 4.49$, $p < 0.04$; set × shape, $F(2,30) = 16.77$, $p < 0.001$; set × consistency, $F(2,30) = 8.31$, $p < 0.005$; target × consistency, $F(1,15) = 21.85$, $p < 0.001$; shape × consistency, $F(1,15) = 31.00$, $p < 0.001$; set × target × shape, $F(2,30) = 19.45$, $p < 0.001$; set × target × consistency, $F(2,30) = 7.01$, $p < 0.005$; set × shape × consistency, $F(2,30) = 22.62$, $p < 0.001$; and target × shape × consistency, $F(1,15) = 23.88$, $p < 0.001$). For the sake of simplicity, and because the nature of such lower-order interactions is qualified by the presence of the higher-order interaction, discussion will be confined to the four-way interaction, which will be addressed by examining effects of target, shape, and consistency for each stimulus set separately.

With regards to consistency, analyses of simple effects indicated that, for the many element set, there were no significant differences between consistent and inconsistent target processing speed for any condition ($F < 1$); thus, there was no interlevel inter-

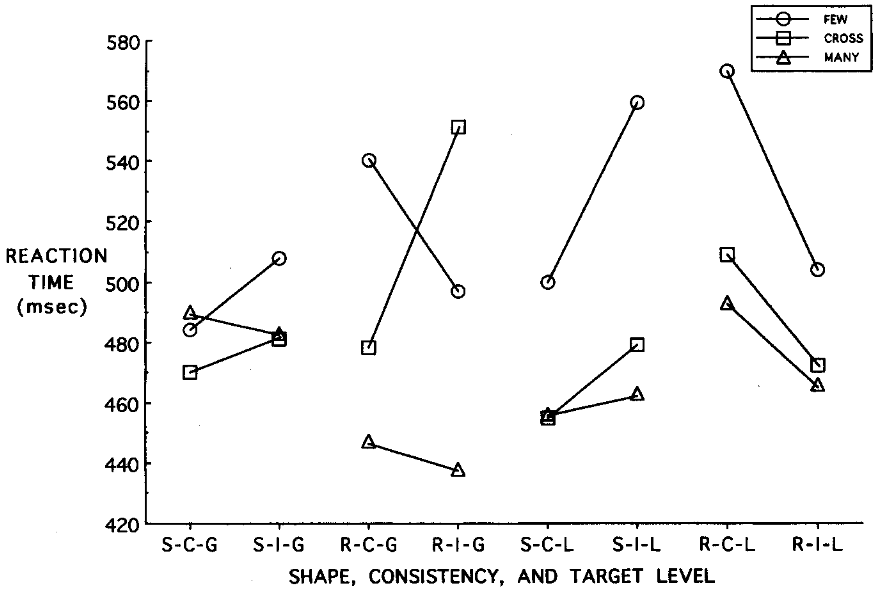

Fig. 2. Set × target level × shape × consistency interaction. S = square target, R = rectangle; C = consistent, I = inconsistent; G = global, L = local.

ference, suggesting that the local level was perceived as texture and the two levels were processed separably. For the crossover element set, there were no significant RT differences between consistent and inconsistent stimuli if the target was a square ($F < 1$). However, if the target was a rectangle, in both the local and global target tasks, there were significant processing speed differences. Consistent global rectangles were processed significantly faster than inconsistent global rectangles, $F(1,62) = 14.88$, $p < 0.001$, and consistent local rectangles were processed significantly slower than inconsistent local rectangles, $F(1,62) = 4.20$, $p < 0.05$. These results suggest that the nature of the target may influence the crossover point at which the local level is perceived as texture versus form, with square targets leading to perception of the local level as texture and rectangle targets leading to perception of the local level as form.

Effects of consistency for the few element set varied with target and shape. For the few element set, global squares yielded a nonsignificant trend toward processing being faster for consistent stimuli, $F(1,62) = 1.35$, $p = 0.25$; if the stimulus was a local square, this trend toward faster processing to consistent stimuli became significant, $F(1,62) = 7.14$, $p < 0.01$. The reverse was true for the rectangular target stimuli. For both global and local targets, responses were significantly faster to the inconsistent stimuli, $F(1,62) = 3.88$, $p < 0.05$ and $F(1,62) = 16.24$, $p < 0.001$, respectively. Thus, interlevel interference effects were obtained for all stimuli comprised of few local elements.

Consistent with Kimchi's hypothesis, therefore, (i) there were no interlevel interference effects for stimuli composed of 16 local elements, consistent with the local level being perceived as texture, (ii) interlevel interference effects for the crossover set were obtained only for rectangle targets, not squares, suggesting that the minimal number of local elements required for texture perception is target shape specific, and (iii) interlevel interference effects were obtained for all stimuli in the few element set, consistent with the local elements being perceived as forms.

A significant set × visual field × target interaction, $F(2,30) = 4.12$, $p < 0.04$, is depicted in Fig. 3. Analyses of simple effects revealed that this interaction was mainly driven by the few element set, which was processed significantly faster in the RVF than in the LVF under the *local* target condition, $F(1,62) = 23.15$, $p < 0.001$. Except for a set × visual field interaction, $F(2,30) = 5.38$, $p < 0.015$, no other interactions involving visual field were significant.

A secondary analysis was performed to determine how the number of local elements in the crossover set interacted with interference and visual field. A 3-way intra-subject ANOVA was performed on data from the crossover set only. The factors were visual field (left and right), number of local elements (6, 8, and 10), and target level (local and global). This analysis was performed using interference RTs. The local interference RTs were obtained by subtracting the RTs for local rectangle–global rectangle stimuli from the RTs for local rectangle–global square stimuli. The global interference RTs were obtained by subtracting the RTs for local rectangle–global rectangle stimuli from the RTs for local square–global rectangle stimuli.

The results revealed a main effect of target level, $F(1,15) = 42.80$, $p < 0.001$, and of number, $F(1,15) = 4.32$, $p < 0.05$. These were part of a significant interaction be-

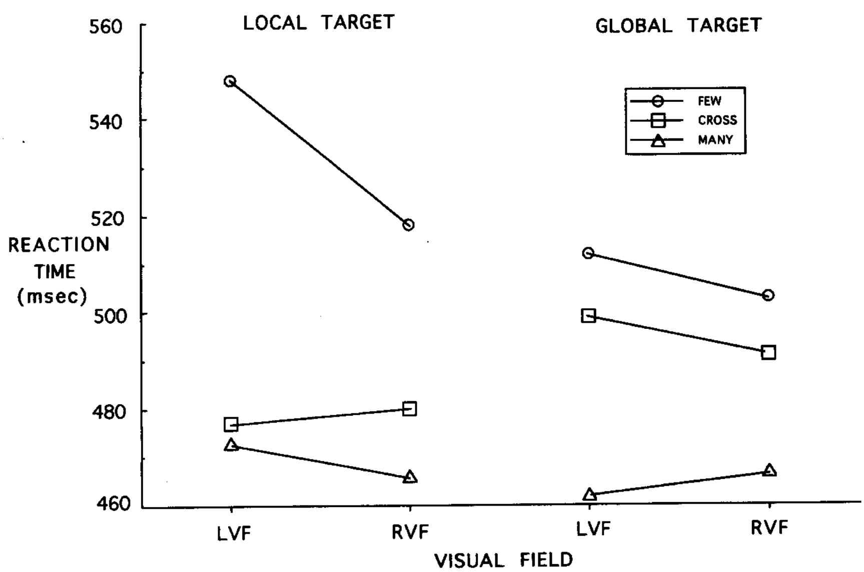

Fig. 3. Set × visual field × target level interaction. LVF = left visual field, RVF = right visual field.

tween target and number, $F(2,30) = 45.31$, $p < 0.001$, reflecting the fact that there was significantly more interlevel interference for the six element set relative to the eight and ten element sets. This interaction is depicted in Fig. 4. The fact that the interference was negative for the local target level condition (that is, subjects responded *faster* when the irrelevant global dimension was inconsistent), while somewhat puzzling, is still consistent with Kimchi's framework, in that there were still greater interlevel interference effects (regardless of direction) with fewer local elements.

Error analyses revealed a main effect for set type, $F(2,30) = 14.04$, $p < 0.001$, with performance on the crossover set (10.3% error rate) being significantly worse than on both the many element set (4.6%), $F(1,15) = 13.67$, $p < 0.002$, and the few element set (3.3%), $F(1,15) = 25.42$, $p < 0.001$; the difference in error rate between the few and many element sets was not significant, $F(1,15) = 4.07$, $p < 0.07$. Results also indicated several interactions (set × shape, $F(2,30) = 10.88$, $p < 0.003$; target × consistency, $F(1,15) = 4.74$, $p < 0.05$; set × target × consistency, $F(2,30) = 11.65$, $p < 0.001$; set × shape × consistency, $F(2,30) = 4.09$, $p < 0.05$; and target × shape × consistency, $F(1,15) = 15.21$, $p < 0.001$), which were all subsumed within a marginally significant four-way interaction between set, target level, global shape, and consistency, $F(2,30) = 4.05$, $p < 0.06$. This interaction reflected no differences between consistent and inconsistent stimuli for the many element set, compatible with the lack of consistency effects in the RT data. In the crossover set, there were again no differences between consistent and inconsistent stimuli when the target was a local or global square. However, for global rectangle targets, subjects were more accurate for incon-

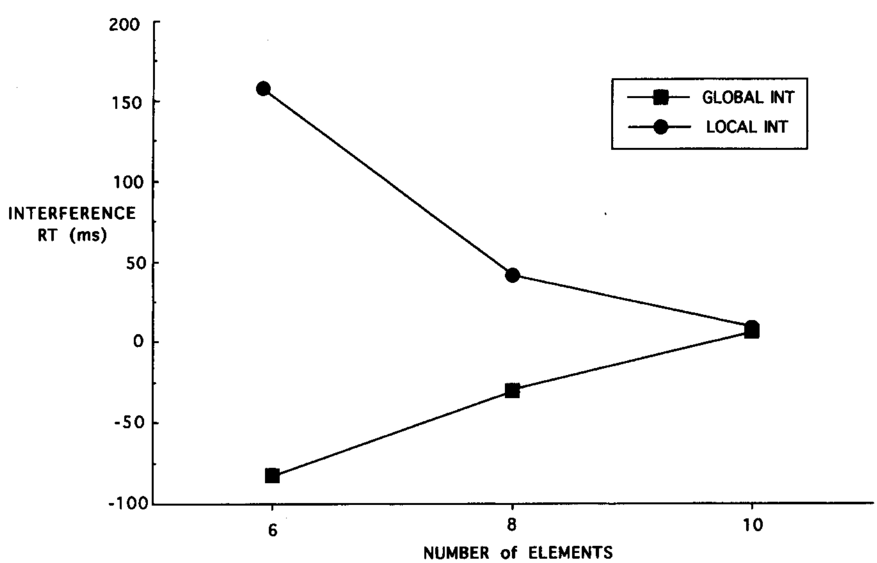

Fig. 4. Inteference (inconsistent RT minus consistent RT) as a function of target level and number of local elements.

sistent than consistent stimuli; conversely, for local rectangle targets, subjects were more accurate for consistent than inconsistent stimuli. This pattern stands in contrast to the RT data, which yielded faster responses to consistent versus inconsistent stimuli for global rectangle targets versus local rectangle targets, respectively, suggesting the presence of speed–accuracy trade-offs for rectangle targets in the crossover condition.

Finally, for the few element set, there were no differences between consistent and inconsistent stimuli for local targets. However, for global targets, subjects tended to make more errors to consistent rectangular stimuli than to inconsistent rectangular stimuli. Thus, subjects were both faster and more accurate when processing inconsistent global rectangles than consistent global rectangles; while the meaning of negative interference is hard to interpret, it is important to note that, as with the RT data, information at the irrelevant level influenced processing of the target level (regardless of the direction of the influence), compatible with Kimchi's hypothesis of interlevel effects being obtained only with stimuli composed of a relatively small number of local elements.

6. Discussion

The current experiment accomplished its main goal of more thoroughly sampling the range of the crossover effect, thereby allowing a more precise test of Kimchi's hypothesis. This is revealed by the findings that (i) no interference effects were obtained with stimuli composed of many local elements and robust interference effects were obtained with stimuli composed of few local elements, and (ii) within the crossover set, as the number of local elements increased from six to ten, the amount of interference approached zero. With regards to hemispheric differences, there was no evidence that the hemispheres differ for the point at which the perception of local elements switches from form to texture (indeed, the only hemispheric differences involved a LH advantage in RT for local targets in the few element condition). It is worth noting that Kimchi's crossover effect refers only to the elimination of *positive* interference. The fact that this study found both positive and negative interference makes it more appropriate to talk about the crossover effect in terms of elimination of interlevel interaction in the Garnerian sense (cf. Garner, 1974). From this perspective, the side from which interference approaches zero is irrelevant to the crossover effect, which merely states that interlevel interaction (in *either* direction) will be eliminated once the local level is perceived as a texture.

The results of the present study support the findings of Polich and Aguilar (1990) that hemispheric processing of hierarchical stimuli composed of geometric shapes does not seem to be strongly lateralized. This result stands in contrast to the relatively more robust hemispheric differences obtained in the processing of alphabetic hierarchical stimuli. A speculative possibility for this arises from the important role that high versus low spatial frequencies play in conveying local versus global information, respectively (e.g., Shulman et al., 1986), and, in turn, the LH versus RH specialization for the processing of high versus low spatial frequencies (e.g., Kitterle et al., 1990). Integrating these findings, a number of studies have suggested that hemispheric differences in local–global processing are dependent in part on underlying hemispheric differences in spatial frequency processing (e.g., Christman et al., 1991; Kitterle et al., 1993). In reference to the current findings, it is important to note that, while removing all frequencies above 2 cycles per degree of visual angle renders the local level of alphabetic stimuli like those developed by Navon (1977) virtually unrecognizable, the simple geometric shapes employed in the current study are still readily identifiable. Thus, processing of the local level of the current geometric stimuli is not as critically dependent on high spatial frequencies as is the local level of alphabetic stimuli, thereby possibly attenuating spatial frequency-based hemispheric differences in processing.

Nonetheless, the presence of a RVF advantage for local targets in the few element set is consistent with Kimchi and Merhav's findings (1991) that visual field differences in local–global processing are restricted to situations wherein the local level elements are perceived as forms; when the local level is perceived as texture, visual field differences seem to disappear. Our study also failed to find a shape by visual field interaction, consistent with the findings of Kimchi and Merhav (1991). This lends further credence to the contention that Polich and Aguilar's findings (Polich and Aguilar, 1990) of a shape by visual field interaction were probably related to confounds within the stimulus set they employed.

With regard to the question of precisely where the crossover between perception of the local level as form versus texture occurs, our results suggest that, while Kimchi's estimate of 7 ± 2 local elements is roughly correct, the precise crossover point appears to be modulated by input characteristics. For example, the crossover happened at a lower number of local elements for rectangle targets than for square targets (although this conclusion is limited by the fact that square stimuli cannot be used to construct consistent stimuli with 5–8 local elements); similarly, given the possible role of the subitizing effect, the crossover from form to texture may occur at smaller numbers of local elements for extremely brief presentation times. Finally, it is possible that studies employing the alphabetic hierarchical stimuli developed by Navon (1977) might also yield varying estimates of the crossover point. This indicates a need for experimenters to consider both the number and type of local elements when choosing and designing stimuli.

An associated factor is revealed by Lasaga (1989) in a discussion of factors influencing local and global interference. She discusses important differences between type C stimuli (where the elements composing the global level are connected to each other, as in the stimuli employed in the current study) and type D stimuli (where the elements composing the global level are not connected to each other, as in the alphabetic stimuli developed by Navon). She concludes that interference and precedence effects (local or global) are affected by the goodness of the form at the irrelevant level, which in turn is influenced by whether the local elements are connected or not. Keeping the connectedness and the number of elements in mind when selecting stimuli will help avoid spurious results based on using stimuli that are composed of different perceptual units. Future research into the neural, perceptual and attentional foundations of local–global processing will need to address such factors as the number, connectedness, sparsity, size, and figural goodness of local elements.

Acknowledgements

This research was partially supported by an Academic Challenge Award to the Department of Psychology, University of Toledo to enhance research in experimental psychology. We are grateful to Wendy Shore and two anonymous reviewers for helpful comments on previous drafts of this paper.

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