Perceptual organization at attended and unattended locations

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Abstract This study examined the effects of attention on forming perceptual units by proximity grouping and by uniform connectedness (UC). In Experiment 1 a row of three global letters defined by either proximity or UC was presented at the center of the visual field. Participants were asked to identify the letter in the middle of stimulus arrays while ignoring the flankers. The stimulus onset asynchrony (SOA) between stimulus arrays and masks varied between 180 and 500 ms. We found that responses to targets defined by proximity grouping were slower than to those defined by UC at median SOAs but there were no differences at short or long SOAs. Incongruent flankers slowed responses to targets and this flanker compatibility effect was larger for UC than for proximity-defined flankers. Experiment 2 examined the effects of spatial precueing on discrimination responses to proximity- and UC-defined targets. The advantage for targets defined by UC over targets defined by proximity grouping was greater at uncued relative to cued locations. The results suggest that the advantage for UC over proximity grouping in forming perceptual units is contingent on the stimuli not being fully attended, and that paying attention to the stimuli differentially benefits proximity grouping.

Keywords: attention, perceptual grouping, UC, proximity, similarity.

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In order to perceive complex visual scenes, the human perceptual system has to organize discrete entities in the visual field into chunks or perceptual units for higher-level processing. Perceptual organization is governed by Gestalt principles such as proximity, similarity, and continuity[1] volve two different UC regions[7]. The results suggest that UC plays an important role in object representation and recognition.

Palmer and Rock[4] suggest that UC operates prior to the Gestalt laws to form the "entry-level units" for perception. The role of Gestalt grouping is to organize these entry-level units into super- or subordinate units for further analysis. In other words, grouping by UC operates earlier than grouping based on the classical Gestalt principles. However, empirical studies have shown a more complex pattern of results. Han et al.[8] had observers identify the orientations of perceptual groups formed by proximity or shape similarity. Responses to groups formed by similarity or weak proximity were facilitated by the addition of UC. However, responses to perceptual groups based on strong proximity were as fast as those to stimuli based on UC (even though the spaces between the elements grouped by proximity remained clearly visible). Kimchi[9] also found evidence that perceptual organization does not always start from units defined by UC. She had observers match a prime to pairs of test stimuli, which were global shapes made up of spatially separated local elements defined by UC. At short prime-test intervals matching was determined by the identities of the local stimuli when the global shapes were composed of a few, relatively large elements; in contrast the global structure was influential when many, relatively small elements were used to form the global shapes. These findings indicate that entry-level units for perceptual processing can be formed by either UC or Gestalt principles (proximity, similarity) depending upon the relations between the global structures and the constituent local elements.

The relative efficiency of UC and proximity grouping is also influenced by the number of global objects in visual displays[10]. In a visual search task, subjects searched for a letter E among distractor letters H. The letters were formed by either local, spatially separated solid rectangles (proximity- defined grouping) or by uniformly connected solid lines (UC-defined grouping). When one or two global letters were present, RTs were not affected by whether targets and distractors were formed by proximity grouping or by UC. However, when four global letters were present, RTs were faster for UC-defined targets than for proximity-defined targets. Han and Humphreys interpreted their findings in terms of the differential role of attention on the processing of proximity and UC-defined stimuli. When multiple items are present, fewer attentional resources are available to support processing. This affects proximity grouping more than UC grouping because proximity grouping is more dependent upon attentional resources being available. If this hypothesis is correct, we may predict that the difference between UC and proximity grouping should be larger at locations where stimuli are unattended relative to when they fall at attended locations. This was examined here.

Experiment 1 employed Eriksen's flanker paradigm[11] to investigate the difference between proximity grouping and UC forming perceptual units at attended and unattended locations. In a typical flanker task, subjects are asked to identify a target letter in the middle of a row of letters and to ignore simultaneously presented flanker letters on both sides of the target. Responses are usually faster when flankers and the target are assigned to the same response than when flankers and target are assigned to different responses. This result is known as the flanker compatibility effect (FCE)[12]. Some researchers suggest that the FCE reflects a failure in the early selective attentional processing of targets so that there is some attentional processing of flankers[13]; others however suggest that the magnitude of FCE is not related to attentional processing of flankers[14] but instead reflects the influence of the identities of automatically processed unattended flankers on target processing[15]. Whatever the case, it is commonly accepted that flanker letters do not receive the same full processing as attended target stimuli[16,17]. We orthogonally manipulated whether targets or distractors were formed by UC or by proximity-grouping, and assessed whether effects of UC vs. proximity grouping emerge at fully attended (target) locations (in overall RTs to UC and proximity-defined targets), or at less well-attended distractor locations. If effects occur at attended locations, then overall RTs should differ to UC and proximity-defined targets. If effects are found at less well-attended locations, then flanker interference should be stronger from UC-defined distractors than from proximity-defined distractors..

Experiment 2 further tested the relative efficiency of proximity grouping and UC in forming perceptual units at attended and unattended locations using Posner's peripheral precue task[18]. In this paradigm a peripheral cue can appear either at the location where a target will subsequently fall (a valid cue trial) or it can appear at another location (on invalid cue trials). Responses are faster when targets appear at cued locations relative to when they fall at uncued locations[18], suggesting that peripheral precues provide stimulus-driven elicitation of attention. A similar paradigm was used in Experiment 2 to examine the difference between proximity grouping and UC in forming perceptual units at attended and unattended locations.

1 Experiment 1

A flanker task was used in Experiment 1 to test how responses to global letters formed by proximity grouping and UC varied as a function of whether a location was fully attended (for the target) or less well-attended (for the flankers). Two sets of stimuli used in Experiment 1 are illustrated in fig. 1. Global letters were made up of small solid rectangles (proximity determined the units for letter recognition) or solid lines (UC determined the units for letter recognition). RTs to UC and proximity-defined targets served as the index of differences between the grouping effects on global letter recognition at an attended location. The magnitude of the flanker effect served as the index of differences in grouping at less well-attended locations. To assess the time course of the possible difference between UC and grouping by proximity, we varied the time delay from the onset of stimulus display to the onset of masks (the stimulus onset asynchrony or SOA).

1.1 Method

(i) Subjects. Sixteen graduate and undergraduate students (6 men, aged between 18 and 24 years, all right handed) from Peking University participated in Experiment 1 as paid volunteers. All had normal or corrected-to-normal vision.

(ii) Stimuli. Two sets of stimuli, black on a grey background, were used, making up either a large letter E or an H (shown in fig. 1). For stimulus Set A, the letters were made up of small solid rectangles that were arranged in a 6×7 matrix. The large letter was 2.1° wide and 2.6° high, and each of the small rectangles was 0.25° wide and 0.28° high at a viewing distance of 57 cm. The vertical and horizontal distances between two adjacent rectangles were each 0.1°. For stimulus Set B, the letters were made up of solid lines.

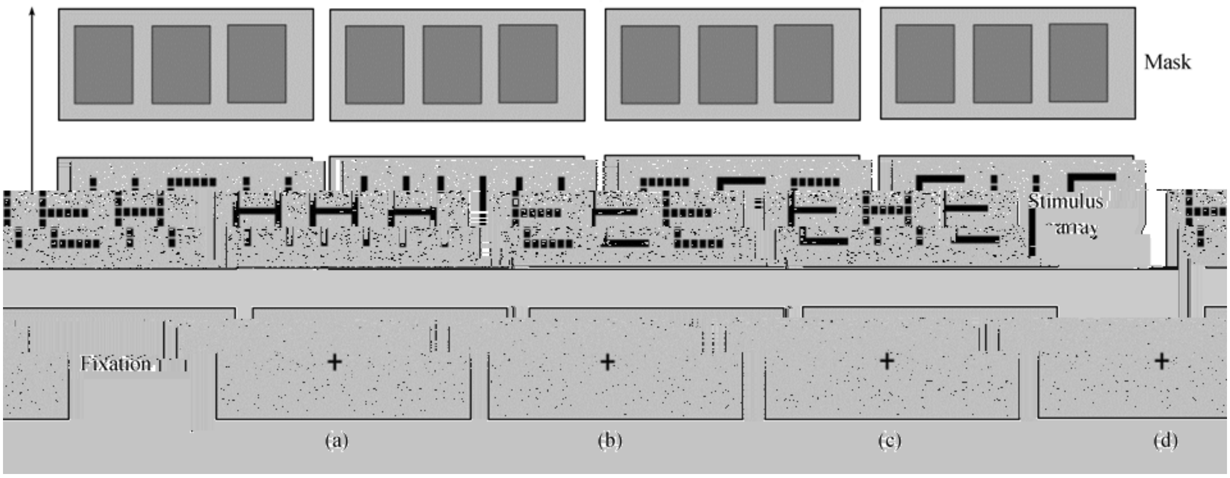

Fig. 1. Illustration of the stimuli displays used in Experiment 1. (a) and (b) Targets and flankers are defined by the same principles; (c) and (d) targets and flankers are defined by different principles; (b) and (c) targets and flankers are congruent; (a) and (d) targets and flankers are incongruent.

The thickness of the vertical lines composing stimulus set B was 0.2°. The thickness of the middle and top (or bottom) horizontal lines composing stimulus set B was 0.12° and 0.15°, respectively. Each letter in set B was as large as that in set A. The total areas of local rectangles composing letters “H” and “E” of Set A were 1.26 and 1.54 cm^2, respectively. The total areas of the solid lines composing letters “H” and “E” of Set B were 1.29 and 1.40 cm^2, respectively. Each stimulus array consisted of a row of three global letters as illustrated in fig. 1. The middle letter was formed by either UC or proximity grouping. The two flankers were always identical to each other and formed by either UC or proximity grouping. The flankers and target could be the same letter (congruent condition) or different letters (incongruent condition). The distance between the inner edges of the two global letters was 1.8°.

(iii) Procedure. The experiment employed a four-factor within-subject design with the factors being Target Grouping (the letter in the middle of a stimulus array was formed by either UC or proximity grouping), Flanker Grouping (the flankers were formed from proximity grouping or UC), Congruency (flankers and target were the same letter or different letters), and SOA between the target and the mask (180, 230, 330, or 500 ms). Each trial began with the presentation of a fixation cross located at the center of the screen. The fixation cross was 0.25° wide and 0.30° high. The stimulus display, consisting of a row of 3 global letters, was presented in a random order and centered at fixation. The stimuli were presented for 150 ms and were then masked by three grey rectangles, each of which was 2.4° wide and 2.9° high and stayed on the screen for 200 ms. The stimulus-mask SOA varied randomly at 180, 230, 330, or 500 ms. The interstimulus interval between the offset of masks and the onset of the next stimulus display was 1300 ms.

After a practice set of 32 trials, each subject was given nine blocks of 192 trials. On half of the trials, the target letters were formed on the basis of proximity. On the other half of the trials, the target letters were formed on the basis of UC. In each condition the flankers were formed by proximity on half of the trials and by UC on the other half of the trials. Subjects were asked to identify the letter in the middle of the stimulus array (H vs. E) by pressing one of two keys on a standard keyboard. Half of the subjects responded to H and E with the left and right index fingers, respectively. The other subjects were given the reverse arrangement. Subjects were encouraged to respond as quickly and accurately as possible.

1.2 Results

RTs and error rates were subjected to repeated measure analyses of variance (ANOVA) with Target Grouping, Flanker Grouping, Congruency, and SOA as independent variables. The mean RTs for each condition of Experiment 1 are shown in fig. 2. The upper panels depict the data from proximity-defined targets, and the lower panels show the data from UC-defined targets. ANOVAs performed on RTs showed significant main effects of Target Grouping ($F(1,15) = 46.22$, $p < 0.001$), Flanker Grouping ($F(1,15) = 13.55$, $p < 0.002$), Congruency ($F(1,15) = 55.90$, $p < 0.001$), and SOA ($F(1,15) = 5.94$, $p < 0.002$). Responses to proximity-defined targets were slower than those to UC-defined targets. Responses were faster when flankers were defined by proximity than by UC. Responses to targets were slower when flankers were incongruent than when they were congruent with targets. Responses also varied as a function of the SOA.

There was a significant interaction between Target Grouping and Congruency ($F(1,15) = 23.22$, $p < 0.001$), indicating that the effect of target-flanker incongruency was larger on responses to proximity-defined than on those to UC-defined targets. The interaction between Flanker Grouping and Congruency was also significant ($F(1,15) = 4.52$, $p < 0.05$); relative to when the flankers were defined by proximity, UC flankers generated larger interference on responses to targets. The interaction between Target Grouping and SOA was also significant ($F(3,45) = 5.71$, $p < 0.002$), due to the fact that the difference between responses to UC- and proximity-defined targets was smaller at short and long SOAs (180 and 500 ms) than at median SOAs (230 and 330 ms). Flankers also produced larger interference effects at long (330 and 500 ms) than at

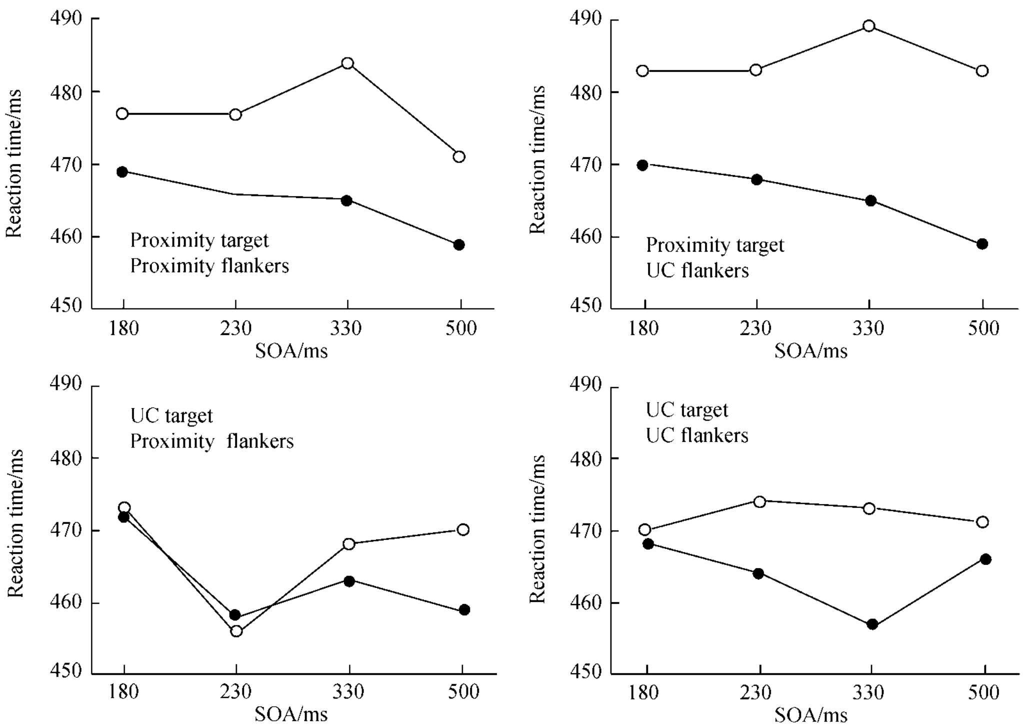

Fig. 2. The results of RTs in Experiment 1. The upper panels show responses to proximity targets as a function of SOA and the lower panels to UC targets. ●, Congruent; ○, incongruent.

short SOAs (180 and 230 ms), resulting in a significant interaction between Congruency and SOA ($F(3,45) = 5.59$, $p < 0.003$). Planned comparisons showed that responses to UC-defined targets at median SOAs (230 and 330 ms) were shorter than those to proximity-defined targets ($F(1,15) = 29.9$ and 36.5, respectively, $p < 0.001$). At short and long SOAs (180 and 500 ms), however, responses to UC targets did not differ from those to proximity-defined targets ($F(1,15) = 3.34$, $p > 0.08$ and $F < 1$, respectively). In addition, responses to UC-defined targets were not influenced by flankers regardless of whether flankers were formed by UC or proximity grouping when SOAs were 180, 230, and 500 ms ($F < 1$, $F(1,15) = 3.34$, $p > 0.08$, $F(1,15) = 3.47$, $p > 0.078$, respectively). The FCE on UC targets was significant only under the condition when the SOA was 330 ms ($F(1,15) = 14.9$, $p < 0.002$). In contrast, proximity targets were slowed by incongruent flankers at all SOAs ($p < 0.01$).

Participants made few errors in responding to targets (an average of 3.3% errors). ANOVAs performed on error rates showed a main effect of Target Grouping ($F(1,15) = 5.35$, $p < 0.03$), error rates to UC-defined targets were slightly lower than those to proximity targets (3.0% vs. 3.5%). The effect of Congruency was also significant ($F(1,15) = 7.59$, $p < 0.014$), suggesting that error rates were slightly higher in the incongruent (3.6%) relative to congruent (3.0%) conditions. The difference in error rates between responses to UC- and proximity-defined targets was larger under the conditions of median SOAs (230 and 330 ms) than short and long SOAs (180 and 500 ms), resulting in a significant interaction between Target Grouping and SOA ($F(3,45) = 9.18$, $p < 0.001$).

1.3 Discussion

Experiment 1 was designed to examine the relative efficiency of proximity grouping and UC in forming global letters at attended and less well-attended locations. We found that responses to UC-defined targets were faster than those to targets defined by proximity, particularly at the medium SOAs. In the present context targets always appeared along with distractors. Hence the advantage for UC targets arose in multi-item displays, consistent with our previous work showing that UC stimuli benefited under this circumstance[10]. The effects of SOA indicate that the dominance of UC over proximity grouping at attended locations developed with time. At early stages of perceptual processing (with a short SOA), proximity was as efficient as UC at defining the stimulus information leading to target identification. Subsequently, however, UC became dominant in forming the perceptual units for identification, before performance asymptoted at the longer SOA.

Flanker interference also varied as a function of whether distractors were created by UC or by proximity grouping. Interference was greater from distractors formed by UC than from distractors formed by proximity. This interference effect also only emerged with targets defined by proximity, which fits well with the idea that the flanker effect depends at least in part on a race between stimulus codes developed to targets and distractors[19]. UC-defined targets win this competition, and so are not vulnerable to interference from flankers. The fact that interference was greatest from UC-defined distractors on proximity-defined targets is also of interest because in terms of similarity grouping we mi normal or corrected-to-normal vision.

(ii) Stimuli and procedure. These were the same as those in Experiment 1 except for the following. Each of the stimulus array in the multiple global object condition consisted of three global letters in a column (see fig. 3). The top and bottom letters were identical to each other and were either congruent or incongruent with the central target. For half of the multiple global object stimuli, the top and bottom letters were defined by UC and the central one was defined by proximity. The arrangement was reversed for the other half of the trials. The distance between the top and bottom edges of the two neighboring global letters was 2.4°. The experiment in the multiple global object condition employed a four-factor within-subject design with the factors being Cue Validity (valid, neutral, or invalid), Target Grouping (targets were formed by UC or proximity grouping), Congruence (flankers were congruent or incongruent with targets), and Visual Field (stimuli were presented in the left or the right visual field). All aspects of the single global object condition were matched to the multiple global object condition except that only the central global letter was present. The multiple and single global object conditions were conducted in the same block of trials. Each trial began with the presentation of a fixation cross at the center of the screen. In the valid and invalid conditions, two small bars were then displayed in either the left or the right visual field as cues. One of the bars fell at a location between the top and middle global letters and the other fell between the middle and bottom global letters. Each of the two bars was 0.45° wide and 0.14° high. In the neutral conditions, cue bars appeared in both visual fields. The duration of the cues was 100 ms for all the three conditions. A stimulus array or a single global letter was presented in the left and right visual field 300 ms after the offset of cues. The center of the middle global letter was located on the meridian and was 5.3° from the fixation. The stimuli were presented for 150 ms. The interstimulus intervals between targets on the previous trial and cues in the next trial varied randomly between 1000 and 1500 ms.

After a practice set of 40 trials, each subject was given ten blocks of 160 trials. Subjects were asked to identify target letter (H vs. E), i.e., the global letter in the middle of a stimulus array in the multiple global object condition or the single global letter in the single global object condition. For 60% of the trials, stimulus arrays appeared at the same location as the precues (the valid condition). For 20% of the trials, the stimuli appeared at locations opposite to the location of the precues (the invalid condition). For 20% of the trials, the cues appeared in bilateral visual fields and the stimulus arrays were presented randomly in the left or the right visual field (the neutral cue condition).

2.2 Results

RTs and error rates were subjected to ANOVAs with Cue Validity, Target Grouping, Congruency, and Visual Field in the multiple stimulus condition, and with Cue Validity, Target Grouping, and Visual Field in the single stimulus condition.

(i) Multiple objects. Analyses of RTs in the multiple object condition showed a significant main effect of Cue Validity ($F(2,30) = 33.85$, $p < 0.001$). Responses in the valid condition were shorter than those in the neutral condition, which were in turn faster than those in the invalid condition. There were also significant main effects of Target Grouping ($F(1,15) = 70.45$, $p < 0.001$) and Congruency ($F(1,15) = 120.19$, $p < 0.001$), reflecting that (i) responses to UC targets were faster than those to proximity targets and (ii) incongruent flankers slowed responses to targets. Interestingly, there was a significant interaction between Cue Validity and Target Grouping ($F(2,30) = 3.67$, $p < 0.036$), suggesting that the difference between responses to UC and proximity targets was influenced by spatial attention——the difference was larger in the invalid than in the neutral condition, which in turn was larger than the difference in the valid condition (see fig. 4). The interaction between Target Grouping and Congruency ($F(1,15) = 21.39$, $p < 0.001$) was also significant, due to the fact that incongruent flankers produced larger interference effects on responses to proximity relative to UC targets. However, the increase in the flanker effect for UC over proximity distractors did not change across the valid, neutral, and invalid conditions (F < 1).

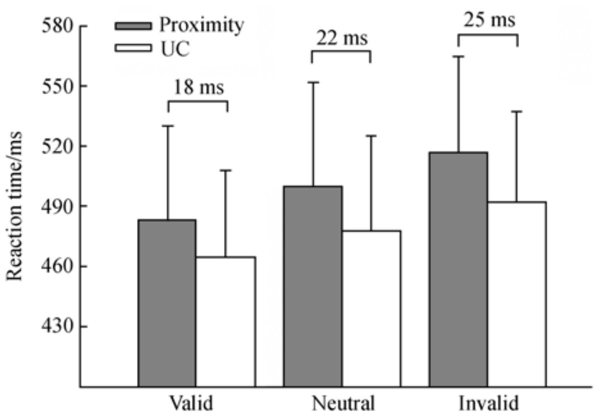

Fig. 4. RTs in the multiple global object condition in Experiment 2. The difference in response speeds between proximity and UC targets was marked on top of each group of histograms that showed RTs in valid, neutral, and invalid conditions.

The error rates in the multiple object condition were low (average 4.3%). The ANOVAs showed a significant main effect of Target Grouping ($F(1,15) = 12.27$, $p < 0.003$), suggesting that subjects made more errors in responding to proximity than to UC targets (5.6% vs. 3.9%). The effect of Congruency was also significant ($F(1,15) = 15.38$, $p < 0.002$), indicating that subjects made more errors when flankers were incongruent than when they were congruent with targets.

(ii) Single objects. RTs and error rates in the single object condition are shown in fig. 5. There was a significant main effect of Cue Validity on both RTs ($F(2,30) = 44.67$, $p < 0.001$) and error rates ($F(2,30) = 8.10$, $p < 0.002$). Responses in the valid condition were faster relative to those in the neural condition, which in turn were shorter than those in the invalid condition. Error rates in the valid condition were lower than in the invalid condition, which in turn were lower in comparison to those in the neutral condition. However, the effect of Target Grouping on both RTs and error rates was not significant, nor was the interaction between Cue Validity and Target Grouping ($p > 0.1$), indicating that response speeds and errors did not differ to UC and proximity targets at cued and uncued locations.

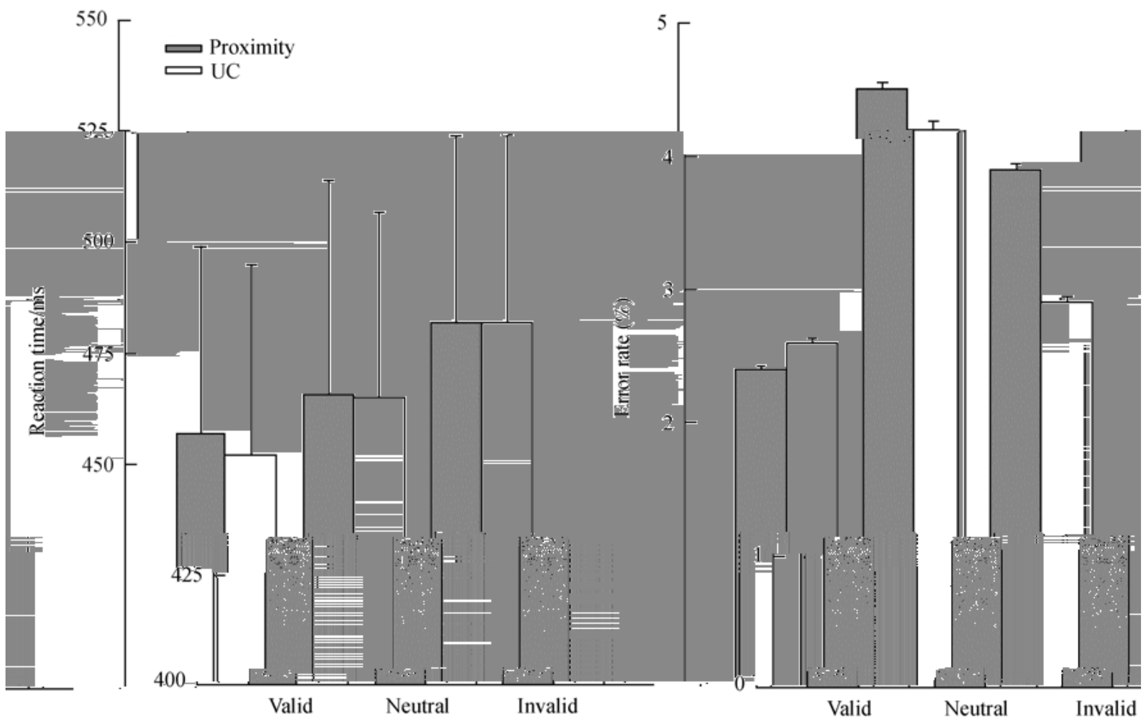

Fig. 5. RTs and error rates in the single global object condition in Experiment 2.

2.3 Discussion

Experiment 2 showed effects of spatial attention on target processing. Responses to targets were faster at cued locations than at uncued locations, and similar attentional effects were found for both proximity and UC targets in both single and multiple global object conditions. These results are in agreement with previous work[18], suggesting that spatial attention facilitates the processing of targets at attended locations regardless of the grouping principles defining target letters.

The results in the multiple object condition confirmed that responses to UC targets were faster than to proximity targets, reflecting a dominance of UC over proximity in forming targets when there was attentional competition from the presence of multiple objects. This is consistent with the results of Experiment 1 where stimulus arrays were presented at the center of the visual field. Most important, Experiment 2 provided clear evidence that the difference between UC and proximity in forming targets increased at unattended locations relative to at attended locations. These results support the hypothesis that more attentional effort is required for forming perceptual units based on proximity grouping than UC under multiple object conditions[10]. As in Experiment 1, incongruent flankers slowed responses to targets, and this effect was larger for UC distractors than for proximity-defined distractors. However, our data revealed that this increased interference effect was not influenced by spatial attention. This suggests a dissociation between the effects of attention on proximity grouping and UC at target and flanker locations. Spatial attention modulates the formation of targets, which follows from these items having to be selected. In contrast, the lack of an interaction between cueing and distractor grouping is consistent with minimal attention being paid to distractors, even under cueing conditions. UC grouping dominates proximity-grouping under conditions when the stimuli are weakly attended[10].

In the single global object condition, however, responses to UC and proximity targets were equally fast at both attended and unattended locations. This is in agreement with our previous work[2], in which global letters were presented at fixation, and suggests that UC is not necessarily more efficient than proximity grouping when they function at the same spatial scale in forming perceptual unit for identification and recognition. The contrast between the results with single and with multiple objects condition provides more evidence that the difference between UC and proximity grouping depends upon attention. UC grouping is stronger than proximity-grouping in forming global letters, but only under the condition when multiple global objects are displayed simultaneously and there is competition for attention. With single objects there is little competition for attention and hence little effect of the cue on the relative efficiency of UC and proximity grouping.

3 General discussion

There is now considerable evidence that, at an early stage of visual processing, visual elements are encoded into clusters to form plausible objects for subsequent higher-level recognition processes[21]. Commonly it is assumed that grouping takes place preattentively and is thus unaffected by attentional resources allocated at the locations where grouping occurs[22]. However, if this were the case, then differences between different grouping processes should not be influenced by attentional allocation. Our data contradict this.

We showed clear evidence that the relative efficiency of proximity grouping and UC in forming perceptual units was influenced by spatial attention. In Experiment 1 we found that responses were faster to UC than to proximity-defined targets, whilst UC flankers generated stronger interference on target processing relative to proximity flankers. These results suggest that UC dominates proximity in forming global letters at both target and flanker locations, when multiple items are presented simultaneously. Moreover, we showed that differences between UC and proximity targets were evident at median but not at short and long target-mask SOAs, whereas the effect of UC on flanker interference did not vary as a function of the SOA. The difference between the effects of target-mask SOA on target responses and on flanker interference indicates that the dominance of UC- over proximity grouping was more robust at unattended than at attended locations. In Experiment 2 we showed that, with multiple objects, the dominance of UC over proximity grouping was more salient at unattended relative to attended locations. The results in both Experiments 1 and 2 could not be interpreted simply by sensory level factors because luminance levels were matched well for both UC and proximity-defined targets. Moreover, if any low level factors contributed to the difference in behavioural responses to the UC and proximity-defined targets, one would expect similar results regardless of numbers of global letters. The fact that responses to UC and proximity-defined targets did not differ in the single object condition indicates that sensory level factors contributed little to the results of our study. Taken together, these results provide converging evidence for the hypothesis that more attentional effort is required for constructing perceptual units by proximity grouping than by UC, when multiple objects are present[10].

These results are not easy to account for if grouping is independent of spatial attention. How then do we reconcile the current data with other results indicating that grouping can take place when stimuli are unattended[22]? One possible explanation is that perceptual grouping can be initiated without attention, but that it can be influenced by subsequent attentional feedback. This is consistent with neurophysiological evidence for late-acting effects of attention on grouping within even the primary visual cortex[23]. It is also consistent with behavioral data indicating that grouping is reduced when participants are distracted by a secondary task[24]. Our results indicate that formation of perceptual units based on proximity grouping and UC presents contrasting demands on attentional resources, with UC demanding fewer resources than grouping by proximity. Studies of functional brain imaging further indicate that stimuli grouped by UC can generate more activation in visual cortical regions than stimuli grouped by other factors, such as collinearity[25]. It is tempting to speculate that the different attentional demands on forming perceptual units based on proximity grouping and UC reflect defining targets by UC in early cortical regions initially unaffected by attention, but this clearly requires empirical validation.

The current data are also consistent with hierarchical accounts of perceptual grouping, which assume that some forms of grouping may be completed earlier than others. Prior behavioral studies have shown that responses to stimuli grouped by proximity are faster than to stimuli grouped by similarity[2,3,8], and this conclusion is supported by recent event related potential (ERP) studies contrasting grouping by proximity and by similarity[26]. In these last studies, proximity grouping was indexed first by a positive activity between 100 and 120 ms after stimulus onset over the medial occipital cortex, which was followed by an occipito-parietal negativity with an onset of 180 ms and larger amplitudes over the right than the left hemisphere. In contrast, grouping by similarity was reflected in a long-latency occipito-temporal negativity with an onset of 260 ms and larger amplitudes over the left than right hemispheres. These findings suggest that grouping processes defined by different Gestalt laws may have both a distinct time course and distinct neural substrates.

In sum, the current work shows evidence that, when a single global object is presented, UC does not differ from proximity-grouping in its contribution to forming target letters. When multiple objects are presented simultaneously, however, UC dominates grouping by proximity at both attended and unattended locations and regardless of whether stimulus arrays appear in the fovea or in the peripheral vision. In addition, the advantage for UC over proximity-grouping at unattended relative to attended locations leads to increased flanker interference from UC-defined flankers across a range of stimulus-mask SOAs (Experiment 1) and when attention is cued to targets (Experiment 2). In contrast, proximity can be as efficient as UC in defining target letters when a single object is presented and there are few attentional demands on processing. Grouping can be modulated by visual attention, but the magnitude of any effect varies with the grouping cues present.

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