Low-level visual interaction in the effect of peripheral cuing

Shigekazu TAKEI***, Tatsuto TAKEUCHI**, and Kazuhiko YOKOSAWA*

The University of Tokyo* and NTT Communication Science Laboratories**

Presenting a precue near the location where a target will appear causes an enhancement of visual performances. This procedure is called peripheral cuing, and the effect of peripheral cuing has been interpreted as a result of an allocation of covert attention. However, a low-level visual interaction between the cue and the target can enhance representation of the target to induce the cuing effect. We examined whether the effect of peripheral cuing is due to an attentional process, or to a low-level visual interaction. To do this, we compared conditions with similar visual interactions, but with attention allocated differently. In one condition, we presented the first cue near the target and the second cue distant from the target, to deprive attention from the target location. In another condition, a single cue was presented near the target to allocate attention at the target. We found that the accuracy of discriminating the tilt of a target was lower in the condition which attention was deprived. This result suggests that the effect of peripheral cuing is due to an attentional process.

Key words: covert attention, feature search, peripheral cuing, visual interaction

When a precue, such as a small circle, is presented at a target position before the onset of the target, detectability and discriminability of the target are more improved than when the precue does not indicate the target position (e.g. Posner, 1980). This type of precue is called a peripheral cue, and the improvement induced by the peripheral cuing has been assumed to be a function of covert visual attention. It is assumed that an abrupt onset of the precue guides attention involuntarily to the cued location. Therefore the performance of the visual task is more improved when attention is guided validly than invalidly. However, presenting a precue should cause an enhancement or inhibition effect between the cue and the target as a consequence of the lateral interactions between spatial filters. This low-level visual interaction can explain the improvement induced by the peripheral cuing. In this study we examined whether an attentional process or a low-level visual interaction causes the effect of peripheral cuing.

Method

Three naive subjects participated in the experiment. The stimuli were displayed on a CRT monitor and controlled by MATLAB and Psych Toolbox on an Apple PowerMacG4. We used the feature search task. The subjects reported the orientation of the target (right or left from the vertical) embedded in the vertically oriented seven distractors.

We used a Gabor patch for the stimuli. The contrast and the orientation of the stimuli were adjusted for each subject in a pilot experiment in order to keep the highest accuracy at 80-85%. The contrast ranged from 10 to 40% and the orientation was about 10°. The Gabor patches subtended 1.7°. A black circle precue subtended 0.7°.

The fixation point was always presented at the center of the display. The stimuli were presented at eight equidistant locations from the fixation point at 2.5° eccentricity. The distances between the neighboring stimuli were the same. The target position was randomized in each trial.

There were four cuing conditions (Figure 1(a)). In the peripheral-central (P–C) condition, the first cue appeared beside the target position and the second cue was presented at the central fixation point. In the peripheral condition, only the first cue of the P–C
condition, was presented. Since the duration of presentation and the position of the first cue were the same for the two cuing conditions a similar visual interaction was expected. However, if the cuing effect was due to an attentional process, target discrimination in the P-C condition would be less accurate as a result of attention being pulled away from the target position by the onset of the second cue.

There remained a possibility that the motion induced by sequential presentation of two cues might mask the perception of the target, and it might result in a lower accuracy in the P-C condition. In order to evaluate such a masking effect, the first cue was presented at the same position as the first cue in the P-C condition and the second cue was presented on the opposite side of the target in the peripheral−peripheral (P−P) condition. In the P−P condition attention should be allocated around the target position. Therefore, if the accuracy of target discrimination was lower in the P−P condition than in the peripheral condition, this would be due to a masking effect and not to inattention. In the central condition only the first cue was presented at the fixation point.

After 800 ms from the start of a trial, the first cue was presented for 59 ms. After an ISI of 11.8 ms, the second cue was presented for 59 ms. The cuing period was followed by 11.8 ms of ISI and the stimuli were presented for 59 ms. Random-dot postmasks replaced the stimuli, and disappeared when a response was made. Because the interval between the cue onset and the stimulus offset was within 250 ms, we assumed that eye movements did not occur while the stimuli were presented.

Results and Discussion

The averaged accuracy of three subjects is shown in Figure 1(b). The lower accuracy in the central cuing condition suggests that presenting a precue near the target improved the discrimination of the orientation. A one-way ANOVA of the three cue types (P−C, P−P, and peripheral) revealed a main effect of cue types (χ²(2) = 14.73, p<.05). A post-hoc test by Ryan’s procedure revealed that the accuracy of the P−C condition was significantly lower than the accuracy in the other conditions.

The results suggest that the deterioration of target discrimination in the P−C condition can not be explained by a low-level visual interaction or a masking effect. Based on a low-level visual interaction, differences would not be observed between the cuing conditions. Based on a masking effect, the accuracy would be lower in the P−P and P−C conditions than in the peripheral condition. However, only accuracy in the P−C condition was lower than the other cuing conditions.

Therefore, we conclude that the deterioration in the P−C condition reflected an attentional process. The abrupt onset of the second cue distant from the target might deprive attention from the target. The present experiment indicates that a peripheral cue can guide covert attention which improves a representation of visual stimuli.

References