The Japanese Journal of Psychonomic Science
2003, Vol. 22, No. 1, 49–50

Prizewinner's Summary **2-B-15**

The effect of contrast change on the motion-in-depth perception

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Contrast is a cue for depth perception; the farther away an object is, the less contrast appears in the surface plane. What happens if the contrast of an object varies in time? Do we perceive the object moves in depth? We examined whether a contrast change induces motion-in-depth perception. The stimulus was a circular sine wave grating of 1 s duration whose phase was shifted by various angles every 250 ms. The contrast of the grating either decreased, remained constant, or increased. The subjects judged whether the stimulus appeared to move towards them, or away from them. When the contrast of the stimulus decreased (increased) the number of 'receding' ('looming') responses increased. The results suggest that a contrast change produces motion-in-depth perception.

Key words: contrast change, motion-in-depth, size change, vision

For static depth perception there is mounting evidence that the human visual system has the ability to estimate the depth from the contrast (Ichihara et al., submitted; Ashley, 1898). To our knowledge however, the contribution of a contrast change to the perception of a dynamic event has not been examined. In the present study we examined whether a change of contrast could induce the perception of motion-in-depth. To assess the contribution of a contrast change to motion-in-depth perception, we used a stimulus which induces an apparent size change. If the contrast change could induce a perception of motion-in-depth then the change in contrast would cancel the impression of motion-in-depth which was induced by the apparent size change.

Methods

The stimuli were circular sine wave gratings of 1 s duration (Figure 1a). The spatial frequency of the gratings was 1.56 c/deg, the size of the stimulus was 9 degrees of visual angle and the average luminance of the stimulus was kept constant at 60 cd/m^2. The contrast of the gratings either decreased, remained constant or increased exponentially between 0.01 and 0.6. The phase of the gratings was shifted by either 120, 150, 180, 210, or 240 every 250 ms. The amount of the shift below (over) 180 produced an apparent motion of expansion (contraction). Each stimulus was presented 50 times in a random order. Five students participated in the experiment. All had normal or corrected-to-normal vision. The subjects were asked to fixate on the center of the stimuli and to judge whether the stimulus appeared to move towards them, or away from them. The experiment was conducted with binocular vision in a dark room.

Results and Discussion

We found that the change of contrast influenced the judgment of the motion-in-depth direction (Figure 1b). When the contrast decreased, the 'receding' responses increased, resulting in a psychometric function which shifted towards the left relative to the function of the constant condition. On the other hand, when the contrast increased, the function shifted towards the right. The function for the constant condition was located between the decreasing and increasing conditions. These trends were observed for all of the subjects except for NA.

To quantitatively analyze the effect of the contrast change we calculated the null points, that is, the angle of the phase shift at which the probability of a 'receding' response was 0.50. A one-way ANOVA with the contrast-change direction as a within-subject factor showed a significant main effect ($F(2, 8)=10.42; p<0.01$). A posterior pairwise comparison

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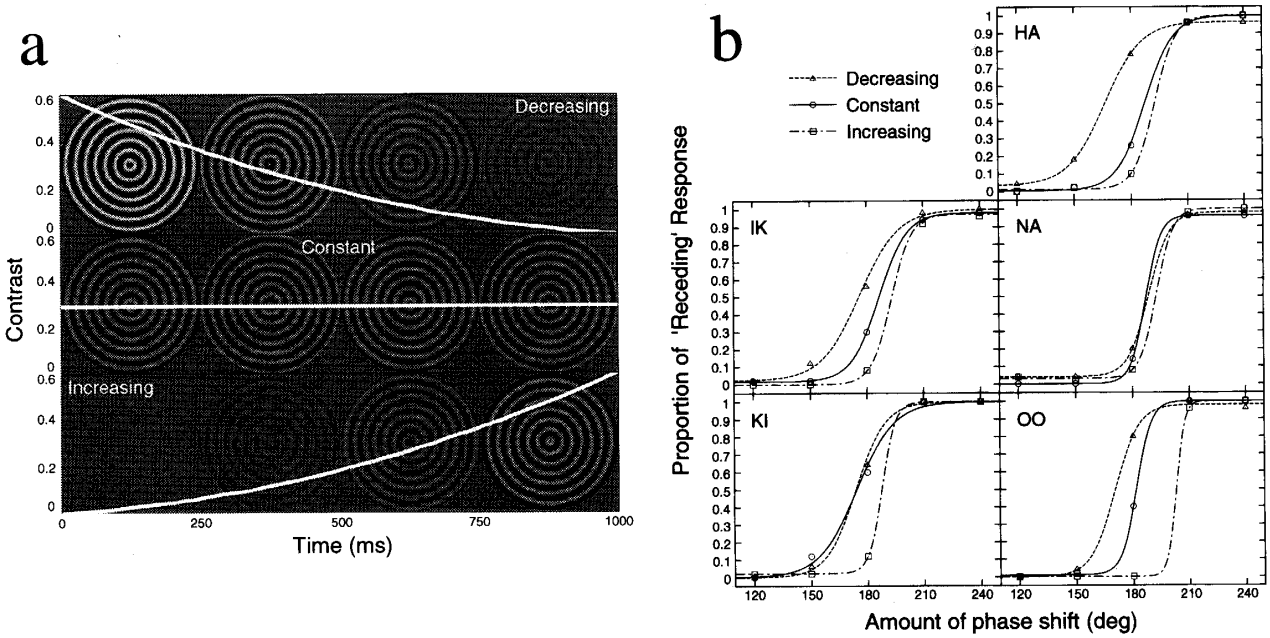

Figure 1. (a) The visual stimuli used in the experiment. The abscissa and ordinate indicate the time and the contrast, respectively. The thick white lines indicate continuous contrast change over time. The top, middle and bottom panels indicate the stimuli with a contrast which decreased, remained constant, and increased, respectively. The stimuli with a phase shift of 180 are shown. Four panels on each row show the stimuli at 0, 250, 500, and 750 ms. (b) The proportion of 'receding' responses as a function of the phase shift. The results for individual subjects are shown. For all of the subjects, except for NA, the psychometric function shifted towards the left (right) when the contrast decreased (increased).

(Tukey's Honestly Significant Difference, $p < 0.01$) indicated a significant difference between the mean for the decreasing condition (175.13) and that for the increasing condition (193.80). But the differences between the mean values of either of these two conditions and the constant condition (183.40) were not significant.

The apparent motion of expansion (contraction) was canceled by the decreasing (increasing) contrast. The results suggest that contrast change produces directly motion-in-depth perception and that the human visual system integrates the contrast information to achieve perception of motion-in-depth. An alternative possibility is that a change of contrast indirectly contributes to motion-in-depth perception. In our preliminary experiment we observed that when we used phase shifted stimuli, a contrast change had a strong effect on the motion-in-depth perception. But the effect of the contrast change was weak when we used static phase stimuli. The contrast change may therefore induce an apparent change in size and then the apparent motion may induce the motion-in-depth perception.

References

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