Spatial location and hyperacuity: flank position within the centre and surround zones

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Abstract—Sensitivity to a horizontal displacement of a vertical line was measured in order to ascertain the influence of the location of parallel flanking lines on the apparent position of features in visual space. The first experiment confirmed that the introduction of the flank added a component to the apparent shift which was towards the flank for small separations (less than 3–4') and away from the flank with larger separations. The second experiment investigated the notion that apparent location is derived by collecting information only from zones adjacent to the target and limited in the vertical extent by the target's height i.e. information orthogonal to the target's main axis. This was done by placing a vertical flank at a horizontal distance from the target that would be clearly within one zone or the other and measuring the effect of a vertical separation between the two flank halves. In the surround zone the amount of repulsion obtained was not influenced by vertical separation of the flank halves, even when they were several minutes higher (or lower) than the target line. In the central zone attraction was only obtained when the vertical separation was small enough to provide some overlap of the lines in the horizontal direction. With larger separations substantial repulsion was obtained. We conclude that while the central 'attraction' zone may only use information distributed in the direction of the line's displacement, it does so only within a 3–4' range on either side of the target line. The surround zone is not similarly limited in the region over which it collects information to influence the apparent location of features.

INTRODUCTION

One of the central problems of hyperacuity concerns the method of localizing target lines with the precision required for the performance obtained. Clearly some special form of spatial processing is required (Barlow, 1979; Fahle and Poggio, 1981; Morgan and Watt, 1982). Ever since Hering (1899) proposed that lines could be more accurately localized by averaging local signs along their length the shape of the zone over which positional information is gathered has been a topic of considerable discussion. Demonstrations that dots can be localized as accurately as lines (Ludvigh, 1953) argued against Hering's proposal and led to suggestions that information orthogonal to the main axis of the target (in the direction of misalignment for vernier acuity) was of central importance (Westheimer and McKee, 1977) although some use of information along the main axis of the stimulus may also be used in some tasks (Watt, Morgan and Ward, 1983b).

The recent results of Badcock and Westheimer (1984) showing how the apparent location of a line is influenced by the presence of flanking lines causes the question to be re-examined. They found that when the flank was close to the target line (less

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than 4' separation) an apparent shift of the target line's position was judged to be towards the flank to a greater extent than would be expected from the veridical shift. At larger target-to-flank separations the apparent shift of the target appeared to be greater than it actually was in the direction away from the flank. We refer to these effects simply as attraction and repulsion. Since these effects on apparent location occur without a change in the hyperacuity threshold it is reasonable to ask whether they are generated by information in the same spatial zones as that used for the threshold.

The current experiments repeat the central demonstration of Badcock and Westheimer (1984) that both attraction and repulsion effects can be obtained depending on the separation between the target and the flanking lines. We then address the question of the shape of the zones over which information is collected to derive the apparent location of stimuli.

We have used a paradigm in which a single line is presented and after 500 ms is instantaneously displaced to the left or the right. At the time of the displacement a flanking line is introduced to one side. The flanking line is presented in either the attraction or the repulsion zone. The flank can be either a continuous line of the same height and vertical position as the target line or broken into two equal halves that are displaced vertically from the centre, one going up and the other down by equal amounts. In this way we can vary the amount of overlap in the horizontal direction without varying the amount of light on the screen and since there is only one target line subtle influences on reference lines, due to the vertical separation of the flank halves, are avoided (this would not be the case with vernier acuity). If one assumes that only information orthogonal to the main axis of the target line is used to derive positional information then the expectations are clear. The apparent location of the line should be influenced when the flank halves and the target line overlap in the horizontal direction. When the flank halves are separated vertically to such an extent that there is no horizontal overlap they should have no influence on the target line's apparent location. This simple prediction is not supported by the data.

**METHOD**

The observer viewed from a distance of 6.8 m an oscilloscope with P31 phosphor that was driven by a PDP 11 minicomputer, in an illuminated room. The screen luminance, with no pattern displayed, was 8.0 cd m$^{-2}$. During an experiment target lines less than half a minute of arc in width, were presented in the centre of the screen and a trial occurred every six seconds. The intensity of the target line was 0.775 cd m$^{-1}$.

In a trial, a target line 9.6 min of arc high was presented and after 500 ms the line was instantaneously displaced 0, 12, 24 or 36 seconds of arc to either the left of the right, and remained in that position for another 500 ms. The direction and the size of the jump were randomly chosen on each trial. At the instant of the jump a flanking line (9.6 min high and 25% of the intensity of the target line) was presented parallel to the test line at 1.2' or 6' to the left or the right of the shifted target line. (The distance between the test line and the flank was held constant within each condition to ensure that no cue to the size or direction of the shift of the line could be obtained from a change in the height of the peaks or the troughs of the luminance profile.) After each stimulus presentation the observer specified whether the jump was to the left or right. No feedback was given and observation was always binocular with natural pupils.