Anisotropies in peripheral vernier acuity

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Abstract—Vernier acuity for short horizontal, vertical and oblique target lines was measured in many locations in the periphery of the visual field in normal human observers. In the 10 deg periphery, the average alignment threshold with oblique vernier lines in eight locations for three observers was 2.29 times higher than that with vertical and horizontal target lines. This oblique effect was found everywhere in the visual field. Similar conclusions are drawn for configurations in which the lines were replaced by just their distal endpoints, but here, additionally, performance was distinctly better when the dot pair was collinear with the fixation point, i.e. oriented radially, than when it was oriented tangentially. Both for vernier lines and for dot pairs, in all observers, horizontal configurations showed somewhat better thresholds than vertical ones. These results suggest an inherent pattern of connectivity throughout the visual field favoring processing in the cardinal orientations over the obliques, the radial over the tangential and, to a limited extent, the horizontal over the vertical.

Keywords: Alignment thresholds; oblique effect; peripheral visual field; retinal eccentricity; radial/tangential anisotropy; vernier acuity.

INTRODUCTION

In his papers on vernier acuity in 1979 and 1985, Jacob Beck used as his departure point the fact that in vernier acuity, under many conditions, two spots can be substituted for the traditional pattern of abutting lines. That dots can replace lines in an alignment task, first reported by Ludvigh in 1953, contradicted the only viable theory of vernier acuity, that of Hering (1899), according to which it is the averaging of local signs along the length of contours that enables localization with such high precision. Properties of dot alignment formed the subject of several studies in addition to Beck’s (Sullivan et al., 1973; Westheimer and McKee, 1977). The possibility of associating the orientation selectivity of cortical neurons (Hubel and Wiesel, 1962) with the task of judging the orientation of lines (Andrews,

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1967) had led to the conjecture that vernier misalignment might be seen as an orientation change and hence have a substrate in orientation-selective neurons in the primary visual cortex. Replacing lines with dots strains this interpretation. Depending on their separation, the implicit orientation of the line joining two points can be judged just as well, and sometimes even better than if the line is drawn in explicitly and this requires enquiry into the adequacy of a pair of dots as a stimulus for such cortical units. Thus it is premature to allow vernier acuity to remain as merely a subset of orientation detection. Instead it suggests that it might be better to examine it within the frameworks of mechanisms for detecting the relative feature position (Beck and Halloran, 1985). The present study concentrates on line and two-dot vernier detection in the retinal periphery. In particular, an attempt is made to seek concordance with two properties that have been found to characterize line-orientation discrimination in the retinal periphery, namely, anisotropies associated with the meridional orientation of the test pattern and whether it is lined up with the fixation point (is oriented radially) or orthogonal to that direction (tangentially). The better the match between the findings on vernier and on line-orientation discrimination, the firmer the postulate of a common substrate.

A wide variety of visual tasks show better performance with horizontally or vertically oriented contours than with oblique ones (Appelle, 1972). There is consensus that the locus for this oblique effect is cortical because it manifests itself in such thresholds as line-orientation and alignment discrimination and the orientation of streaming random dots (Matthews and Qian, 1999; Westheimer, 2003b) but not in those depending predominantly on retinal processing, such as detection of the presence or discrimination of brightness of single lines, and to some extent also of resolution (Westheimer and Beard, 1998). Most of these experiments were performed with central vision, but when specifically looked for, an oblique effect can also be found in the periphery of the visual field (Davey and Zanker, 1998; Vandenbusche et al., 1986). Line orientation discrimination is better by a factor of about 2 for horizontal and vertical lines than for obliques in all locations in the retinal periphery (Westheimer, 2003a).

That foveal alignment acuity is poorer with oblique than horizontal and vertical lines has been adequately documented (Corwin et al., 1977; McKee and Westheimer, 1978; Saarinen and Levi, 1995; Westheimer, 2001; Westheimer and Beard, 1998). To ascertain whether this applies throughout the visual field, measurements in the periphery of the visual field are reported for vernier acuity with patterns that are oriented along the horizontal, vertical and the two principal obliques, 45 degrees and 135 degrees (see Note 1).

**METHODS**

The observer’s task was to judge the direction of misalignment of either two short, almost abutting, lines, i.e. the traditional vernier stimulus, or two dots with fixed