Mirror symmetry and parallelism: two opposite rules for the identity transform in space perception and their unified treatment by the Great Circle Model

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Received 25 April 1994; revised 2 September 1994; accepted 16 September 1994

Abstract—Two opposite rules control the contributions of individual lines to the perceptual processing of two different spatial dimensions of egocentric localization and orientation. For lines restricted to the frontal plane, a tilted line on one side of the median plane induces a rotation of the orientation visually perceived as vertical (VPV) identical to that induced by the same tilt on the other side of the median plane, but the influences exerted on the elevation of visually perceived eye level (VPEL) are mirror symmetric. The rule for VPV fits our intuitions; the rule for VPEL does not. However, the reverse peculiarity holds when the inducing lines are rotated within sagittal planes (pitched): Two parallel, pitched-from-vertical lines on opposite sides of the median plane generate identical effects on VPEL but mirror symmetric effects on VPV. These counterintuitive symmetry reversals are reconciled by the Great Circle Model of spatial orientation (GCM), in which line orientations are represented by the great circle coordinates of their images on a sphere centered at the nodal point of the eye via central projection.

1. INTRODUCTION

It would be relatively easy to gain agreement among a group of observers that the two solid lines in Fig. 1a are identically oriented but that the two lines in Fig. 1b are not, that the two solid lines in Fig. 1b are mirror symmetrical with respect to the dashed line as an axis of symmetry. We would also expect to gain quick agreement among workers in spatial vision and space perception to the statement that the two lines in Fig. 1a, presented within a frontal plane, are treated identically by perception while those in Fig. 1b are treated differently. For, certainly, the two lines in Fig. 1a appear more similar than do those in Fig. 1b. The parallelness between the lines in Fig. 1a adds an aspect of similarity to whatever aspects of similarity are perceived between the two lines in Fig. 1b so that at most the two lines in Fig. 1a are only differently located whereas the two lines in Fig. 1b are both differently located and differently oriented.

If some segments of the above statements are interchanged to read that the two lines in Fig. 1b are treated more similarly by perception than are those in Fig. 1a we
Figure 1. Tilted lines with centers equidistant from the median plane. (a) Parallel lines. (b) Mirror symmetrical lines.

would expect to be greeted with puzzlement if not outright denial. It would be even more difficult to gain agreement if we stated that perception treats the two lines in Fig. 1b identically under conditions for which the two lines in Fig. 1a are treated as opposites. Nevertheless the latter, counterintuitive statement holds for the perception of elevation. For a second dimension of egocentric localization and orientation — perceived orientation within a frontal plane — the reverse, more intuitive relation, holds as it does for the more usual perception of patterns. Thus, for the perception of elevation, mirror symmetry between lines is the identity transform and parallelness the negative transform; for perceived orientation within a frontal plane, parallelness is the identity transform and mirror symmetry the negative transform. The present article will describe the evidence for this and demonstrate that although both perceptual dimensions are controlled by the same fundamental property of individual lines, each is controlled by a separate and different mechanism.

The experiments involve measurements of a norm within each of the two dimensions. For perceived elevation an observer sets the physical elevation of a visual target to appear at eye level (VPEL). For perceived orientation, an observer rotates a test line within a frontal plane to the orientation at which it appears vertical (VPV). The present article will describe measurements of the two norms, VPEL and VPV, exclusively. But, it should be clear that by measuring the physical location corresponding to a single point within a perceptual dimension we also learn about the correspondence between large portions of the physical and perceptual dimensions. For example, a shift in the elevation of VPEL relative to true eye level suggests a linear translation between the physical elevation and perceived elevation of points above and below VPEL, a suggestion supported by manual matches to visual targets at different elevations (Robison, Li, and Matin, unpublished experiments). Similar statements apply to relations between frontal plane orientation and VPV.

VPEL and VPV are set with good accuracy and reliability in total darkness. Thus, standard deviations for VPEL are typically less than 1 deg and constant errors less than