Anisotropy and polarization of space: Evidence from naïve optics and phenomenological psychophysics

doi:10.1017/S0140525X13000332

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Abstract: Additional evidence is presented concerning the anisotropy between vertical and horizontal encoding, which emerges from studies of human perception and cognition of space in plane mirror reflections. Moreover, it is suggested that the non-metric characteristic of polarization – that Jeffery et al. discuss with respect to gravity – is not limited to the vertical dimension.

As discussed by Jeffery et al., evidence for true volumetric coding is weak, and a bicoded map is the most likely encoding spatial scheme (at least in mammals). Moreover, allocentric encoding of the horizontal dimension is metric, whereas encoding of the vertical dimension is non-metric. Among the features of the vertical dimension is its polarization. In this commentary we focus on these two aspects (anisotropy and polarization). Jeffery et al. explicitly say that they confine their discussion to studies of navigation rather than spatial cognition. However, some parallels are strong. We draw attention to behavioral findings from naïve optics and phenomenological psychophysics. These data, respectively, (a) provide further evidence concerning the anisotropy between vertical and horizontal encoding of space in humans, and (b) suggest that polarization is a general characteristic of non-metric encoding of ecological space, not exclusive to the vertical dimension.

Many adults hold mistaken beliefs concerning the spatial behavior of reflections. For example, when adults imagine a person entering a room and walking parallel to a wall, they predict that the person will see his or her reflection in a mirror on the wall before it is possible (i.e., before being aligned with the mirror's edge – this has been called the "early error"). A minority also predict that the image will appear at the mirror's farther edge rather than at the nearer edge. The same mistake applies when moving in a real room, not just when predicting an event in a paper-and-pencil task (Croucher et al. 2002).

The early error is compatible with overestimation of what is visible in a mirror from left and right. In other words, people expect a cone of visibility for a given mirror, largely independent of the viewpoint of the observer and of distance (Bertamini et al. 2010; Bianchi & Savardi 2012b). The second error (the location of the image) is compatible with the idea that the virtual world is spatially rotated around a vertical axis (Bertamini et al. 2003). However, an alternative explanation was found in later studies: The virtual space is thought of as allocentrically organized in an opposite way with respect to the real environment (Savardi et al. 2010).

These mistaken beliefs, which are similar in males and females, and in psychology and physics students, are confined to the horizontal plane. They disappear when vertical movements are considered. For instance, if the imagined character approaches the mirror by moving vertically – say, climbing up a rope parallel to the wall (Croucher et al. 2002) or moving in a glass lift (Bertamini et al. 2003) – people neither expect to see the reflection before reaching the near edge of the mirror, nor to see it appearing at the farther edge (i.e., opposite relative to the direction of the approach). Experience does not lead to better understanding of mirror reflections; on the contrary, adults make larger errors compared to children (Bertamini & Wynne 2009).

Further evidence of a difference between transformations around horizontal and vertical axes comes from studies of perception of mirror reflections of the human body: Mirror-reflecting a picture or a real body around the horizontal axis – upside-down reversal – resulted in larger differences than did reflecting it around the vertical axis – left-right reversal (Bianchi & Savardi 2008; Cornelis et al. 2009).

With respect to polarization, Jeffery et al. argue that this is a feature typical of the dimension orthogonal to the plane of locomotion (i.e., usually the vertical). They do not explicitly claim that it is confined only to this dimension, but they do not specify that polarization can also characterize the representation of the horizontal dimension (at least in humans). However, spatial polarization emerges as a key aspect in both dimensions from studies on the perception and cognition of space and objects in mirrors (Bianchi & Savardi 2008; 2012b; Savardi et al. 2010), and it is a non-metric characteristic of direct experience of space that goes beyond mirror perception. This aspect of space has been emphasized in various anthropological (e.g., Brown & Levinson 1993) and linguistic (e.g., Cruse 1986; Hill 1982) analyses of human cognition and in studies of memory errors in object recognition (Gregory & McCloskey 2010). Only recently has its importance been recognized within what has been defined "phenomenological psychophysics" (Kubovy 2002; Kubovy & Gepshtein 2003). The basic structure of phenomenological experiences of space and its geometry invariably manifests properties of polarization (Bianchi et al. 2011a; 2011b; Bianchi & Savardi 2012a; Savardi & Bianchi 2009). In addition, Stimulus-Response spatial compatibility can be thought of as a direct effect of an allocentrically polarized encoding of space in humans (Boyer et al. 2012; Chan & Chan 2005; Roswarski & Proctor 1996; Umiltà & Nicoletti 1990).

Emerging from phenomenological psychophysics regarding polarization is the operationalization in metric and topological terms of spatial dimensions and the finding that these dimensions differ in the extent of the polarized area. This in turn depends on the extension of a central set of experiences perceived as neither one pole nor the other. For instance, the perception of an object as positioned "on top" of something (e.g., a flag on top of a mountain) is confined to one specific position; the same holds for "at the bottom." In between these two extremes there is a range of positions that are "neither on top, nor at the bottom." In contrast, in the dimension "in front of–behind" (e.g., two runners) there is only one state that is perceived as "neither in front, nor behind" (i.e., when the two runners are alongside). Similarly, in the dimension "ascending-descending" there is only one state that is perceived as "neither ascending, nor descending" (i.e., being level); all the other slants are recognized as gradations of ascending or of descending (Bianchi et al. 2011b; Bianchi et al. 2013). Furthermore, perhaps counter-intuitively, polarization is not to be thought of necessarily as a continuum: Ratings of high/low, large/small, wide/narrow, and long/short (dimensions relevant for navigation) applied to ecological objects or to spatial extensions do not behave as inverse measurements of the same continuum (Bianchi et al. 2011a).