A Misunderstanding of Principal and Medial Axes? Reply to Sturz and Bodily (2011)

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Sturz and Bodily 2011 [1] propose an alternative interpretation for the results presented by Kelly, Chiandetti and Vallortigara (2010) [2], who trained pigeons and chicks in a rectangular environment to find food located in one of two geometrically identical corners. Once the birds were locating the food accurately, they were presented with a novel L-shaped arena. The L-shaped arena provides unique predictions of search behavior for principal axis, medial axis and local geometry–based strategies. The patterns of search behavior reported support that pigeons were showing primary reliance on the medial axis, whereas chicks showed a primary reliance on local geometric cues with a secondary reliance on the medial axis.

Sturz and Bodily agree that the birds could not be using the principal axis. However, they qualify this position by stating that the birds were not using "the principal axis as computed by the authors" (pp.2-3). The computation of principal axes of an object is not subjective. To quote Cheng (2005):

> "The principal axes of a shape go through the centroid (centre of mass)…The first or major principal axis goes roughly through the length of the space. Mechanically, it minimizes the angular momentum when the space is spun around it." [3,pp.8]

Perhaps this misunderstanding of the calculation of the major principal axis accounts for the authors' suggestion that "something analogous to a principal-axis based strategy" (a strategy based on "subjectively experienced views") underlies the responses of the birds in Kelly et al. The error is that the principal axis is not calculated based on subjective viewpoints but are rather based on the shape as a whole, whereas the medial axis is defined locally.

The argument that the navigator must determine the environment's shape from "subjectively experienced views" is problematic. It assumes that vision is the guiding sensory modality. Research has not shown that vision is required for encoding geometry as rats can encode geometry in complete darkness [4]. Furthermore, the necessity of knowing the navigator's subjective experience makes this alternative explanation virtually impossible to test empirically – even if one focused on visual experiences, these may differ remarkably (e.g., degree of lateral visual fields).

We argue that the use of medial axis is an objective strategy that can be empirically evaluated. The medial axis provides a *tree* structure – a collection of arcs joined at vertices such that for any pair of vertices there is a unique sequence of arcs connecting them (see Figure 1A). The leaves are the vertices of the polygon. As opposed to the principal axis that records a single orientation (i.e., a line); this tree structure allows the medial axis to capture multiple orientations. Unlike the principal axis, the medial axis is defined locally. A point, x, on the medial axis is determined by the maximal circle for which it is the centre; the circle is determined by the points on the boundary that lie on the circle. These points are local. For example, extending the polygon on the left-hand side of the L-arena results in a local change to the medial axis but a global change to the principal axis (see Figure 1B). The medial axis remains defined in a curved environment for which there is no natural division into rectangular subregions, whereas the principal axis is uninformative with respect to defining local orientation (see Figure 1C).

Sturz and Bodily's strategy does not clearly delineate the search distribution at the center of the L-arena, nor does it account for the species differences reported by Kelly et al. Starting from the central position, the birds had a global view of the arena (see Figure 1A). Furthermore, in response to Sturz and Bodily, comparisons between the three start positions showed no significant differences in search behavior. Research has also shown that environmental size manipulations affect search behavior by chicks [5] – size changes would not affect the principal nor medial axes, but would influence a local cue-based strategy. Examining the alternative strategy, it is clear that the birds in group AC should search at corner A when heading towards that area of the L – but where should they search when heading towards the center? Where does one draw the hypothetical wall to separate the L into two independent rectangular environments?

Thus, we argue that the conclusions drawn by Kelly et al. offer a more robust interpretation of the data than by Sturz and Bodily. This explanation allows future researchers to make objective predictions that may be examined empirically and is not based on subjective experiences. Furthermore, it is a strategy available to many species for which vision may or may not be the primary means of spatial encoding.

References

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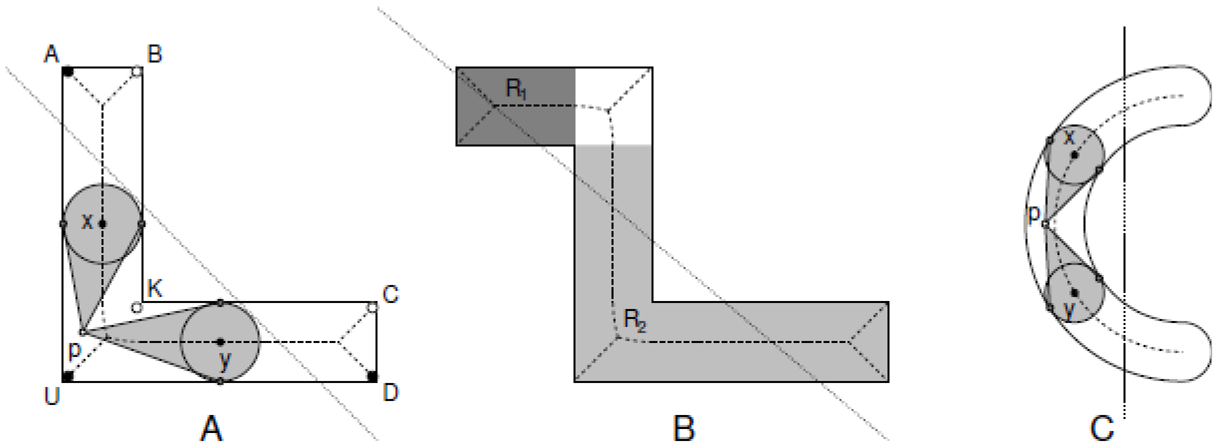

Figure 1A) A bird at point p can see the medial axis in either direction (dashed line). B) A local change to the polygonal region (R_1) results in a local change to the medial axis but a global change to the principal axis. The medial axis in R_2 remains unchanged. C). The medial axis remains defined in a curved area for which there is no natural division into rectangular subregions; the principal axis is of little use in defining orientation locally.