



## Review

## From natural geometry to spatial cognition

Luca Tommasi<sup>a,\*</sup>, Cinzia Chiandetti<sup>b,c</sup>, Tommaso Pecchia<sup>b</sup>, Valeria Anna Sovrano<sup>b</sup>,  
Giorgio Vallortigara<sup>b</sup>

<sup>a</sup> Department of Neuroscience and Imaging, University of Chieti, Chieti, Italy

<sup>b</sup> Centre for Mind/Brain Sciences, University of Trento, Rovereto, Italy

<sup>c</sup> Department of Psychology, University of Trieste, Trieste, Italy

## ARTICLE INFO

## Article history:

Received 6 May 2011

Received in revised form 7 December 2011

Accepted 13 December 2011

## Keywords:

Spatial memory

Comparative cognition

Spatial cognition

Geometry

Landmarks

Reorientation

## ABSTRACT

A review of selected works on spatial memory in animals and humans is presented, and some ideas about the encoding of geometry and its role in evolution are presented, based on recently accumulated evidence from psychology, ethology and the neurosciences. It is argued that comparative analyses at the level of both spatial navigation behaviors and their underlying neural mechanisms may provide a solid foundation for the biological origins of organisms' spontaneous ability in dealing with geometric concepts. To this aim, the representations of space underlying memory tasks involving discrete (i.e., landmark arrays) or continuous elements (i.e., enclosed environments) are evaluated and compared as regards the impact of their geometric arrangement.

© 2011 Elsevier Ltd. All rights reserved.

## Contents

|                                                                                   |     |
|-----------------------------------------------------------------------------------|-----|
| 1. Introduction .....                                                             | 799 |
| 2. The building blocks of phenomenal space .....                                  | 802 |
| 3. Landmarks and spatial relationships .....                                      | 802 |
| 3.1. Encoding distance and direction from single objects .....                    | 802 |
| 3.2. Encoding geometric information in simple arrays .....                        | 803 |
| 3.3. Encoding geometric information in complex arrays .....                       | 806 |
| 3.4. Discriminating objects by geometry in an array .....                         | 808 |
| 4. Geometry of enclosed spaces .....                                              | 809 |
| 4.1. The hypothesis of modularity in the spatial domain .....                     | 809 |
| 4.2. Reorienting in large and small spaces .....                                  | 815 |
| 4.3. Middle, center and other singularities .....                                 | 816 |
| 5. Natural geometry: the role of experience and innate factors .....              | 818 |
| 6. Neural mechanisms underlying the encoding of geometry in enclosed spaces ..... | 818 |
| References .....                                                                  | 820 |

## 1. Introduction

Since the early days of empirical research on comparative psychology, a vibrant interest for the phenomena of animal orientation, and for the mental processes (and the underlying neural

functions) that allow animals to store, process and retrieve spatial information, was soon established (Darwin, 1873; Viguier, 1883). This proved particularly true in the domain of research on spatial navigation, namely “the process of determining and maintaining a course or trajectory from one place to another” (Gallistel, 1990). Although comparative cognition is a relatively young field in the scenario of science, the number of researchers devoting their interest and efforts to this topic over the last century has increased exponentially. Just to give an example, international conferences in ethology, psychology and the neurosciences nowadays always include at least one session on spatial memory or spatial

\* Corresponding author. Tel.: +39 08713554210; fax: +39 08713554163.

E-mail addresses: [luca.tommasi@unich.it](mailto:luca.tommasi@unich.it) (L. Tommasi),  
[cinzia.chiandetti@unitn.it](mailto:cinzia.chiandetti@unitn.it) (C. Chiandetti), [tommaso.pecchia@unitn.it](mailto:tommaso.pecchia@unitn.it)  
(T. Pecchia), [valeriaanna.sovrano@unitn.it](mailto:valeriaanna.sovrano@unitn.it) (V.A. Sovrano),  
[giorgio.vallortigara@unitn.it](mailto:giorgio.vallortigara@unitn.it) (G. Vallortigara).

**Table 1**

A list of fundamental terms, basic concepts and mechanisms dealt with in the article.

| Building blocks                                                                                                                                                                                                                                                                                  | Basic concepts                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Basic mechanisms                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Left–right</b><br>Directional sense<br>The direction or position on a certain side in relation to a specific point of reference as assumed by an agent                                                                                                                                        | <b>Point</b><br>A point is that which has no part                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>Dead reckoning</b><br>Process of estimating one's current location based on movements made since the last known position or a fix one by integrating speeds over elapsed time, and course. Also known as path integration. New values are always calculated from previous values, hence any errors are cumulative; any external uncontrolled displacement disrupt the estimated calibration with the external world (Collett and Collett, 2000; Etienne and Jeffery, 2004)                                                                         |
| <b>Above–below</b><br>The point or area in or to a higher position or place in space – the point or area at or to a lower position or place in space                                                                                                                                             | <b>Line</b><br>A line is breadthless length                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | <b>View-based navigation</b><br>A process for navigation which involves a quantitative reduction of mismatch between a remembered local view of the environment (snapshot) as seen from a certain point and orientation, without information about distances or specific spatial relations but retinal sizes and separations (Cartwright and Collett, 1983). With the increase of locations there is an overload of stored images                                                                                                                     |
|                                                                                                                                                                                                                                                                                                  | <b>Surface</b><br>In Euclid terms a surface is that which has length and breadth only; a surface does not have to be a plane; a face of a solid is a surface. Animals seem to use the surface layout geometry to be successful in spatial reorientation when they represent a target location by the metric (long/short) and sense (left–right) disposition of the surfaces                                                                                                                                                                                                                                                                                                                               | <b>Guidance</b><br>Association between a conspicuous feature perceptible at a certain distance and destination. A change in the beacon may only lead to failure in reaching the destination (O'Keefe and Nadel, 1978)                                                                                                                                                                                                                                                                                                                                 |
| <b>Front–Back</b><br>The point or area that lies ahead to a specific point of reference as assumed by an agent – the point or area that lies at the back                                                                                                                                         | <b>Volume</b><br>A volume is that which has length, breadth, and depth                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | <b>Piloting</b><br>Identification of a spatial position and orientation with respect to a configuration of familiar landmarks, or reference points, with directions and distances (and related features such as size and appearance of a visual landmark) to those reference points (Gallistel, 1990)                                                                                                                                                                                                                                                 |
| <b>Inside–outside</b><br>The space closest to a specific point of reference and in between it and a certain boundary or limit – the space beyond a boundary or limit                                                                                                                             | <b>Boundary</b><br>In Euclid terms a boundary is that which is an extremity of anything                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | <b>Compass</b><br>A biological compass is a mechanism that allows an animal to determine and to maintain a direction in space during navigation. The local inclination of the geomagnetic field (Wiltchko and Merkel, 1966), the pattern of polarized light (von Frisch, 1949) and the apparent movement of celestial bodies (sun: Schmidt-Koenig, 1958; stars: Emlen, 1970) can all provide the sensory basis for the biological compasses. Directional information obtained from stationary visual landmarks in an environment are considered apart |
| <b>Local–global</b><br>Phenomenal domain of the visual field that determines a definite region or portion of space, a restriction to one place or region – the infinite space surrounding an individual but that goes well beyond the restriction of the visual field                            | <b>Angle</b><br>From the Latin word <i>angulus</i> , meaning “a corner”. In Euclid terms, a plane angle is the inclination to one another of two lines in a plane which meet one another and do not lie in a straight line                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>Navigation</b><br>Navigation is the process of determining and maintaining a course or trajectory from one place to another (Gallistel, 1990)                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Proximal–distal</b><br>Information gathered by direct exploration in the immediate action range of an individual–information inferred at a distance                                                                                                                                           | <b>Axis</b><br>Comprises a variety of parameters describing a shape, or a local portion of a shape, in terms of its global geometric properties (Cheng, 2005a,b)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Idiothetic–allothetic</b><br>Endogenous information (proprioception of an actuator and vestibular information) – information gathered from the external world (vision, audition, touch, smell). These two sources are supposed to be merged for an effective representation during navigation | <b>Shape</b><br>In Euclid terms a shape is a set of points; a part of the space occupied by the set as determined by its external boundary invariant to location and orientation, translations and size and other featural properties. The concept has been applied also to describe the arrangement of discrete objects in arrays of small numerosity, assuming elements as point in space and boundaries as a closed polygonal line connecting each element in a sequence<br><b>Position</b><br>Spatial location identified by the relations of objects in a certain frame of reference<br><b>Distance</b><br>In Euclid terms a distance is a metric measure of length separating two points in a plane |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

Download English Version:

<https://daneshyari.com/en/article/10461511>

Download Persian Version:

<https://daneshyari.com/article/10461511>

[Daneshyari.com](https://daneshyari.com)