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<CT>**Navigating through a volumetric world does not imply needing a full three-dimensional representation**

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<C-AB>**Abstract:** Jeffery et al. extensively and thoroughly describe how different species navigate through a three-dimensional environment. Undeniably, the world offers numerous three-dimensional opportunities. For most navigation tasks, we argue, a two-dimensional representation is nevertheless sufficient, as physical conditions and limitations such as gravity, thermoclines, or layers of earth encountered in a specific situation provide the very elevation data the navigating individual needs.

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As Jeffery et al. correctly note, most scientific efforts on large-scale spatial relations have focused on two-dimensional settings while neglecting further, potentially important dimensions such as elevation, slant, and distortion. In theoretical terms, generating a more complete three-dimensional representation of the environment by integrating such information presumably enhances navigation accuracy. However, it is rather debatable whether this also leads to a significant improvement in actual navigation and localization performance in everyday tasks (Montello & Pick 1993).

As a series of empirical works confronting (human) participants with navigation tasks has documented, specific deficits in the assessing of the azimuth angle, for example, arise in multi-floored/three-dimensional versus single-floored/two-dimensional settings (Holscher et al. 2006; Thibault et al. 2013). In ecological contexts, offering a variety of orientation cues, humans are nevertheless able to actively navigate through three-dimensional environments without any problems. This might again indicate here that it is not obligatory to have access to a perfect cognitive three-dimensional representation of the environment. Furthermore, the mismatch of evidence provided by empirical studies and everyday experience might point to a lack of ecological validity in the paradigms commonly used to investigate the premises of actual navigation. This is partly due to laboratory and real-life navigation tasks requiring completely different, and sometimes even converse, strategies or behaviors. In a study by Carbon (2007), for example, participants were asked to estimate national large-scale distances as the crow flies – but what did they do in the end? Although they obviously used a consistent and steady strategy, as indicated by estimates being highly reliable as well as strongly correlated with the factual physical distances (cf. Montello 1991), they applied a strategy that differed entirely from the one specified in the instructions: Instead of linear distances, they used German autobahn distances as the basis for their estimations, replacing the requested but unfamiliar mode (no human was ever found to behave like a bird) with one derived from everyday behavior – that is, from actually travelling these distances by car (instead of aircraft). Thus, everyday knowledge was found to be preferred over (artificial) task affordances, which is indeed reasonable, as it is easier and more economical to do something on the basis of knowledge and familiar routines.

Let us get back to a point mentioned already and elaborate on the question of why a complete three-dimensional representation of the environment is not obligatory for the majority of typical real-life navigation tasks. Surface-travelling species, for example, are limited to the surface they are travelling on; they might hop and dig from time to time, but they mainly orient themselves to the surface, therefore inherently to the current elevation of the given structure of this surface. Basically, they navigate on an idealized plane. When directions of places are to be assessed within a single plane, azimuthal errors are relatively small (Montello & Pick 1993), so navigation will be quite accurate. If sensory (e.g., visual) cues are additionally taken into account, it can be further tuned and optimized (Foo et al. 2005). Concerning navigation through three-dimensional environments, the ability of extracting and using supplemental information provided by external or sensory cues turns out to be quite economic: Even a subject climbing a mountain can still locate its target destination (the peak) on an idealized two-dimensional map, provided that some supplemental information on the elevation of this target is available. This information can be “gleaned,” for example, from the required expenditure of energy while climbing. Considering that most parts of the three-dimensional space can thus be reduced to a surface-map representation with sparse data requirements, a cognitive system encoding topographies in full three-dimensional coordinates seems rather unnecessary, as it would be too cost-intensive.

Regarding species such as flying insects, birds, or fish that move more freely through the third dimension, very similar navigation routines can be found (e.g., for honeybees: Lehrer 1994). Research has indeed revealed specific skills in communicating elevation (e.g., for fish: Holbrook & Burt de Perera 2009; e.g., for stingless bees: Nieh & Roubik 1998), and that elevation information can be highly relevant in some tasks (e.g., finding a bird's nest). Still, it is improbable that this information is fully integrated within a complete cognitive three-dimensional representation. From an information theory perspective, most parts of volumetric representations of real-world contexts would comprise a great number of "empty cells." Furthermore, reliable locations can hardly be imagined without any physical connection to the surface. A bird's nest, for example, may be situated in a treetop that is part of a tree that is itself solidly enrooted in the ground (i.e., the surface). Navigation requirements in the water, where spatial constraints are also obvious, are similar: Most relevant and reliable locations for hiding or for finding prey are near the bottom or the surface of the sea. For navigating through the sea, elevation information might be needed, but not necessarily in the form of a complete three-dimensional representation. Gibson's (1979) ecological approach offers a solid basis for reducing data for navigating tasks quite efficiently: Moving through a three-dimensional world itself provides important directly visual, acoustic, and proprioceptive cues (cf. Allen 1999), which help us to assess distances, elevations, and drifts of our movement trajectories both easily and accurately.

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