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A sense of direction: spatial boundaries in a cognitive, cultural, and deep time perspective

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ABSTRACT

This brief note points toward new potentials that lie at the interface between research on landscape archaeology and cognitive science. Recent advances in the cognitive and neural sciences have sharpened our understanding of spatial cognition, by providing new explanations for how the brain reduces the dimensionality of complex topography and geography for effective navigation. This research suggests that space is represented in grid-like structures in the brain, and that grid-like forms are a basic ingredient of spatial processing. At the same time, recent archaeological research shows that the organization of larger-scale space into linear forms, and in particular grid-like landscapes, is a relatively recent social invention, which suggests that these forms are historically and culturally contingent. Taken together, this research raises the question of how the dimensionality-reducing function of grid-like processing in the brain is related to higher-level conceptual and imaginative processing of space needed to plan and negotiate large-scale landscape structures. This brief note motivates this question and argues for further exploration of the relationships between biological, cognitive, and cultural processes related to space and its conceptualization between these fields of research.

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We are living in worlds of boundaries (McInturff et al. 2020). Wherever we look, when glancing out of the window or walking across the countryside of Northern Europe, space is segmented by fences, hedges, borders, and grids, to such an extent that we are mostly unaware of their insistent physical presence. However, their physical presence is in no way given. There was a long time in the past when linear landscape boundary features were not part of the social and economic vocabular. This short note questions how the emergence of social landscapes structured by boundary grids might have changed and significantly structured people's spatial awareness. As our archaeological case example, we consider how artificial physical boundaries such as fences, hedges, and walls

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spread across northwestern Europe in the Bronze Age and Iron Age as well as in historical times during the Enclosure.

Artificial boundaries – fences, borders, and grids – are products of a complex interplay between the environments, minds, and biosocial worlds which boundaries organize. The ability to build large-scale boundaries according to a plan requires cognitive capacities related to spatial reasoning about things we cannot see. This includes cognitive capacities for visuospatial processing, spatial memory, and mental imagery; as well as the ability to navigate environmental and social constraints related to different conceptions of spatial configurations. At the same time, the boundaries we encounter also influence how we think and talk about space. They scaffold our ability to remember, imagine, communicate about, and orient ourselves spatially in the environment.

The cognitive and neural sciences have made significant advances in understanding the mechanisms implementing basic spatial cognitive capacities. Research in rodents has demonstrated the existence of two specialized types of neurons: grid cells in the entorhinal cortex, and place cells in the hippocampus (Hafting et al. 2005; Horner et al. 2016). These cells represent space in separate functional layers, with grid cells coding the basic spatial metric, and place cells coding points of reference within that metric. Together these systems provide a powerfully simple way to understand how the mammalian brain enables spatial navigation, even in the absence of visual inputs. At a basic level, grid cell firing is irregular in ways that are sensitive to environmental geometry (Krupic et al. 2015, 2016); and brain circuits have been identified which represent the location of objects in relation to boundaries as opposed to landmarks (Julian et al. 2016).

Research in humans indicates that this grid/place cell system has been coopted to implement spatial processing in higher cognition. At a higher cognitive level, grid-like structures provide the cortical substrate for visuospatial imagery, or thinking about space more abstractly (Horner et al. 2016). Grid-like structures even appear to be involved in non-spatial conceptualization and reasoning, providing a spatial-like framework for the purely conceptual 'mental maps' used in relational thinking more generally (Constantinescu, O'Reilly, and Behrens 2016; Spier 2016). These discoveries are anticipated to provide neural mechanisms for how features of low-level visual processing – such as ecological constraints on vision, and Gestalt principles – scale up to higher-level cartographic and conceptual representations of space (Wagemans et al. 2012).

One theoretical explanation for the primary cognitive function of the grid cell system is that it provides the neural encoding for the abstraction of complex three-dimensional topography into low-dimensional Cartesian representations (Löroncz et al. 2017). These help animals use memory to navigate space, and would also be essential for the emergence of more uniquely human spatial-cognitive activities, like cartography and large-scale boundary construction. Co-opted into conceptual reasoning, the system may also help explain relationships between conceptual and cartographic representations of space in human cognition. A famous example of this relationship includes map distortions (Tversky 2015), which occur when our conceptual knowledge of space distorts our judgements about geographic relationships. As an example, most Northern Europeans would confidently say that Gothenburg is east of Copenhagen, even though it is not. This occurs because the conceptually higher-levelled geographic unit 'Sweden' is east of the geographic unit 'Denmark', and the relationship between these units affects how we construct the lower-dimensional spatial frame that we use to think about the relationship between the two cities.

By linking mechanisms for low-dimensional Cartesian representation to more conceptual representations of space (and even to non-spatial reasoning), this research opens broader questions about how linguistic, social, and even cultural processes involved in conceptualization are related to the more basic cognitive process of spatial abstraction of topography. If the grid/place cell system identified in rodents has been co-opted for higher cognition in humans, how has this system's function been elaborated by human social processes? Are there any cultural or developmental contingencies involved, such that the way that humans construct low-dimensional spatial representations of their topography is conditioned by the cultural repertoire of technologies that they have developed across deep time for carving up and negotiating space?

Some work related to these questions is already being conducted in linguistics. For example, relevant laboratory research has shown how sloped spatial topography shapes linguistic conventions used in communication and navigation (Nölle et al. 2020). Field research suggests that similar processes may account for natural linguistic variation in the way different cultures talk and think about elevation (Willemsen 2021). In a similar way, archaeological research on the development of boundaries through deep time may be well positioned to allow us to investigate whether historical differences in boundary structures between regions are visible as differences in how complex space is represented by different people today.

Grid-like structures are not a necessary feature of natural or human-made environments. Constructed boundaries, such as linear fences, hedges, and crop and livestock enclosures, emerged relatively recently in evolutionary time, across the landscapes of Northern Europe around 2000 BCE. These boundaries are introduced as ad-hoc, temporary enclosures of crops and corrals for livestock. Linear landscape boundary features are only sparsely represented in the archaeological record before then and often within specific ceremonial events. This suggests that although this spatial technology was available to people, there was still a certain cultural inertia in how they were introduced and received (Løvschal 2014, 2020). In the following centuries, linear boundaries developed into extensive forms of grid-like terrain-oblivious structures – canonical Cartesian forms – spanning thousands of hectares. These later forms of landscape boundaries were deeply associated with regulation of pastures, including concentrational farming and crop rotation, as well as sedentary, agrarian livelihoods. This caused a more permanent landscape fractioning and, in many regions, once such boundaries had become anchored in the landscape, materially and culturally, they never disappeared again. Rather, boundaries remained a key organizational principle and material pivot for political reforms such as the Enclosure (Blomley 2007). Field boundaries obstructed movement along existing routes and began to amplify across new social domains. For example, people began to enclose their farmsteads and villages with boundaries, and new kinds of defensive boundaries, palisades, cross-country barrages, and ramparts began to spread. They created new visuospatial barriers, centred on new allocentric social-organizational principles that provided a new structure for humans to conceptualize space within. Thus, what we see in the archaeological record is probably a process of positive feedback between the Cartesian reduction of topography in large-scale boundary construction, followed by increased use of linear and grid-like forms in the construction, conceptualization, and negotiation of space.

The fact that this was a contingent process raises questions about how our basic neural machinery for spatial cognition interacts with culture, landscape use, and technology, to be jointly investigated by archaeology and the cognitive sciences. For instance, what is the role of the grid/place cell system in large-scale spatial representations, and how does this role vary historically culturally? If the cognitive function of the grid/place cell system is to construct low-dimensional representations of the spatial environment, how are these representations dependent on the kinds of environment traditionally built by the cultures in which individuals live?

At a more operational level, are cognitive map distortions – like the belief that Gothenburg is east of Copenhagen – culturally contingent? In other words, are regionally defined map distortions the product of the particular Northern European way of reducing the dimensionality of large-scale spatial representations into linear and grid structures, and do other forms of spatial distortion occur in cultures that have historically organized their physical and social spaces differently? Do people from mountainous or heavily forested terrains reduce space in a way that is different to people from societies in which linear structures form the basic for the social and physical organization of the land, and do will they express map distortions that are fundamentally different to those observed in Northern European cultures? In cultural evolutionary terms, is there any written historical record of how the adoption of linear grid-like structures might have changed the way we talk about space in Northern Europe and the cultures it influenced? Such work is important, because it might engender a broadening of how we understand the relationship between the grid/place cell system in the brain, and the different ways it has been used to simplify and organize our spatial representations cognitively and culturally, drawing history and culture into our conceptions of the biology of spatial representation and reasoning.

Concluding thoughts

With this brief note, we wish to point out the intriguing potentials for interdisciplinary research collaboration at the interface between landscape archaeology, social anthropology, and cognitive science. Archaeology provides an opportunity to investigate cognition–environment couplings at their early establishments and could contribute in a useful manner because it provides an experimental ground for investigating the interaction between different constraints, inside and outside the cognitive substrate. Moreover, the archaeological and anthropological record holds important information about the ways in which the conception of and use of space has varied across cultural settings and throughout time. On the other side, cognitive science adds experimental and theoretical context and depth to interpret neural mechanisms and connect them to cultural landscapes.

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