

KNO-006 · Maps and Spatial Representation

KNO · Ways of Knowing

Juan Segurola

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Ways of Knowing

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Article Abstract

What is a map, and how much of human spatial knowledge does the word actually cover? This article separates three things that are often collapsed into one: the capacity to orient and navigate, the external artefact that stands for spatial relations, and the practices called cartography. It asks what neural findings about place and grid cells do and do not establish about the format of spatial thought. It examines wave charts and moving reference frames, the disputed prehistoric candidates, and the geometric constraint that forces every flat map of a sphere to distort something. It then asks what follows for reading maps as arguments once distortion and selection are unavoidable, why the dominance of one projection online does not dissolve the constraint, and which of the questions raised the evidence assembled here cannot settle.

In 60 Seconds

Spatial knowledge, external spatial representation and cartography are three separable things, and an expert navigator may hold the first at a high order while using no graphic artefact during the voyage. Place cells and grid cells are robust findings about neural activity, but they do not establish that human spatial thought takes the form of a graphic map; route knowledge can support successful travel without being a degraded survey map. Marshallese wave charts and the Caroline Islands technique known as etak show that spatial reasoning can be organised around models of ocean behaviour and around reference frames other than the fixed frame of a scaled plan. Geometry then imposes a hard limit: because a sphere and a plane differ in Gaussian curvature, no flat map of a sphere can preserve everything, so a projection encodes a decision about which distortions to accept. Separately, every map selects, so selection, scale, orientation and classification are editorial choices rather than neutral reporting, and Web Mercator shows the geometric constraint persisting in interactive media.

Why This Question Matters

A map can be read as a transparent account of space. A road atlas, a weather chart or a world map on a classroom wall is read as a picture of what is there, and the reading is usually harmless until the map is used to compare sizes, infer distances or settle an argument about the world. Knowing that every flat map of the globe distorts something, and that the kind of distortion it carries follows from a choice rather than a mistake, changes what a reader can responsibly conclude from one. Separating maps from spatial knowledge also changes which spatial systems count as knowledge.

1. Three things that are not the same

Spatial knowledge is the capacity to orient, locate or navigate. An external spatial representation is an artefact that stands for spatial relations. Cartography is the study and practice of making and using maps under explicit or implicit conventions, with histories in many societies. These three are related but not identical.

An expert navigator crossing open ocean without instruments has spatial knowledge of a high order and may use no graphic artefact during the voyage. A Marshallese training chart can foreground swell behaviour rather than act as a scaled plan. A modern road atlas is an external representation whose user may know little of the terrain it covers. Nothing forces the three capacities to coincide.

The article uses *map* broadly for an external artefact that represents spatial relations. *Projected map* refers more narrowly to a representation that transforms locations from a curved surface to a plane. Neither term is reserved for a European tradition.

Where That Leaves Us

The three can come apart, as the examples show, so nothing licenses treating them as one thing under three names. The article fixes its vocabulary rather than discovering it: map covers any external artefact standing for spatial relations. Whether human spatial thought resembles a graphic map is a separate empirical question, and the next section asks what neuroscience actually supports.

2. What the brain does with space

Two findings anchor the biological side and neither of them says what the popular phrase cognitive map is usually taken to say.

Hippocampal place cells fire when an animal occupies a particular location. O'Keefe and Nadel proposed that the hippocampus supports an allocentric representation organised relative to the environment (O'Keefe and Nadel 1978). Here, allocentric summarises the work's nonegocentric framework; it is not presented as a literal quotation from pp. 89–90. In rats, certain cells in dorsocaudal medial entorhinal cortex were later found to activate at the vertices of a periodic triangular grid across the experimental environment (Hafting et al. 2005). Their role in a more general spatial system is an interpretation supported by, but not identical to, that firing pattern.

What these findings do not establish is that the brain builds a map in the everyday graphic sense. A classic developmental account distinguishes landmark knowledge, route knowledge organised around sequences, and survey knowledge that integrates spatial relations beyond one route (Siegel and White 1975). The proposed sequence has been influential, but it should not be converted into a universal developmental law. Route knowledge can support successful travel without being a degraded survey map, while its flexibility varies with learning and task.

The relevance to the rest of the article is direct. If human spatial competence rests substantially on sequenced, viewpoint dependent knowledge, then the survey style representation that Europeans came to call a map is not the natural externalisation of how people think about space. It is one option among several, and the others are well attested.

Where That Leaves Us

Place and grid cells are robust findings about neural activity, and they do not show that spatial thought takes graphic form. The landmark, route and survey distinction stays influential without being a universal developmental law. If sequenced, viewpoint dependent knowledge carries much of human competence, the survey style map is one externalisation among several rather than the natural one.

3. Representations that are not pictures of terrain

3.1 Wave charts

Marshallese stick charts are training and teaching artefacts associated with wave navigation. Their elements can encode relations among islands and swell patterns, including the ways islands disturb waves; different chart types do not all have the same function. They are therefore not equivalent to scaled geographic plans, but it is too broad to say that they never represent island arrangement (Genz et al. 2009; Genz 2016). At sea, navigators detect relevant patterns partly through the motion of the canoe.

The important point is not that the charts lack spatial content, but that their spatial content is inseparable from a model of ocean behaviour and navigational practice. Reading them as ordinary topographic maps loses the function for which they were taught.

3.2 Reference frames that move

Caroline Islands navigation includes a technique known as *etak*, in which progress can be conceptualised by reference islands passing through successive star bearings. The system is described in the ethnographic literature on Puluwat and in comparative work on Pacific navigation (Gladwin 1995; Lewis 1994).

The analytical point is that spatial reasoning can organise motion around different reference frames. The ethnographic description establishes the practice; it does not by itself establish that one frame is computationally optimal or that an entire European tradition uses only its opposite.

3.3 The general point

The three books of volume 2 of *The History of Cartography* examine Islamic and South Asian, East and Southeast Asian, African, American, Arctic, Australian and Pacific traditions in their own historical settings (Harley and Woodward 1992; 1994; Woodward and Lewis 1998). Their organisation supports comparison without treating one tradition as the universal template.

Where That Leaves Us

An artefact can carry spatial content while refusing the form of a scaled plan, and reading it as a topographic map discards the function it was made to serve. A wave chart is inseparable from a model of ocean behaviour, and *etak* can organise motion around a reference frame that moves. Older candidate artefacts raise a harder problem of identification.

4. The earliest candidate maps are disputed

The wall painting at Çatalhöyük is usually introduced as the oldest known map, showing a village plan beneath an erupting volcano. The reading has been challenged in detail, with the argument that the composition is better explained as a leopard skin and a geometric design than as a plan

and a mountain (Meece 2006). A later study accepted a representational reading of the upper element, arguing on geochronological grounds that it may depict an eruption, without settling the question of whether the lower element is a plan (Schmitt et al. 2014).

The methodological risk is circularity: resemblance to a modern category motivates an identification, and the identification is then cited as proof that the category is ancient. Independent contextual evidence can strengthen the inference, but resemblance alone cannot settle function.

This is not scepticism about ancient spatial representation, for which there is no shortage of unambiguous later evidence. It is scepticism about the specific move that turns a suggestive image into the first map.

Where That Leaves Us

Identifying a prehistoric image as a map from resemblance alone invites circularity: the modern category motivates the reading, and the reading is then offered as proof that the category is ancient. Independent contextual evidence can strengthen such an inference; resemblance alone cannot fix function. The doubt is narrow and does not reach ancient spatial representation generally. What follows does not depend on history.

5. Why no flat map of a sphere can be faithful

Here the argument stops being historical.

A sphere and a plane have different Gaussian curvature, and Gaussian curvature is preserved by local isometries, the Theorema Egregium (do Carmo 1976, p. 234). This article deduces from it that no open region of a sphere can be mapped isometrically onto a plane: some metric property must be distorted. The source states the sphere-plane impossibility explicitly as exercise 4 on p. 237; the demonstration developed here is the article's own reasoning.

That result converts what looks like an engineering problem into a constraint. Every flat map of a surface with nonzero Gaussian curvature, the sphere included, distorts. A projection can preserve angles, or areas, or distances along particular lines, or a compromise among them, and it cannot preserve everything. The cartographer must therefore choose which distortions to accept, while accuracy remains assessable against the map's intended purpose.

The Mercator projection is the standard illustration. On its spherical model it is conformal, and a line of constant compass bearing is straight; its scale and area inflation increase toward the poles. Monmonier documents both its navigational value and its later use in wall maps and other non-navigational settings, where the trade-off may be poorly matched to purpose (Monmonier 2004).

The general lesson is that a projection encodes a decision about what matters, and that a reader who does not know the decision will misread the map in a direction the map does not disclose.

Where That Leaves Us

Because sphere and plane differ in Gaussian curvature, no open region of one lies isometrically on the other, so every flat map of a sphere distorts something. That consequence is this article's deduction from the Theorema Egregium, not a result quoted from the cited book. What looks like an engineering limit is a constraint: projections distribute unavoidable distortion differently, and accuracy must be assessed against purpose.

6. Maps as arguments

Once distortion is unavoidable and selection is necessary, the claim that a map merely shows what is there becomes untenable. The critical cartography literature makes this its central point: maps are rhetorical artefacts whose apparent neutrality is itself an effect they produce (Harley 1989), and it has been argued that cartographic form can naturalise the interests a map serves rather than stating them (Wood 1992; Wood, Fels and Krygier 2010).

Four recurring editorial decisions help expose this selectivity.

Selection. What is on the map. Every map omits almost everything, and the omissions are not random.

Scale. What is too small to appear. Scale is a claim about what counts as a feature.

Orientation. North at the top is a convention with a history, not a property of the Earth. Maps can adopt other orientations according to purpose and tradition.

Classification. What counts as the same kind of thing, which imports a taxonomy that the map then displays as if it were terrain.

This does not make maps arbitrary or unreliable, and the critical literature is often misread as saying so. A map can be checked, corrected and used, and the geometry of section 5 is not a matter of opinion. What follows is narrower: the neutrality a map projects is a property of the genre, and evaluating a map requires knowing its purpose.

Where That Leaves Us

If distortion is unavoidable and selection necessary, a map cannot merely show what is there. Selection, scale, orientation and classification are recurring decisions through which that selectivity works, and the neutrality a map projects is an effect of the genre rather than a property of terrain. This does not make maps arbitrary, and the geometry stands apart from the critique.

7. The digital case

Online interactive mapping has made Web Mercator the dominant display projection. Battersby and colleagues document that dominance and analyse its technical advantages, cartographic limitations and cognitive implications; they do not establish one exclusive cause for its adoption (Battersby et al. 2014). Web Mercator uses spherical Mercator equations, is well suited to tiled display, and retains the severe high-latitude area inflation associated with Mercator-type world views.

The case shows that the geometric constraint in section 5 does not disappear when the medium becomes interactive. Technical architecture, interoperability, inherited standards and design choices can all shape which projection users encounter. Assigning their relative causal weight requires historical evidence beyond the projection's mathematical properties.

Where That Leaves Us

Web Mercator's dominance online shows the geometric constraint surviving the move to interactive media, carrying the same severe area inflation at high latitudes. Technical architecture, interoperability, inherited standards and design can each shape which projection a user meets, and the cited analysis isolates no exclusive cause. Assigning causal weight would need historical evidence the mathematics cannot supply.

8. What the evidence cannot settle

Whether a given artefact is a map. Without independent evidence of use, identifying a prehistoric image as a map is an inference from resemblance, and resemblance to a modern category is weak evidence about an ancient one.

What cognitive maps are. Place cells and grid cells are robust findings about neural activity. The step from that to a claim about the format of human spatial thought is an interpretation, and the route versus survey distinction suggests the format varies by task and by person.

Whether non cartographic systems are maps. Whether a wave chart or a sung route is a map depends on the definition adopted, and this article does not pretend that its own stipulation settles a question that is partly terminological.

Intent behind selection. That maps can encode interests is argued in the critical literature. That a particular map encodes a particular intent requires evidence about its makers, and the critical literature is stronger on the general claim than on individual attributions.

Where That Leaves Us

Four questions resist the evidence assembled here: whether a given artefact was used as a map, what format spatial thought takes, whether non cartographic systems fall under the term, and what intent a particular map encodes. One is partly terminological rather than empirical, and this article's stipulated vocabulary does not settle it. The closing synthesis states what does follow.

9. Conclusion

Space can be known without a graphic artefact, represented without a scaled picture of terrain, and projected from a sphere onto a plane only by accepting geometric trade-offs. A cartographic map is one powerful family of solutions, not the universal form of spatial knowledge.

The recurring error is to treat one solution as the general case and everything else as an approximation to it. A wave model, a star sequence, a route description and a projected grid answer different questions about space. A conformal world map accepts area distortion in order to preserve local angles; that trade-off is precise enough without calling the map a lie.

Where That Leaves Us

Knowing space needs no graphic artefact and representing it needs no scaled picture, but a sphere maps onto a plane only with geometric trade offs. A cartographic map is therefore one powerful family of solutions, not the general form of spatial knowledge. The recurring error takes that family as the standard and reads everything else as an approximation to it, when the alternatives answer different questions.

Boundary note

With KNO-005, Oral Language and Transmission. Spatial knowledge held and transmitted orally, including route instruction and sung routes, is treated in KNO-005 as an instance of constrained transmission. This article takes up the representational question that KNO-005 explicitly deferred: what an external artefact does when it stands for spatial relations. Transmission mechanisms, fidelity and memory are not re examined here.

With KNO-007, Calendars and Time Measurement. The representation of time, the division of cycles and the instruments of timekeeping belong to KNO-007. Where this article touches time, in navigation by star sequence and in dead reckoning, it does so only as an element of spatial method. The general question of how a periodic process becomes a measure is KNO-007's.

With KNO-004 and KNO-013. Notation and the graphic encoding of language belong to KNO-004. The wider question of what a model is and how models relate to reality is KNO-013's, and this article does not anticipate it: it treats projection as a geometric constraint, not as a case study in modelling.

What We Know, and How

- Grid cells are an established finding from single-unit recording in rats (Hafting et al. 2005). O'Keefe and Nadel proposed that the hippocampus supports an allocentric representation (O'Keefe and Nadel 1978).
- Local isometries preserve Gaussian curvature, the Theorema Egregium (do Carmo 1976, p. 234). From it this article deduces that no open region of a sphere maps isometrically onto a plane.
- Mercator's navigational value and its later non-navigational use are both documented (Monmonier 2004).
- Web Mercator's dominance in online mapping, its technical advantages and its limitations are documented, without one exclusive cause of adoption being established (Battersby et al. 2014).
- Comparative volumes cover Islamic, South Asian, East and Southeast Asian, African, American, Arctic, Australian and Pacific traditions in their own settings (Harley and Woodward 1992; 1994; Woodward and Lewis 1998).

What We Still Don't Know

Whether a given prehistoric artefact was made or used as a map remains open, because resemblance to a modern category is weak evidence about an ancient one. What format human spatial thought takes is not settled by the neural findings, and the route versus survey distinction suggests it varies by task and person. Whether a wave chart or a sung route counts as a map is partly terminological. And attributing a particular intent to a particular map needs evidence about its makers that the general argument does not supply.

What Could Change Our Minds

Independent contextual evidence of use, rather than resemblance, could settle several disputed identifications in either direction. Behavioural or neural work showing that survey style representation is the default format of human spatial thought, rather than one format among several, would weaken the article's claim that the survey style map is not the natural externalisation. Historical evidence isolating why Web Mercator was adopted would convert a list of plausible factors into a causal account. The geometric constraint of section 5 is not open to this kind of revision.

If You Remember Only One Thing

No flat map of a sphere preserves every metric property, so the question to ask of one is not whether it distorts but which distortions it accepts.

Related Articles

- KNO-004 · From Symbols to Writing
- KNO-005 · Oral Language and Transmission
- KNO-007 · Calendars and Time Measurement
- KNO-013 · Models, Maps and Reality

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