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Experiencing mapping and maps: a human cognition perspective

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ABSTRACT

This paper addresses further possibilities of enhancing our understanding of why maps are successful, exploring additional associated topics in cartographic research, primarily concentrating on human cognitive activities, processes, and behaviours. It starts by revisiting two previous papers by the authors, reflecting on the augmentation and integration of adopted paradigms of cartographic theory, and then presenting some disparate examples of such enhancements, under the over-riding framework of ‘context’. The paper investigates several ideas associated with human cognition and its impact on, and exposure to, maps and mapping: the nature of a human ‘mapping impulse’; the origin of mapping as a human activity; the neuro-cognitive aspects of spatial processes in the human brain; the form and role of internal cognitive maps. We then address the externalization of human internal cognition, detailing the prime example of such creativity, the sketch map. Finally, the paper reflects on the feedback-type role of external maps in internally (re-)shaping the human mind and influencing human behaviour. The map is a fundamental product, but it is uncertain whether its creation is impulsive or derived from innate human abilities. It is clear, however, that its nature and operation match, and also shape, certain neurological and cognitive characteristics of humans.

Cet article étudie les possibilités d’améliorer notre compréhension des raisons pour lesquelles les cartes sont des succès, en explorant des sujets connexes dans la recherche cartographique et en se concentrant principalement sur les activités, les processus et les comportements cognitifs humains. L’article commence par résumer deux papiers écrits par les auteurs en réfléchissant à l’augmentation et à l’intégration de paradigmes utilisés dans la théorie cartographique, puis en présentant quelques exemples de ces améliorations, dans le cadre général du « contexte ». L’article questionne plusieurs idées liées à la cognition humaine et son impact sur les cartes et la cartographie ainsi que l’exposition de la cognition aux cartes et à la cartographie : la nature de l’impulsion cartographique humaine,

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l'origine de la cartographie en temps qu'activité humaine, les aspects neurocognitifs des processus spatiaux dans le cerveau humain, la forme et le rôle des cartes cognitives internes. Puis nous regardons l'externalisation de la cognition interne humaine en détaillant l'exemple parfait de cette créativité : le croquis cartographique. Enfin l'article examine le rôle de rétroaction des cartes externes dans la remodelage interne du cerveau humain et leurs influences sur le comportement humain. La carte est un produit fondamental mais on ne sait pas si sa création est impulsive ou si elle découle de capacités humaines innées. Cependant il est clair que sa nature et son fonctionnement correspondent et façonnent certaines caractéristiques neurologiques et cognitives des êtres humains.

Introduction and aim

This paper is the third in a sequence which attempts to understand why mapping, as an activity, and maps, as artefacts (however presented), are core to the human experience. A range of varying subsequent questions can be identified, which have exercised those investigators and philosophers who seek to explain such endeavours and objects. Why have maps been developed by human societies throughout recorded history (and possibly before); what are the advantages of maps over other human inventions for a large number of human tasks, actions and interests; what determines the value of a map when it is used by humans; what is the link between the physical map artefacts and the internal human behaviours which are prompted by exposure to maps; are there inherent human perceptual and cognitive capabilities which drive and optimise mapping activities; what contextual factors are most important to define and describe when examining and understanding the human interaction with maps? These questions address the fundamental relationship between human cognition and mapping and this paper therefore examines how maps shape, and reflect, human cognition; and suggests that the development of cartographic theory requires an enhanced understanding of the role of human cognitive behaviour.

The persistent aim of this investigation has involved addressing the evident success of maps, and the focus has been on the pragmatic question, why is a map effective and persuasive? In the context of a critical review of cartography and mapping, Crampton (2009) considered that 'these wretched unreconstructed things [maps] appear to work so unreasonably well' (p. 6), but the answer to why that should be the case is complex and unclear.

In addressing further elements in our study, we build on our conclusions about the utility of certain paradigms guiding the study of cartography in the first paper in this series (Fairbairn et al., 2021), and our extensions to the models as considered in a subsequent article (Fairbairn et al., 2023), which embrace the wide notion of 'context', driving all human engagement with maps and mapping. We start, therefore, with a re-iteration of our previous comments, and explore further aspects of the 'context of cartography' by considering some of the foundational ideas about the human drive to create maps and develop techniques of mapping, and about human engagement with maps, which may profitably be considered in elucidating reasons for maps' success.

Background

In Fairbairn et al. (2021) we started to address the role and efficacy of successive paradigms applied to the study of cartography as a discipline. Whilst acknowledging many problems inherent in the ‘cartographic communication’ paradigm, we highlighted some possible enhancements to this approach in particular, to incorporate the nature of contemporary maps, their functions and the integral and essential role of the human being throughout the activity of mapping.

The paradigms influencing cartographic research form a variety of approaches to cartographic theory. Distinctly different frameworks have been presented, notably over the most recent 70 years of the long history of cartography, each having merit. Fairbairn et al. (2021) suggested that some form of enhancement and integration of the varying approaches of each paradigm might prove useful. Woodward and Lewis (1998) note that ‘different eyes’ have viewed maps in different ways, depending ‘not only on the background and predilections of individual researchers, but also on the differing roles and meanings of maps in various cultures’ (p. 1).

Woodward and Lewis (Woodward & Lewis, 1998) go on to suggest that a map can be viewed as ‘cognitive system ... as material culture ... and as social construction’; and indeed further distinct interpretations of maps and their study can be identified, including maps as creative (and also artistic) objects, as information sources, as crafted artefacts, as communication devices for representing spatial relationships, as symbolic representations, and as interactive discursive tools. Woodward and Lewis argue that *all* approaches which address such extent and diversity are necessary to fully understand how maps function in society.

The development of specific paradigms, and their engagement in investigating cartography as human endeavour, has resulted in (and could be the result of) a fragmented and incomplete understanding of maps and mapping: the ‘diversification of cartographic thought’ as presented by Hanchard (2024), encompasses the adoption, through time, of map communication models, cognitive-semiotic approaches, positivist analytical cartography, cultural approaches, social-constructivism and others. The character of these paradigms is detailed in Azocar and Buchroithner (2013), and our approach to the specific value of several of these is presented in Fairbairn et al. (2021).

The nature of paradigms, as interpreted by Kuhn (1962), is that they do shift, are superseded, and can be discarded completely. Within cartography, attempts to integrate and reconcile different paradigms and approaches are limited. The work of Desai (2023) is notable, as a focussed attempt to understand the perceived incompatibilities of a positivist approach to cartography (for example, a communication paradigm) and a deconstructionist approach (for example, a critical cartography paradigm). His exercise used reconciliation theory and an intermediary hermeneutics-based epistemology of cartography to identify common aspects of maps and mapping derived from the differing paradigms.

The following paper (Fairbairn et al., 2023) took a somewhat different approach to this attempt to confirm a universal epistemology of cartography, by more pragmatically identifying some elements of human behaviour, human engagement with the map, and map possibilities which could *enhance* the paradigm of cartography. Whilst it took the map communication paradigm as the foundation to build this revised structure for our enquiry into cartographic endeavour, some of these enhancements are sourced in

alternative paradigms. Our view is that the communication paradigm, especially in its graphical presentation, can be (and indeed has been) modified and extended in an effective manner. We showed that several disparate components could be incorporated anew into the communication-oriented framework of cartographic study, and this paper enlarges the scope of those paradigm extensions, particularly to cover distinctly human cognitive effects.

Modification of the cartographic communication paradigm

The ‘cartographic communication’ paradigm as originally proposed regarded the map as an information channel, defining it in terms of a communication function. In addition to any information processing function which the map triggers, we must however also recognise the potential added value of the map, the role of the map as a catalyst for human behaviour, and the functions which the map affords. Following Freitag (1993), Torok (1993) and others we presented some additional functions – a cognitive function, a decision-support function, a social function, a representation function – which we believe characterise the map. Our investigation, into why maps have been so successful and core to human society over such a long period, can benefit from a deeper consideration of their functions.

Fairbairn et al. (2023), therefore, addressed the functions and use of maps, speculated on the added-value which maps bring to human activity, and proposed additional factors integral to the success of the map, and which are valuable to consider. We initially considered the value (not explicitly addressed in the initial cartographic communication paradigm) of the affordances of maps – ‘action possibilities’ for the human – which we feel pervade the entire cartographic endeavour; then, associated with affordances, we moved on to address the nature, possibilities and limitations of the media through which maps are engaged with; a natural further issue was then to try to understand the strengths, weaknesses and centrality of human perceptual and cognitive abilities when engaged with mapping and maps.

Finally (Fairbairn et al., 2023), we considered the pragmatics of the human-map interaction. In investigating these potential adjustments and additions to a specific theory and model of cartography, the wider, overall role of ‘context’ was also introduced as a central driver for the mapping process. In fact, ‘context’ covers an extraordinarily wide range of factors, issues, ideas and processes which go to make up the milieu within which mapping is undertaken and maps are engaged with.

Expanding contextual aspects with human engagement

This paper concentrates further on the human aspects, notably the relationship between human beings and the creative act of mapping. These aspects are presented here as being additional central elements, like context mentioned above, contributing to a general theory of cartography. The popular characterization of a map artefact as being an external manifestation of an internal human cognitive map is a useful starting point for any investigation of the human issues associated with engagement with maps – the initiation and creation of maps, the properties and qualities of maps, and the applications, use and societal impact of maps.

Thus, this paper will address a number of wide-ranging ideas: the possibility of an inherent human impulse to map; the characteristics of the cognitive system that impacts on the nature of maps produced by human beings; the way in which artefacts sourced in human cognition and creativity are presented; the actualization of maps as externalizations of the cognitive system; and then the prime example of externalization – the ‘sketch map’. We conclude by addressing a ‘reverse process’, the ‘internalization’ of maps into the human cognitive system – notably the ways in which maps influence human spatial knowledge and behaviour.

Maps and the ‘mapping impulse’

We re-iterate our definition of the map presented in Fairbairn et al. (2021) as a perceivable (although not always tangible), designed, enabling interface that represents and communicates spatial entities and relations. Maps are therefore human constructs, and they are sourced from cognitive stimuli which may be conscious and deliberate, or innate and impulsive. The nature of the map is not standardized, and although we use the word ‘artefact’ to refer to a map in many places throughout this paper, we do not intend to imply that it is required to be a physical or visible ‘object’. However, we feel that it is important to define a ‘thing’ called a ‘map’ to distinguish it from those things which are ‘not maps’.

We follow Denil (2024) who takes exception to the view that, because maps are so varied, there is no sense in trying to define them in a universal fashion. Denil does accept that each map is unique, and indeed that a map only becomes a map when an individual human engages with it, but in order to investigate the activity of mapping, the relationship between humans and maps, and the role of maps in human society, we do need to identify the nature of maps as ‘things’ separate from the human body (whilst also acknowledging the use of the term ‘map’ as a mental construct, and in many other contexts and human activities).

That human beings have a capacity for mapping (the activity of creating maps) is not particularly contentious, but whether there is an inherent innateness or impulse to create and engage with maps is more debateable: does the human impulse exist; how is it manifest; how much of it is shared with other sentient species; have maps developed from the constraints of the human sensory systems; is there a separation between considering maps as learned, and maps as internal cognitive structures?

In terms of our definition, it is clear that no other species on the planet produces maps, although it is equally clear that a wide variety of species (perhaps most species) do have an inborn appreciation of spatial structures in their environment: innate navigational skill, for example, is demonstrated in migratory birds, and every mobile species utilizes spatial information. Humans may not have such innate abilities to navigate, but they are better than other species at ‘externalizing’. From a human perspective, there may well be evolutionary advantages of mapping and map use, and an impulse to create and use maps may have developed for survival purposes. These maps may match how people think and behave, although there are obviously significant differences in individual humans’ physiological characteristics, their abilities to externalize, and their mapping ability.

For example, several contemporary human societies, such as Botswanan bush tribes, Bedouin desert groups, Australian aborigines, and Amazonian rainforest peoples, which all have a symbiotic relationship with the natural environment, exist without maps in a

form with which most other contemporary societies can identify (Fernandez-Velasco & Spiers, 2024). Some such groups have been able to engage with maps produced by external researchers and identify and record their own spatial behaviour (e.g. the Quichua community in Amazonian Ecuador reported by Siren et al., 2004), but others have little understanding of two-dimensional graphic map images (e.g. indigenous Kucapungane hunters in Taiwan researched by Sasala et al., 2019), or demonstrate a complete absence of map products (e.g. in the nomadic and hunting culture of the Raute people in Nepal, reported by Reinhard, 1974).

There are examples of map artefacts created by other similar groups, including Pacific islanders and Inuit communities, which are regarded as manifestations of some human instinct: in the context of research into Arctic cultures, Cogos et al. (2017) suggest that 'mapping, like speaking, is a universal process, shared by all societies', whilst they also suggest that 'mapmaking, like writing, is a specific expression of mapping, characteristic of societies with a writing culture' (p. 43).

From a more philosophical perspective, Said (1994) has identified a 'cartographic impulse' as meeting the human need to 'reclaim, rename, and reinhabit the land' (p. 272), suggesting that mapping has been practiced, not just as an impulse for survival, but in order to demonstrate power over the environment. In addition to that control over the physical environment, maps afford social power over human beings, and it may well be that there is a sub-conscious human impulse to exert such control through the medium of maps created extemporaneously. Alpers (1983) has indicated that mapping can be more prosaically characterised as 'an impulse to record or describe the land in pictures, (an interest) shared ... by surveyors, artists, printers, and the general public' (p. 147).

Our view, supported by studies described in the remainder of this paper, is that there has been (and may still be) some form of limited inherent mapping impulse in human beings, capable of explaining how maps are created as externalized, perceived, designed 'things'. It may be that there has been, and still is, unexplained variability between human groups and societies in their propensity to create maps; it may be that different, isolated peoples independently adopted practices which could be interpreted as 'mapping' and these methods somehow later merged; or one might speculate that the transformation of human cognition into a map product took place only once, through a mutant human, whose instinct to order their internal spatial awareness in a more durable form, or to communicate their internal knowledge of spatial relationships to others, resulted in a map.

It is equally plausible to suggest that this one 'ur-map' was copied by other human beings (the German prefix 'ur' conveys the meaning of 'original', 'primitive', 'ancient' or 'fundamental'), with the result that every map created since then has been guided much more by exposure to previously existing maps, than by reference to any 'impulse'. In order for this chain of events to happen, we must examine the nature of the internal cognitive system, its links to the physiological make-up of the brain, its impact on human behaviour, and the way in which it could be manifest as a 'map' artefact.

Human cognition and mapping

Such speculation on the innateness of mapping, and the nature of spatial knowledge and behaviour, addresses perhaps more primal neuro-cognitive aspects of human

consciousness: does the brain itself operate in a ‘map-like’ way; has the development of the human brain paralleled the development of a mapping ability, or have maps (been) developed as a response to limitations of the human sensory system; are maps successful because they impact on cognition and affect the brain, helping humans to deal with space better?

In contrast to stimulus-response and behavioural approaches to the understanding of human learning and actions, cognitive psychology views internal mental states as explanations for observable behaviour. These two contested views have been played out over several decades in the appropriate (for practical studies of human psychology) test arena of spatial-learning (Holland, 2008), as researchers examined whether learning in spatial tasks was more ‘map-like’ or more ‘habit-like’ i.e. whether there was an internal cognitive map created and made available to understand space, or whether environmental perception, interaction and experience were the main drivers for understanding. Early behavioural psychologists (Spence, 1950) dismissed the former, claiming that so-called ‘brain fields’ and their supposed properties were inferred from introspection, rather than physiological investigation.

The hippocampus

In the latter half of the twentieth century, such physiological experiments *were* carried out, most notably by O’Keefe (O’Keefe & Nadel, 1978), whose studies of the human brain and its workings revealed the important role of the hippocampus (*Figure 1*) in developing spatial aptitude and behaviour. O’Keefe’s research initially examined navigation as a fundamental human behaviour and he concluded that by integrating spatial navigation with episodic memory, the hippocampus enables humans to link locations with experiences. This ability to process and recall spatial relationships was pivotal in transforming what were called ‘mental maps’ into tangible forms, shaping how humans share and interpret spatial knowledge.

Further investigation revealed the existence of ‘place cells’ in that part of the brain which may form the basis for quantitative spatio-temporal representation of places, routes, and associated experiences during behaviour and in memory. These cells developed throughout human evolutionary history, largely attributable to a combination of genetic mutations, natural selection, and environmental pressures. They include grid cells in the entorhinal cortex, which provide a hexagonal coordinate system for space; boundary cells that respond to edges and linear features (including routes) in the environment; and head direction cells that signal the orientation of the head.

Physiological investigations of part of the brain have resulted in an intrinsic link to associated neuro-scientific research on internal cognitive maps. Jacobs and Schenk (2003) also subdivide the hippocampus by proposing that the central dentate gyrus section constructs a ‘bearing map’ from some of the directional cells occurring there, whilst the ‘hippocampus proper’ is able to construct a ‘sketch map’ (i.e. for Jacobs and Schenk, an internal image-based cognitive map) from positional cues triggered by the grid and boundary cells (*Figure 1*). It is only when these two are integrated that a usable cognitive map can be accessed, and variability in the combination can explain individual differences in spatial learning.

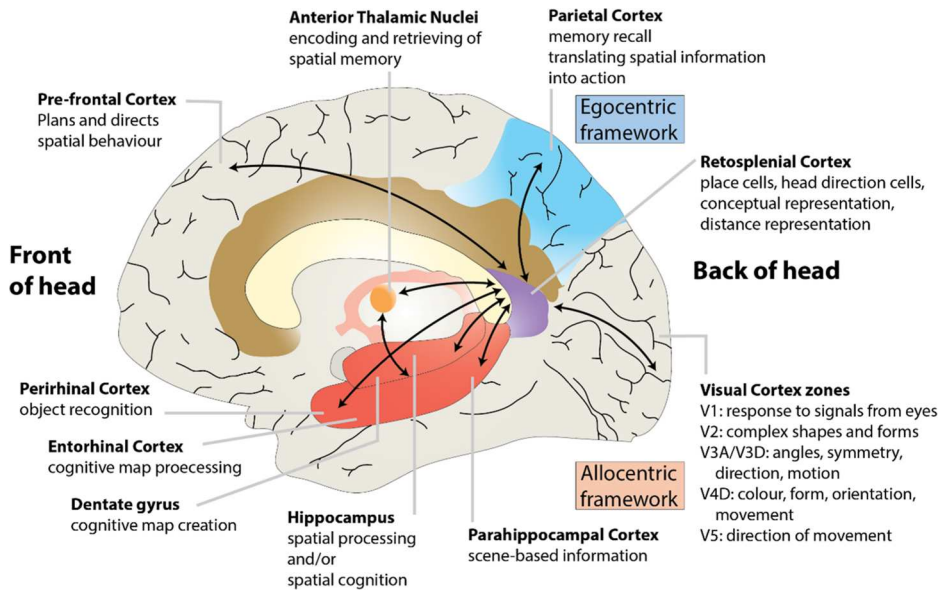


Figure 1. The complex nature of the sub-regions of the brain, and the spatial tasks and behaviour associated with them. The visual sensory flows among these regions, shown by black arrows, can be distinguished as either dorsal pathways handling egocentric information on spatial context, location and motion, or ventral pathways handling allocentric object-based information. The brain's experience and coding of space from a personal perspective is actioned in the blue egocentric cortex, whilst processing of spatial information from an external or scene perspective is connected with the red geocentric-enabled parts of the brain (from Tung & Chang, 2024; Vann et al., 2009).

Internal cognitive maps

Human spatial behaviour, including engagement with mapping and with maps, is enabled by cognition. Kitchin and Blades (2002) consider the origin of 'cognitive maps', their nature, structure, content, completeness, inaccuracy/bias, frames of reference, hierarchy, schema, form (coding/image) and their variability (by age, gender, disability (including visual impairment)). Their development can be traced to early human behaviour. Initially the approach is to examine the way in which a humanoid relates to the environment and their position in it. The primary urge is survival, and the means of achieving this rely on acting in space to seek food, create shelter and avoid predators.

Behaviour and the 'internal map'

The location of a food source could be determined by using known directions, landmarks and cues i.e. using topological knowledge, from an *egocentric* perspective. Alternatively, it could be that human behaviour is driven by a *geocentric* coding, whereby the perception of the environment reflects a Euclidean cognition of space, somewhat similar to a map (Jang et al., 2019). Several experiments rooted in classical Piagetian pedagogy have been undertaken which suggest that human children use egocentric methods, later learning about geocentric coding as they develop into explorers of their surrounding environment (Inhelder, 1967). However, the work of Haun et al. (2011) is somewhat sceptical of

the utility of testing very young children and suggest that the default human approach is to use a variety of differing types of geocentric spatial coding, influenced by the impact of culture, language, and ecological and social conditions.

The way in which different codings are created and used within the human mind is not confirmed. It may be that the use of egocentric or geocentric approaches can be triggered by the spatial task undertaken, or by the circumstances within which some definitive spatial behaviour is required; it may be that a hybridization of the two can be applied within the human mind. However, it is generally acknowledged that human spatial behaviours, including spatial learning, spatial memory and navigation, lead to the initiation of ‘cognitive maps’, which are some form of internal ‘representation’ or ‘coding’ of the physical environment. These ‘maps’ allow humans to navigate and remember locations even in the absence of external tools. Experimental work in the past 70 years has explored and confirmed the vital role of the hippocampus area of the brain in managing such cognitive maps.

The form of a cognitive map

The cognitive map is central to understanding how the human being initiates and manages the mapping process, and how maps are created, but there is a lack of consensus on its form, its manifestation and its utility. Following the physiological investigation of the hippocampus and its connection to spatial behaviour, it is recognized that the cognitive map is a spatial encoding, which is an internal representation of our environment (Epstein et al., 2017). These maps are generated by integrating different kinds of perceptual information, including visual, auditory, and tactile, to create and store a spatial map of one’s environment. If one knows where one is, it is possible to create a vector within a cognitive map, allowing one to navigate through an environment. Blind people have particularly well-developed cognitive maps and can navigate complex environments like cities by merely relying on their cane and their hearing and smell (Heersmink, 2021).

The nature of the cognitive map is difficult to identify: some cognitive psychologists would claim that the cognitive map is an ‘image’ of a conventional external map – it has picture quality, a one-to-one relationship with reality and can be interrogated spatially (Kosslyn et al., 1995). Such a map should be coded in a geocentric manner, such that it could be considered (‘envisioned’) as invariant, fixed in terms of perspective, and yielding replicable answers when queried – consulted and queried much like a map artefact. Such mental imagery is fundamentally spatial (analogue), with mental images represented in the brain in a quasi-pictorial or spatial format, similar to actual visual perception. Mental scanning experiments (e.g. Kosslyn et al., 1978) involved participants being asked to imagine a map and mentally scan between two points. The time taken to scan was proportional to the distance between them, suggesting a spatial representation.

Kosslyn’s work gained support through neuro-imaging studies showing that visual mental imagery activates the same brain regions involved in actual vision. Neuro-imaging studies show that visual mental imagery activates parts of the visual cortex, particularly V1 (primary visual cortex), which processes spatial and visual details. The work of Kosslyn and that from neuro-imaging suggests that imagery retains spatial properties similar to perception. Behavioural experiments (e.g. mental rotation, image scanning) support the idea that the mental imagery preserves spatial structure, meaning it behaves like a ‘picture in the mind’. The analogue component of the cognitive map is

further suggested by studies on brain-damaged patients which show that lesions in visual processing areas impair mental imagery.

By contrast, the work of another cognitive psychologist, Zenon Pylyshyn, has supported the view that the internal cognitive map is a more unsystematic series of sensory stimuli and responses to locations, landmarks and events, which needs significant internal processing before it can be interrogated, queried or externalized. In this view, mental imagery does not require an analogue, spatial representation, but instead operates on a propositional (symbolic) level. Pylyshyn emphasized computational and symbolic processing, suggesting that imagery relies on abstract descriptions rather than a pictorial format. He introduced the ‘tacit knowledge’ hypothesis, which argues that people unconsciously use real-world knowledge to guide their responses in mental imagery tasks.

Cognitive biases and task demands can influence the type of mental imagery experiments which Kosslyn and his followers undertook. Pylyshyn (1981) suggests that the effects seen in mental scanning experiments can be explained by cognitive strategies rather than an internal image. For example, people may take longer to scan across a mental image because they assume they should, not because a ‘scaled’, picture-like representation exists in their mind. Some of Kosslyn’s results could be explained by expectation effects (i.e. participants intuitively responding as if images were spatial, rather than actually experiencing them that way).

Abstract and conceptual thought often doesn’t involve imagery. For example, people can reason about meaningful symbols (e.g. language, logic, numbers) without requiring visual representations. Blind individuals can perform certain mental imagery tasks using non-visual representations, suggesting that an underlying propositional structure might exist. Cole et al. (2022) claim that Kosslyn’s experimental results are not convincing and that ‘attempting to give mental imagery a causal status in a cognitive process is unwarranted.’

Resolving the nature of the cognitive map

Kuipers (1982) suggested that what he termed the ‘map in the head’ metaphor, inspired by Kosslyn and others in cognitive psychology and by Tobler in direct cartographic terms (1976), was acknowledged as the ‘most persuasive and useful image for knowledge of large-scale space’ (by which he meant ‘extensive’ space). But, in examining sketch map manifestations of the image-like ‘map in the head’, empirical results led him to replace this metaphor with a ‘more complex and sophisticated metaphor including separate metrical and topological components’, whilst further experimentation suggested that the internal cognitive map may be based on ‘computational structures that occasionally reveal their non-map-like properties’.

In fact, it appears that a hybrid approach to the nature of the internal cognitive map is now most readily accepted: the brain may use an analogue image when visualizing real world scenes, but use more symbolic approaches when handling more abstract thoughts. Some spatial tasks rely on analogue representations, whilst others use abstract internal structures. Tversky (2005) argues that internal ‘imagery’ serves different functional purposes depending on the cognitive task, with both spatial (analogue) and propositional (symbolic) representations being used to differing extents in differing scenarios.

Whilst examining some spatial tasks, Istomin and Dwyer (2009) tested wayfinding among European Arctic Komi and Nenets tribes of reindeer herders, and found reliance on what they call 'mental maps', but also that the herders memorize vistas while navigating. Further, an individual's navigation method, ability, and the form of the 'mental map' is likely to depend on a situation as well as on factors such as age, sex, familiarity with the environment, and life history. They identified differences in spatial thinking between different people and peoples, but concluded that both cognitive maps and route knowledge, vista recognition and landmark memory (together termed 'practical mastery') are integral to spatial cognition. Weisberg and Newcombe (2018) concur that 'some people derive flexible map-like representations from information acquired during navigation, whereas others store much less accurate information': individuals differ in their level of spatial skills and abilities in retaining working spatial memory.

It is clear that a hybrid approach to the nature of the cognitive map and its use is required. Our view is to suggest that the internal cognitive map is not really a 'picture in the head', but more a generalized, symbolized representation in the brain which has image-like qualities. In some ways it is 'map-like', to the extent it is viable to infer that map artefacts are successful because they hold spatial knowledge and promote spatial understanding as externalizations of an equivalent internal cognition. But there is inherent variability among humans' cognitive maps and differing roles for spatial memories dependent on the task being performed and behaviour being practiced, and the actual tasks of mapping and map creation reflect that variability. Even if we can derive a common picture of the hybrid nature of the internal cognitive system when engaging with spatial behaviour, it may be impossible to generalize a common working model of the cognitive map.

Further reflections on the hippocampus

Those relative differences in cognitive maps, and the separate existence and use of internal symbolic patterns, particularly for spontaneous spatial behavioural tasks such as wayfinding, reflect some of the recent, even more precise, examination of the hippocampus. For example, Epstein et al. (2017) suggest that the human hippocampus and entorhinal cortex support spatial codes resembling maps; posterior brain regions, such as the parahippocampal and retrosplenial cortices, provide essential inputs, anchoring cognitive maps to stable environmental landmarks; and hippocampal and entorhinal spatial codes interact with frontal lobe mechanisms to plan navigation routes.

However, there are still gaps in understanding the role of the various subdivisions of the hippocampus (*Figure 1*), its link to spatial cognition, the way in which place cells help develop cognitive maps, the role of spatial memory, and the manner in which spatial behaviour tasks are carried out: 'the field has reached an impasse between models suggesting that the hippocampus is fundamentally involved in spatial processing and models suggesting that the hippocampus automatically encodes all dimensions of experience in the service of memory' (Ekstrom & Ranganath, 2018, p. 680).

Human creativity, externalization and cognitive artefacts

Our definition of a map implies that they are tangible i.e. they are perceivable 'things', which are different to other 'things' which are not maps. Contemporary maps can, of

course, be regarded as virtual, as services, and as performances, as much as they can be regarded as artefacts. Their 'medium' is one aspect of the context within which mapping is undertaken and maps are created. Each of this variety of perceived and designed 'things' are manifestations of the human instinct to 'externalise'.

Just as there is uncertainty in the way in which the human cognitive system, primarily through the hippocampus, experiences, represents and directs behaviour in space, so there is also a lack of clarity in how that system is used to create externalizations. What is the 'spark' which allows for a 'translation' of the internal understanding of space and the environment into a representation or interpretation, which could be regarded as a map? At the most basic level, this question addresses the whole process of human creativity, as other 'externalizations' such as written works, created images, documents, and perceivable outputs from performances (each delivered using structures such as language, music, and art) can be examined in a similar way – 'externalization' as a concept can be applied for all human creative endeavour, not just mapping.

Farzanfar et al. (2022) introduce the concept of an overall internal knowledge structure as a 'schema', compiled from a collection of cognitive maps, themselves varying from a precise 'highly detailed map to a (much more general) gist'. Sometimes schemas include predictions of what is in the environment, generalizable and abstracted representations, and spatial memories – all comparatively indefinable ideas which they characterize as forming a 'gist'. In attempting to identify the link between the physical elements of the brain and the cognitive maps and spatial behaviours exhibited by humans, Farzanfar et al. go further by speculating of the fine structure of the brain and the possibility of identifying more precise task-specific zones, including the task of externalizing. A cognitive psychology approach to externalizations is to view them as supports for human activity: the types of externalizations previously mentioned are developed to assist in 'cognitive offloading' – whereby the burden of holding important information or knowledge in internal memory is lessened by having such material held in accessible, external, media.

The link between the internal cognitive system and the externalized artefact is articulated by the term 'cognitive artefact', first introduced by Norman (1991) to define human-created, intentionally-designed things that assist or enhance cognitive abilities. For Levinson (2024), the power of human thinking is based on its externalizations, which allow the effective handling of ideas represented in things, devices, or external codes. He considers writing as a prime example of a cognitive artefact, allowing the externalization of thought, and the freezing of an internal cognitive-linguistic signal for subsequent use. In fact, Levinson suggests that writing makes new modes of cognition available: the signal can be inspected, reordered, dissected and quantified, and edited – it enables 'meta-cognition'. He held that these cognitive effects were revolutionary, and that writing therefore 'changes the type of data an individual is dealing with, and it changes the repertoire of programs available for treating this data' (Levinson, quoting Goody, 1977).

Following Heersmink (2021), who places maps at the head of his comprehensive taxonomy listing of iconic cognitive artefacts, we suggest that mapping can be directly equated to writing in developing new modes of cognition, and revealing varying possibilities (affordances) for the map itself: e.g. problem-solving, task assistance, recording and archival tasks etc. MacEachren and Ganter (1990) suggest that 'visual externalizations allow individuals to offload cognitive processing onto information graphics, using

perceptual (seeing-that), cognitive (reasoning-why), and motor (interacting-with) processes to re-integrate the external knowledge into existing internal schema.'

A key affordance of an externalized map is the possibility of transferring knowledge from one human internal cognitive system to another – the map function which is central to the communication paradigm we have explored earlier. Further, externalization involves the instinctive formalization of the internal cognitive system into an object which can be co-engaged with and shared. But, due to variable human engagements and environmental experiences, each person's internal cognitive system is different, so all externalized maps will differ ... and different contexts will also have an effect on the nature of the externalized map. Despite such variability, however, it is clear that these (and most other) cognitive artefacts can be commonly shared, understood, modified and used within a group of different humans (or with other individual), for different purposes, in different forms, and in different scenarios.

Maps as externalizations

Externalization of the cognitive map does not need to be directly image- or graphics-based. Australian aboriginal songlines or dreaming tracks, for example, are songs that weave together spatial awareness, mythology, and cultural knowledge. The lyrics describe landmarks, waterholes, and other important spatial entities, and their relationships (Peterson, 2006). Whilst intangible, a property they share with the vast majority of contemporary (digital) maps, such externalizations do fit our definition of a map as being a 'perceivable' device. Indeed, songlines can act as an enabling interface to spatial knowledge, and they may be a prime example of how an internal cognitive map can be effectively externalized. Other non-graphical externalizations of a cognitive map can include a set of verbal directions for navigation, whilst a range of methods for graphically constructing tactile maps, including using thin embossed magnetic strips on a panel, have been implemented and tested with visually blind participants (Miao et al., 2017).

It should be noted that there are spatial behaviours and spatial problem-solving activities which do not rely on externalizations. Because externalization is a conscious action resulting from cognitive offloading, there is a distinct choice involved: 'humans perform a meta-cognitive evaluation on whether to use internal (e.g. rely on the internal cognitive map) or external resources (e.g. create a map or other artefact) for a task, select a strategy, and subsequently apply it' (Skulmowski, 2023).

As might be expected from the study of varied human experiences, abilities and applications, a full mechanistic understanding of why, when and how externalizations are created is not clear. The link to the internal cognitive map is fundamental, yet the act of creation of the externalization is not understood. Further, understanding how, once created, graphical externalizations actually work is not complete. There is a recognition that they are different externalizations to language, and that the formal methodologies which have been developed for analysing text are not applicable to the syntactics and semantics of graphical artefacts. There are interesting information-theoretic approaches, calculating the entropy of street networks or space syntax measures, for example, or more specific studies quantifying encountered wave patterns or the sinuosity of foraging routes for analysing externalization-based spatial behaviour in environments (Fernandez-Velasco & Spiers, 2024).

However, attempts to develop new methods of analysing the wide variety of graphical artefacts have not been successful, primarily because of their unjustified (in experimental terms) reliance on the resemblance of a supposed internal image-map (as proposed by Kosslyn) to the graphical manifestation of an externalized artefact (Scaife & Rogers, 1996). Scaife and Rogers suggest that making such an equivalence is purely intuitive, and that a new approach to the development of, and research into, externalizations from internal structures *and* a thorough examination of the reverse process, the influence of the externalizations on the human cognitive system, is necessary. We will consider, later, the impact of that reverse process, as we believe that there is a significant influence exerted by the map, as an externalized cognitive artefact, on the human internal cognitive system, on the physiology of the hippocampus, on human spatial understanding, on human behaviour, and on the process of mapping (the creation of map artefacts) itself.

An example of externalization: the sketch map

Empirical investigation of the human cognitive system, and notably its spatial nature, can be undertaken in a variety of ways – Kitchin and Blades (2002) provide a comprehensive set of methodologies – for example, through practical testing of distance and direction estimation using existing internal cognitive maps, or recognition and matching of presented map products by human observers. However, one of the most common relies on the supposed revealing of the internal cognitive map by participants, in the form of physical sketch maps (Downs & Stea, 1973; Kitchin & Blades, 2002; Kosslyn & Pomerantz, 1977). There is an assumption that creating a sketch map can reveal participants' knowledge of spatial relationships and help investigate the nature of their cognitive maps.

The soliciting of sketch maps is a widely used procedure and can be done in a variety of ways: Kitchin and Blades (2002) suggest research scenarios where participants are given free rein, with no specific instruction; or alternatively with some guidance as to the spatial extent and level of detail sought; or by asking subjects to use specific code (legend, symbology etc) to obtain a more standardised graphical product. The sequential nature of mapping and the progressive creation of a sketch map can be recorded to assess how sketch map creation is attempted, and this is of particular interest to those examining how a dimensionless internal cognitive map can be externalized as a 2D sequentially created sketch map. In research terms, sketch maps are considered reliable tools for investigating internal cognitive maps because of their repeatability: an individual human is likely to be able to replicate their sketch map if asked, hence the data presented on it can be examined confidently.

The broader context of sketch maps can be considered, because the vast majority are not produced to gain research insight into the internal cognitive map, but to solve specific tasks (notably navigation), to orientate oneself within an environment, to record spatial knowledge at both large and small scales, and to (re-)present and communicate an abstraction of the environment to another human. Sketch maps, therefore, offer immense variety in scale, graphic design, appearance, function and efficiency.

The Japanese cartographer, Takashi Morita, conceived of the very first map in the sand (equivalent to our 'ur-map') resulting from a cognitive map (Figure 2). Such an externalization of an internal map construct may be seen as constituting the first map. It also

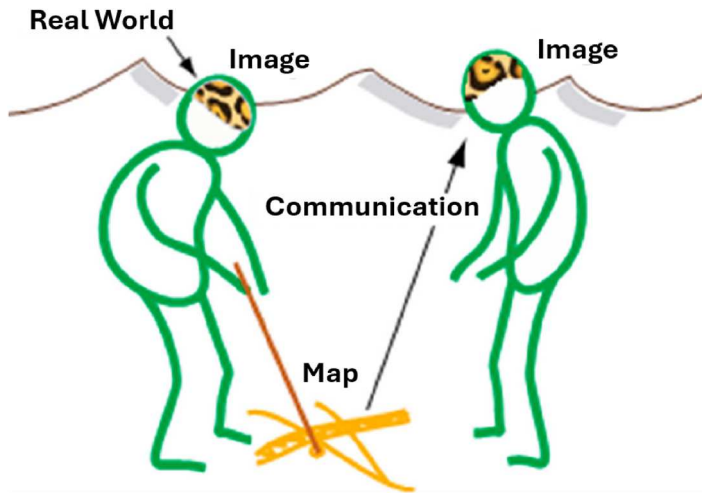


Figure 2. A hypothetical illustration of the drawing of an early map. One individual is sketching their cognitive map in the sand with a stick. A second individual creates a cognitive map by looking at the map in the sand (after illustration by Takashi Morita).

represented the first time that a cognitive map would have been formed from an externalized map, in the mind of a second individual.

Notwithstanding the varying propensities to construct such sketch maps on the part of contemporary societies, and, by extension, the existence and use of such artefacts in earlier cultures, mentioned in Section B above, for many groups the sketch map would have been, or is, the prime externalization of a cognitive map; and its communication to another individual, or group of individuals, would have represented a tool for survival, for the purposes of assisting in the capture of prey, to demarcate land ownership, the manifestation of accumulated knowledge of spatial relationships, and for tasks such as navigation.

The term 'sketch map' also covers those conceptual sketches, equally sourced in the human cognitive system, which convey spatial information beyond the immediate experience of humans e.g. maps of the shapes of continents and global images which help us to structure spatial information about the world beyond our direct perception. In contrast with those maps based on experience of space and the local environment, the cognitive map humans have of the shape of continents must, by necessity, be based on maps we have already seen. Human cognitive maps can therefore not only help us in navigating within the world, both physically and conceptually, but also help us to structure information about the world beyond our direct experience.

Sketch maps, either based on direct environmental perception by a human or by human engagement with an already existing externalized map, help us to organize information about the environment, helping us to think, in both spatial and non-spatial ways. The externalization of these internal representations can be problematic. It has been noted, during experimental testing, that individuals are rarely satisfied with a sketch map they have drawn. Evaluating the map afterwards, many will admit that it's not 'right' – even pointing-out specific inaccuracies and incompleteness. It seems that

most individuals are not capable of effectively externalizing these internal representations to their own satisfaction. This would suggest that these externalizations are only partial representations of what our internal cognitive map reveals: even whilst searching for more effective spatial behaviour by cognitive offloading, there may be more in the brain than we can bring out.

Further issues in examining sketch maps for cognitive map research investigations include a fundamental reliance on the graphical skill of the participant; potential constraints on design and appearance due to the tools used to sketch; the high levels of uncertainty in the participants in understanding what is required, due to the spontaneous and uncontrolled setting of the tests; and, of course, for most humans the actual process of making anything beyond a simple sketch is not easy nor intuitive. In fact, ‘the main limitation of this method [of using sketch maps to assess cognitive maps] is the individual’s drawing skills needed to convert information to a medium of good quality’ (Hátlová & Hanus, 2020).

Some researchers have attempted to quantify the actual (as opposed to the perceived) differences between sketch maps and geographical reality (Cauvin, 2002; Roulier, 2023). The methodology involves quantitatively comparing the sketch map to an actual map using a method such as bidimensional regression (Friedman & Kohler, 2003; Kitchen, 1993; Tobler, 1994). This requires digitizing the externalized map and comparing it point-by-point to an official map. This research has demonstrated the varying abilities of sketch mappers in terms of positional fidelity.

Despite such perceived shortcomings, sketch maps have proven to be an acceptable and much-used proxy for the study of internalized cognitive maps. Further consideration reveals the extent to which they, and the cognitive maps on which they are based, along with the overall human cognitive system, are themselves influenced by other maps. Most individuals draw sketch maps with north at the top and with standardized symbols, indicating that the internal structure of cognitive maps, and the resultant sketch maps, are like internalized copies of existing maps already engaged with by humans. We learn how to make them, and how to structure them internally, based on maps that we have seen. Maps train all of us how to be cartographers. This view supports the notion that our graphical view of the world is a learned behaviour – it is not innate. The map is not a reflection of the environment based on some internal, naturally occurring simulacrum. Some would suggest that mapping as a human activity is a learned, refined ability, and that the human brain has been *trained, resulting in neuro-plastic changes*, to create and use maps successfully.

Whether, as explored earlier in this paper, we have the innate ability to draw a map, or we learn how to do so from looking at existing maps, mapping does reflect the human mental ability for spatial cognition. At some point, humans learned how to externalize these internal representations in a way that was useful to others. Then, the form and structure of this externalization influenced how spatial information was both internalized and externalized.

‘Internalization’ and further cognitive issues

As with other externalizations, including writing, art, and performance, the prime purpose of the map is to have an *internal* effect on human behaviour, world-view, policy, activity,

social standing, or any of a host of human emotions. They also ‘add value’ in a form of feedback, enhancing the development of the very cognitive system which is used to produce them. Further, in presenting his definition and explanation, Levinson (op.cit) indicates that ‘a cognitive artifact is an aid to solving a mental problem by means of an external instrument, *which returns some value which can be re-internalized*’ (p. 63, our emphasis).

From a conceptual point of view, there is a contemporary acceptance by the majority of cartographic researchers, sourced from the critical cartography paradigm, that a graphical (or non-graphical) externalization of an internal cognitive system is not a ‘map’ until it is engaged with by a human being – which could be the same individual responsible for its production. It could be argued that such engagement is evident in the externalization process itself, but the prevailing doctrine is that once an artefact is perceived, interacted with, learned and acted upon, it becomes a ‘thing’ which can be defined as a map. It then has the power to impact human understanding, knowledge, behaviour, activity, and development. Further opinions would contend that maps actually change reality, and can also construct reality: they describe space, but they also create space.

We have already speculated that the process of externalization of maps relies, to a greater or lesser extent, on the internal human knowledge and memory of maps to which that human has been exposed previously. Both the generic creation by a human of a generalised, symbolised, spatially-infused map and the specific creation of a focussed, location-specific sketch-map of a neighbourhood rely on the recollection of maps which that person has engaged with or initiated previously. Map use has likely had a significant impact on the cognitive development of humans throughout history, and the ability to create and interpret maps has enhanced spatial reasoning, memory, and overall cognitive abilities, possibly providing some evolutionary advantages over time. Thus, the internal cognitive system is directed by external influences, and this ‘feedback loop’ means that it is susceptible to change, enhancement, and re-interpretation. Numerous studies on modern humans have shown that frequent use of maps and navigation tools actually enhance spatial memory and the ability to visualize and manipulate spatial information (Burgess, 2008).

There is also evidence that the physiology of the human brain itself has changed and developed as a result of exposure to maps, the increasing complexity of spatial tasks, and the increasing sophistication of spatial behaviour. Such change, manifest in the ability of neural networks to alter, expand and re-arrange, is referred to as ‘neuro-plasticity’, and its existence is taken as evidence that external factors can have an impact on the physiology of the brain itself. Because of the variety of place cells in different parts of the hippocampus, and because spatial tasks require complex cognitive processes including memory, orientation, spatial reasoning, and map reading, the hippocampus is more susceptible to neuro-plasticity than most other parts of the brain (Weerasinghe-Mudiyanselage et al., 2022). The classic example is the series of studies showing that London taxi drivers, who must navigate a complex urban environment using knowledge and memory of spatial entities and relationships, have a larger hippocampus compared to non-taxi drivers (Maguire et al., 2006; Weisberg et al., 2019).

Conclusion

This paper has tried to explore the complex nature of human cognition, and its impact *on*, and how it is impacted *by*, mapping activity and maps themselves. The human drive to undertake mapping and the human engagement with maps are each fundamental to any development of cartographic theory and explanatory epistemology. We have shown that humans are able to capture and process spatial information cognitively (i.e. internally, within their mind), and this is necessary to allow us to be aware of space, to think spatially, to act in space, indeed, to survive in the environment. These cognitive abilities are connected to the type of processing that addresses the presence or absence of something in the environment (an entity, a phenomenon), its relations to something else (spatial relationship), and the fact that each (the entity, the relation) can have some kind of attribute.

Human beings started to externalize the entity-relation information at some unknown stage, either pre-language, possibly using graphical means, or in the language of that time. The externalization (=map) is an essential instrument for humans because it allows them to store, use, inform and gain knowledge about the fact that every activity and event happens somewhere: this is fundamental to our life, society, and economy – so the map is an artefact, a product among many others, created by human beings.

Our view is that the map is a *fundamental* product, born of the necessity for thinking spatially, storing and organizing spatial information, and transmitting spatial knowledge; but shared, refined and used by humans in an effective manner, to enhance and optimise a wide range of activities and behaviours. It is uncertain whether the birth of the map was at all impulsive or derived from innate human abilities, but it is clear that its nature and operation matches certain neurological and cognitive characteristics of humans. In particular, the externalization of the map and the recognition of its role as a cognitive artefact reveal the complex nature of our relationship with the activity of mapping and the map product itself. We have also discussed how exposure to maps changes internal human cognitive structures over time, and how prior experience with maps can shape renewed spatial reasoning and the creation of new maps, leading to a ‘feedback loop’ in the human activity of mapping.

In order to explore the nature of the map and its inter-relationship with humans, we need to develop an explanatory model summarising the character of cartography: such a model can be similar to that promoted by the cartographic communication paradigm, but it needs significant enhancement to explain the nature, the role, and the success of maps and the human behaviour which directs and is impacted by mapping activity. Such a model must be integrated to incorporate cognitive science, technology and cultural perspectives. As part of the epistemology of cartography (the study of mapping and maps), this paper has attempted to enhance the understanding of the human cognitive system, which is needed for a full explanation of why humans map, the nature of the maps created by humans, the use of maps by humans, the role of maps in shaping human evolution, and the success of maps.

Disclosure statement

No potential conflict of interest was reported by the authors.

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