

[Special Contribution]

## Spatial Cognition, Empathy and Language Evolution\*

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The evolution of language and spatial cognition may have been deeply interconnected. The argument goes as follows: 1. Human native spatial abilities are poor, but we make up for it with linguistic and cultural prostheses; 2. The explanation for the loss of native spatial abilities may be that language has cannibalized the hippocampus, the mammalian mental ‘GPS’; 3. Consequently, language may have borrowed conceptual primitives from spatial cognition (in line with ‘localism’), these being differentially combined in different languages; 4. The hippocampus may have been colonized because: (a) space was prime subject matter for communication, (b) gesture uses space to represent space, and was likely precursor to language. In order to explain why the other great apes haven’t gone in the same direction, we need to invoke other factors, notably the ‘interaction engine’, the ensemble of interactional abilities that make cooperative communication possible and provide the matrix for the evolution and learning of language.

**Keywords:** spacial cognition, hippocampus, gesture language, interaction engine, empathetic capacity, cuteness selection

In this lecture I argued that language evolution may have been closely tied to spatial cognition. A first observation is that we are natively poor navigators, compared to many animal species. Many animals have special senses dedicated to spatial navigation (Hughes 1999); birds for example have magnetoreception and polarized light detectors, which allow them to literally see compass directions (Johnsen & Lohmann 2005). Birds are remote from us, but bats are fellow mammals, and they (or at least some species) also have both magnetoreception (Holland et al. 2007) and polarized light detectors (Greif et al. 2014); moreover they have echolocation and keen olfaction for piloting their flight. Humans by contrast are natively poor navigators, but they make up for this by elaborate cultural prostheses—maps, compasses, GPS reception and so forth. Hunter gatherers may lack the technology, but they typically have enhanced spatial abilities enabled by linguistic specialization (e.g. cardinal direction systems) and the cognitive underpinnings that make this an automatic resource (Levinson 1997, 2003). Our own

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work has shown how differently different languages conceive of space, and how this makes spatial cognition a surprisingly culturally variable matter (Levinson & Wilkins 2006). There are peoples, for example, who don't know their lefts and rights, but have unerring senses of geographical location—as required by their language.

It's worth asking what happened to our native spatial abilities, our instinctive directional senses, during human evolution. Spatial cognition has its seat in the hippocampus, as shown by the work of the 2014 Nobel laureates John O'Keefe and Edvard & May-Brit Moser. In humans, though, the hippocampus has been given additional tasks—it plays a critical role in memory, but also as recent work has shown in language processing. In addition, it handles our social networks. Interestingly, our social networks end up spatialized: we think about our social relations as close or distant, and vertically in terms of authority relations (Tavares et al. 2015). My suggestion is that language is also spatialized by virtue of taking over part of the functions of the hippocampus. The suggestion is not new—O'Keefe (1996) for example suggested linguistic structure is vector-based as a result. This would be an example of what Dehaene & Cohen (2007) have called cultural recycling of neuronal resources, their example being the way in which reading has invaded the occipitotemporal sulcus, with costs to our face and object recognition.

Now, the idea called “localism” (Lyons 1977: 718–724), that linguistic concepts have a spatial basis is actually ancient. It can be traced back to ancient Greek grammarians, is expressed e.g. in Harris' (1765) *Hermes*, and had full blown development in the work of nineteenth century philologists like Wüllner (1827) looking at the development of case systems (see Fortis 2011). It resurfaced in the twentieth century with the Case Grammarians (Gruber 1965, Anderson 1971), and then more recently in Cognitive Semantics in the works of Talmy, Langacker and Jackendoff (e.g. Jackendoff 1983). Indeed, the case is strong that spatial concepts evident in language are more than metaphors: we see spatialization of many domains like time ('through the night'), social relations ('close cousins'), numbers ('nearest prime'), state changes ('rising prices', 'changing from red to green'), qualities ('top quality'), emotions ('low spirits') and much more. In addition the spatial concepts 'to', 'from', 'in', 'at', 'place', 'path', 'go', and so on—concepts encoded in the cells of the hippocampus—seem to provide the underlying primitives for grammatical relations. Spatial cognition seems to play a foundational role in our semantics and cognition in general.

So language seems to have invaded the hippocampus, with the consequence that language has inherited the architecture of spatial cognition. But why? What attracted language into this spatial area? Here in the evolution of language gesture may have been crucial. Gesture, and fully developed sign language, constitutes a spatially-expressed language largely about space—most gestures accompanying speech today have spatial meanings, and sign languages also are deeply rooted in spatial concepts. If, as will be discussed below, early human language was basically gestural, then gesture may have been the Trojan horse that allowed language to cannibalize part of the functions of

the hippocampus. Although the hippocampus had not previously been thought to be a key part of the language circuitry (but see O’Keefe & Nadel 1978), increasing evidence points to its important role in language processing (Alamri 2017). Just as the hippocampus enlarges in response to repeated and demanding spatial tasks (Maguire et al. 2000), so it grows during second-language learning (Martensson et al. 2012). The structure is heavily involved in reference tracking (Duff & Brown-Schmidt 2012) and binding problems (MacKay et al. 2007). And depth electrodes inserted in the human hippocampus—just where rats show spatial functions—show that the hippocampus tracks cloze probabilities, thus being part of the prediction apparatus that makes speech comprehension possible (Piai et al. 2016).

The idea that gesture may have played this crucial role fits neatly with recent evidence about the evolution of language (Levinson & Holler 2014). The recovery of ancient DNA now makes clear that as far as genes are concerned, Neanderthals are essentially modern, and certainly there are no coding regions associated with language that demarcate us from Neanderthals (non-coding regions may differ a little, but the functions are unclear; see Dediu & Levinson 2018). In so far as it is possible to tell, the vocal tract and the breathing system are essentially modern (Dediu & Levinson 2013). It is telling that the vertebral column show the same enlarged canal to the thorax which is the index of modern human breath control. This is missing from the great apes and our ancestral form of *Homo erectus*, the African form called *H. ergaster*, implying he was not an articulate animal. But since right across the great apes, flexible gestural communication is evident, one must assume by the normal phylogenetic reasoning that *H. erectus* had some kind of gestural language. Thus the timing for the change from a predominantly gestural to vocal language can be narrowed to between 1.2mya and 700kya (the date of the last common ancestor for us and Neanderthals).

So a possible story is that through a gesture language, perhaps elaborated by the tool-using *H. erectus*, spatial concepts became deeply embedded in our linguistic cognition. This at least provides some evolutionary account of where the architecture of linguistic concepts originated (unlike the idea in Berwick & Chomsky 2016 that language is a chance mutation or improbable freak). But a possible problem for this view is that there are many species with elaborate spatial senses and cognition that show no such exploitation of spatial concepts in their communicational systems. Great apes gestures do exploit spatial properties, often though in a simple way by a ritualization of part of an interactional sequence—for example, an outstretched arm to an infant meaning in effect “come here and I’ll put you on my back”. But the question remains: why haven’t they also exploited the rich cognitive resources of the spatial domain?

Here, obviously, other factors are at play. Many have speculated that as scavengers and hunters humans had to act cooperatively to hold off larger predators, and the capacity for coordinated joint action is one of the hallmarks of human adaptation (e.g. Tomasello 2014). That capacity in turn relies on deep foundations, what I have called the ‘interaction engine’, an ensemble of cognitive and ethological properties. Critical is

what has been called ‘theory of mind’, essentially cognitive and emotional empathy—intention-reading rests on being able to take the perspective of the other. I have argued that this empathetic capacity is typical of primate (and perhaps more generally mammalian) mothers of helpless infants. Ape gestural communication seems to be especially prevalent in mother-infant interaction (see e.g. Fröhlich et al. 2016). The curiosity is how this maternal empathy (and the communication it affords) has become generalized across the genders and ages in human society, so that e.g. Obama can openly weep when speaking about the victims of a school massacre whom he has never met. We see here a possible connection to Lorenz’s (1971) ‘herzig’ or ‘cuteness’: ‘cute’ signals (large eyes, bulging head, reduced jaw, wobbly stance, juvenile vocalizations) release maternal instincts on Lorenz’s account. But these features are just the features that have often been described in terms of human neoteny, the evolutionary trend in our line towards gracile and juvenile form (see Gould 1977). The idea then suggests itself: perhaps human evolution was subject to a runaway process of ‘cuteness selection’ (similar to RA Fisher’s account of extreme sexual selection): an infant that remains cute for as long as possible will maximize maternal care, so being selected for, while a parent who falls for cuteness will maximize parental contributions and thus infant fitness, so contributing to a virtuous circle of maternalization and infantilization.

Other aspects of the ‘interactional engine’ are more behavioural. Communicational turn-taking for example can be traced right across the primate order (Levinson 2016), but it is particularly embedded in human communication where the speed of transitions (c. 200 ms) puts enormous burdens on cognitive processing: in effect, we are squeezing enormously complex clauses generated on the fly into small turns (average under 2 secs) with little preparation time (Levinson & Torreira 2015). This is suggestive that the 200 ms timing (which is also found in ape gestural communication, Fröhlich et al. 2016) antecedes complex language, which has evolved within an antecedent temporal constraint. Ontogeny here perhaps recapitulates phylogeny, with complex language developing in children slowly within tight timing (Hilbrink et al. 2015), and with children struggling to match adult response times until age 10 or so (Stivers et al. 2018). In any case, despite the fact that the interaction engine has disparate components, it is interesting to note that as far as clinical populations go they act together as ensembles (Baron-Cohen et al. 1985). So there are double dissociations between linguistic and interactional competence, with e.g. high functioning autists with good language competence and restricted interactional competence (Bishop & Norbury 2002), contrasting with Down syndrome subjects with restricted language competence but good interactional skills (Jenkins & Ramruttan 1998).

It is the possession of the interaction engine that has made it possible for humans to develop advanced communication, because it provides a niche in which languages can be learnt and culture accumulated. But the source of the cognitive architecture for language may be spatial, and gesture may be answerable for its adoption.

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