Visuo-spatial integration and spatial cognition: a comment on Bruner & Lozano (2014)

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Bruner & Lozano (JASs forum 2014, vol. 92: 273) highlight the potential significance of structural differences in the brains of anatomically modern humans (AMHs) and Neanderthals. Compared with Neanderthals, AMHs have a distinctively round cranium. The spatial flattening of the parietal outline of the Neanderthal skull contrasts sharply with the bulging of the upper parietal region in humans (Bruner, 2004, 2010; Bruner *et al.*, 2014). These observed differences in the shape of the skull are correlated with morphological differences in the parietal region, which is associated with key processes of visuospatial integration. While the anterior region of the parietal cortex performs somatosensory functions, the posterior parietal complex (PPC) is thought to play a critical role in spatial perception and the coordination of world-referenced and body referenced signals (Whitlock *et al.*, 2008). In other words, visuospatial integration enables the creation of an “inner virtual space”, to use Bruner & Lozano’s terminology, where signals from the external world are organised and courses of action worked out. It is possible, therefore, that structural differences in the parietal region of the brain reflect functional differences in the way that Neanderthals and AMHs interacted with the world. Evidence that Neanderthals used their teeth as tools significantly more often than AMHs did (or do) is offered as an indication that they interacted with their environment in a fundamentally different way.

Bruner & Lozano raise several interesting questions with respects to cognitive differences between Neanderthals and AMHs, specifically with regards to the visuospatial system. This, in turn, has important ramifications for spatial cognition and models of the internal representation of space as well as for the study of human evolution.

Wayfinding, the ability to plan and carry out navigation tasks, is thought to involve the use of two distinct internal representations of the world linked by a process of translation. The first spatial representation contains “transient action-oriented egocentric self-object associations” (Burgess, 2006), i.e., it is a representation of the world from an individual perspective that conveys where objects and other people are in space in relation to the self. The second representation is a more enduring, allocentric representation of “object-object or environment-object associations” (Burgess, 2006, p. 555). This allocentric spatial representation is equivalent to the “cognitive map” originally defined by O’Keefe & Nadel (O’Keefe & Nadel, 1978) and constitutes a framework for action that can also be used metaphorically in the process of memory recall (Golledge, 2003). The allocentric representation is similar to a road map which adopts a “bird’s eye view” rather than representing the world from the individual’s perspective. Path integration, or spatial updating, is the key cognitive process that links the two spatial representations, allowing people to orient themselves and translate their position onto the enduring representation. Landmark recognition, the ability to select relevant features of the landscape and consign their position to memory, is one of the skills used during path integration to orient the agent (from an egocentric perspective) and to align the egocentric and allocentric representations. Both
forms of spatial representation imply the motivated and deliberate encoding of environmental information which takes place as an individual moves through the landscape, although allocentric spatial representations can also be built using external aids (such as a map). The allocentric representation, or cognitive map, is updated with new information as an individual experiences their environment directly.

With the advent of magnetic resonance imagery (MRI), it is now possible to map brain activity in healthy subjects with a high degree of spatial resolution. Thus, neurophysiologists have identified which regions of the brain are recruited at different steps of the wayfinding process, from the initial encoding of environmental information to path integration and the retrieval and use of cognitive maps during goal-directed movement. The observation that the hippocampus plays a key role in storing mental representations of space in rats (O’Keefe & Nadel, 1978) has been experimentally proven in humans, e.g. (Hartley et al., 2003; Maguire et al., 2000, 2003; Nadel & Hardt, 2004). It is now clear that both the hippocampus (and associated structures) and the medial entorhinal complex (MEC) are important for generating mental representations of space (Moser et al., 2008; Roche et al., 2005; Whitlock et al., 2008). The posterior parietal complex (PPC) encodes environmental signals (Roche et al., 2005; Whitlock et al., 2008) and coordinates internal and external sensory inputs in order to align the egocentric and allocentric representations, which enables the planning and carrying out of goal-directed patterns of movement (Spiers & Maguire, 2006; Whitlock et al., 2008). The “inner virtual space” referred to by Bruner & Lozano describes the function of the parietal complex during the retrieval and co-registration of the spatial representations and the planning of goal-directed movement. Enlargement of the parietal region could conceivably create differences in wayfinding ability, therefore, and is a question worth pursuing further.

I have previously argued (Burke, 2012) that cognitive differences between humans and Neanderthals could have arisen as a result of *H. sapiens*’ adoption of a fully modern hunting-gathering way of life including the construction and maintenance of complex and spatially extensive social networks. The archaeological record indicates that human populations developed the ability to maintain spatially extensive social networks during the Middle Stone Age. Supporting evidence for this includes raw material circulation patterns and the manufacture of symbolic items such as items of personal adornment which could have functioned as markers of social identity and been used for reciprocal exchanges. The development of more spatially extensive social networks would have placed new demands on the neural substrate underpinning spatial cognition as individuals strove to maintain relatedness over greater distances, hypothetically resulting in cognitive differences between humans and Neanderthals. Neurophysiologists have demonstrated that human brain structure responds to the demands of spatial cognition (Maguire et al., 1999, 2000, 2003) and the proposed cognitive differences could therefore have arisen ontogenetically rather than phylogenetically, however.

I also proposed that differences in cognitive style could have arisen between humans and Neanderthals as a result of their different lifestyles, with implications for the pattern of dispersal. Humans use two spatial strategies for wayfinding: an egocentric “route-finding” strategy (using path integration and landmark recognition for spatial updating along a memorized route) and an allocentric “survey” strategy (spatial updating on the allocentric representation using speed, distance and heading estimates). Children begin by learning route-finding and adopt the use of a “survey” strategy as they mature. Adult humans use a combination of both strategies although individuals tend to develop a cognitive style that favours one or the other. Men and women develop preferences that may be rooted in gendered activity patterns, for example (Burke et al., 2012). The social organisation of human populations might have promoted the use of an allocentric strategy, which is more efficient in the context of long-distance, goal-oriented travel. In the context of exploratory travel (which would
presumably have been important for dispersing populations of humans) an allocentric strategy would also have been more effective since it is more easily transferable to novel landscapes (Kelly, 2003). Again, these arguments do not imply the existence of phylogenetic differences in brain structure.

The implications of Bruner & Lozano’s article for the proposed development of differences in spatial cognition in AMHs and Neanderthals are very interesting. While I suggested that the development of complex and spatially extensive social networks during the MSA could have stimulated the development of spatial cognition in AMHs, the reverse may be true. It is possible that structural changes in the brain enhanced spatial cognition in AMHs, thus facilitating the development of spatially extensive social networks. Whether or not enlargement of the parietal region translates into more efficient wayfinding remains to be proven, but it is hypothetically possible that the role of the PPC in coordinating goal-directed movement could have been enhanced, as could its’ role in encoding environmental signals and therefore, path integration. This would imply that inter-specific differences in spatial cognition arose phylogenetically rather than as a result of human social organisation and patterns of activity. If this were the case, phylogenetic differences in the human brain could have contributed to creating an environment in which more spatially extensive social networks could develop (rather than the other way around). This, in turn, could have fostered the development of a cognitive style that facilitated dispersal.

Bruner & Lozano’s research raises a series of fascinating questions that are well worth pursuing. For example, how exactly does expansion of the parietal region affect spatial cognition and wayfinding? Does the archaeological record provide evidence for the emergence of phylogenetically based differences in spatial cognition before the establishment of spatially extensive social networks? Finally, it is worth considering whether archaeological evidence for the adoption of symbolic expression by some Neanderthal groups could be seen as the expression of an innate ability to develop similar cognitive abilities to humans, which would weaken the case for phylogenetic differences in the parietal region as the basis for differences in spatial cognition.

References

Maguire E.A., Burgess N. & O’Keefe J. 1999. Human spatial navigation: cognitive maps,