

The exaptation of the parietal lobes in *Homo sapiens*

Frederick L. Coolidge

University of Colorado, Colorado Springs, USA
e-mail: fcoolidg@uccs.edu

As duly noted by Bruner & Lozano (this volume), paleoneurological evidence reveals that the most dramatic morphological changes in *Homo sapiens*' brain evolution have occurred in the areas which process and integrate visual and spatial information, the parietal lobes. Further, they purport that one derived feature of Neandertal behavior was the use of their teeth as a third hand or tool. While this behavior was both common and widespread in the ancestor of Neandertals, *Homo heidelbergensis*, it appears that this behavior was nearly universal in Neandertals. Bruner and Lozano further argued that "... a marked used [sic] of the mouth as an additional interface may be a sign of an inefficient visuo-spatial integration system..." (p. 5). They also noted that Wynn & Coolidge (2004) proposed that *Homo sapiens* had greater working memory capacity, which may have resided in either the phonological loop or in the central executive of Baddeley & Hitch's (1974) multicomponent working memory model. Bruner & Lozano, however, have decided to emphasize the visuospatial sketchpad in the working memory model as perhaps a differentiating feature between *Homo sapiens* and Neandertals, given the visuospatial sketchpad's role in creating an internal virtual space and its coordination of the body's interface between the brain and the environment. They further argue that Neandertal's use of the mouth as an additional interface was a symptom of a defective brain-body interface and perhaps also demonstrated a limitation or inefficiency of Neandertal's visuospatial sketchpad.

There may, however, be a complimentary interpretation of the Neandertal "third hand" hypothesis. Trinkaus (2006) noted that of 75

cranial, mandibular, dental, axial, and appendicular derived traits shared between Neandertals/modern *Homo sapiens* relative to Early and Middle Pleistocene *Homo*, about 25% were shared between Neandertals and modern *Homo sapiens*, 25% were derived traits of Neandertals, and about 50% were unique to modern humans. Thus, Trinkaus concluded that modern humans are more morphologically derived than Neandertals, and "...it is not the Neandertals who appear unusual, special, derived, autapomorphous. It is we." (p. 607). Further, he perhaps presciently (with regard to Bruner & Lozano's hypothesis) noted that the major focus of evolutionary biology should *not* be upon the "deviant nature of the Neandertals" but the focus of study should be shared between Neandertals and the derived characteristics of *Homo sapiens*. It is the purpose of the present paper to reflect upon some of these derived traits that may have been critical to the evolutionary ascendance of *Homo sapiens*.

In evolutionary studies, an adaptation is thought to be the stabilization of a trait for a specific function in a population, primarily through genetic or epigenetic events. An exaptation is thought to be a change in the original function of a trait, which thus expresses itself as a new function of the original adaptive trait. A common example given for an evolutionary exaptation is feathers, which were originally selected for thermoregulation but later exapted for flying.

Provocatively, it may be argued that the most critical exaptation in the evolution of modern brains may be the parietal lobes. The parietal lobes' role in visual and spatial processing and integration has long been established phylogenetically, at least as distant as the beginnings of

complex animal life, perhaps 500 to 400 million years ago, and thus, it may be argued that visuospatial processing and integration was an adaptation of the parietal lobes. Further, Bruner (2003, 2004, 2010; Bruner *et al.*, 2014) has noted there is a clear spatial dilation of the entire parietal surface in modern *Homo sapiens* not seen in Neandertals, while Neandertals demonstrate a lateral bulging not evident in *Homo erectus* or *Homo heidelbergensis*. It appears unlikely that this parietal lobe enlargement in *Homo sapiens* simply and only enhanced visual and spatial skills in modern *Homo sapiens*. There is, however, a raft of new information that suggests the parietal lobes may have been exapted for their ability to host a vast and critical array of higher complex cognitive functions in *Homo sapiens*.

First, Dehaene (2011) and Dehaene & Brannon (2011) have clearly established the role of the parietal lobes in numerosity, an appreciation of numbers, which is independent of language as it has been demonstrated in human infants and monkeys. These authors have also presented evidence that the superior portion of the parietal lobes, the intraparietal sulcus, may be particularly involved in numerosity. Recently, Harvey, Klein, Petridou & Dumoulin (2013) have demonstrated with high-field magnetic resonance imaging that the parietal lobes topographically represent numbers, both in the subitization range (1 to 3 things) and discriminations between large and small sets of things. Of course, if human infants and monkeys display numerosity, then Neandertals certainly must have had it. However, as Harvey *et al.* have noted, if topographic representations for numbers in modern humans represents higher-level abstractive thinking then an expanded parietal surface in modern humans may have boosted their abstractive abilities, i.e., the ability to conduct higher level mathematical abstractions and complex economical transactions. The latter abilities are thought to be rare or absent in the Neandertal archaeological record (Coolidge & Wynn, 2009; Wynn & Coolidge, 2012).

A second higher-level cognitive function ascribed to modern parietal lobes is the complex

interplay of egocentric/episodic/autobiographical memory. Land (2014) has shown that the medial posterior portion of the parietal lobes, the precuneus, produces a self-centered mental image, which not only allows successful retrieval of past episodes from one's life but also an egocentric representation of one's place in the surrounding environment. Land further argues that the precuneus thus provides a stable environmental model for "finding the sources of information we need for action..." and helps us "retain usable information about the identity and direction of the some of the objects behind us, as well as in front." (p. 6).

Episodic memory, the recall of past events as a coherent whole with what, where, and when characteristics, has been granted to birds (e.g. Allen & Fortyn, 2013), and thus, must be granted to modern humans and Neandertals. However, autobiographical memories, all of which have a strong emotional valence, have the added feature of placing one's self in the memory, a type of memory then that might be restricted to human types. Autobiographical memories may carry the additional important feature that humans can consciously and willfully travel backward and forward in time (also called mental time travel, chronesthesia, or auto-noetic thinking [Tulving, 2002]). An adaptive advantage that auto-noesis provides is prospective memory simulation (e.g., Schacter, Addis, & Buckner, 2007), where humans can imagine various future scenarios, partly based on past experiences, and partly based on the simulation of the likely success of various future possibilities for solving problems. The neurons that have been shown to be active in auto-noetic thinking (past, present, and future) are in the precuneus (e.g., Cavanna & Trimble, 2006; Schacter *et al.*, 2007). Interestingly, Lou and his colleagues (Lou *et al.*, 2004, 2005) have found that this "auto-noetic consciousness" also provides a nodal structure for the representation of one's self. Indeed, medial parietal lobe neuronal involvement (precuneus) is greatest when human subjects are asked to think about themselves. Further, the medial portions of the parietal lobes appear to be the default-mode network for

the resting (but not sleeping) brain. Their fMRI evidence so clearly indicates precuneal involvement in these self-referential cognitive activities that Lou and his colleagues have postulated that the “Self” as a core in the “unity of conscious experience” (Lou *et al.*, 2004, p. 6832). The medial portions of the parietal lobes also appears to integrate anterior and posterior brain functions, left and right hemisphere functions, and limbic and subcortical functions, and, thus, Lou *et al.* (2004) propose that the precuneus provides informational gateways to the rest of the brain, allowing ‘a “global workspace” of consciousness, as proposed by Baars [2002]’ (p. 6832).

Thus, building upon Trinkaus’s suggestion that the study of the uniquely derived traits of modern *Homo sapiens* may be equally worthy of study as the factors which led to Neandertals’ demise, Bruner & Lozano (this volume) may be correct in emphasizing the visuospatial sketchpad’s role in creating internal virtual spaces and coordinating the body’s interface between one’s brain and one’s environment as critical to the rise of *Homo sapiens* and the demise of Neandertals. However, the visuospatial sketchpad may not represent a defective, limited, or inefficient Neandertal brain-body interface but may be more representative of exapted parietal lobes functions in the expanded parietal surface of *Homo sapiens*. These exaptations which may be associated with higher level abstractions, more complex mathematical and economic reasoning, and a more distinct sense of self and higher levels self-consciousness, may have been some of the critical reasons for our evolutionary ascendancy and Neandertals’ demise.

References

- Allen T.A. & Fortyn N.J. 2013. The evolution of episodic memory. *Proc. Natl. Acad. Sci. U.S.A.*, 110: 10379–10386.
- Baddeley A. & Hitch J. 1974. Working memory. In Bower G.A. (ed): *Recent advances in learning and motivation*, p. 47–90. Academic Press, New York.
- Baars B.J. 2002. The conscious access hypothesis: origins and recent evidence. *Trends Cog. Sci.*, 6:47-52.
- Bruner E., Manzi G. & Arsuaga J. L. 2003. Encephalization and allometric trajectories in the genus *Homo*: Evidence from the Neandertal and modern lineages. *Proc. Natl. Acad. Sci. U.S.A.*, 100: 15335-15340.
- Bruner E. 2004. Geometric morphometrics and paleoneurology: brain shape evolution in the genus *Homo*. *J. Hum. Evol.*, 47:279-303.
- Bruner E. 2010. Morphological differences in the parietal lobes within the human genus. *Curr. Anthropol.*, 51: S77-S88.
- Bruner E., Rangel de Lázaro G., de la Cuétara J.M., Martín-Loeches M., Colom R. & Jacobs H.I.L. 2014. Midsagittal brain variation and MRI shape analysis of the precuneus in adult individuals. *J. Anat.*, doi: 10.1111/joa.12155.
- Bruner E. & Lozano M. 2014. Extended mind and visuo-spatial integration: three hands for the Neandertal. *J. Antropol. Sci.* (this volume)
- Cavanna A.E. & Trimble M.R. 2006. The precuneus: a review of its functional anatomy and behavioural correlates. *Brain*, 129:564-583.
- Coolidge F.L. & Wynn T. 2009. *The rise of Homo sapiens*. Wiley-Blackwell, New York, NY.
- Dehaene S. 2011. *The number sense: how the mind creates mathematics*. Oxford University Press, New York, NY.
- Dehaene S. & Brannon E. 2011. *Space, time and number in the brain: searching for the foundations of mathematical thought*. Academic Press, London, UK.
- Harvey B.M., Klein B.P., Petridou N. & Dumoulin S.O. 2013. Topographic representation of numerosity in the human parietal cortex. *Science*, 341:1123-1126.
- Land M.F. 2014. Do we have an internal model of the outside world? *Philos. Trans. R. Soc. Lond. B*, 369:1-6.
- Lou H.C., Luber B., Crupain M., Keenan J.P., Nowak M., Kjaer T.W., Sackeim H.A. & Lisanby S.H. 2004. Parietal cortex and representation of the mental self. *Proc. Natl. Acad. Sci. U.S.A.*, 101:6827-6832.
- Lou H.C., Nowak M. & Kjaer T.W. 2005. The mental self. *Proc. Brain Res.*, 150:197-204.
- Schacter D.L., Addis D.R. & Buckner R.L. 2007. Remembering the past to imagine the future: The prospective brain. *Nat. Rev. Neurosci.*, 8:657-661.

- Trinkaus E. 2006. Modern human versus Neandertal evolutionary distinctiveness. *Curr. Anthropol.*, 47:597-620.
- Tulving E. 2002. Episodic memory: From mind to brain. *Ann. Rev. Psychol.*, 53:1-25.
- Wynn T. & Coolidge F.L. 2012. *How to think like a Neandertal*. Oxford University Press, New York, NY.
- Wynn T. & Coolidge F.L. 2004. The expert Neandertal mind. *J. Hum. Evol.*, 46:467-487.