

## Right-handedness, lateralization and language in Neanderthals: a comment on Frayer *et al.* (2010)

Antonio Benítez-Burraco<sup>1</sup> & Víctor M. Longa<sup>2</sup>

1) University of Huelva, Spain

2) University of Santiago de Compostela, Spain

e-mail: victormanuel.longa@usc.es

A lot of ink has been spilt in Paleoanthropology in discussing whether or not Neanderthals possessed complex language (which means “human language in the modern sense”, quoting Arbib, 2005, p. 21, that is, a representational and communicative system with hierarchical and recursive structure), given their phylogenetic closeness to modern humans. Recently, Frayer *et al.* (2010) (this journal, vol. 88; henceforth, F) have found that Neanderthals had a right-handedness ratio “similar to living people” (F, p. 113). This leads them to infer that this species had a pattern of brain lateralization resembling ours, and, ultimately, that “Neandertals (and, very likely, their European ancestors) had linguistic capacities similar to living humans” (F, p. 113).

It is not our intention to cast doubt on F’s remarkable finding. However, the point is made that their inference according to which Neanderthals had complex language is questionable. Some reasons will be brought to the fore.

To begin with, “there are some drawbacks in determining hand preference from tooth scratches” (F, p. 115; see Bax & Ungar, 1999, who question the link between hand-use and teeth striations). In addition, other types of evidence (such as tools) could be more suitable for inferring whether extinct hominid species showed lateralization of motor tasks, given that in our species (and in great apes, in general) handedness is correlated to task complexity, as discussed by Uomini (2009, pp. 413-414, 416 and ss.). Leaving that aside, the relationships between right-handedness, (structural and functional) brain lateralization, and language are perhaps not significant enough, or illuminating from an evolutionary perspective.

In our species, a positive correlation exists between general verbal skill and precociousness of language development on the one hand, and the degree of lateralization in hand use, on the other (in general, between lateralization and cognitive abilities, including language). However, that correlation is responsible for a variation of about only 1% in both the General Ability Index and the Intelligence Quotient; the same applies to the Quotient’s verbal component (Nettle, 2003). Hence, Natsopoulos *et al.* (2002, p. 223) claim that there is not a “significant association of language proficiency with variations of lateralization regarding hand-preference and hand-skill”. It becomes even more relevant that in about 30% of left-handed people, the cortical areas related to linguistic processing are not so lateralized to the left hemisphere (Foundas *et al.*, 2002). In addition, and crucially, left-handed people do not show qualitative differences concerning structural aspects of language (Foundas *et al.*, 1994), nor a greater prevalence of specific language impairments (Bishop, 2001).

Comparatively, although it is usually agreed that the rate of right-handedness is lower in great apes (Corballis, 2007; Cashmore *et al.*, 2008), “the manipulative skills of human and non human apes are not qualitatively but rather quantitatively, different”, because in both groups “hand preferences [...] are similarly influenced by the effects of task complexity” (Uomini, 2009, p. 416).

The fossil record does show that modern right-handedness seems to be a shared trait with Neanderthals (and even older; Frayer *et al.*, 2011 and references). But, at the same time, the main structural and functional asymmetries related to

lateralization (including those concerned with the areas linked to language in modern humans) have been taken to be an archaic trait, for they seem to be present in the genus *Homo* (Holloway, 1981; see Holloway, 1983 and Tobias, 1983 for Broca's area; for a general review, see Kyriacou & Bruner, 2011, who state that "the human fossil record does not show marked differences from the modern human variation"; Kyriacou & Bruner, 2011, p. 135), and also in great apes (Holloway & De La Costelareymondie, 1982; Cantalupo & Hopkins, 2001; for an opposite view, which suggests that some of these asymmetries could be absent in this family, see Keller *et al.*, 2009a; Schenker *et al.*, 2010). Additionally, it should be noted that recent research suggests that Neanderthals and modern humans could exhibit different patterns of brain hemispheres asymmetry (Peña-Melián *et al.*, 2011).

Therefore, structural and functional asymmetries, if they really exist, would predate the evidence for (modern) right-handedness (thus meaning that all the human species had language), or would be not informative in that sense. Nonetheless, the real problem is that those traces have been customarily considered to show the presence of (the neuronal substrate for) modern language, but caution is also in order: the presence of a biological structure does not presuppose the existence of the function associated to that structure in other species (the opposite also applies), as illustrated by the fact that the primate homologue area to human Broca's area contains mirror neurons linked to hand motor control (Rizzolatti & Arbib, 1998). It could be speculated that in the evolution of our species a reutilization with linguistic purposes of the corresponding ancestral homologue areas took place; however, to date that change cannot be (solely) inferred from evidence about structural and functional lateralization of those areas.

Other proposals have claimed that some mutations (or chromosomal reorganizations) would be responsible for the augmentation of the right-handedness ratio in the most recent *Homo* species, those mutations triggering a modification of the brain lateralization pattern which would

be responsible for language origins (Chance & Crow, 2007; Crow, 2008). However, considering the molecular data currently available, those proposals could exhibit the additional problem of a potential disparity between the antiquity of genetic events and the relatively recent nature of (modern) right-handedness (see, for instance, figure 3 in Williams *et al.*, 2006, p. 631).

Even if (structural and functional) brain lateralization patterns could be accurately inferred from the fossil record, we should deal with the issue that in our species brain asymmetries could not be as frequent as commonly held (see for instance Keller *et al.*, 2009b for Broca's area), and more importantly, that language does not crucially depend on a specific pattern of structural and functional lateralization of the brain regions that contribute to linguistic processing, but mainly on a specific interconnection program that links some neuronal devices functionally.

To begin with, a significant imbalance exists among the indices of structural and functional lateralization of those areas (Selnes & Whitaker, 2006, p. 242), and this fact may condition inferences based on endocrania of extinct hominids. Moreover, as indicated by F, p. 122 themselves, there are proofs of alternative configurations of the 'linguistic areas' (language transference to the right hemisphere in pathological conditions, or specular organizations in left-handed individuals); however, language integrity is not substantially affected, neither quantitatively (size of the lexicon, number of utterances, etc.) nor qualitatively (types, patterns and complexity of linguistic structures, etc.) (Liégeois *et al.*, 2008). In addition, alleged evidence on language lateralization in the left hemisphere mainly concerns specific cortical structures (usually Broca's area and *planum temporale*, but remember Keller *et al.*, 2009b). Nevertheless, according to some scholars, the larger development of subcortical structures, which are crucial for language processing (Lieberman, 2000, 2006), corresponds to the right hemisphere (see Ifthikharuddin *et al.*, 2000 for the caudate nucleus and basal ganglia and Watkins *et al.*, 2001 for the caudate nucleus specifically; but see Gunning-Dixon *et al.*, 1998 and

Glenthøj *et al.*, 2007 for an opposite view). Also, evidence exists of a greater activation of the right portion of those structures in nuclear aspects of linguistic processing, like those concerning derivational morphology (Marangolo & Piras, 2010).

Finally, as the message complexity increases, a progressive recruitment of other cortical areas occurs (mainly reflecting a growing demand of verbal working memory capacity), including several areas of the right hemisphere (Just *et al.*, 1996). The validity of alleged inferences on linguistic capabilities of extinct species from fossil remains of neuronal structures (especially, the lateralization pattern) will be affected, and the same applies to the outcomes of their activity (right-handedness ratios), if we also consider the crucial fact that the anatomical delimitation and the purely linguistic interpretation of all those areas is evidently problematic. Hence, many of them show a multifunctional nature, in the sense that they are concerned with linguistic and nonlinguistic tasks. Moreover, the activation pattern of those “language areas” differs (in some ways) according to the nature of the tasks, and among individuals even executing the same task, whereas their exact localization varies (through some ways) in ontogeny. Those difficulties illustrate significant limitations Neurobiology has to face when analyzing language (Poeppl & Embick, 2005).

F’s claim that Neanderthals had complex language, as allegedly revealed by the right-handedness ratio, is taken to converge on independent lines of evidence: “up-to-date behavioral and anatomical studies of Neanderthal fossils and the recent discovery of their possession of the *FOXP2* gene” (F, p. 113). We believe, though, that those kinds of evidence are not as clear as they assume.

Firstly, the many reconstructions of vocal tract anatomy have proven to be completely inconclusive, for they suggest one thing, or quite the opposite (see Balari *et al.*, in press and Fitch, 2009 for discussion). Furthermore, comparative analysis has weakened them even more (Fitch, 2002, 2009): animal vocal tracts are highly flexible and mobile, in such a way that a descended larynx is not uniquely human and, accordingly, cannot be considered as a hallmark of speech.

Furthermore, exteriorization of linguistic messages through a vocal-auditory channel seems a contingent fact: sign languages are as complex as oral languages (see Brentari ed., 2010) although they use another channel.

Secondly, F (p. 122) claim that “an accumulation of considerable evidence for Neanderthal culture and symbolic behavior” exists. However, the attribution of symbolic capacities to Neanderthals is controversial to say the least. As Mithen (2005, p.229) puts it: “There are a few objects made by Neanderthals and immediate ancestors that have been claimed to have symbolic significance. These are so rare, so varied in nature, and so unconvincing, that basing an argument for symbolic thought and language on their existence –as some do– is frankly bizarre” (it should be noted that such evidence has recently weakened; see Higham *et al.*, 2010 and Mellars, 2010). Ultimately, a (cultural) system of symbols cannot be conflated with the productive and compositional nature of linguistic meaning (see Balari *et al.*, 2011, for a reassessment of the traditionally assumed relationship between symbolism and complex language).

Finally, the modern sequence of *FOXP2* (or of any other gene related to language in our species, if found in Neanderthals) cannot show by itself that Neanderthals had complex language. That inference implicitly considers that genes are simple causal agents (Jablonka & Lamb, 2005, p. 6) and also assumes a direct causal relationship between genotype and phenotype, both ideas being clearly inaccurate. Ontogenetic processes are regulated by many factors, both genetic and non-genetic, and highly tortuous developmental paths exist between genotype and phenotype (Oyama, 2000). As regards Neanderthals, only a reduced part of genetic factors (*FOXP2* codifying sequence) have been identified, but not, for instance, the genetic context in which the gene displayed its regulatory function in that species. Therefore, we cannot predict the reaction norm of their genotype (Pigliucci *et al.*, 1996), or infer their possession of a human-like linguistic capacity.

To sum up, F’s conclusion according to which Neanderthals had complex language is far from obvious.

## Acknowledgements

Research funded by the Spanish Ministerio de Ciencia e Innovación and FEDER under the Project "Biolinguistics: evolution, development, and fossils of language" (FFI2010-14955).

## References

- Arbib M. 2005. The Mirror System hypothesis: How did protolanguage evolve? In M. Tallerman (ed): *Language Origins*, pp. 21-47. Oxford University Press, New York.
- Balari S., Benítez-Burraco A., Camps M., Longa V.M., Lorenzo G. & Uriagereka J. 2011. The archaeological record speaks: Bridging Anthropology and Linguistics. *Int. J. Evol. Biol.*, 2011:article ID 382679.
- Balari S., Benítez-Burraco A., Longa V.M. & Lorenzo G. In press. The fossils of language: What are they, who has them, how did they evolve? In C. Boeckx & K.K. Grohmann (eds): *Handbook of Biolinguistics*. Cambridge University Press, New York.
- Bax J.S. & Ungar P.S. 1999. Incisor labial surface wear striations in modern humans and the implications for handedness in Middle and Late Pleistocene hominids. *Int. J. Osteoarchaeol.*, 9:189-198.
- Bishop D.V.M. 2001. Individual differences in handedness and specific speech and language impairment: evidence against a genetic link. *Behav. Genet.*, 31:339-351.
- Brentari D. (ed) 2010. *Sign Languages*. Cambridge University Press, New York.
- Cantalupo C. & Hopkins W.D. 2001. Asymmetric Broca's area in great apes. *Nature*, 414:505.
- Cashmore L., Uomini N.T. & Chapelain A. 2008. The evolution of handedness in humans and great apes: a review and current issues. *J. Anthropol. Sci.*, 86:7-35.
- Chance S.A. & Crow T.J. 2007. Distinctively human: cerebral lateralisation and language in *Homo sapiens*. *J. Anthropol. Sci.*, 85:83-100.
- Corballis, M.C. 2007. Cerebral asymmetry and human uniqueness. In W.D. Hopkins (ed): *The Evolution of Hemispheric Specialization in Primates*, pp. 1-21. Elsevier, Amsterdam.
- Crow T.J. 2008. The 'big bang' theory of the origin of psychosis and the faculty of language. *Schizophr. Res.*, 102:31-52.
- Fitch W.T. 2002. Comparative vocal production and the evolution of speech: reinterpreting the descent of the larynx. In A. Wray (ed): *The Transition to Language*, pp. 21-45. Oxford University Press, New York.
- Fitch, W.T. 2009. Fossil cues to the evolution of speech. In R. Botha & C. Knight (eds): *The Cradle of Language*, pp. 112-134. Oxford University Press, New York.
- Foundas A.L., Leonard C.M. & Hanna-Pladdy B. 2002. Variability in the anatomy of the planum temporale and posterior ascending ramus: Do right- and left handers differ?. *Brain Lang.*, 83:403-424.
- Foundas A.L., Leonard C.M., Gilmore R., Fennell E. & Heilman K.M. 1994. Planum temporale asymmetry and language dominance. *Neuropsychologia*, 32:1225-1231.
- Frayer D.W., Fiore I., Lalueza-Fox C., Radović J. & Bondioli L. 2010. Right handed Neandertals: Vindija and beyond. *J. Anthropol. Sci.*, 88:113-127.
- Frayer D.W., Lozano M., Bermúdez de Castro J.M., Carbonell E., Arsuaga J.L., Radović J., Fiore I. & Bondioli L. 2011. More than 500,000 years of right-handedness in Europe. *Laterality*, doi: 10.1080/1357650X.2010.529451.
- Glenthøj A., Glenthøj B.Y., Mackeprang T., Pagsberg A.K., Hemmingsen R.P., Jernigan T.L. & Baaré W.F. 2007. Basal ganglia volumes in drug-naïve first-episode schizophrenia patients before and after short-term treatment with either a typical or an atypical antipsychotic drug. *Psychiatry Res.*, 154:199-208.
- Gunning-Dixon F.M., Head D., McQuain J., Acker J.D. & Raz N. 1998. Differential aging of the human striatum: a prospective MR imaging study. *Am. J. Neuroradiol.*, 19:1501-1507.
- Higham, T., Jacobi R., Julien M., David F., Basell L., Wood R., Davies W. & C.B. 2010. Chronology of the Grotte Du Renne (France) and implications for the context of

- ornaments and human remains within the Châtelperronian. *Proc. Natl. Acad. Sci. U.S.A.*, 107:20234-20239.
- Holloway, R.L. 1981. Volumetric and asymmetry determinations on recent hominid endocasts: Spy I and Spy II, Djebel Ihroud I, and the Salé *Homo erectus* specimen. With some notes on Neandertal brain size. *Am. J. Phys. Anthropol.*, 55:385-393.
- Holloway R.L. 1983. Human paleontological evidence relevant to language behavior. *Hum. Neurobiol.*, 2:105-114.
- Holloway, R.L. & De La Costelareymondie, M.C. 1982. Brain endocast asymmetry in pongids and hominids: some preliminary findings on the paleontology of cerebral dominance. *Am. J. Phys. Anthropol.*, 58:101-110.
- Ifthikharuddin S.F., Shrier D.A., Numaguchi Y., Tang X., Ning R., Shibata D.K. & Kurlan R. 2000. MR volumetric analysis of the human basal ganglia: normative data. *Acad. Radiol.*, 7:627-634.
- Jablonka E. & Lamb M.J. 2005. *Evolution in Four Dimensions*. MIT Press, Cambridge (MA).
- Just M.A., Carpenter P.A., Keller T.A., Eddy W.F. & Thulborn B. 1996. Brain activation modulated by sentence comprehension. *Science*, 274:114-116.
- Keller, S.S., Roberts, N. & Hopkins, W. 2009a. A comparative magnetic resonance imaging study of the anatomy, variability, and asymmetry of Broca's area in the human and chimpanzee brain. *J. Neurosci.*, 29/46:14607-14616.
- Keller S.S., Crow T., Foundas A., Amunts K & Roberts N. 2009b. Broca's area: Nomenclature, anatomy, typology and asymmetry. *Brain Lang.*, 109:29-48.
- Kyriacou A. & Bruner E. 2011. Brain evolution, innovation, and endocranial variations in fossil Hominids. *PaleoAnthropology*, 2011: 130-143.
- Lieberman P. 2000. *Human Language and Our Reptilian Brain*. Harvard University Press, Cambridge (MA).
- Lieberman P. 2006. *Toward an Evolutionary Biology of Language*. Harvard University Press, Cambridge (MA).
- Liégeois F., Connelly A., Baldeweg T. & Vargha-Khadem F. 2008. Speaking with a single cerebral hemisphere: fMRI language organization after hemispherectomy in childhood". *Brain Lang.*, 106:195-203.
- Marangolo P. & Piras F. 2010. Language and its interacting components: the right hemisphere hypothesis in derivational morphology". *Brain Res.*, 1320:114-122.
- Mellars P. 2010. Neanderthal symbolism and ornament manufacture: The bursting of a bubble? *Proc. Natl. Acad. Sci. U.S.A.*, 107/47:20147-20148.
- Mithen S. 2005. *The Singing Neanderthals*. Weidenfeld & Nicholson, London.
- Natsopoulos D., Koutselini M., Kiosseoglou G. & Koundouris F. 2002. Differences in language performance in variations of lateralization. *Brain Lang.*, 82:223-240.
- Nettle D. 2003. Hand laterality and cognitive ability: A multiple regression approach. *Brain Cogn.*, 52:390-398.
- Oyama S. 2000. *The Ontogeny of Information*. Duke University Press, Durham.
- Peña-Melián A., Rosas A., García-Tabernero A., Bastir M. & De La Rasilla M. 2011. Paleoneurology of two new neandertal occipitals from El Sidrón (Asturias, Spain) in the context of homo endocranial evolution. *Anat. Rec.*, 294:1370-1381.
- Pigliucci M., Schlichting C.D., Jones C.S. & Schwenk K. 1996. Developmental reaction norms: the interactions among allometry, ontogeny, and plasticity. *Plant Species Biol.*, 11:69-85.
- Poeppel D. & Embick D. 2005. Defining the relation between linguistics and neuroscience. In A. Cutler (ed): *Twenty-first Century Psycholinguistics: Four Cornerstones*, pp. 103-120. Lawrence Erlbaum, Hillsdale.
- Rizzolatti G. & Arbib M.A. 1998. Language within our grasp. *Trends Neurosci.*, 21:188-194.
- Schenker N.M., Hopkins W.D., Spocter M.A., Garrison A.R., Stimpson C.D., Erwin J.M., Hof P.R. & Sherwood C.C. 2010. Broca's area homologue in chimpanzees (*Pan troglodytes*): probabilistic mapping, asymmetry, and comparison to humans. *Cereb. Cortex*, 20:730-742.
- Selnes O. & Whitaker H.A. 2006. Anatomical asymmetries versus variability of language areas of the brain. In K. Brown (ed): *Encyclopedia of*

- Language and Linguistics*, vol. 1, pp. 240-244. Elsevier, Oxford.
- Tobias P.V. 1983. Recent advances in the evolution of the hominids with especial reference to brain and speech. In C. Chagas (ed): *Recent Advances in the Evolution of Primates*, pp. 85-140. Pontificia Academia Scientiarum, Vaticano City.
- Uomini N.T. 2009. The prehistory of handedness: archaeological data and comparative ethology. *J. Hum. Evol.*, 57:411-419.
- Watkins K.E., Paus T., Lerch J.P., Zijdenbos A., Collins D.L., Neelin P., Taylor J., Worsley K.J. & Evans A.C. 2001. Structural asymmetries in the human brain: a voxelbased statistical analysis of 142 MRI scans. *Cereb. Cortex*, 11:868-877.
- Williams N.A., Close J.P., Giouzeli M. & Crow T.J. 2006. Accelerated evolution of Protocadherin11X/Y: a candidate gene-pair for cerebral asymmetry and language. *Am. J. Med. Genet. B Neuropsychiatr. Genet.*, 141B:623-633.

Associate Editor, Emiliano Bruner