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Three hands for the Neandertal lineage: reply to the comments

Emiliano Bruner[1,2] & Marina Lozano[3,4]

1) Centro Nacional de Investigación sobre la Evolución Humana, Burgos, Spain
e-mail: emiliano.bruner@cenieh.es

2) Istituto Italiano di Antropología, Roma, Italy

3) Institut Català de Paleoecologia Humana i Evolució Social, Tarragona, Spain

4) Universitat Rovira i Virgili, Tarragona, Spain

The comments made in response to our hypothesis add further relevant points on the use of the mouth as a "third hand" in a perspective of extended mind. Lambros Malafouris stresses that the whole body must be intended as an interface, which is, however, incomplete and always ameliorable. In this sense, an excessive attention to the eye-hand system alone may be misleading. Alternatives to these main "ports" are feasible, and improvements (or at least changes) can pass through very different pathways at any time. Marco Langbroek suggests that the "Neandertal-way" could be interpreted not as a limit or mismatch, but as a different arrangement, suited for a differently structured brain. He provocatively even suggests that those differences could evidence some limits in the "modern-way", which is excessively anchored and constrained to visual and physical inputs in their cultural niche. Thomas Wynn is skeptical about the possibility that visuospatial improvements can be detected later in hominid evolution, dating the latest changes little after the origin of the human genus. Frederick Coolidge points at other functional characters of the parietal areas as the main factors involved in parietal changes. In particular, he proposes that processes associated with numerosity or autonoetic consciousness are better candidates which could influence changes in the deep parietal elements, more than visuospatial integration alone. Changes in visuospatial functions can be a sort of by-product, in this sense. Manuel Martín-Loeches adds a further component to the model: the corticospinal system and all the neural architecture necessary to fine motor control. According to our hypothesis, this factor should be seriously considered indeed.

A general criticism of our hypothesis was a supposed tendency to consider an old-fashion linear and progressive scenario: from the incompleteness of intermediate pre-modern attempts, to the successful final product of our species. This point is crucial and somewhat interesting, given that it was not our intention to present our hypothesis in this way and that, in fact, we make no mention in any passage of things like linearity, intermediate stages, or even "superior" evolutionary steps.

In evolutionary studies, we should carefully consider the probability of hypotheses and processes, more than their possibility to happen (Bruner, 2013). Hence, it is surely "possible" that using the mouth for praxis can be adaptive and efficient but, is this really "probable"? Our hypothesis is based on a naïve but reasonable assumption: mouth is to eat, hand is to handle. This is a longstanding fact in the evolutionary history of vertebrates and, most of all, of Primates. Recycling of elements and characters is not rare in evolution, but in general it does not occur at low taxonomic level (that is, between strictly related species). More importantly, patent re-investments of anatomical components are generally limited to structures with minor functions, repeated parts,

or even vestigial characters. This is true mostly when the new function is particularly different from the original one. The reason is pretty simple: the original function, if important, cannot be compromised. It is difficult, in evolutionary terms, to change the function of a complex and fundamental element. The mouth is delicate and essential, and a quick recycling for praxis sounds risky and very complicated. In other words: very unlikely. Having hands, the most parsimonious interpretation of using the mouth for praxis is that this could have been an improvised solution. A hammer is a good tool to open nuts if you have no alternatives, but it is inappropriate, inefficient, and risky if there is a nutcracker on the table.

Therefore, recognizing that alternatives are possible, our hypothesis is based on the simple but logical reasoning that a good and stable arrangement is associated with enhancing and integrating handling ability for the hands, eating ability for the teeth, and vision ability for the eyes, taking advantage of the long evolutionary background of primates.

A second point concerns the "incompleteness" of the Neandertal visuospatial complex. Incompleteness refers to a lack of balance, a sub-optimal organization which arises from constraints and lack of integration. Such a mismatch in not necessarily associated with "intermediate" steps but, in evolution, it is frequently associated with blind alleys and extinction. It is worth noting that, in a similar way, constraints and imbalances have been also hypothesized concerning the structure of the Neandertals' braincase (Bruner, 2014). A hypothetical Neandertal mismatch between biological and cultural systems, interpreted as a given degree of uncoupling between brain and body evolution, might have occurred as an independent event irrespective of the existence of another species following a different scheme. That is, and excessive use of the mouth in handling sounds inappropriate for a human species irrespectively whether or not another lineage is making it differently. The assumption of linear and gradual evolution is not at all necessary to our hypothesis (and definitely never mentioned), and a mismatch of the Neandertal visuospatial integration system could have occurred even if modern humans had never existed.

Hence, we see no trace of linear or progressive anthropocentrism in our hypothesis. The fact that anthropocentrism (better to say "*Homosapienscentrism*") is not a necessary part of our hypothesis, and the fact that there are many commentaries which point in that direction, may suggest that an implicit idea of gradual and progressive evolution is so rooted in our culture that it induces defensive responses also when that delicate nerve is not even touched.

If on the one hand, the mismatch of the Neandertal system can be "incomplete" because of a lack of fine tuning between organic and super-organic relationships, on the other, the "completeness" of modern humans must not be intended as the final perfect solution. It is just a "more proper" solution, because it is based on a more coherent enhancement of the resources: mouth to eat, hand to handle, eye to see. The cultural processes following the origin of our species evidenced that those solutions were essential but not definitive: technology will come to integrate further this interface (Iriki & Taoka, 2012).

Although in cognitive archaeology, most hypotheses cannot be tested by direct experimental paradigms, we can, nonetheless, add information supporting or contrasting a given logical scenario, increasing or decreasing the probability for the hypothesis to be correct. Our hypothesis is based on a specific behavior (use of mouth for praxis), paleoneurological data (evolution of the parietal areas associated with visuospatial integration functions) and archeological information (cultural complexity). The next step is to find other evidence which can support or contrast our proposal. If *Homo heidelbergensis* and Neandertals experienced a mismatch between cultural and biological networks at visuospatial level, this must be reflected in other behaviors. In this sense it is worth noting that, as recalled by Thomas Wynn, it was suggested that Neandertals were not able to manage projectile technology. They display traumatic features suggesting hunting techniques based on a close-in approach and physical conflict (Berger & Trinkaus, 1995). This

supposed lack of ability in coordinating long-distance hunting techniques is however much debated, and there is no agreement in this sense (Boeda *et al.*, 1999; Lazuén *et al.*, 2011; Hardy *et al.*, 2013). Nonetheless, these kinds of evidence on visuospatial capacities are the ones that can, in the future, support or contrast our hypothesis.

We strongly agree with the viewpoint supplied by Marco Langbroek (2012), which is definitely welcome after decades of misleading linear perspectives in human evolution: the evolutionary history of independent lineages must be interpreted independently, and extinct species may have had cognitive capacities which have been lost or never attained by *Homo sapiens*. The recent hypothesis on the Neandertals' occipital lobes put forward according to indirect quantitative evidence represents a step in this direction (Pearce *et al.*, 2013). Recognizing the independence of the Neandertal and modern lineages, and recognizing the importance of theories in the extended mind and embodiment, we must consider to what extent these two human forms have managed to integrate their brain, body, and culture. They shared similar brain volume, similar environments, and similar chronology. Neandertals even shared with early anatomically modern humans a similar technology too. One branch is currently extinct, after producing basic tools for a hunter-gatherer lifestyle. The other one is still on the road, producing pendrives. It is not a matter of superiority, but probably it is more a question of cognitive levels of integration, which is the ultimate topic of cognitive archaeology.

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