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Gabrić, Petar; Banda, Marko

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Did early *Homo* have language? Neurocognition behind stone tool-making

Petar Gabrić[1], Marko Banda[2]
[1]University of Zagreb, Faculty of Humanities and Social Sciences, Department of Linguistics, Zagreb, Croatia
[2]University of Zagreb, Faculty of Humanities and Social Sciences, Department of Archaeology, Zagreb, Croatia

Recently, considerable interest for language evolution has arisen. Many researchers believe that language evolved via exaptation of domain-general cognitive systems such as long-term memory, visuospatial processing and executive functioning. Therefore, many studies on language evolution have focused on determining when specific cognitive functions, which might have supported language, developed. One approach in this area has been to establish the neurocognitive and neural correlates of specific behaviours during the Palaeolithic period (from ~3.3 mya to ~10 kya). The focus has been on stone-toolmaking-related behaviours because of the higher preservation of stone in the archaeological record compared to other materials. The earliest stone industry is the pre-*Homo* Lomekwian. It has been hypothesized based on experimental replication of the knapping process that the Lomekwian findings are suggestive of lesser functional lateralization of the motoric and prefrontal cortex compared to modern humans. The next stone industry, the Oldowan, typically associated with *Homo habilis*, has been linked to more complex subsistence strategies and social behaviours. Neuroimaging studies have shown that Oldowan toolmaking predominantly involves frontoparietal sensorimotor areas and the cerebellum, which is why this industry has been described as cognitively relatively „ape-like“. The following industry, the Acheulean, taxonomically linked to *Homo erectus* and chronologically coinciding with significant brain enlargements in our genus, is believed to be more demanding in hierarchical and sequential action processing compared to earlier technologies. Additionally, neuroimaging studies have shown higher activation of the right Broca's area and temporal cortici during Acheulean compared to Oldowan toolmaking. Recently, a study by our lab comparing sidescraper manufacture, associated with *Homo heidelbergensis* and Neanderthals, and Oldowan toolmaking has found higher involvement of visuospatial and executive functions in the former task. While it is hard to generalize based on this data, we will suggest some implications for the existence of language in early *Homo*.

CONTACT: petar.gabric1@gmail.com

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Did early *Homo* have language?

Neurocognition behind stone toolmaking

PETAR GABRIĆ, Department of Linguistics, University of Zagreb, petar.gabric1@gmail.com
MARKO BANDA, Department of Archaeology, University of Zagreb, markobanda0@gmail.com

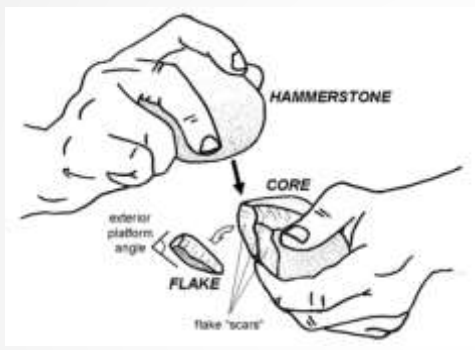
INTRODUCTION

Language is an emergent phenomenon – it is achieved through interaction of various „domain-general" cognitive domains and it is processed in diverse areas of the brain.
It is believed that language evolved via **exaptation** – the reuse of previously existing structures/functions.

One way to study this is to find **neural and neurocognitive correlates of Palaeolithic behaviours**. Due to favourable preservation of stone compared to other materials, **stone toolmaking** is the most intensely researched Palaeolithic behaviour.

OLDOWAN

Dating: from ~2.6 to ~1.42 mya
Hominins: australopithecines, *H. habilis*, early *H. erectus*
Types of artefacts: pebble tools and flakes



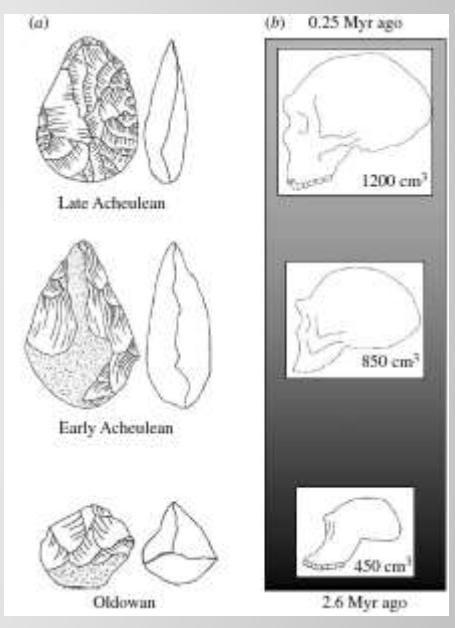
from: Stout & Chaminade (2007)

Trends: increase in body size and modern limb-like proportions, reduction in tooth size and jaw robusticity, planning in raw material management

Oldowan flaking has been described as involving mainly the **frontoparietal sensorimotor areas**, most notably the vPrCG, SMA and IPS, and the **cerebellum** while it is not associated with prefrontal activity.
It relies, therefore, mostly on **motor and visuospatial processing**, with no apparent role of e.g. executive functioning, suggestive of more **„ape-like" cognitive abilities** .

ACHEULEAN

Dating: from ~1.7 mya to ~100 kya
Hominins: *H. erectus*, *H. heidelbergensis*
Types of artifacts: handaxes, retouched flakes etc.
Trends: increase in brain size, evidence of functional lateralisation, control of fire, „symbolic" behaviour



from: Stout et al. (2008)

Higher activation during Acheulean handaxe manufacture relative to Oldowan flaking was found **bilaterally in the vPMC, inferior parietal areas, right Broca's area and bilaterally in the temporal areas** .
Gabrić et al. (in preparation) studied the **neurocognitive correlates of sidescraper** manufacture. Compared to the Oldowan chopper manufacture it showed to have **higher visuospatial and executive demands**.

CONCLUSIONS

It seems that Oldowan cognition shows more resemblance to the earliest hominins and australopithecines than to modern humans.
While it is hard to say whether Acheulean hominins had language, data suggests that **some crucial aspects of modern human cognition might have been in place in the Acheulean, more probably from later Acheulean**. This might imply that the cognitive prerequisites for language had been met during that time.

Behavioural escalation during the Acheulean suggests that more **enhanced modes of communication**, not necessarily linguistic communication, were appearing.
Language in Oldowan populations seems unlikely.
Much more empirical research is needed to clarify these issues and **escape the speculative inferring** which has plagued much of the research on the evolution of cognition and language.

REFERENCES: See handout

DID EARLY *HOMO* HAVE LANGUAGE? NEUROCOGNITION BEHIND STONE TOOLMAKING (handout)

Petar Gabrić[a], Marko Banda[b]

[a]Department of Linguistics, Faculty of Humanities and Social Sciences, University of Zagreb

petar.gabric1@gmail.com

[b]Department of Archaeology, Faculty of Humanities and Social Sciences, University of Zagreb

markobanda0@gmail.com

9th Student Congress of Neuroscience „NeuRi“, 26.–28. April 2019, Faculty of Medicine, University of Rijeka / Psychiatric Hospital „Rab“, Rijeka/Rab (Croatia)

INTRODUCTION

There is no one conventional definition of language. The neurocognitive approach to linguistics shows that **language is an emergent phenomenon** – it is achieved through interaction of various „domain-general“ cognitive domains and it is processed in diverse areas of the brain.

E.g. language acquisition is served by systems of **declarative and procedural memory** (Hamrick et al. 2018), and semantic knowledge is largely comprised of **sensorimotor information** (Pulvermüller 2013).

Language is „old” and it supposedly emerged sometime during the Lower or Middle Palaeolithic. It is believed that language evolved via **exaptation** – the reuse of previously existing structures/functions.

WHICH COGNITIVE FUNCTIONS UNDERLIE LANGUAGE?

WHEN WERE THESE COGNITIVE FUNCTIONS EVOLUTIONARILY PRESENT, SO THAT THEY COULD ENABLE THE EMERGENCE OF LANGUAGE?

One way to study this question is to find **neural and neurocognitive correlates of Palaeolithic behaviours**. Due to favourable preservation of stone compared to other materials, **stone toolmaking** is the most intensely researched Palaeolithic behaviour.

Earliest found stone tools are dated to ~3.3 mya (Lomekwi, Kenya), yet their implications for human evolution remain enigmatic (Harmand et al. 2015).

Some non-human primates also exhibit simple stone tool use, but it is unclear if there are phylogenetic ties between non-human primate and human tool use (Haslam et al. 2017).

OLDOWAN (Haviland et al. 2008; Schick & Toth 2006; Toth & Schick 2018)

Dating: from ~2.6 to ~1.42 mya

Geography: mostly limited to Africa

Hominins: the genus *Australopithecus*, *Homo habilis*, early *Homo erectus*

Types of artefacts: mostly pebble tools, but also, predominantly simple, flakes probably used for butchering, plant processing and woodworking

The industry is characterized by simple flaked and battered artefacts, most notably pebble and unretouched flake tools, although simple retouched tools can be found in Oldowan assebmblages. During the Oldowan, stone tools are made exclusively with the use of a hard stone hammer, either by direct percussion, bipolar percussion, anvil technique or by throwing.

Toolmaking: well-developed mastery of knapping, planning in raw material procurement and management (but materials most often collected from the „immediate“ environment)

While raw material procurement depended upon specific geological conditions of a surrounding area, it appears that in the earlier stages of Oldowan igneous rocks were used for tool production and in later stages quartz and quartzite played a more significant. On the basis of bone taphonomy, use-wear microscopic analysis and experiments it has been suggested that Oldowan tools were used for butchering (meat-cutting and bone fracturing), plant processing and woodworking. Unretouched, sharp-edged flakes were commonly employed for such tasks, suggesting they were an important part of the technological system.

Biological trends: increase in brain size (in later Oldowan sites), increase in body size and modern limb-like proportions, reduction in tooth size and jaw robusticity, beginnings of functional lateralisation

Behavioural trends: increased technological complexity compared to the earliest found stone tools from Lomekwi, processing of large mammalian carcasses

ACHEULEAN (de la Torre 2016; Haviland et al. 2008)

Dating: from ~1.7 mya to ~100 kya in some parts of the world

Geography: spread from Africa to other continents

Hominins: *Homo erectus* (but the taxonomic picture remains complicated), middle Pleistocene hominins (*Homo heidelbergensis* etc.)

The emergence of the Acheulean industry is generally linked with the appearance of *Homo erectus/ergaster*, but a more detailed perspective suggests that this connection is quite complicated, as the earliest Homo erectus found outside of Africa have been associated with industries of Oldowan character and the Acheulean in Africa also coincides with the presence of another hominin, *Paranthropus boisei*. Be that as it may, later stages of the Acheulean are firmly associated with *Homo erectus* and other Middle Pleistocene hominins (i.e. *Homo heidelbergensis*).

Types of artifacts: handaxes, retouched flakes (in greater quantities compared to Oldowan)

The industry is characterised by the presence of handaxes, large, more or less symmetrical tools that can be flaked on both sides and usually have an amygdaloidal form. Furthermore, retouched flakes make up a greater portion of assemblages than in Oldowan industries, while the issue of their standardization is still contentious (Brumm & McLaren 2011; Hosfield 2013). The Acheulean tool-makers utilised a number of techniques for production, besides those used in the previous Oldowan, most notably bifacial flaking (shaping), large flake production (for handaxe blanks) (Sharon 2010) and direct soft hammer percussion (antler, bone or wood).

Toolmaking: manufacture of symmetrical tools, longer distances in the transport of raw materials compared to Oldowan

Biological trends: high increase in brain size over time, further reduction in tooth size and jaw robusticity, more evidence for functional lateralisation

Behavioural trends: increased technological complexity compared to Oldowan (soft hammer use, diversification of tools etc.), terrestrial as well as maritime migrations, control of fire, possible „symbolic“ behaviour, hunting

The earliest evidence of controlled use of fire comes from Acheulean contexts, dated to 1 mya (Berna et al. 2012). Homo erectus/ergaster was also the first hominin species that spread from Africa, with the oldest known fossils found in Dmanisi, Georgia at around 1,8 mya (Lordkipanidze et al. 2013), suggesting adaptation to various ecological environments. Recent finds of lithic artefacts from Shangchen (China), dated to 2,1 mya, suggests that hominins may have left Africa earlier than previously thought (Zhu et al. 2018).

OLDOWAN AND ACHEULEAN TOOLMAKING: NEURAL AND NEUROCOGNITIVE CORRELATES

Oldowan

Oldowan flaking has been described as involving mainly the **frontoparietal sensorimotor areas**, most notably the vPrCG, SMA and IPS, and the **cerebellum** while it is not associated with prefrontal activity (Stout et al. 2000; Stout & Chaminade 2007).

It relies, therefore, mostly on **motor and visuospatial processing**, with no apparent role of e.g. executive functioning, suggestive of more **„ape-like" cognitive abilities** (Putt et al. 2017). Still, the cerebellum has been implicated in „higher" cognitive functions, including attention, planning and language (Vandervert 2018).

Acheulean

Higher activation during Acheulean handaxe manufacture relative to Oldowan flaking was found **bilaterally in the vPMC, inferior parietal areas, right Broca's area and bilaterally in the temporal areas** (Stout et al. 2008; Putt et al. 2017).

However, **Putt et al. (2017) have cast doubt on the potential role of Broca' area** in Acheulean toolmaking. In their fNIRS study they reported that acquiring Acheulean handaxe manufacture in a verbal teaching condition had increased activation in the right pars triangularis compared to the non-verbal condition. Nevertheless, comparisons between the toolmaking and control tasks were not reported. Be that as it may, it has been proposed that Broca's area poses a possible connection between the evolution of toolmaking and language because of its prominent role in schematic body representation as well as sequential and hierarchical goal-directed action processing (e.g. Ruck 2014). Additionally, Kemmerer (2012) suggested that the cross-linguistically most prevalent word orders SOV and SVO reflect the ways Broca's area processes actions and/or events.

Putt et al. (2017) and Putt & Wijeakumar (2018) suggest that the Acheulean-related temporal activation is associated with **auditory working memory**, a possible precursor to language, and that the **vPMC** was a further potential point of convergence.

Gabrić et al. (in preparation) studied via a neuropsychological test battery the **neurocognitive correlates of sidescraper manufacture**, a tool first appearing in late Acheulean, but gaining a prominent role during the Neanderthal-related Mousterian. Compared to the Oldowan

chopper manufacture it showed to have **higher visuospatial and executive demands**, especially the manufacture steps involving **retouch**.

CONCLUSIONS

- Evidence from the Oldowan displays increased complexity in behaviour and cognition compared to previous stages of hominin evolution, as seen in e.g. stone toolmaking, raw material management, subsistence strategies etc.
- Compared to simply striking two stones together with no intention of toolmaking there is a significantly greater activation in the frontoparietal sensorimotor areas and the cerebellum. Although these areas probably developed through Oldowan, they are not typically associated with modern human cognition, with the exception of the cerebellum.
- Therefore, it seems that **Oldowan cognition shows more resemblance to the earliest hominins and australopithecines than to modern humans.**
- Evidence from Acheulean, and especially from later Acheulean, shows significantly increased complexity in behaviour and cogntion compared to Oldowan, as seen in technology, raw material procurement, spatial navigation, subsistence strategies and possible „symbolic“ behaviour.
- Compared to Oldowan there is a significantly higher activation during Acheulean toolmaking, among others, in the prefrontal and temporal cortici, suggesting higher cognitive demands. Notably, both prefrontal and temporal areas are crucial for linguistic functioning.
- Gabrić et al. (in preparation) showed that compared to Oldowan chopper manufacture the manufacture of the sidescraper, a tool appearing in greater quantities in the Acheulean and becoming highly frequent in the Neanderthal-related Mousterian, has significantly higher visuospatial and executive demands.
- While it is hard to say whether Acheulean hominins had language, data suggests that **some crucial aspects of modern human cognition might have been in place in the Acheulean, more probably from later Acheulean**. This might imply that the cognitive prerequisites for language had been met during that time.
- Behavioural escalation during the Acheulean suggests that more **enhanced modes of communication**, not necessarily linguistic communication, were appearing.

- **Language in Oldowan populations seems unlikely.**
- Much more empirical research is needed to clarify these issues and **escape the speculative inferring** which has plagued much of the research on the evolution of cognition and language.

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