Semiotic Evolution of Toolmaking: the Role of Symbols for Work towards Delayed Reward

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ABSTRACT. Tools depend on mental models that mediate their construction by way of motor acts. Given that tools are signs of semiotic behavior, the semiotic characterization of Neolithic weapon production has the potential to elucidate the broad cognitive processes underlying the origins of tool-making. Spatio-temporal correlation is the defining property of indexes, while laws characterize symbols. Stones picked and thrown at a prey or predator can instantaneously index fight and social rank, but carefully manufactured stone weapons, which require elaborate and tiring work over extended periods of time, require by necessity the symbolic association of complex motor habits with anticipatory images of successful tool use, i.e. specific classes of effects such as prey chase, kill, transportation, preparation, sharing and eating. Reward-related symbolization during tool manufacture would allow for active mnemonic traces in the cerebral cortex and hippocampus to engage limbic circuits related to emotion and reward seeking. This would provide the motivation required for work towards a distant goal, leading to the sustained and repetitive activation of motor cortex and striatum. Additional symbolization at the level of gestures, postures, vocalizations, sand drawing and wall painting were the likely waking motivators of Neolithic weapon making, in addition to dreams depicting the hunting act and the associated symbols. We propose that Neolithic tool-making would have been impossible without symbolization.

Keywords: Symbols, symbolic mind, tools manufacture, evolution of cognition.

RÉSUMÉ L'évolution sémiotique de la fabrication d'outils : le rôle des symboles pour un travail avec récompense différée. Les outils dépendent des modèles mentaux qui servent de médiateurs dans leur production par le biais d'actes moteurs. Étant donné que les outils sont une des expressions du comportement sémiotique général, la caractérisation sémiotique de la manufacture des armes au Néolithique peut permettre d'élucider les divers processus cognitifs sous-jacents aux origines de la production d'outils. La corrélation spatio-temporelle est la propriété définissant les indices, alors que les symboles se caractérisent par le fait d'être régis par des lois. Des pierres prises et jetées sur une proie ou sur un prédateur peuvent instantanément être des indices de lutte et de classification sociale, mais des armes en pierre soigneusement manufacturées, qui demandent un long travail élaboré et fatigant, demandent nécessairement la présence d'une association symbolique entre des habitudes motrices complexes et des images anticipant l'usage fructueux de ces mêmes outils, c'est-à-dire des classes spécifiques d'effets possibles, comme pourraient l'être la capture, la mise à mort, le transport, la préparation, le partage ou la

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consommation des proies. La symbolisation des outils lors de la manufacture permettrait de relier les traces mnémoniques actives au niveau du cortex cérébral et de l'hippocampe aux circuits limbiques liés aux émotions et au système de récompenses. Ceci fournirait la motivation nécessaire pour accomplir un travail orienté vers un but lointain, par l'activation prolongée et répétitive du cortex moteur et du strié. La progressive symbolisation des gestes, des postures, des vocalisations, des dessins sur le sable ainsi que la peinture murale constituèrent probablement, avec les rêves représentant la chasse et l'ensemble des symboles précédemment mentionnés, la motivation première de la production des armes au Néolithique. Notre hypothèse est que, sans ce travail de symbolisation, toute production d'outils au Néolithique aurait été impossible.

Mots-clés : Symboles, pensée symbolique, manufacture des outils, évolution de la cognition.

THE PROBLEM:

The relation between tool-manufacture, tool-manipulation and the emergence of symbolic behavior in the hominid evolutionary history has attracted researchers in fields as diverse as comparative psychology, cognitive archaeology, ethology, and evolutionary psychology (Wurz 2010; Stout 2010; Davidson & Nowel 2010; Gibson & Ingold 1993). Tools depend on mental models that mediate their construction by way of motor acts: tools are dependent on 'the ability to envisage such geometric relations as symmetry of plan-form and cross-section' (Toth & Schick 1993: 351); they are dependent on the 'capacity for conceiving and executing increasingly elaborate material culture designs' (Isaac 1976: 276). What is the relationship between the emergence of symbols and the construction of complex artifacts?

SEMIOTIC BEHAVIOR:

Many researchers have speculated on the relations of correspondence regarding the origins and general cognitive structures that can be established between different types of semiotic behavior, and the manufacture and manipulation of different tools (Stout 2010; Wynn 1993, 1999; Davidson & Noble 1996; Graves 1994; Ingold 1994; Toth & Schick 1993). Despite the fact that the relation between symbolic behavior (currently associated with the foreseeing and planning of events) and tool manufacture and manipulation remains controversial, it is generally agreed that language phenomena are related to tool manufacture and manipulation in evolutionary and cognitive terms (Greenfield 1991; Savage-Rumbaugh et al. 1998; Matsuzawa 1996; McGrew 1993; Snowdon 1993; Tomasello 1999). For example, tool use is related to the capacity of solving problems involving the hierarchical organization of elements. According to Greenfield (1991: 532), the 'structural combinatorial development' of objects and symbols follows a hierarchy of strategies: 'pairing, pot, and subassembly'.

However, there is yet no consensus about how to associate specific aspects and properties of stone-tool technologies with semiotic competences such as grammaticality, recursiveness, theory of mind, symbolism and arbitrariness of the sign. In this work we propose that Peirce's pragmatic model of *semiosis* (considered as a process) can explain tool manufacture and manipulation as

semiotic behaviors. We use this approach to discuss how stone-tool technologies may be related to the origins of symbolic processes in the hominid lineage.

Wynn's model of semiotic behavior assumes that hominid tool-use began ~ 2 million years ago (mya). Wynn noted that although the ecological context of hominids 2 mya was very similar to that of modern apes, the construction and function of hominid tools was already very different from what is found in modern apes. Still, Wynn considers that these early hominid tools do not constitute evidence of language ability, since there is no symbolic behavior strongly associated with these tools. Hominid tools dating from 300.000 ya are very conservative in style, failing to showing the 'volatile fashion of modern tools'. Although Wynn considers tools from 85.000 ya as "between biface assemblages and modern technology", they have not changed much in style, showing a negligible semiotic role in comparison with modern tools, but "perhaps represent[ing] the very beginnings of modern forms of tools". For the author, only more recent tools should be considered as having an indexical role comparable to that of modern tools, so that "the style of most of the artifacts acted as an index of social identity", and reflected a specialized dynamic in the social environment directly related to the cultural communication of information (1999: 264-79). Wynn's semiotic analysis is related to cultural or social aspects of tool making and use. However, he did not consider ancient tools as signs of ancestral cognitive capacities. He simply compared the cultural and social aspects of early tool usage with modern technological behavior. Although he does not consider ancient tools as signs of ancestral cognitive capacities, he describes technical behavior as semiotic behavior, introducing a powerful model for recognizing cognitive capacities in tool use.

SEMIOTIC THEORETICAL FRAMEWORK:

Peirce's semiotics is defined as the theory of all possible varieties of sign-mediated processes. The notion of semiosis (meaning processes) as a form communicated from object to interpreter through the mediation of a sign allows us to conceive meaning in a processual (non-substantive) way, as a constraining factor of possible patterns of interpretative behavior through habit and change of habit (see Peirce EP 2.544).

Figure 1

Semiosis as a relation between three irreducibly connected terms (sign-object-interpretant, S-O-I). This triadic relationship communicates a form from the object to the interpretant through the sign.

The form is defined as something that is embodied in the object as a “regularity”, a “habit or a “disposition”. It is important to notice that the habit embodied in the object allows a semiotic system to interpret the sign as representative of a class of entities or phenomena. The communication of a form from the object to the interpretant constrains the behavior of the interpreter in the sense that it brings about a constrained set of object effects on the interpreter through the mediation of a sign.

Sign-mediated processes show a remarkable variety. There are three fundamental kinds of signs underlying meaning processes – icons, indexes, and symbols. Respectively, a sign may be analogous to its object, spatio-temporally connected to it, or might represent it by means of a law or norm. These classes correspond to relations of similarity, contiguity, and law between sign and object. Generally speaking, an iconic sign communicates a form embodied in an object to the interpretant as a result of a certain quality that the sign and the object share. Among the iconic examples mentioned by Peirce, we find images, diagrams, metaphors, pictures, maps, ideographs and hieroglyphs. In terms of cognitive processes, icons are associated with sensory tasks. They are present in the sensorial recognition of external stimuli of any modality, and in the cognitive relation of analogy. The notion of spatio-temporal co-variation is the most characteristic property of indexical processes. The examples range from a demonstrative or relative pronoun, which “forces the attention to the particular object intended without describing it” (Peirce CP 1.369), to physical symptoms of diseases, photographs, weathercocks, thermometers. Generally speaking, an indexical sign communicates a form embodied in an object to the interpretant as a result of a direct physical connection between sign and object. Finally, in a symbol, the relation between sign and object is logically dependent on the third term, the interpretant. “The symbol is connected with its object by virtue of the idea of the symbol-using mind, without which no such connection would exist” (CP 2.299). In a symbolic relation, the interpretant stands for “the object through the sign” by a determinative relation of law, rule or convention (CP 2.276). According to Peirce (CP 2.307), a symbol is “a Sign (q.v.) which is constituted a sign merely or mainly by the fact that it is used and understood as such, whether the habit is natural or conventional, and without regard to the motives which originally governed its selection.” In the symbolic sign process the form that is communicated from the object to the interpretant through the sign is a lawful relationship between a given type of sign and a given type of object.

Therefore, a symbolic sign communicates a habit embodied in an object to the interpretant as a result of a law-like regularity in the relationship between sign and object. While indexes are causally anchored at the spatio-temporal co-occurrence of sign and object, symbols are able to represent things that do not even exist, or exist but are not perceptually manifest. The constraints imposed by the spatio-temporal presence of the indexical object are not functional in symbolic processes. Symbols, on the other hand, are strongly constrained by the necessity to reactivate, in the absence of the object signified, the neural circuits involved in the past encoding of the same kind of object. Therefore, while indexes only require the fleeting use of a perceptual apparatus able to detect synchrony, symbols demand in addition the sustained use of a memory

database, such as the hippocampo-cortical loop that underlies the encoding of episodic memories (Eichenbaum 2006).

OLDOWAN AND ACHEULEAN TOOLS:

The construction of stone tools is a subtractive activity – “one removes material to achieve a result” (Wynn 1999: 266). The three basic kinds of stone tools are cores, modified flakes, and unmodified flakes (*ibid.*). Some characteristics that define Oldowan tools are the alternated removal of flakes in one or more edges of the stones (they are called choppers, polyhedrons and spheroids), and unmodified or casually retouched stone flakes in many sizes and forms. Oldowan tools were made of quartz, basalt and quartzite, and were probably used to scratch wooden objects, to cut, to hammer and to chip stones (Wynn 1993, 1999; Mithen 1996). Acheulean tools were produced differently, in distinct sizes and shapes, and were probably used for a wider variety of purposes. The chip patterns follow a stone tangential fracture (Leroi-Gourhan 1964), completely modifying the original material. Some characteristics that define the Acheulean tools are: chipped stones in the form of a pear; symmetrical bifacial chipping, removal of flakes from both sides of the artifact to produce hand axes; and stones with a plain edge, rather than pointed or bent, to produce chipping tools. These tools were employed to sharpen wooden tools, break bones, chip stones, cut meat, tendons and leather (Wynn 1999; Mithen 1996), and maybe to drill and to dig (Leroi-Gourhan 1964).

For Wynn (1999: 284), bifacial tools are indexes of something, but “we do not know what that something was”. According to his model (1993, 1999: 263), there are four topics related to stone tools – ecological utility, the user’s intelligence, implications for the evolution of language, and their indexical role. We are especially interested in the last topic, but from a very different perspective. Wynn postulates that processes of tool manufacture and manipulation function as semiotic phenomena, so that tools constitute indices of social structure (Wynn 1999: 279). We consider tools as signs of general semiotic behavior, so that the characterization of tool production indicates the broad cognitive processes underlying the process. In that sense, a tool will be indexical to its user if it can signal a physical relation between what it stands for and how it is used. By the same token, a tool is a symbol when it is connected to some entity or process by means of a law, convention or habit.

The emergence of symbolic behavior is currently attributed to the Upper Paleolithic period (see Chase 1999; Aiello & Dunbar 1993). For several authors, there is no archaeological evidence dating from before that period that can be considered symbolic. With regard to tool manufacture and manipulation, what is considered symbolic behavior is the capacity of foreseeing the effects of specific tools in the course of their construction. This capacity is associated to the prediction and planning of events involving tool use.

According to Ingold (1993: 338), summarizing Davidson and Noble, “the shapes of bifaces can be fully accounted [for by] the mechanical constraints of the manufacturing process”, leading to the interpretation that the kind of semiosis involved in tool production is indexical. But for Toth and Schick (1993: 351), there is evidence of planning in the construction of biface tools,

which requires months of practice before refined preparations of raw material can be achieved. Symmetrical regular bifaces clearly express the hominid capacity for planned production, by means of the detailed anticipation of many physical effects. This capacity is accepted as a “cognitive symptom” associated to the emergence of symbolic cognition, or the “capacity for manipulating symbols” (Isaac 1976: 276).

It is quite clear that the emergence of symbolic activity may be related to the emergence of an agent that handle artifacts with the purpose of obtaining oriented effects (Wurz 2010). Symbols are inextricably linked to the capacity to anticipate events. What still seems quite unclear is how the activity of designing artifacts is dependent on symbolization, not as a by-product but as a very strict necessity. There is no agreement regarding the most appropriate criteria for classifying ‘tool-manufacture/tool-manipulation’ as a symbolic process. Peirce’s model of semiosis provides an operational criterion to determine the nature of symbols (see Queiroz 2012; Queiroz & Ribeiro 2002). According to Peirce, a symbol is a Sign-Object relationship logically dependent on the Interpretant. By contrast, an index is an Object-dependent semiotic process. Constraints resulting from the space-time presence of the object represented by the index are irrelevant in symbolic processes. Symbols depend logically on the effects produced by their use (Ribeiro *et al.* 2007).

TOWARDS A SEMIOTIC DESCRIPTION OF TOOL MAKING AND USE:

A distinction must be established between patterns of tool use and production. This distinction was suggested by van Schaik (*et al.* 1999: 719-721) and can be summarized as follows: Tool production requires a modification of the raw material used (*e.g.* leaf removal from a twig); patterns of tool use do not involve material modification but require a sequence of manipulations that includes selection, handling in specific angles, and use in specific ways. When we analyze tools as signs, we observe patterns of use, or habits of action, meaning the effects of the sign for an interpreter, as the very interpretant (I) of the sign (S). By the same token, patterns of tool production (*e.g.* chipping) *stand for* the tool as the object of the sign. Actually, we can only infer the sign type if we reconstruct the habit that the object communicates to the interpretant through the sign itself. Motor patterns underlying tool production communicate a habit to the patterns of tool use (specific ways of manipulation), through the sign (the tool). Therefore: (i) there is a sign, the tool (S); (ii) there is the object of the sign, designated here as patterns of chipping (O), potentially capable of producing specific consequences (effects of the tool), constraining the action of interpreters. These consequences are the interpretants (I), designated here as patterns of use; (iii) the relation chipping-tool (O-S) has its semiotic nature determined by the form that is communicated from O (patterns of chipping) to I (patterns of use) through S (tool); (iv) this operational definition allows us to classify tools as either icons, indexes or symbols. In addition, it allows us to infer the semiotic behavior of the tool’s producer or user. The most relevant question here is to know how the form incorporated in the object, by way of a repetitive motor pattern (chipping), is communicated through the tool to an interpreter.

Figure 2

Semiotic tool as a relation between three irreducibly connected terms (tool/ patterns of chipping/patterns of use, S-O-I). This triadic relationship communicates a form from the object to the interpretant through the sign.

The technical behavior involved in tool production can be considered a semiotic process, which can be characterized as symbolic, indexical and iconic. The tool involves a symbolic process if the *patterns of tool use* mediate the relation between the tool and the patterns of chipping. Oldowan and Acheulean tools satisfy this last criterion (see Toth & Schick 1993; Wynn 1993, 1999; Mithen 1996), since they could not be produced exclusively by indexical processes, i.e. the future effects of the tool must be anticipated during its manufacture. In this scheme, the relation between S (tool) and O (patterns of chipping) logically depends on the mediation of the patterns of use (specific ways of manipulation: cutting, hammering etc.).

THE ROLE OF SIGNS FOR TOOL CONSTRUCTION IN THE STONE AGE:

When hominid tools were first built and employed, what sort of signs were they? Primitive tools for cutting and hammering were likely seen as icons of teeth and claws, natural objects very well known by the entire hominid lineage. Tools were also indices of imminent aggression, and therefore must have quickly acquired symbolic meaning related to social dominance. If it is easy to conceive the multiple semiotic roles played by early tools, can we say the same with regard to the process of tool-making? Can the repetitive motor patterns required for the construction of stone tools be described as signs themselves? And, perhaps more importantly, were these patterns motivated by other signs, thus comprising a full-blown concatenation of meanings?

Several lithic attributes are considered indications of human cognition (McBrearty & Brooks 2000: 492). However, as Wurz (2010: 140) has stressed, “concepts like inventiveness, capacity for logical thinking, creativity, and innovation have little operational value if the relationship between them and symbolic communication (or language) is not developed theoretically”. Here we provide what can be considered conceptual and operational criteria to distinguish symbolic from indexical semiotic processes. Even though Cognitive Archaeology establishes a distinction between different kinds of cognitive processes supporting the design and construction of tools and artifacts, the field did not clearly describe the dynamics responsible for the

transition from iconic and indexical semiotic processes to symbolic ones. To achieve a categorization of these interactions, we developed a model grounded on Peirce's theory and classification of signs. Here we are interested in understanding the semiotic cognitive mechanisms related to the transition from the capacity of manipulating indexes to the capacity of manipulating symbols.

Following this thread, it is reasonable to suppose that it would be impossible to develop sophisticated stone tools without imagining the long-term rewards associated with their use. Primitive tool making by stone percussion may have mimicked the very movements required for killing, so that early hominids likely symbolized the manufacture of their tools by means of the actual motor patterns required for the intended use in the immediate future. However, at later stages, refined techniques for tool making completely decoupled from these movements. Instead, complicated tool production must have engaged rewarding symbols of the complex chain of events related to prey hunting and utilization. The progressive complexification of tool making must have involved a mounting ability to work for delayed gratification, leading to anticipatory symbols increasingly more distant in the future. In particular, the fabrication of hunting tools must have involved the association of motor habits with anticipatory images of successful tool use, such as prey chase, kill, transportation and eating by the hominid group. The adaptive value of tool symbolization during the manufacture process would be therefore to raise motivation against distraction, boredom or tiredness. Tool symbolization during manufacture, based on the activation of mnemonic traces distributed over several areas of the cerebral sensory neocortex and the hippocampus, as well as limbic structures related to emotion and reward seeking, would provide the motivation required for sustained work towards a distant goal leading to the sustained and repetitive activation of motor neocortex and striatum. Additional symbolization at the level of gestures, postures, vocalizations, sand drawing and wall painting were the likely waking motivators of Neolithic weapon making, in addition to dreams depicting the hunting act and its associated symbols. Symbolization, therefore, must have occupied a central role for the establishment of tool making, constituting the foundations of the human capacity for sustained work towards non-immediate reward.

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REFERENCES

- Chase, P.G. (1999). Symbolism as Reference and Symbolism as Culture. In: R. Dunbar, C. Knight & C. Power. *The Evolution of Human Culture*. New Jersey: Rutgers University Press, 34-49.
- Davidson, I. & Nowel, A. (2010). Introduction and Overview. In: A Nowell & I. Davidson (eds.), *Stone Tools and Evolution of Human Cognition* (pp. 1-12). Colorado: University Press of Colorado.
- Davidson, I. & Noble, E.W. (1993). Tools and Language in Human Evolution. In: K.R. Gibson & T. Ingold. (eds.), *Tools, Language and Cognition in Human Evolution* (pp. 363-387). Cambridge: Cambridge University Press.
- Eichenbaum, H. (2006). Remembering: Functional Organization of the Declarative Memory System. *Curr. Biol.* 2006 Aug 22; 16 (16): R643-5. Review.

- Gibson, K. & Ingold, T. (eds.) (1993). *Tools, Language and Cognition in Human Evolution*. Cambridge: Cambridge University Press.
- Graves, P. (1994). Flakes and Ladders: What the Archaeological Record Cannot Tell Us about the Origins of Language. *World Archaeology*, 26, 2, 158-171.
- Greenfield, P. (1991). Language, Tools and Brain: the Ontogeny and Phylogeny of Hierarchically Organized Sequential Behavior. *Behavioral and Brain Sciences*, 14, 531-595.
- Kirby, S., Dowman, M. Griffiths, T.L. (2007). Innateness and Culture in the Evolution of Language. *PNAS*, 104, 1-2, 5241-5245.
- Ingold, T. (1993). Tools, Techniques and Technology. In: K.R. Gibson & T. Ingold (eds.), *Tools, Language and Cognition in Human Evolution* (pp. 337-345). Cambridge: Cambridge University Press.
- Ingold, T. (1993). Tool-use, Sociality and Intelligence. In: K.R. Gibson & T. Ingold (eds.), *Tools, Language and Cognition in Human Evolution* (pp. 429-445). Cambridge: Cambridge University Press.
- Isaac, G. (1976). Stages of Cultural Elaboration in the Pleistocene: Possible Archaeological Indicators of the Development of Language Capabilities. In: S. Harnad, H. Steklis & J. Lancaster (eds.), *Origins and Evolution of Language and Speech. Annals of New York academy of Sciences*, (280), 275-288.
- Leroi-Gourhan, A. (1964). *O gesto e a palavra. Volume I – técnica e linguagem*. Lisboa: Martins Fontes.
- McBrearty, S. & Brooks, A. (2000). The Revolution that wasn't: a New Interpretation of the Origin of Modern Human Behavior. *Journal of Human Evolution*, 39, 5, 453-563.
- McGaugh, J.L. (2002). Memory Consolidation and the Amygdala: a Systems Perspective. *Trends Neurosci.*, Sep, 25, 9, 456.
- Mithen, S.J. (1999). Cognitive Archaeology. In: R.A. Wilson & F. Keil (eds.), *The MIT Encyclopedia of the Cognitive Sciences* (pp. 122-123). Massachusetts: MIT Press.
- Noble, W. & Davidson, I. (1996). *Human Evolution, Language and Mind: a Psychological and Archaeological Inquiry*. Cambridge, New York, Melbourne: Cambridge University Press.
- Peirce, C. S. (1935, 1958). *Collected Papers of Charles Sanders Peirce*. C Hartshorne, P. Weiss & A.W. Burks (eds). Cambridge: Harvard University Press.
- Peirce, C.S. (1982-). *Writings of Charles Sanders Peirce: A Chronological Edition*. M. Fisch (ed). Bloomington: Indiana University Press.
- Peirce, C.S. (1998). *The Essential Peirce: Selected Philosophical Writings* (Vol. I-II). Peirce Edition Project. Bloomington: Indiana University Press.
- Queiroz, J. (2012) Complexification. In: D. Favareau, P. Cobley & K. Kull. (orgs.), *A More Developed Sign – Interpreting the Work of Jesper Hoffmeyer* (pp. 67-70). Tartu: Tartu University Press.
- Queiroz, J. & Ribeiro, S. (2002). The Biological Substrate of Icons, Indexes and Symbols in Animal Communication: a Neurosemiotic Analysis of Vervet Monkey Alarm-calls. In: M. Shapiro (ed.), *The Peirce Seminar Papers – the State of the Art*. Vol. V (pp. 69-78). Berghahn Books.
- Ribeiro, S., Loula, A., Araújo, I., Gudwin, R. & Queiroz, J. (2007). Symbols are not Uniquely Human. *Biosystems*, 90, 263-272.
- Savage-Rumbaugh, S., Shanker, S.G. & Taylor, T.J. (1998). *Apes, Language, and the Human Mind*. Oxford: Oxford University Press.
- Stout, D. (2010). Possible Relations between Language and Technology in Human Evolution. In: A. Nowell & I. Davidson (eds.), *Stone Tools and Evolution of Human Cognition* (pp. 159-184). Colorado: University Press of Colorado.
- Tomasello, M. (1999). A Puzzle and a Hypothesis. In: M. Tomasello, *The Cultural Origins of Human Cognition*. Cambridge, Mass.: Harvard University Press.

- Toth, N. & Schick, K. (1993). Early stone industry and inferences regarding language and cognition. In: K.R. Gibson & T. Ingold (eds.), *Tools, Language and Cognition in Human Evolution*. (pp. 346-362). Cambridge: Cambridge University Press.
- Van Schaik, C.P., Deaner, R.O. & Merrill, M.Y. (1999). The Conditions for Tool Use in Primates: Implications for the Evolution of Material Culture. *Journal of Human Evolution*, 36, 719-741.
- Wurz, S. (2010). Middle Stone Age Stone Tools from Klasies River Main Site and Symbolic Cognition. In: A. Nowell & I. Davidson (eds.), *Stone tools and evolution of human cognition* (pp. 135-158). Colorado: University Press of Colorado.
- Wynn, T. (1988). Tools and the Evolution of Human Intelligence. In: R. Byrne & A. Whiten (eds.), *Machiavellian Intelligence: Social Expertise and Evolution of Intellect in Monkeys, Apes, and Humans* (pp. 271-284). New York: Oxford University Press.
- Wynn, T. (1993). Layers of Thinking in Tool Behavior. In: K.R. Gibson & T. Ingold (eds.), *Tools, language and cognition in human evolution* (pp. 389-406). Cambridge: Cambridge University Press.
- Wynn, T. (1999). The Evolution of Tools and Symbolic Behaviour. In: A. Lock & C.R. Peters (eds.), *Handbook of human symbolic evolution* (pp. 263-287). Oxford: Clarendon Press.