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at a certain level links between biology and behavior undoubtedly exist, when one considers specific links, caution is necessary.

The behavioral implications of later Lower Paleolithic archaeology (the period Donald uses as his model of the behavior of *Homo erectus*) are also less clear than was generally believed until only recently. In particular, the characterization of Lower Paleolithic peoples as regular hunters of very large game, such as elephants, has come under attack (Binford 1987; Klein 1987, pp. 11–32), although in my opinion even elephants were probably hunted, at least on occasion (Adam 1951; Scott 1980 – also see Villa 1990). What is not clear is how much social complexity this hunting required. I doubt that the need for communication in hunting would have played a very big role in the evolution of mimesis. In fact, the one thing that would be most useful in cooperative hunting, the ability to discuss future and conditional events with precision, would probably not be possible without the syntactic structures provided by language.

Inferring sexual division of labor and cooperation on the basis of (1) hunting or (2) the clustering of stone tools and animal bones into the concentrations we call sites has also come under very serious attack over the last two decades, although the primary arena for this debate has been the basal Paleolithic sites of East Africa (usually attributed to *Homo habilis*; see Isaac 1983 and Klein 1989, pp. 170–80, for summaries). It is possible (but not demonstrated) that division of labor was common by the later Lower Paleolithic. By the Middle Paleolithic of Europe there is little doubt that Neanderthals were at the very least transporting meat from place to place on a regular basis (e.g., Chase 1986, pp. 46–57) and it may be that this reflected sharing (1) between hunting/foraging parties and those remaining at home, (2) between different hunting/foraging parties, or (3) between hunting parties and foraging parties.

Many scholars have drawn conclusions about intelligence or symbolism from Middle Pleistocene stone tools. However, their cognitive implications are not entirely clear. Donald may overestimate the difficulty of making stone tools. It is true that it takes practice, but a few months of practice should be seen in terms of a young hominid growing up doing what the surrounding grownups are doing. In fact, it is doubtful that pedagogy is necessary for Lower Paleolithic stone tool technology. After all, the making of Paleolithic-style stone tools was a lost art, reconstructed by archaeologists working without even the benefit of someone to observe. On the other hand, it is also true that the skills involved are apparently beyond the ability of chimpanzees to master. However, exactly what new cognitive abilities are required has not been analyzed in the kind of detail the subject deserves. The only in-depth study has been done by Wynn (1979; 1981; 1985; 1989), using a Piagetian perspective, and for the most part he considered secondary attributes of stone tools such as the relative placement of different flake scars rather than the fundamental problem of learning how to remove a flake from a stone core. It is thus difficult to evaluate the need for a new cognitive structure such as Donald's mimesis.

Another old archaeological belief coming under increasing attack is the idea that the stone tools of the Lower or Middle Paleolithic (or even, for that matter, many of the tools of the Upper Paleolithic) required a great deal of time to manufacture and were made for specific purposes well in advance of actual need. Some lithics specialists (Dibble 1987; 1988; Rolland & Dibble 1990, pp. 482–86, see also Chase 1990) feel that such tools were often if not usually *ad hoc* in nature, and even more elaborate tools such as bifaces were probably usually multipurpose tools not destined for a particular purpose.

Not all of these comments are critiques of Donald's book, and certainly none go to the heart of what he has to say. The most important point is that, in general, the meaning of archaeological data in psychological terms is either unclear or controversial or both. One reason is a lack of communication between archaeology and psychology. If more researchers follow Donald's

example in the future, there is every reason to hope that the dialogue between archaeology and psychology will benefit both disciplines.

Symbolic invention: The missing (computational) link?

Andy Clark

School of Cognitive and Computing Sciences, University of Sussex, Sussex BN1 9QH, England

Electronic mail: andycl@cogs.sussex.ac.uk

There is much to applaud in Merlin Donald's careful and imaginative reworking of our collective cognitive history. The head-on confrontation of so many major puzzles concerning how any sequence of individually viable transitions might bridge the abyss between ape and man is a delight, as is the author's sensitive and balanced treatment of the powerful role of external symbol systems in reconfiguring human cognition. My purpose in this commentary is merely to draw attention to what I see as the major cognitive scientific problem which Donald's discussion isolates, and to make a suggestion concerning how best to view it.

The key unsolved mystery, if we accept the bulk of Donald's discussion, concerns what he calls "symbolic invention." The problem of symbolic invention (which may or may not be identical with what the author calls "the problem of reference," p. 368 – I found the latter usage puzzling) concerns how we achieve the spontaneous and repeated development of new symbols. It is this ability which both distinguishes our use of symbolic media from that of the apes (p. 160) and which the author depicts as the vital innovation of the so-called mimetic mind ("mimesis is fundamentally different . . . in that it involves the *invention* of intentional representations," p. 169). Again and again in the book Donald comments on the important difference between the spontaneous and repeated *invention* of symbols and the mere ability to exploit them once they are available (see, e.g., pp. 134, 160, 169, 368). Once symbolic invention is achieved, the organism is on the royal road to the third transition and genetic evolution can be replaced by cultural evolution grounded in the exploitation of a burgeoning series of external symbol systems and external memory systems. Symbolic invention thus seems to be the real "missing link." But what exactly is missing? How best to conceptualize this pivotal issue?

One possibility (which I think of as pretty much Daniel Dennett's view of the problem – see Dennett [1991] and especially Dennett [forthcoming] is to try deflationary tactics. [See also Dennett: "Intentional Systems in Cognitive Ethology" *BBS* 6(3) 1983; "Précis of *The Intentional Stance*" *BBS* 11(3) 1988; and Dennett & Kinsbourne "Time and the Observer" *BBS* 15(2) 1992.] One key deflationary tactic is to reverse Donald's order of events. Instead of depicting some complex of biological adaptations as the root of a capacity for symbolic invention and public language as an *effect* of symbolic invention, the presence of public language is itself depicted as the root of symbolic invention! This sounds paradoxical. But a story can be told. A tortuous sequence of chance discoveries (e.g., of the usefulness of using some external items as labels for others) eventually puts a kind of protolanguage in place. Exposure to this new kind of input reconfigures the next generation's cognitive architecture in a way which promotes the development by them of a *little* more language. And so on, until we reach the present state of affairs in which the average child is exposed to the fantastically potent reconfiguring forces of the whole external symbolic apparatus of the "theoretic mind." Children's rich abilities of symbolic invention are, in this scenario, then *explained by* their experience with the symbols of public language. Public lan-

guage is seen as the software which reconfigures the mind so as to make symbolic invention possible.

The deflationary response is, I think, interesting and deserves some careful consideration. My own view is that Donald is right to opt for the other scenario, in which there is a computational "missing link" which puts a capacity for symbolic invention in place and thus *primes* the onset of public language. I close, however, with the suggestion that it may be fruitful to broaden the notion of symbolic invention, for, as Donald uses it, symbolic invention implies the spontaneous and repeated creation of new *external* symbols. But a prior question concerns the ability of a system already capable of episodic thought to recode those thoughts in a series of increasingly abstract ways which support more flexible (but still nonlinguistic) behaviors. This notion of progressive recoding is the heart of Karmiloff-Smith's (1979; 1992) theory of representational redescription. Its computational implications are further discussed in Clark and Karmiloff-Smith (forthcoming) and Clark (forthcoming).

The simple suggestion I want to make here is that instead of focussing directly on external symbolic invention as the central issue, we may see the creation of new external symbols as continuous with the progressive creation of new *internal* symbols and structures. Thus refocussed, what emerges as crucial is the ability to engage in forms of computation that construct higher and higher orders of representational content. And one fascinating feature of the recent connectionist work which Donald later mentions is that such systems *are* able spontaneously to construct new (higher order) internal representations, although they do so only in quite limited ways (see e.g., Rumelhart et al. 1986). Understanding the nature of these abilities and finding ways to overcome these limitations may provide a practical means of one day illuminating the much more opaque issue of how we invent and use new external symbols. The key issue thus construed is *representational* invention: symbolic invention is best seen as a special case.

A natural history of the mind: A guide for cognitive science

Thomas L. Clarke

Institute for Simulation and Training, University of Central Florida, Orlando, FL 32826

Electronic mail: clarke@acme.ucf.edu

Cognitive science seeks to understand how the mind emerges from the brain. Artificial intelligence seeks to implant a mind within the machine. To their detriment, both have largely ignored work on the natural history of the mind. They would do well to pay close attention to Merlin Donald's account of mental evolution.

The archeology of mental evolution is of course a difficult project since the mind leaves no fossils. Only the artifacts produced by brains containing minds controlling bodies are available for examination. Not until the advent of writing do we apparently have direct access to the thoughts of others. Looking back to the dawn of history, Snell (1960), comparing the language of Homer's *Iliad* and *Odyssey*, concludes that mentality changed between the periods represented in the two works. In the *Iliad*, there is no word for the modern concept of mind. The stormers of Troy seem to be sleep walkers controlled by godly visions. But after the fall of Troy, clever Odysseus appears a modern man, fully self-aware and introspective.

The more controversial Jaynes (1977) also finds a phase change when comparing earlier written records with more modern. His evidence is Biblical; the book of Amos sounds alien to a modern ear, whereas the more modern book of Job is fully modern (it is even the basis for contemporary song). Jaynes seeks reasons for the change within the structures of the brain, but his

explanations involving the formation of laterality in the brain do not ring true.

Although ancient literature hints at a different style of thinking, ancient artifacts do not. Allowing for a more primitive technology, the equipment of the Neolithic hunter recently found frozen in the Alps does not seem strange to a modern backpacker. Donald's *Origins of the Modern Mind* provides a natural explanation for these observations.

Briefly, Donald divides the evolution of mind into four stages. First at about 2 million years B.P., ape becomes hominid. The hominid mental culture is an extension of the episodic culture characteristic of apes. The penultimate ape, the hominids are able to respond to very complex sets of stimulus scripts or episodes, but they do not plan ahead.

Around 700,000 years B.P., *Homo erectus* appears. The *Homo erectus* mental culture is mimetic; they think and plan ahead, but do so without language. As a modern example, Donald cites the case history of Brother John. When epileptic attacks deprive Br. John of language, he is nevertheless able to plan and carry out quite complex scenarios. *H. erectus* brings the ability to manipulate the environment through tool use to modern levels. Properly educated, a *H. erectus* could make a living through manual labor in the modern world.

Around 60,000 years B.P. modern man, *Homo sapiens*, appears. *H. sapiens* has spoken language and has a mental mythic or linguistic culture. Communication is oral and societal structure is maintained through ritual. Perhaps the peak of mythic culture was reached with the world-wide rule of Roman oratory. Nevertheless, the fully modern mind does not appear until after the advent of writing. Early systems of writing, cuneiform and so on, however, access the linguistic part of the brain only indirectly, through the earlier episodic and mimetic portions. As a result, these systems implemented linguistic storage and communication imperfectly, and were not widespread among *H. sapiens* culture.

The breakthrough into theoretic culture comes with the invention of the phonetic alphabet. The direct mapping of visual, physical symbols to phonemes enables the linguistic portion of the brain to begin directly processing writing. Phonetic writing provides an organizing center, linking external memory storage to all three portions of the brain – episodic, mimetic, and linguistic. The brain plus external storage is thus more capable than what came before; the modern mind has been born. A feel for the brain/phonetic writing synergism can be gotten from Donald's metaphor for reading. In reading, the contents of the book take control of the brain of the reader. The book is the source material and the brain is merely the player. The brain/written word is thus something more than the brain alone.

Thus, our modern manual skills date back to the era of *H. erectus*, and similarly, our rituals and icons originate in the Paleolithic. Only in historic time, however, does the synergistic combination of brain and environment occur that is the modern mind. As Snell and Jaynes argue, traces of this change can be found in written literature.

Donald's mental architecture is quite different from the computational paradigm much used in cognitive science. His architecture makes explicit allowance for the external environment through the central organizing principle of phonetic written language. The architecture is also vastly different from the low-level approaches advocated by connectionists. Although Donald does discuss neurophysiological features such as Broca's area, this is mostly to argue that natural selection has worked on the brain. Donald's work suggests new approaches based on the natural history of the mind. It deserves close attention by both cognitive scientists and AI researchers.

On a final speculative note, echoed by Donald himself in his final sentences, the ideas in *Origins of the Modern Mind* should be applied to the present. The current developments in interactive, networked, multi-media, and virtual means of communica-