Rewriting the Meaning of Cognitive Adaptation

Jorge Simão*
Max Planck Institute for Human Development, Berlin

The Cultural Origin of Human Cognition, Michael Tomasello, Harvard University Press, 1999/2001.

Ever since I read about the theory of self-organized criticality — where complex systems such as piles of sand can exhibit effects of all sizes, including large scale catastrophies, when disturbed by insignificant events such as the falling of a diminutive grain of sand — I started to look at the mood swings of science in an similar way. That is to say, an unexpected individual can always step in as mighty as those tiny grains and unleash a wave of new ideas that grows to shape a truly Kuhnian revolution. This could be welcome for instance in my home fields of cognitive science and adaptive behavior, where research can still be, contrary to what one might want to say or think, a flaky affair. How much could be gained if one is willing to leave some refurbished engineering tricks behind in exchange for some new and exciting thoughts? Here is where Michael Tomasello and his recent book *The Cultural Origin of Human Cognition* come in, threatening to unleash a whole bunch of free sliding sand.

Tomasello opens his book by presenting us with a puzzle. If we take for granted that humans and modern apes split apart in their phylogenetic lineages no more than 6 million years ago, how can the differences in individual cognitive and behavioral skills be so great? Surely, there is just so much genetic "tinkering" that natural selection can do is so little time. The fact that humans and their closest living cousins, the chimpanzees, share more than 98% of their DNA seems to be an indication of that. And if we trim this short time frame to the emergence of the genus *homo*, about 2 million years ago, things become even harder for a unilateral genetic account. Tomasello ventures to provide an answer to this riddle.

According to Tomasello, the human lineage developed the ability to preserve individual and cooperative innovations in a way that no other group of primates (or any other animal order for that matter) did. This ability allowed humans to develop a cumulative material and symbolic culture, in which innovations brought about in one generation can build upon the cultural artifacts preserved from the previous generations, which in turn are amenable to improvement in

*Correspondence to: J. Simão, Center for Adaptive Behavior and Cognition, Max Planck Institute for Human Development, Lentzeallee 94, 14195 Berlin, Germany. Email: jsimao@di.fct.unl.pt

succeeding generations. This uniquely human phenomenon Tomasello designates as the "ratchet effect". Thus, while chimps and other animals are able on rare occasion to individually come up with (usually simple) innovations, the newly acquired expertise is most often lost with the death of the inventor. That is, no trans-generational transfer of knowledge occurs and, consequently, little or no cumulative refinements of the original cultural themes can ever be made.

For Tomasello, the key reason for the human state of affairs is that at the cognitive level our lineage developed the ability to empathize with other conspecifics and perceive them as intentional agents in ways that other animals, including apes and other primates, did not. He points to a (small) set of socio-cognitive skills such as *shared attention* and *perspective taking*, which in addition to whatever cognitive mechanisms our ancestors shared with other apes, are sufficient during ontogenetic time to lead to an ever more complex set of social skills such as imitation of behavioral acts, language, and tight team collaboration. In contrast, chimps transfer knowledge between individuals using a smaller set of socio-cognitive skills such as *behavior emulation*: bringing forth the end product of a (desirable) behavioral act using each individual's own idiosyncratic means without much regard to the specifics of the motor sequences performed by the instructor. While this is still a huge adaptive achievement (just think about how many existing autonomous robots can do the same), it does not allow the kind of cultural preservation that according to Tomasello is required to produce the "ratchet effect".

To substantiate his claim, Tomasello presents us with a battery of comparative experimental studies with chimps and children of different ages, many of them done by him and his collaborators over the last decade, which make many of his points quite convincingly. At about 9 months of age, human children start (gradually) to behave in ways that carry the distinct trademark of their species. They start to engage in *triadic interactions*, where child, caregiver, and objects enter in complex behavioral choreography involving gaze following, social referencing, and directing of attention. This not only enables children to explore more easily the affordances of their local environment (e.g. tools), but most importantly also allows for the creation of an inter-subjective context where self and other become connected. This entails that the children develop the ability to mentally simulate and recreate the actions of others, which in time leads to the emergence of the ability for true imitation. These initial skills further allow the child to enter into the symbolic and linguistic domain. This takes place as the child becomes aware of the intentions of the caregiver to call attention to specific objects, events, or states of affairs, using some gesture or verbal act. Armed with the ability to mentally simulate the caregiver, the child can reverse roles and become the communicative intentional agent. Although initially much of this communication takes place directly between the child and the caregiver, eventually the same kind of process takes place when the child is a mere observer of adult interactions. No continuous supervised learning is required. All that is needed is that the child develops the basic skills mentioned above, which allow her to become immersed in ways of living and communicating culture — what Tomasello calls the child's *cultural line of development*. Thus, while a child definitely inherits the psychic niche created by the cultural history of her community and develops through an *individual line of development* (e.g. learning to use available tools by herself), it is through the more social-interactionist cultural line of development that the child acquires much of the cognitive skills that make her become a fully-fledged human — imitation, language, planning, and cooperative team work. This is, in a nutshell, Tomasello's boldest claim.

Instead of formulating a pick-and-mix view of the human mind as a large array of domain-specific mechanisms or modules — a view very much pervasive in the cognitivist, internalist evolutionary psychology (Barkow, Cosmides, & Tooby, 1992; Pinker, 1997) and adaptive behavior literature (Pfeifer & Scheier, 1999) — Tomasello argues that many human cognitive skills come about through an interactive-constructivist process of social development, bootstrapped by at most a small set of generic innate propensities (attentional, motivational, etc.). Tomasello supports his proposal by elaborating in great detail the invariant steps that children in all cultures take in their development during the first years of life. He focus in particular in language development, and it is in this domain that he is most convincing.

A possible criticism of Tomasello's book, particularly relevant for the SAB community, is that nothing is said about the specific computational or neuronal substrates of the small set of crucial socio-cognitive mechanisms that he postulates. Clearly, this is work to be done if a complete scientific account is to be given for humans' impressive adaptability. Still, this goes beyond the range of Tomasello's main scientific discipline, so the challenge falls back to the SAB community. If Tomasello is on the right track, and my guess is that he is, this book can have profound influences on the way we conceive of human psychological adaptations (and maybe for other animals, too). His view gives human cognition a character of open-endedness that cannot easily be accommodated within a framework that postulates a fixed set of cognitive modules or adaptations. On the other hand, it fits well with a computational foundation in which the mental representations supporting acquired cultural artifacts are built upon substrates that are to some extent content-free — that is, that can be recruited to perform functions not pre-defined by (evolutionary) design. This would account for the emergence of novel functionality over historical time (e.g. writing, musical, and mathematical skills) far better than the simplistic and recursive notion of *exaptation* (Gould, 2002).

Most importantly, Tomasello's view matches well with a conception of the workings of the central nervous systems of animals as a self-organizing dynamic system whose role is to explore and accommodate the local environmental information structure in the pursuit of purposeful (adaptive) behavior. Only in this way can we explain the ability for fine-grained behavioral adaptation at all behavior time scales in complex animals — including adaptability to moment-to-moment fluxes in perceptual space. This position has long been championed by ecological psychologists, who despite being heart and soul Darwinists, always refused the excessively internalist view of cognitivism transported in many ways to most research in human evolutionary psychology (Reed, 1996). While SAB research, with its focus on biologically inspired complete creature design, is an important step forward in the development of the cognitive sciences, it still inherits much of the established computational metaphors and tools of the past. It would not be totally unfair to characterize much of autonomous behavior research as a high-tech revival of control theory and cybernetics, whose conceptual and methodological underpinnings are still far from proving their ability to scale up to the high dimensionality of the sensorimotor couplings of even the humblest of the vertebrates.

Taken to its ultimate consequences, Tomasello's work thus undermines the fundamental assumption, or at least the unspoken hope, of much SAB research — that the same cognitive design principles apply to all levels of organismic complexity, from insects to humans (Brooks, 1991; Pfeifer & Scheier, 1999). The idea that we can obtain more and more intelligence with more and more pre-fixed modular, domain-specific design — the position that Andy Clark has aptly termed "biological incrementalism" — is simply wrong (Clark, 2001). Empirical support for this view has been gathered at an increasing rate in the last decade or so through research in cognitive neuroscience. Much of the functional specialization of the cortical brain areas in vertebrates has been found not to be specified by some kinds of genetic-molecular markers, but rather to emerge as a result of global physical and informational constrains (Elman et al., 1996). Most of these constraints are imposed by the organism's body architecture, morphogenic and topological developmental principles of its nervous system (Edelman, 1987), and the continuous incoming stream of perceptual and proprioceptive signals imposed by the exploratory activity of the organism while navigating through the structures of its local environment. Environmentally contingent information is especially relevant in altricial species, where long periods of parental care can yield fields of protected actions for the newborns and youngsters to develop their behavioral and cognitive skills (Reed, 1996) — which ties back to Tomasello's views on highly altricial human infants.

For the SAB community, the constructivist-interactionist view that Tomasello puts forward is an indication that (even) more research emphasis should be put on principles of global self-organization of animal nervous systems (Edelman, 1987), and the constraints imposed by embodiment in the context of natural environments (Reed, 1996). While the pragmatics of scientific analysis invites the modular decomposition and study of individual parts and functions of the nervous system (Churchland & Sejnowski, 1992/99), it will be through the study of complex global dynamics that true understanding of complex adaptive behavior can be brought to light (Keijzer, 1998). Work in the field of complex dynamic systems can become especially inspiring in this regard, and has already started to bring about new insights (Stassinopoulos & Bak, 1995).

To conclude, I would risk claiming that Tomasello's book marks, or at least highlights, the beginning of a new era for how cognitive science looks at the meaning of cognitive adaptations. It is important that SAB research does not fail to notice this scientific landmark. Accepting the challenge of modeling and studying the mechanisms that Tomasello proposes can only make SAB research an even more central discipline in the study of the behavioral, cognitive, and social sciences.

References

Barkow, J. H., Cosmides, L., & Tooby, J. (Eds.). (1992). *The adapted mind: Evolutionary psychology and the generation of culture.* New York: Oxford University Press.

Brooks, R. A. (1991). Challenges for complete creature architectures. In J.-A. Meyer & S. W. Wilson (Eds.), *Simulation of adaptive behavior* (p. 434-443). MIT Press, Cambridge.

Churchland, P. S., & Sejnowski, T. J. (1992/99). *The computational brain.* Cambridge, MA: MIT Press/Bradford Books.

Clark, A. (2001). Reasons, robots and the extended mind. *Mind and Language*, *16*(2), 121–145.

Edelman, G. M. (1987). *Neural darwinism: The theory of neuronal group selection.* New York: BasicBooks.

Elman, J. L., Bates, E. A., Johnson, M. H., Karmiloff-Smith, A., Parisi, D., & Plunkett, K. (1996). *Rethinking innateness.* Cambridge, MA: Bradford/MIT Press.

Gould, S. J. (2002). *The structure of evolutionary theory.* Cambridge, MA:Belknap Press.

Keijzer, F. A. (1998). Some armchair worries about wheeled behavior. In R. Pfeifer, B. Blumberg, J.-A. Meyer, & S. W. Wilson (Eds.), *From animals to animats 5: Proceedings of the fifth international conference on simulation of adaptive behaviour* (pp. 13–21). MIT Press/Bradford Books.

Pfeifer, R., & Scheier, C. (1999). *Understanding intelligence.* MIT Press.

Pinker, S. (1997). *How the mind works.* London: Penguin books.

Reed, E. S. (1996). *Encountering the world: Toward an ecological psychology.* New York: Oxford University Press.

Stassinopoulos, D., & Bak, P. (1995). Democratic reinforcement: A principle for brain function. *Physical Review E*, *51*(5), 5033–5039.