

Evolutionary Roots and Cognitive Precursors of the Ontogeny and Phylogeny of Theory of Mind

The term “theory of mind” (ToM) was originally proposed in 1978, by the primatologists Premack and Woodruff, to name a concept which suggests that chimpanzees, and maybe other apes, may be capable of inferring mental states of conspecifics. It was later adapted to define the ontogenetic and phylogenetic development of mental perspective taking in infants and young children (that is, attributing desires, beliefs, intents and knowledge to oneself and others) (Towner, 2010).

The main focus of this paper will be the evolutionary emergence of the cognitive abilities that effectively promotes ToM in humans. The evolutionary origins of ToM can be traced back in extant non-human primates, who offers us a window into the cognitive abilities of our past ancestors: researchers conclude that ToM probably emerged as an adaptive response to increasingly complex primate social interaction. When the social groups become larger and more sophisticated, the cognitive demands enabling the individuals to decode the behavior of other individuals also increased, creating a selective pressure and an evolutionary arms race, between, and within, groups and species (Brune & Brune-Cohrs, 2006).

According to Brune and Brune-Cohrs (2006), there is an evolutionary cost that comes with the emergence of this sophisticated metacognitive ability: the far complexity and intricacy of multiple cognitive abilities and thought skills behind the neural network of ToM turn the whole system vulnerable to certain problems or delays during development and this “reflects in a broad spectrum of psychopathological conditions (autism spectrum disorders, schizophrenia, bipolar and affective disorders, some forms of dementia among other psychiatric disorders)” (Brune & Brune-Cohrs, 2006).

Primates - the taxa where high-level ToM appeared - are essentially gregarious and prosocial animals (except a few species, like the orangutan and the slow loris), and even though group living certainly confers many adaptive advantages to the individual (by having a better understanding of the behaviors of other individuals, it's able to teach and learn more effectively), it also incurs the cost of directly competing for resources, sexual partners and the necessity of avoiding deception from both inside and outside of the social group. This kind of situations may have created specific selective pressures in primates to favor an evolution of “social intelligence”, creating an evolutionary arms race between, as well within, species (Brune & Brune-Cohrs, 2006). This led to the development

behaviors that are designated as “Machiavellian intelligence”: with a higher social cognition set of abilities the individual has the opportunity to harness power, status, territory, females, food and water, by clever and cunning deception and manipulation of its conspecifics, hence the name after a XVI century political writer.

The study of animal behavior and cognition, as well as when and how ToM developed in the hominids has identified certain precursor behaviors that anticipate and form the basis of the emergence of a full-fledged human-like ToM: between them are understanding attention, understanding others’ intentions and imitative experience (Brune & Brune-Cohrs, 2006).

Having a ToM set of abilities may convey numerous advantages to a species (e.g. better social cohesion and cooperation between group members) and facilitate abilities such as learning and communication. This higher social cognition requires more brain capacity, which explains the additional brain volumes in the primates taxa compared to other species of mammals and birds (Towner, 2010). In humans, the neocortex is three times greater and much more convoluted than the expected for a primate of our body size (Brune & Brune-Cohrs, 2006). According to Dunbar (*in* Brune & Brune-Cohrs, 2006), this is due to the vast and highly complex social life of humans that appeared during the Pleistocene. The selective pressures enabled a social intelligence to grow and originate bigger villages and bigger, more complex, social networks.

The social environment may provide both the pressure and the context for the evolution of a higher social intelligence, so it’s not surprising that it’s in the great apes – with more complex social systems (fusion-fission type, e.g.) – that we find the most evidence of ToM abilities. All great apes show recognition of the self and this is probably in the basis of the self-other distinction that is required for a full-blown ToM like the human case (Towner, 2010).

In the neuroscience field, the mirror-neurons (MN) found both in humans and non-human primates have been suggested as the neural basis and evolutionary precursor for the achievement of such kind of abilities. The MN are neurons that fire both when the individual acts physically and when the individual observes the same action performed by another individual. These MN appear to act as facilitators for imitation and teaching, and both of which have been demonstrated in non-human primates (Towner, 2010).

This mirror system “might underlie our ability to understand other people’s intentions by providing us with an automatic simulation of their actions, goals and intentions” (Singer, 2006) and offers an explanation of how the ability to imitate others has evolved into the capacity to simulate mental states of other individuals (Brune & Brune-Cohrs, 2006). Thus, the evolution of ToM-like abilities is some sort of a progressive build-up of increasingly more complex and sophisticated neural structures and cognitive capacities that began with adaptive selection of better imitation, teaching/learning and communication skills and has emerged, in the

humans, as a full-fledged metacognitive ability that becomes fully developed in children around four years old.

In the scientific “hunt” for the cognitive precursors of ToM, it has been found (Brune & Brune-Cohrs, 2006) in non-human primate brains certain structures, besides MN, that have undergone adaptive modifications to constitute, in humans, a neural network responsible for ToM as in: the middle portion of the temporal lobe (specifically the superior temporal sulcus), which is linked to observation of intentional movements; and the anterior cingulate cortex, that works as an important mediator of motor control, cognition and arousal regulation

Initially these behaviors and neural networks evolved under the control of “low-level” psychological structures, and as some lineages evolved social interactions increasingly more complex, the brain systems dedicated to processing information about regularities of the behaviors of others also became increasingly more complicated. About four million years ago the human lineage began to evolve the additional and remarkable ability of interpreting the behaviors of others in terms of mental states. This psychological interpretation of behavior was applied to already-existing behaviors not created from new structures (Povinelly & Giambrone, 2001).

The initial evolutionary advantage of this new sophisticated psychological system (ToM) was that it allowed already-existing behaviors (such as deception and gaze following) to be used in more flexible and proactive ways, without discarding the low-level ancestral psychological systems (Povinelly & Giambrone, 2001).

ToM is certainly most highly developed in humans but that comes with its inherent cost: the evolution of big brains (required for the complex social environments) is energetically expensive and the ontogenetic acquisition of human-like ToM abilities is extremely time-consuming (hence the slow growth of human infants when compared to the other apes) (Povinelly & Giambrone, 2001).

ToM comprises an innate cognitive capacity represented in a dedicated neural network but the actual development of ToM is critically dependent on environmental input (Brune & Brune-Cohrs, 2006). The high level ToM (responsible for the metacognition) is unique to our species and its original function was to provide a more abstract level of describing ancient behavioral patterns (deception, reconciliation, gaze following, among others), and those behaviors (of an “inferior” cognitive level) are shared by humans with many other species. The initial selective advantage of ToM may have been because it increased the flexibility of already-existing behaviors, not because it radically generated new ones (Povinelly & Giambrone, 2001).

Since the conception of the term “Theory of Mind”, the issue has evolved beyond if there is, or not, a ToM on non-human primates to a more sophisticated appreciation that the concept of mind has many facets and some of these may exist in non-human primates while others may not (Towner, 2010). In “real-life” situations, ToM is entrenched in a neural network that constitutes the “social

brain” of both human and non-human primates (Dunbar *in* Brune & Brune-Cohrs, 2006).

ToM only represents one particular aspect of what is labeled as “social cognition”, others equally important aspects that contribute to the actual behavioral output in social interactions are the perception of social signals, motivation, emotion, attention, memory and decision-making (Brune & Brune-Cohrs, 2006).

Early intention understanding, of the sort shared among primates; predict the development of ToM understanding in four years old children. That is, those early understandings provide a platform for the ontogenesis of further, deeper achievements in the human case (Wellman & Brandone). However, we know very little about the ontogenesis of any such skills and understandings in primates (Wellman & Brandone, 2009) and further studies in the field of social cognition and primatology are required to a better knowledge of such ontogenetic and phylogenetic development.

A better understanding of the evolutionary pressures and constrains that promoted evolution of the cognitive precursors of human-like ToM can help in the unveiling of how certain psychopathologies (e.g. autism) appear and manifest.

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