

The eyes, the hand, and the mind: behavioral and neurophysiological aspects of social cognition.

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Introduction

"Nevertheless, the difference in mind between man and the higher animals, great as it is, certainly is one of degree and not of kind." (Darwin 1871)

What most clearly distinguishes primates from other mammal species in terms of cognition concerns the social domain. Although not deeply understood, many authors have proposed that the uniqueness of the intelligence of primates has to be sought in their complex social world (see Humphrey 1976). Primates are not the only mammals displaying complex social systems, but it seems that the quality and complexity of their relationships within their social groups, when a comparison with other taxa is made, are different.

In the evolution of primate cognition the relationships between group members have played a fundamental role. As Tomasello and Call (1997) pointed out, non-human primates understand the *quality* of the relationships within their social group, not only in terms of kin and hierarchies, but also in terms of coalitions, friendship and alliances. Primate cognition can be considered very different from that of other mammalian species because primates can categorize and understand third-party social relationships.

In the last few decades an ever-growing literature has raised questions about the possibility that social behaviors of non-human primates are driven by intentions and that they understand others' behaviors as intentional. Most scientists would agree on the fact that monkeys and apes behave *as if* possessing objectives and goals, although, contrary to humans, their awareness of purpose is not assumed. The fact that non-human primates may understand conspecifics' behaviors as goal-related can have considerable benefits in the individuals' life as they can predict others' actions.

The problem of intentionality in primates was almost simultaneously and independently raised by Humphrey (1980), and Premack and Woodruff (1978). The capacity to attribute mental states - such as intentions, beliefs and desires - to others has been defined as theory of mind (ToM, Premack and Woodruff 1978). Up to now there is no firm evidence that non-human primates possess a ToM. For most authors, ToM constitutes the mental Rubicon between humans and non-human primates.

One of the most influential models of ToM is that proposed by Baron-Cohen (1994, 1995). According to this author, separate brain modules constitute a mindreading system layered on multiple modularized levels of increasing complexity. The importance of such a model for the study of social cognition is two-folded. First, it enables to investigate several aspects of mindreading abilities both at the behavioral and the brain level. Second, it allows the empirical evaluation of the cognitive stage reached by a given species, thus paving the road to comparative investigations. Even if anything like ToM really underpins mindreading abilities in humans, this cognitive feature of the human mind must have evolved from a non-human ancestor who shared with the present primates - humans included - several cognitive features. In this context, one of the major tasks of cognitive neuroscience should be to investigate the behavioral and neural basis of intentional behavior. The behavioral study of social cognition of non-human primates and the enquiry of the neural mechanisms supporting it are therefore necessary for a thorough understanding of how the human mind evolved and how it works.

In the present article we will review a series of investigations of the social behavior of macaque monkeys conducted both at behavioral and neurophysiological level. To this purpose, in the first part of the chapter we will summarize some recent behavioral experiments carried out in our lab whose aim was to investigate the presence of gaze-following behavior in monkeys. In the second part, we will review neurophysiological data concerning the neural