# Great ape communication as contextual inference: a cognitive modeling perspective

Manuel Bohn[1], Katja Liebal[2] & Michael Henry Tessler[3]

[1]Max Planck Institute for Evolutionary Anthropology
[2] Leipzig University
[3] Massachusetts Institute of Technology

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Non-human great ape communication is multimodal, flexible, and intentional. It includes the flexible use of a range of gestures, vocalizations, and facial expressions. Research from the last three decades has shown that apes use and interpret these signals in a cognitively sophisticated way.

Much of this work has focused on the intentional use of communicative signals. Researchers probe whether apes use signals to achieve a particular goal (Townsend, et al., 2017). This work contrasts with a more reflexive view on animal communication in which signals are emitted as a response to an external stimulus. For example, Leavens and colleagues (2005) showed that chimpanzees adjust their signaling to the attentional state of the recipient. When requesting food from a human, they use manual gestures when the human looks at them but use auditory gestures when the human is looking away. Such results suggest two things: first, apes flexibly alternate between different ways of signaling, and second, they take into account the psychological states of their recipient.

Solid evidence is now available that apes use gestures and vocalizations in such an intentional way (Liebal et al., 2013, Crockford et al., 2012). Researchers have since moved on to study not just how but what apes communicate. Several studies compiled so-called "dictionaries" for different species and analyzed to what extend they resemble one another (Graham, et al., 2018).

Although impressive, we think this work neglects the situated and interactive nature of communication because the main focus rests on the signals themselves. Psychologists and linguists working on the pragmatics of human language have long recognized that human communication is not reducible to the words used (Sperber & Wilson, 1995). What people mean by an utterance is very much a function of the context in which they are used and the relationship between the communicators.

Computational modelers have started to formalize these pragmatic inferences (Frank & Goodman, 2012). The resulting models make accurate predictions about how listeners interpret seemingly ambiguous and vague utterances (Goodman & Frank, 2016). More recent work has used the cognitive modeling toolkit to study how adults and children use and integrate different types of contextual information (Bohn et al., 2021).

In this paper, we use cognitive modeling to study great ape communication. We formalize how great apes interpret communicative signals in context. We assume that apes use a range of different information sources -- the context of the utterance, the relation between the communicators, the gestures, and facial expressions being used --  and integrate them in a rational (Bayesian) way. We show that such a model

can be used to recover the outcome of actual communicative interactions between semi-wild living chimpanzees observed in a recent study (Ona, et al., 2019).

In a final step, we use this modeling framework to ask questions about the differences between ape and human communication. We explore the possibility that human communication relies more heavily on social-cognitive inferences compared to apes. This assumption offers a way of explaining qualitative differences between apes and humans when interpreting novel signals, as reported in the recent literature (Bohn, et al., 2019).

This paper aims to draw attention to the situated and interactive nature of great ape communication. Using tools from cognitive modeling, we show that the context and relationship between communicators offer rich information that helps to predict the outcome of communicative interactions.