Animal Cognition (2019) 22:597–604
https://doi.org/10.1007/s10071-019-01278-x

CONCLUSION

Gesturing towards the future: cognition, big data, and the future of comparative gesture research

Erica A. Cartmill[1] · **Catherine Hobaiter**[2,3]

Published online: 2 July 2019

Abstract
The field of ape gesture research has grown significantly in the past two decades, but progress on the question of gesture development has been limited by methodological and terminological disagreements, small sample sizes, and a lack of fine-grained longitudinal data. The main theories of gesture acquisition are often portrayed as mutually exclusive, but only some theories actually detail learning mechanisms, and differences in the level of analysis may help explain some of the apparent disagreements. Gesture research would benefit greatly from the articulation of more testable hypotheses. We propose two hypotheses that follow from dominant theories of gesture acquisition. We urge scholars to collect new data and leverage existing data in ways that maximize the potential for comparison across datasets and articulation with studies of other communicative modalities. Finally, we advocate for a transition away from using intentionality as a marker of the 'special status' of gesture, and towards using gesture as a window onto the lives and minds of apes.

Keywords Gesture · Ape · Mechanisms · Intentionality · Origins of mind

Introduction

The gestures of apes have been described in the scientific literature for over 100 years. Over the past few decades, the field of primate gesture studies has grown significantly and now includes a wide range of scholars working across countries and species. The last few years have seen an increase in the range of scholars across disciplines who are now taking note of gesture, either in its own right or in combination with other modalities, in studies of primate communication (e.g., Slocombe et al. 2011).

There are many points of agreement amongst gesture researchers: apes have large repertoires of gestures and employ them in flexible and intentional ways to achieve specific social goals. However, despite decades of work, researchers remain divided on the question of gesture ontogeny. This volume assembles the current range of perspectives on the question of how gestural communication develops in non-human great apes. The authors in this volume present different views of gesture development and make suggestions for new methodological approaches to studying gesture. We applaud these suggestions, but in order for the study of ape gesture to make significant progress on the question of development in the coming years (to say nothing about the coming century), we argue that it will be necessary to clearly *define the scope of the learning problem*, to *recognize points of agreement and disagreement* between studies, to *generate testable hypotheses*, and to *collect and leverage data in smarter ways* to increase the power and generalizability of the studies we conduct. We also advocate for a pivot from using intentionality to argue for gesture's uniqueness, to using gesture as a tool to study the minds of apes.

This article is part of the Special Issue Evolving the Study of Gesture.

✉ Erica A. Cartmill
cartmill@anthro.ucla.edu

[1] Department of Anthropology, University of California, Los Angeles, Box 951553, Los Angeles, CA 90095, USA

[2] School of Psychology and Neuroscience, University of St Andrews, St Andrews, Scotland KY16 9JP, UK

[3] Budongo Conservation Field Station, P. O. Box 362, Masindi, Uganda

Defining the scope of the learning problem

To compare the data and theories about apes' learning of gestural signals, we first must define the scope of the learning problem. What sorts of things are involved in knowing how to gesture (and thus must be learned or acquired in some way)? What kinds of acquisition mechanisms might be applied to this task? And finally, is the task of learning to gesture unique in any way, or is it similar to learning other kinds of things? This set of questions—defining the scope, mechanisms, and specificity of learning—is not by any means unique to ape gesture, but is broadly shared by researchers working in other domains of learning in humans and other animals.

What do apes need to know to gesture?

To be a competent gesturer, apes need to (1) produce specific gesture *forms*, (2) employ or modify them to *maximize perceptibility*, (3) use them toward appropriate *goals*, and (4) use them in different ways with particular *interlocutors*. These capacities are only those limited to gesture production. To respond appropriately to others' gesturing, apes must also be able to (5) *recognize* when another is gesturing, (6) distinguish and *identify* gestures, and (7) *infer* meaning.

However, this does not mean that all of these necessarily represent learning tasks. For example, an animal may have an innate visual signal in its communicative repertoire that it initially uses with little regard to the visual attention of others. Then, over repeated interactions in which only some uses of the signal are rewarded with successful responses, the animal learns to use the signal only when it can be seen by others (thus maximizing its perceptibility). The four production problems above (form, perceptibility, context, interlocuter) are complex tasks that involve integrating many kinds of highly variable information; it may be necessary to learn a range of different things to accomplish only one of them. For example, to adjust your gesturing to a particular interlocuter, you must be able to recognize individuals, retain some memory of past interactions (or have updated your strategies during past interactions), and perceive and recognize the other's responses to your gestures.

Clarifying the scope of the learning problem is important, both in moving the field forward and in identifying points of difference between studies or theories. The field would be more aligned on learning mechanisms if we were aligned on *what* was being learned. Some differences would undoubtedly remain—some resulting from philosophical differences or perspectives on ape cognition that extend beyond the communicative realm—but there would be more points of agreement. In cases where learning has been defined in different ways or discussed at different levels, it is almost inevitable that disagreements about the role of learning in ape gesture arise. Some scholars may choose to focus on the gross action patterns that form the core of gestures, and thus perceive similarity across time and individuals (e.g., Hobaiter and Byrne 2011a; Byrne et al. 2017). Others may focus more on learning how to use a physical movement in an interaction to maximize perceptibility by others or how to use a gesture form to achieve a specific goal with different social partners, resulting in a more situated perspective (e.g., Bard et al. 2017). These approaches highlight different aspects of the learning space and lean towards different conclusions about the degree to which apes learn features of their gesturing.

Points of agreement and disagreement surrounding learning mechanisms

Scholars today agree that learning of some kind is involved in ape gesture, but to understand the extent to which learning influences gestural communication, it is important to distinguish between different levels of analysis: for example to distinguish between *repertoires* of available gesture types and gesture *usage*. There is a general consensus in the field that learning applies to features of gesture use, but there is less consensus on whether this is also the case in building gestural repertoires.

As many of the papers in this special issue discuss, there are three main theories about the acquisition of ape gesture: *genetic channeling* (GC), *ontogenetic ritualization* (OR), and *imitation*. All theories grant that learning occurs, but while both OR and imitation propose specific learning mechanisms, GC remains agnostic. Genetic channeling proposes that apes are born with simple action patterns that form the core movements of gestures. These core movements are the basic forms of the available gesture types within a repertoire. GC allows that apes may learn to produce these forms in more effective ways or learn to modify them further (Hobaiter and Byrne 2011b); but, it does not specify the way in which this learning might occur.

Imitation has largely been abandoned as a likely explanation for ape gesture acquisition, due to the lack of evidence for local traditions in gesture. Ape gesture studies followed the paradigm employed in comparing ape material culture (e.g. Whiten et al. 1999), by looking for behavioral differences across geographically-separated groups of apes. If those differences were not clearly linked to differences in environment or genetics, they were seen as providing evidence that the behaviors were acquired via cultural transmission, a process that should lead to local traditions. Ape

gesture studies adopted this framework and focused on cataloguing individual gestural repertoires for apes, which could be compared across age classes and groups. It was argued that higher similarity within groups than between groups would provide some evidence for social learning of gestures, but this pattern has not been found (Tomasello et al. 1989; Genty et al. 2009). Indeed, gestural repertoires are largely similar across groups of apes who are unrelated and who have never interacted (Genty et al. 2009; Hobaiter and Byrne 2011a).

Ontogenetic ritualization (OR) is a process that arises through social interaction, but it is fundamentally more similar to individual learning than to social imitation. Inspired by Plooij's (1978) descriptions of the conventionalization of action into gesture, OR proposes that gestures are ritualized from instrumental actions into symbolic shorthand gestures (Call and Tomasello 2007). Rather than observing another's actions and learning to imitate their movements or emulate their goals, in OR, an ape is rewarded part of the way through an action and thus learns to associate the first movement(s) of the action with the goal (Tomasello et al. 1985, 1989, 1994). Ritualized behaviors, in the strictest sense, are reinforced rather than learned, and the original articulations of this theory were closer to this cognitively 'lean' approach (Tomasello and Call 2018). As a result, some have argued that this type of acquisition—like other ritualized behavior—would be specific to a particular interaction, and interaction partner, and would not transfer to other social partners, and thus the process of OR would need to take place between all pairs of individuals for all gestures (Genty et al. 2009). However, recently, more cognitively-rich modifications of this theory have been proposed, arguing that if apes are able to generalize across partners (as humans do), and ritualization occurs in fairly similar ways between pairs, then a gesturing ape might produce the ritualized form of the movement in an initial encounter with a new partner (Halina et al. 2013; Tomasello and Call 2018). Much of the disagreement between authors surrounding OR comes down not to the proposed acquisition process of ritualization, but to whether a ritualized action would be transferable to a new partner. This seems like a testable question that could be at least partially answered through experiments in which apes ritualize gestures and then attempt to use them with new partners. We return to this in our discussion of testable hypotheses.

In their contribution to this special issue, Pika and Fröhlich (2018) advocate revisiting the role that social interaction plays in gesture development, and propose a theory they call the Social Negotiation Hypothesis. At the heart of their proposal is a developmental transition from responding to the behavior and intent of others to using behaviors to initiate interactions. This proposed developmental transition would also be testable: you should expect young infants to mainly respond to signals and only later to use those signals to initiate interactions. However, as the learning mechanism in this theory is unspecified, it is not yet clear what particular pattern of behavior you would expect during the learning process, only that a change would be detectable.

Genetic channeling (GC) proposes that the basic forms of gestures are inherited rather than learned, and that apes then learn how and when to use the gestures and perhaps to modify them in various ways. It has also been described as ritualization at the phylogenetic, rather than ontogenetic, level, and is perhaps best summarized as largely-fixed forms but flexible use. It bears resemblance to theories about the communication of species across other taxa, in which signal repertoires are typically fixed but usage can be flexible.

Since the learning mechanism in GC is not specified, learning to modify existing gesture forms and gesture use through trial-and-error learning, social learning, OR, or some combination of different mechanisms for different aspects of gesturing all remain possible. The critical difference between GC and other theories is that the range of available forms that gestures take is not open. Like many inherited traits, however, there is likely a gene-environment interaction, such that an ape may not produce a particular gesture form unless it encounters the right developmental environment. Given that apes are long-lived, this may take decades, or, for a particular individual, may rarely or perhaps never occur. As a result, it may be difficult to disprove the presence of a genetic component to ape gestures, but evidence suggestive of some genetic component comes from the pattern of overlap in the repertoires of available gestures across ape species. As they outline in their contribution to this special issue, Byrne et al. (2017) show that the more closely related two ape species are, the greater the overlap in their gestural repertoires. This case was strengthened by a recent study showing that of all of the ways in which chimpanzees could move their body to produce gestures, only a little over 10% of these were regularly used in their gesturing (Hobaiter and Byrne 2017). Thus, the similarity in gesture repertoires across ape species may not be solely ascribed to similarity across ape body plans and kinematic potential.

The hypotheses outlined above have typically been framed as mutually exclusive, with evidence for one taken as evidence against another; however, it is worth revisiting whether or not these theories necessarily stand in opposition to each other.

First, with an increasing diversity and density of data comes an appreciation for the flexibility present in great ape gesture. Great apes are capable, in other domains, of acquiring behavior through ritualization, via genetic channeling, or even through imitation. One's ability to learn through social interaction depends on opportunities to interact socially with other individuals. Different groups and populations of apes under study have very different socio-ecological

environments, even within a species. Wild East African chimpanzees, for example, live in groups with a high level of fission–fusion: encountering some community members regularly and others only on occasion. In contrast, individuals in captive settings are rarely, if ever, out of (at least auditory) contact with each other. These different socio-ecological circumstances likely have a profound impact on day-to-day communication: from which gesture forms apes use, to what information they already know or need to find out about other individuals. Evidence suggesting that gesture forms are acquired through genetic channeling under one set of socio-ecological conditions does not prohibit some gesture forms from being acquired through other mechanisms, particularly under very different circumstances.

Second, cases of apparent disagreement may center on variation in the researchers' methodological approaches, rather than on the gesturing itself. Exploring the repertoire of gesture forms available to an individual across contexts over their lifetime generates very different data than describing the repertoire of a particular individual, or group of individuals, at a single point in development, or for one particular goal. A learning mechanism may be involved in the use of none, some, or all of these 'repertoires'. Discriminating available repertoires from deployed ones is an example of why clarifying *what* is being explored, even in an apparently narrow field of research, is fundamental to generating testable hypotheses and meaningful comparisons. Substantial progress in reconciling different approaches may be achieved by remembering Tinbergen (1963), and reframing the different perspectives as representing different levels of analysis (Liebal et al. 2018; Fröhlich and Hobaiter 2018). Questions about gesture acquisition and expression can be explored at the level of *phylogeny* (Byrne et al. 2017; Kersken et al. 2018), *ontogeny* (Tomasello and Call 2018; Pika and Fröhlich 2018; Leavens et al. 2017), or in the real-time adaptation of an individual *interaction* (Bard et al. 2017; Genty 2019). No one single approach is 'correct', whether we are exploring the potential communicative tool-kit of available gestures in chimpanzees, or the use of a particular communicative tool, for example, Frank giving an 'arm shake' gesture to Fred (his older brother) while traveling on Tuesday of last week. Careful articulation of the level of the research question will allow for more meaningful comparison of hypotheses and datasets across studies.

Generating testable hypotheses

To create more points of agreement in the field, we advocate coming together to generate or agree upon testable hypotheses following from proposed learning mechanisms or other points of debate. This community-generated challenge could be useful both in catalizing new research, and in encouraging researchers to be more specific in describing or advocating for theories. When researchers propose theories about gesture acquisition, it is important that they articulate how those theories could be supported or refuted and how they differ from existing theories. In some cases, it might not be possible to differentiate between theories using observable behavior, but recognizing when hypotheses are and are not falsifiable is critical to continuing to develop the study of ape gesture as a rigorous scientific field.

It is also critical to acknowledge differences in ontogeny, rearing, and testing environments of apes, as done by Leavens et al. (2017). In experimental studies, comparisons are frequently made between human children, reared in enculturated environments and tested in spaces with their parents using game-like paradigms that resemble familiar types of interactions, and adult apes, reared in symbol-poor environments and tested using unfamiliar paradigms in which they interact with human experimenters behind barriers at a distance. Recognizing the limitations of such methodological differences and minimizing them when possible is important when making comparisons between the cognitive or communicative abilities of humans and other apes.

This paper is meant to summarize perspectives in the field as well as to point some directions forward. Although we do not presume to have a comprehensive list of the testable hypotheses the field should adopt, we would be remiss if we failed to generate any. Several hypotheses arise from comparing the points of disagreement expressed in the papers in this special issue. We articulate two here: (1) ontogenetically-ritualized signals should be transferrable to new partners, and (2) repertoire overlap in species-typical gestures should reflect phylogenetic relationships.

A research question arising from the disagreements around OR is whether a gesture that has undergone ritualization with one partner or in one context could be easily transferred to another. This could be turned into a testable hypothesis to be explored in communication experiments in which an ape ritualizes an action into a gesture through repeated interactions with one human partner and is then given the opportunity to interact with a different partner. If the ape did not use the gesture with the new partner, careful consideration of why it failed to do so would be needed. However, if the ape used the ritualized signal in an initial interaction with a new partner, it would provide support for the transferability of ritualized gestures.[1]

[1] This proposed transfer task is similar to the final step of the training procedure reported in the Lamaury et al. (2017) study of olive baboons learning reaching gestures. However, more details about the initial interaction with a novel partner and the similarity between this task and others in which they may have learned to generalize from one human to another are needed to determine whether it would provide support for the transferability of OR.

The Genetic Channeling theory suggests a hypothesis about the similarity between gestures and the relatedness between species. Many of the gestures apes use are shared with other ape species (Byrne et al. 2017). When the methods used to study ape gesture are applied to human children, they are also seen to produce these gestures (Kersken et al. 2018). As more primate species are studied with comparable methods, it is likely that their gestures will also overlap with the ape repertoire. Genetic channeling predicts that the repertoire overlap should reflect phylogenetic relationships between species. For example, in apes, orangutans and bonobos should not share gestures that are missing in gorillas and chimpanzees. Siamangs should not share gestures with gorillas that are not also seen in orangutans. Of course, there may be more overlap in the *individual* repertoires of two apes of different species than there is in the individual repertoires of two apes of the same species (e.g., an infant chimpanzee and an infant bonobo might share more gestures because they are infants than an infant chimpanzee and an adult chimpanzee would). Available repertoires of *species-typical* gestures, however, should show more overlap between closely related species than more distantly related ones. It is difficult to test this hypothesis using only data from the great apes, but as more primate species are studied using comparable methods, such an analysis should become possible.

A particular challenge for generating testable hypotheses is that it is nearly impossible to capture all of an infant's interactions to accurately measure all the input available for learning. Perhaps if it were possible to continuously record an infant ape's communicative interactions the way MIT scientist Deb Roy did with his son, we would be able to more accurately model the relationship between social interactions and early gesture production. Barring such methods, however, we desperately need more longitudinal data, particularly from early development when infant apes are not yet gesturing, or are not yet gesturing much (see discussion in Liebal et al. 2018). Even case studies would be useful if they provided high-resolution temporal data that would allow researchers to capture the earliest production of new gestures. Halina et al. (2013) attempted this type of study by focusing on a particular social context (the mother carrying the infant) rather than on a gesture. By shifting the focus to the social context and recording infants starting around 10 months of age, Halina and colleagues were able to link patterns of social actions to the use of particular gestures performed by different mother-infant dyads. But even here, this evidence applied only to a particular learning environment and to one gesture function. More studies of this type are needed to explore the developmental patterns of different social actions and gesture forms under different social conditions. However, it is very difficult to get substantial data on infant apes over developmental time. Data collection and coding are extremely time intensive and infant apes are limited in number. Studies should thus try to maximize the potential future use of the data they collect, and researchers should simultaneously explore ways of more thoroughly using extant datasets.

Collecting and leveraging data in smarter ways

More data is always useful in building a field of study, but many studies of ape gesture, including our own, have small sample sizes and tend to overgeneralize their results: studies of a small group of individuals over a short period of time, in a specific socio-ecological environment are used to characterize the communication of whole species. Combine this with the fact that many studies focus on counting gestures and describing gestural repertoires despite disagreeing on what constitutes a gesture or a repertoire of possible signals, and you have a field where our collective knowledge does not always increase with the collection of additional data. Importantly, we need to avoid the so-called WEIRD phenomenon, where data from a small number of populations is described as representing the normative behavior or capacity of an entire species (Henrich et al. 2010). Some field sites (i.e., Budongo) and some captive populations (i.e., Leipzig Zoo) are greatly over-represented in studies of ape gesture. This bias does not mean that further studies at these locations are not useful, but rather that interpretations about the generalizability of results need to take into account how representative a studied group is of the species more generally.

The practice of compiling and comparing gestural repertoires relies on the gesture as the unit of analysis. A potential problem with this is that there is no clear agreement about what constitutes a gesture. Different researchers classify gestures in different ways, and the practice of grouping instances of gesturing (tokens) into different gestures (types) is a largely subjective one. The granularity (i.e., level of detail) with which gesture types are defined varies considerably from study to study (Cartmill and Byrne 2011; Bard et al. 2017). Some studies differentiate gesture types by the limb used or the location on the recipient's body towards which a gesture is directed (e.g., right-hand slap or touch back). Other studies use a coarser granularity for gesture type (e.g., slap or touch), and would then code the hand used or the location as variables pertaining to gesture usage. These differences can be aligned for the purposes of comparison between studies (as in Hobaiter and Byrne 2011a; Byrne et al. 2017), but the process is not a simple one, since gesture types in one study may not always be subsets of gesture types in another.

Avoiding human subjectivity in grouping gesture tokens into relevant types is particularly important for studies that investigate gesture meaning. Imagine learning a new form of

spoken language where you don't know whether a change in tone represents a change in emphasis (as it might in English or French) or a change in meaning (as it might in Mandarin or Vietnamese). Exploring another system of communication requires that we are able to parse continuous graded streams of behavior, whether sound or movement, into relevant chunks, and those chunks should be relevant not to us, as human observers, but to the species using them to communicate.

In vocalization research, playback studies have been used to determine the parameters of a call type, but we have no good way of experimentally testing whether two ape movements that appear similar to human observers are perceived as two tokens of the same gesture type by conspecific apes. Nevertheless, we do now have large datasets of the apes' own behavior. In a recent attempt to start to address this issue, Hobaiter and Byrne (2017) employed all of the features (e.g. movement, body part, rhythmic repetition, etc.) used to discriminate gesture types in their studies and compiled a theoretically maximum repertoire. Initially containing over 6000 gesture types, this potential repertoire was reduced significantly by removing those that were physically impossible (e.g. movement = SPIN + body part = HEAD). This process left just over 1000 possible gesture types, of which only 124 were recorded in their chimpanzee data. They then used the apes' own behavioral responses to these gesture types to explore whether or not two possible types should be lumped, leaving a final repertoire of around 80 distinct types (Hobaiter and Byrne 2017).

Using existing data in new ways will help the field leverage existing resources to increase analytic power and generalizability, but these efforts can be hindered by a lack of shared methods or measurements. In their contribution to this issue, Gasser and Arbib (2018) propose bringing big data to ape gesture research by adopting a shared database to facilitate data sharing and pooled analysis (also see discussion in Gasser et al. 2014). The platform they created (the Gesture and Behavior Database, or GBDB for short) would support these efforts, but the community itself would need to properly structure incentives for data sharing. Since different research groups do not agree on what constitutes a gesture, considerable effort may need to be invested in either adopting similar methodological standards or in providing a way to 'translate' across studies.

The next 10 years: a cognitive turn?

Reports of a deictic gesture in fish (in a cooperative hunting context no less, Vail et al. 2013) surprised and shook the field of ape gesture research. Scholars studying ape gesture have long argued that ape gesture is of interest because of the evidence that apes use it *intentionally*, something that had not been claimed, until recently, for other primate signals (e.g., Schel et al. 2013). Markers of intentionality adapted from the child language literature, like response waiting and persistence, are coded and used as evidence that gestures are used with an intent to communicate (Tomasello et al. 1985). If a particular gesture does not meet the intentionality criteria, it is frequently removed from the dataset. Researchers have used the evidence for intentional communication to set ape gestures apart from other animal signals and to argue for the importance of studying gesture.

Moving forward, the field has two pathways available. We can—as has been done in the past—shift the goal posts. We could argue that response-waiting, or sensitivity to the audience's attention is no longer sufficient to demonstrate intentional use, and that instead signals must demonstrate persistence with elaboration, or other increasingly specific measures of intentionality. Doing so may, for a while, allow gestural researchers to continue to claim 'special' status for great ape gestural signals within non-human communication. However, we suspect that, as has been shown time and time again across behavioral studies, sooner or later another signal, or another species would pass whatever new 'test' of intentional use we devise. With improving methodology, we will likely detect examples of intentional communication more widely across animal species.

The alternative pathway is to relinquish intentionality as a way to demonstrate the uniqueness of ape gesture. Indeed, to accept that gesture may not be unique. Once we do that, we are free to move on from cataloguing ever more detailed lists of signals. Ceasing to use intentionality as a marker of gesture's uniqueness would not mean abandoning questions about the cognitive foundations and entailments of gesture. To the contrary, whether we are interested in ape gesture in its own right, or in terms of its apparent similarities to human language, we may find far more fruitful ground in using gesture as a means to explore ape cognition. What does their gesture use tell us about what it means to be a chimpanzee or a gorilla? Or a subadult female chimpanzee from Budongo, Uganda, born in Sonso and recently moved to neighboring Waibira? Importantly, this will also involve broadening our perspective to include the study of gesture comprehension and inference, in addition to gesture production.

As part of the turn towards using gesture to understand cognition, we should attempt to ask what apes understand about the communicative nature of their gesturing. Although different acquisition mechanisms may be present at different levels of gesture acquisition (whether in phylogeny, ontogeny, across socio-ecological niches, or within interactions), gesture use within a rich social landscape of different goals, behavioral contexts, and relationships likely requires the ability to generalize across individual interactions. To generalize learning from a single encounter to other partners

or contexts, some type of 'metacommunicative awareness' (similar to human metalinguistic awareness) may be involved. In other words, apes may learn to see gestures as something they could use to achieve communicative goals; they may have an awareness of their own gesturing as communicative. This is an ability that develops in young human children as they learn that language is something that can be modified, played with, and employed at will to achieve a range of goals (Cummins 1978). This is often described as children learning to see language as an object. Apes almost certainly do not possess human-like levels of metalinguistic awareness, but they may have some antecedents of this ability, as has been found for Theory of Mind (e.g. Krupenye and Call 2019). The difference here may be one of degree, not of kind. Ape metacommunicative awareness may exist in a radically different form than it does in humans, or it may not exist at all, but it would help explain the flexibility seen in the ways that apes combine and modify their gesturing to achieve their communicative goals.

We advocate shifting from using cognition primarily as a rationale to study gesture to using gesture as a tool to study the mind. This shift mirrors work in human gesture research that uses gesture to study speakers' understanding, reasoning, decision-making, and the choices people make when communicating with others. Goldin-Meadow (2003) describes human gesture as a 'window onto the mind'. By adopting this perspective in ape gesture research, we can focus on gesture as a tool to ask questions about the lives and minds of the apes we study. Just as it is problematic to elevate ape gesture through its intentionality in order to justify studying it, so it would be to demote gesture as a target of study because it may not be unique in its intentionality. Instead, gesture researchers should feel empowered by the spread of multimodal research and research on gesture in other species. Rather than see this as a challenge to the 'special status' of ape gesture, we should view this as an opportunity to evolve our own research goals. Where once we were trying to convince others that gesture was a valid (and important) subject of study, we now have an opportunity to shift our efforts towards using gesture as a window onto the minds, practices, and social worlds of great apes.

References

Bard KA, Maguire-Herring V, Tomonaga M, Matsuzawa T (2017) The gesture 'Touch': does meaning-making develop in chimpanzees' use of a very flexible gesture? Anim Cogn. https://doi.org/10.1007/s10071-017-1136-0

Byrne RW, Cartmill E, Genty E, Graham KE, Hobaiter C, Tanner J (2017) Great ape gestures: intentional communication with a rich set of innate signals. Anim Cogn 20(4):755–769

Call JE, Tomasello ME (2007) The gestural communication of apes and monkeys. Taylor & Francis Group, Routledge

Cartmill EA, Byrne RW (2011) Addressing the problems of intentionality and granularity in non-human primate gesture. In: Stam G, Ishino M (eds) Integrating gestures: the interdisciplinary nature of gesture. John Benjamins, Amsterdam

Cummins J (1978) Bilingualism and the development of metalinguistic awareness. Cross-Cult Psychol 9(2):131–149

Fröhlich M, Hobaiter C (2018) The development of gestural communication in great apes. Behav Ecol Sociobiol 72(12):194

Gasser B, Arbib M (2018) A dyadic brain model of ape gestural learning, production and representation. Anim Cogn. https://doi.org/10.1007/s10071-018-1228-5

Gasser B, Cartmill EA, Arbib MA (2014) Ontogenetic ritualization of primate gesture as a case study in dyadic brain modeling. Neuroinformatics 12(1):93–109

Genty E (2019) Anim Cogn. https://doi.org/10.1007/s10071-019-01267-0

Genty E, Breuer T, Hobaiter C, Byrne RW (2009) Gestural communication of the gorilla (*Gorilla gorilla*): repertoire, intentionality and possible origins. Anim Cogn 12:527–546

Goldin-Meadow S (2003) Hearing gesture: how our hands help us think. The Belknap Press of Harvard University Press, Cambridge

Halina M, Rossano F, Tomasello M (2013) The ontogenetic ritualization of bonobo gestures. Anim Cogn 16(4):653–666

Henrich J, Heine SJ, Norenzayan A (2010) Beyond WEIRD: towards a broad-based behavioral science. BehavBrain Sci 33(2–3):111–135

Hobaiter C, Byrne RW (2011a) The gestural repertoire of the wild chimpanzee. Anim Cogn 14(5):745–767

Hobaiter C, Byrne RW (2011b) Serial gesturing by wild chimpanzees: its nature and function for communication. Anim Cogn 14(6):827–838

Hobaiter C, Byrne RW (2017) What is a gesture? A meaning-based approach to defining gestural repertoires. Neurosci Biobehav Rev 82:3–12

Kersken V, Gómez JC, Liszkowski U, Soldati A, Hobaiter C (2018) A gestural repertoire of 1- to 2-year-old human children: in search of the ape gestures. Anim Cogn. https://doi.org/10.1007/s10071-018-1213-z

Krupenye C, Call J (2019) Theory of mind in animals: current and future directions. WIREs Cogn Sci 1:503. https://doi.org/10.1002/wcs.1503

Lamaury A, Cochet H, Bourjade M (2017) Acquisition of joint attention by olive baboons gesturing toward humans. Anim Cogn. https://doi.org/10.1007/s10071-017-1111-9

Leavens DA, Bard KA, Hopkins WD (2017) The mismeasure of ape social cognition. Anim Cogn. https://doi.org/10.1007/s10071-017-1119-1

Liebal K, Schneider C, Errson-Lembeck M (2018) How primates acquire their gestures: evaluating current theories and evidence. Anim Cogn. https://doi.org/10.1007/s10071-018-1187-x

Pika S, Fröhlich M (2018) Gestural acquisition in great apes: the social negotiation hypothesis. Anim Cogn. https://doi.org/10.1007/s10071-017-1159-6

Plooij FX (1978) Some basic traits of language in wild chimpanzees. In: Lock A (ed) Action gesture and symbol: the emergence of language. Academic Press, London

Schel AM, Townsend SW, Machanda Z, Zuberbühler K, Slocombe KE (2013) Chimpanzee alarm call production meets key criteria for intentionality. PLoS One 8(10):e76674

Slocombe KE, Waller BM, Liebal K (2011) The language void: the need for multimodality in primate communication research. Anim Behav 81(5):919–924

Tinbergen N (1963) On aims and methods of ethology. Zeitschrift für Tierpsychologie 20(4):410–433

Tomasello M, Call J (2018) Thirty years of great ape gestures. Anim Cogn. https://doi.org/10.1007/s10071-018-1167-1

Tomasello M, George B, Kruger A, Farrar J, Evans E (1985) The development of gestural communication in young chimpanzees. J Hum Evol 14:175–186

Tomasello M, Gust D, Frost TA (1989) A longitudinal investigation of gestural communication in young chimpanzees. Primates 30:35–50

Tomasello M, Call J, Nagell K, Olguin R, Carpenter M (1994) The learning and use of gestural signals by young chimpanzees: a trans-generational study. Primates 35(2):137–154

Vail AL, Manica A, Bshary R (2013) Referential gestures in fish collaborative hunting. Nat Commun 4:1765

Whiten A, Goodall J, McGrew WC, Nishida T, Reynolds V, Sugiyama Y, Tutin C, Wrangham RW, Boesch C (1999) Cultures in chimpanzees. Nature 399(6737):682