A mother gorilla's variable use of touch to guide her infant

Insights into iconicity and the relationship between gesture and action

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This chapter examines how gestures of the great apes are created from instrumental actions. Ape gestures are generally believed to form through phylogenetic or ontogenetic ritualization, or – at least in humans – "iconic" gestures are created spontaneously during online interaction. These alternatives are evaluated with respect to data on the tactile *pushes* used by a mother gorilla to direct her infant around their enclosure. Analysis shows that the *pushes* exhibit variability in form and force in ways that are tuned to the present physical and social context, indicating the underlying activation of afforded instrumental actions and thus iconic processes in the creation of these gestures, opposed to ritualization. We discuss how this variability reveals continuity between gesture and action that is compatible with recent simulation-based accounts of iconic gesture.

1. Introduction

The great apes – human and nonhuman alike – use an array of bodily gestures to communicate with one another about action. Gestures may initiate play, grooming, and nursing; coordinate movement; indicate dominance and submission; and negotiate sexual interactions (Call & Tomasello 2007). A close relationship between gesture and action is to be expected (Arbib 2002; Armstrong & Wilcox 2007; King 2004; Tanner & Byrne 1996). Gesture, after all, is itself a sort of action, and there often exists a visible similarity between the form of a gesture and the implied action that constitutes the basis for its meaning. Indeed, researchers have examined the similarity between particular gestures and the actions they resemble to gain insight into the gestures' origins and the cognitive processes that enable their use.

Traditionally, however, there is thought to be an important psychological distinction between communicative acts, such as gestures, and direct instrumental acts on a social partner:

> [Communicative] acts achieve their ends indirectly. That is, the actor does not act physically to alter things to suit his needs, pushing or dragging other individuals about, beating them into submission, or the like. Instead, the actor's behavior provides other individuals with information, and the actions that *they* take on the basis of this information lead to any functions that are obtained (Smith 1980: 389, quoted in Call & Tomasello 2007: 7)

Thus communicative gestures are considered to be those social acts that influence another individual by conveying information rather than by physical force, and it is typically assumed that these processes can be categorically distinguished from one another.

The processes by which a communicative gesture originates from an instrumental action are generally reasoned to occur along the time scales of phylogeny, ontogeny, or during the moments of online interaction. The first two of these are well accepted by ethologists to play a crucial role in the gestures used by both nonhuman and human apes (Eibl-Eibesfeldt 1972; van Hooff 1972). The third class of gestures, however, is more controversial. These gestures – often referred to as iconic – are created spontaneously and bear a visual or otherwise perceivable similarity to the meaning they express. Thus action-related iconic gestures are motivated by an active sense of an underlying instrumental act, such as Tomasello's (2008) creation of a sprinkling-grated-cheese gesture to place an order for Parmesan at an Italian cheese shop. While iconic gestures are believed to be a universal part of human communication (Kendon 2004; McNeill 1992), the ability of apes to use these gestures is debated (Call & Tomasello 2007; Pika 2007a,b; Tanner & Byrne 1996; Tanner, Patterson, & Byrne 2006).

Our purpose in this chapter is to gain insight into the relationship between gesture and action by examining the *pushes* used by a mother gorilla to direct her infant around their enclosure. We first review research on the three basic ways that gestures are thought to arise from action, and then present description, analysis, and discussion of the mother-infant *pushes*.

1.1 Gestures from phylogenetic ritualization

The ethology literature offers many well-documented examples across a wide range of animal species of how a signal movement can evolve through the ritualization of a functional action sequence (Darwin 1872; Tinbergen 1952). This process – known as phylogenetic ritualization – is illustrated by the snarl of a wolf, a facial expression derived from the practical action of retracting the lips to bite. Another

animal interacting with an ancestral wolf would have gained an advantage from reading this intention movement and anticipating the ensuing bite. In turn, a later generation of wolf that instinctively exaggerated this lip retraction could benefit by triggering other animals to respond as if to an oncoming bite, and so on through the generations to evolve the ritualized snarl observed today. This process is also believed to play a major role in the evolution of many of the bodily signals of the great apes including various facial expressions, postures, and vocalizations (Darwin 1872; Van Hooff 1972).

To the extent that ritualization is an operating force in the development of a gesture, it can be expected to display certain hallmark qualities related to its use and form (Blest 1961/1966). One such quality is "emancipation" from the gesture's original proximal stimulus. The increasingly ritualized act, over the course of evolution, becomes independent of the causal factors that mediated its ancestral precursor, and is thereby free to become stylized into a standard, stereotyped form. Blest describes:

> Whereas stimuli of varying strength for the release of the unritualized precursors of display movements elicit responses of varying intensity and form, following ritualization the derived responses acquire an almost constant form and intensity to a wide range of stimulus strengths". (p. 104)

However, the stereotyping forces of ritualization often compete with the advantage provided by the continuous variability exhibited by functional actions (Morris 1957). The result is often that a signal comes to be expressed with a stable, "typical intensity" in response to a wide but intermediate range of stimulus strengths, but can vary in response to more extreme stimuli. According to Morris, the variable expression of a ritualized signal is modulated essentially along two parameters – intensity and frequency – that correspond to differential motivation to display the signal. Yet, important to note is that a signal's variable intensity refers to the variable degree of enactment of the *ritualized* act. Thus, a maximally motivated ritualized signal manifests in an extreme form of the ritualized behavior, not the full execution of the instrumental act from which it was derived.

Specific accounts of how bodily signals of the great apes derive from functional actions through phylogenetic ritualization have predominantly been reserved for behaviors like facial expressions and have not often been offered for manual gestures (e.g. Eibl-Ebesfeldt 1972; Van Hooff 1972). However, one recent study takes a strong position consistent with the idea that phylogenetic ritualization is fundamental to the manual gestures of gorillas (Genty, Breuer, Hobaiter, & Byrne 2009). Based on studies across three captive facilities and one wild population, Genty et al. identify a repertoire of 102 different gestures and conclude that it is built of species-typical, biologically inherited gestural forms. Although little explanation

is offered for how these gestures would come to be innately specified, phylogenetic ritualization would presumably be a major operating force in their creation, as this is generally understood to be the main evolutionary process through which communicative signals are created (Morris 1957; Tinbergen 1951).

1.2 Gestures from ontogenetic ritualization

Researchers have also suggested that ape gestures develop over the course of an individual animal's interactional experience (Call & Tomasello 2007; Plooij 1978). Borrowing from the ethological concept, Tomasello and colleagues propose that a large number of great ape gestures arise through a process called ontogenetic ritualization. For example, a young chimpanzee may repeatedly raise his arm to play-hit a companion, to which his social partner gradually learns to anticipate that an arm-raise attends a play invitation (Tomasello 2008). The arm-raiser in turn comes to recognize his partner's anticipation and waits for a play response after making the arm-raise movement. Thus a ritualized gesture is created as two individuals anticipate and shape one another's behavior over repeated instances of the same interaction.

Importantly, by the essential nature of the ritualization process, ontogenetic ritualization also leads to stylized communicative gestures that lack graded variation in form and meaning (Burling 1999). Notably, however, this lack of variation is different from a lack of flexibility in the deployment of the gesture, which is granted by the emancipation of the signal from its original functional action.

1.3 Iconic gestures

Numerous researchers have also described apes' use of gestures derived more spontaneously from action. Tanner and Byrne (1996), for example, report the iconic gestures created by Kubie, a captive gorilla, who used them to coordinate playful action with a young female Zura. Using both visual and tactile gestures, Kubie indicated how he apparently desired Zura to move, with the direction of the gesture depicting the desired direction of movement. Kubie utilized a similar repertoire with three different females at different time periods, making ontogenetic ritualization an unlikely explanation. Tanner and Byrne (1999) also note a great deal of gradation and variation in the parameters of Kubie's iconic gestures that made them difficult to categorize as "types," a quality not predicted by ritualization.

A number of other studies also document the use of iconic gestures by apes (Crawford 1937; Hayes & Nissen 1971; Köhler 1925/1948; Pika & Mitani 2006; Russon & Andrews 2010; Savage-Rumbaugh et al. 1977; Savage-Rumbaugh et al. 1986; Tanner, Patterson, & Byrne 2006; Yerkes 1947), with more sophisticated gestures described for enculturated apes. For instance, Kanzi and his sister Mulika,

two bonobos raised with intensive human contact and symbolic communication from a young age, are reported to have spontaneously created iconic gestures for actions they wanted performed (Savage-Rumbaugh et al. 1986). Savage-Rumbaugh et al. describe that they "made twisting motions toward containers when they needed help in opening twist-top lids" and "hitting motions toward nuts they wanted others to crack for them" (p. 218).

2. Present study

Despite numerous reports of iconic gestures, studies on the origins of great ape gestures have tended to focus on individual learning processes such as ontogenetic ritualization (Call & Tomasello 2007; see also Schneider & Liebal this volume) or biological inheritance (Genty et al. 2009), and have given less direct attention to iconic processes. Here we evaluate each of these three alternative explanations as they may account for the directive *pushes* used by a mother gorilla Bawang to guide her infant Barney.

Specifically, we examine (1) the variation in the form and physical force of Bawang's directive *pushes*, (2) whether this variation appears to be motivated by details of the physical and social context such as presently-afforded instrumental actions or Barney's attitude towards coordinating with his mother, and (3) whether Barney's attitude is influenced by the degree of physical force used by Bawang.

According to phylogenetic or ontogenetic ritualization, Bawang's directive *pushes*, if they function as communicative gestures, are stylized signals that ought to be consistent in form and distinct from any particular instrumental act, to which they would not be expected to exhibit any systematic, graded similarity. More or less similarity in the performance of the ritualized gesture to its original instrumental action would be random and not differentially meaningful to Barney. He would not, for example, be expected to respond more coordinatively to *pushes* that are performed with instrumental force, as these would be the same acts that are signaled by the ritualized gesture.

Alternatively, in an iconic account, Bawang's directive *pushes*, when communicative, are created spontaneously in the moment of interaction. They would be formed through an active sense of a particular instrumental action (i.e. actual physical manipulations of Barney), and thus may exhibit variability in form, such as in angle and trajectory, as opposed to fixed stylization. Furthermore, an iconic gesture could potentially vary systematically in its degree of enactment and mechanical effectiveness, motivated, for instance, by the social context of Barney's attitude towards coordinating with his mother. In turn, Barney may be sensitive to this motivated variation, responding more coordinatively to more forceful *pushes*.

3. Method

3.1 Subjects and setting

At the time of the video recording, the subjects, Bawang and her infant son Barney, were members of a stable social group at the San Francisco Zoo. Bawang was 13 years old, and Barney, her second son, was 10–11 months old. The group also included Bawang's first son, five-year-old Shango, their father, the silverback Kubie, and two unrelated adult females Zura and Pogo. The gorillas had access to a large outdoor area (2,300 m^2, 38 x 50 m at maximum parameters) covered with grass and other vegetation and containing large, climbable live trees as well as several dead trees, large stumps, and rock structures.

3.2 Data recording and scene selection

Video recordings of Bawang and Barney were made once a week during August and September of 1994 by JET using focal animal sampling (Altmann 1974). Although JET's observations extended before and after this time period, it was only during this two-month window when Bawang was observed to use such directive *pushes*, and they often appeared motivated by Bawang's interest to remove Barney from situations of rough play with his older brother. JET selected all scenes recorded from this period in which Bawang used directive touches with Barney, which included in addition to *pushes,* various forms of *grabs, pulls, swings,* and *carries*. For the present work, we selected only clips of interactions involving two or more directive *pushes* within a contiguous interaction, resulting in 21 video clips. The mean length of each clip was 36.1 s, with a standard deviation of 11.9 s.

3.3 Coding and analysis

All directive *pushes* were analyzed, irrespective of mechanical effectiveness. Bawang's intent to direct Barney was established by observing that the two began moving immediately after the touch, or when Barney did not begin moving, by Bawang's repeated efforts. The coding was conducted by MP, according to the operating definitions provided in Table 1. For reliability, a second coder, naïve to the hypotheses and theoretical motivation of the study, also coded the data according to the same criteria.

Pushes were considered as any act in which Bawang touched Barney with her palm or the back of her hand, without grabbing him, in an apparent attempt to direct him to move. Mechanical force for each was coded as *light, medium,* or *heavy/full.* Barney's attitude towards coordinating his movements with Bawang, both before and after each *push*, was coded as *passive* or *active* and *coordinative* or *discoordinative*.

Table 1. Definitions of coding categories

Force	**Amount of physical pressure applied by Bawang to Barney**
Heavy/Full	Substantial lasting physical impact on position and/or orientation, or transmits a sharply jarring impact.
Medium	Clear but not jarring physical impact on position and/or orientation; without a lasting, substantial change.
Light	Minimal physical effect on position and/or orientation.
Attitude	**Barney's attitude immediately before and after Bawang's *push*.**
Active	Actively moving or orienting.
Passive	Mostly still and passive.
Discoordinative	Acts in direct opposition to previous *push*, with either active or passive resistance.
Coordinative	Acts in accordance with previous *push* by moving in the desired direction; may be passive if not yet directed anywhere.
Push Form	**Bawang touches Barney with her hand, without grabbing him**
Backhand	With the back of the hand.
Inside Out	Inside-out motion with the palm of the hand away from the body.
Overhand	Mostly forward-facing palm, may be directed downward.
Underhand	From underneath with an upward facing palm, sometimes rolling over the hand.

4. Results

The 21 qualifying sequences of Bawang and Barney contained a total of 54 *pushes* for analysis, with an average of 2.57 per sequence and standard deviation of 1.72 (four instances were discarded because physical contact could not be clearly determined). Table 2 summarizes the use of force by each type of *push* and also by Barney's attitude immediately prior to contact. For comparison, the results from both coders are presented.

Table 2. Use of force by *push* type and Barney's attitude

	Total	**Light**	**Medium**	**Heavy/Full**
***Push* Type**				
Backhand	6 (11.1%)	2 (33.3%)	3 (50.0%)	1 (16.7%)
	8 (14.8%)	3 (37.5%)	5 (62.5%)	0 (0.0%)
Inside out	2 (3.7%)	2 (100.0%)	0 (0.0%)	0 (0.0%)
	2 (3.7%)	2 (100.0%)	0 (0.0%)	0 (0.0%)
Overhand	35 (64.8%)	15 (42.9%)	9 (25.7%)	11 (31.4%)
	33 (61.1%)	11 (33.3%)	13 (39.4%)	9 (27.3%)
Underhand	11 (20.4%)	3 (27.3%)	3 (27.3%)	5 (45.5%)
	11 (20.4%)	3 (27.3%)	3 (27.3%)	5 (45.5%)
Total	54	22 (40.7%)	15 (27.8%)	17 (31.5%)
	54	19 (35.2%)	21 (38.9%)	14 (25.9%)

(*Continued*)

Table 2. Use of force by *push* type and Barney's attitude (Continued)

	Total	Light	Medium	Heavy/Full
Prior Attitude				
Coordinative	23 (43.4%)	13 (56.5%)	7 (30.4%)	3 (13.0%)
Active	22 (41.5%)	12 (54.5%)	6 (27.2%)	4 (18.2%)
Coordinative	4 (7.5%)	3 (75.0%)	0 (0.0%)	1 (25.0%)
Passive	10 (18.9%)	5 (50.0%)	4 (40.0%)	1 (10.0%)
Discoordinative	9 (17.0%)	3 (33.3%)	3 (33.3%)	3 (33.3%)
Active	7 (13.2%)	1 (14.3%)	5 (71.4%)	1 (14.3%)
Discoordinative	17 (32.1%)	3 (17.6%)	5 (29.4%)	9 (52.9%)
Passive	14 (26.4%)	1 (7.1%)	6 (42.9%)	7 (50.0%)

In each cell: Top two numbers from Coder 1, bottom two numbers from Coder 2; left number = number of *pushes*, right number = percentage of *pushes* by force for given *push* type or attitude (three right columns) or percentage of total for given *push* type or attitude (left column).

4.1 Form and force

Four basic types of *pushes* were identified (see Table 1) and were confirmed by the second coder with 85% reliability (Cohen's kappa k = 0.73). Overhand *pushes* were used most frequently (n = 35, 64.8%), but underhand (n = 11, 20.4%) and backhand *pushes* (n = 8, 11.1%) were also used with substantial frequency. Inside out *pushes* were used just twice (3.7%).

The distribution of force exhibits a considerable amount of variation across gesture types (coded with 71.7% agreement, linear Cohen's kappa k = 0.67; see Table 2). Excluding the rare inside out form, each other type of *push* was employed with light, medium, and heavy/full force, with each category represented at least 16.7% of the time. 40.7% of the observed *pushes* involved light, non-instrumental force.

4.2 Attitude

Barney's attitude was coded immediately before and after Bawang performed each *push*. First it was determined whether his willingness to coordinate with his mother influenced the degree of force she used. Barney's attitude was coded by the second rater with 83.3% agreement for active/passive (k = 0.66) and 84.9% agreement for coordinative/discoordinative (k = 0.69).

A chi-square compared the distribution of force for Barney's coordinative and discoordinative attitudes, showing a significant difference between them ($\chi^2 = 8.60$, df = 2, $p < 0.05$; for the second coder, $\chi^2 = 10.76$, df = 2, $p < 0.01$). Specifically, Barney's discoordinative attitude was associated with more forceful *pushes* by Bawang.

We also looked at Barney's attitude immediately following Bawang's pushes to determine whether it was influenced by the degree of force used by Bawang. Barney's subsequent attitude was coded by the second rater with 88.9% agreement for active/passive (k = 0.74) and 87.0% agreement for coordinative/discoordinative (k = 0.72). Of 27 interactions in which Barney began with a coordinative attitude, his attitude changed to discoordinative only twice, once after a light *push* and once after a medium *push*. Conversely, of 26 interactions in which Barney began with a discoordinative attitude, his attitude changed to coordinative five times, four times after a heavy/full *push* (4 of 12 heavy/full *pushes* or 33.3% led to reversal) and once after a medium *push* (1 of 14 light and medium *pushes* or 7.1% led to reversal). The small number of observations in these conditions was not sufficient to reach statistical significance ($\chi^2 = 1.42$, df = 1, p = 0.23).

5. Discussion

The present study examined the *pushes* used by a mother gorilla Bawang to direct her infant Barney around their enclosure. Specifically, it sought to assess the variation (or lack of it) in the form and physical force of Bawang's directive *pushes* and to determine whether it appeared to be motivated by details of the physical and social context. We further examined whether variation in the physical force of Bawang's *pushes* might be differentially meaningful to Barney, influencing his willingness to coordinate action with his mother. Our goal was to gain insight into how gestures may originate from instrumental actions by comparing an iconic account of gesture to theories of ontogenetic and phylogenetic ritualization in their ability to explain the results of the study.

The results show that Bawang's *pushes* are variable along several dimensions. They frequently vary in their degree of mechanical effectiveness, sometimes employing an instrumental degree of force, other times a light, ineffective touch, and yet other times a degree of force somewhere in between. Furthermore, they appear molded to the context at hand and reflect, at least in a number of cases, actually afforded instrumental manipulations of Barney. For example, Bawang tended to employ directive touches involving an upward facing palm and lifting movement, an underhand *push,* when Barney was passively lying or sitting down. Of 11 total underhand *pushes*, 8 (72.7%) were used when Barney was passive, compared to 11 of 35 overhand *pushes* (31.4%) used in this context.

Bawang's *pushes* also appear to be tuned to the social context of Barney's attitude, a point demonstrated by her tendency to apply more forceful, and hence, more "instrumental" *pushes* when Barney was being discoordinative, and less forceful, more "gestural" *pushes* when he was coordinative. In turn, there is

tentative evidence (limited by the number of observations) to suggest that Barney is responsive to the differential use of force by his mother, showing an increased tendency to change from a discoordinative to coordinative attitude after the application of heavy/full forced *pushes*.

This physically and socially motivated variability in Bawang's *pushes* is not consistent with the hypothesis that ritualization, whether through evolution or ontogeny, is predominantly responsible for their creation. Both processes of ritualization lead to stylized forms that are consistently distinct from any particular afforded instrumental act. Instead, Bawang's directive *pushes* appear actively shaped by the physical and social context, with even her less forceful gestures, through their orientation and trajectory, formed according to the afforded *push* that would move Barney in the desired direction. Moreover, Barney appears able to understand his mother's intentions (e.g. her desired direction, her emotional state) through the particulars of the *push* as it resembles an actual instrumental act. These observations all point to an active role of iconic processes in the creation of Bawang's *pushes*.

Yet, one potential reservation in interpreting these results rests in the reliability of the data coding. Variables like degree of force and attitude are difficult to determine precisely, and this imprecision is reflected in the moderate degrees of interrater reliability. However, sufficient reliability exists to confirm a substantial degree of variability in the force and form of the *pushes*, and as evident from Table 1, the two coders observed very similar patterns of variability. Moreover, some limited degree of variance is expected in the categorization of continuously varying as opposed to categorically distinct forms of behavior such as ritualized gestures.

5.1 Iconicity and gesture-action continuity

Reports observing the ability of the great apes to spontaneously create iconic gestures have generally been received with a good deal of skepticism (Call & Tomasello 2007; Pika 2007a, 2007; Tomasello 2008). For example, Tomasello (2008) considers iconic gestures reported by Tanner and Byrne (1996) in which a silverback gorilla (Kubie) moved his arms in a particular direction to communicate to a female (Zura) to move in that direction (i.e. gestures quite similar to the ones reported here). According to Tomasello, these are most likely "garden-variety ritualized behaviors" that appear iconic to human observers because they "derive from attempts to actually move the body of the other in the desired direction" (2008: 27). Such dismissal is summarized by Tomasello and Call's conclusion that "Iconic gestures... are basically not used by apes" (2007: 234).

We suggest that a primary reason for doubting that apes are able to produce iconic gestures is based on the *a priori* assumption that the use of iconic gestures

depends on highly developed social-cognitive abilities related to imitation and theory of mind. Tomasello, for instance, reasons (2008: 203):

> To use an iconic gesture one must first be able to enact actions in simulated form, outside their normal instrumental context – which would seem to require skills of imitation, if not pretense… [T]o comprehend an iconic action as a communicative gesture, one must first understand to some degree the Gricean communicative intention; otherwise the recipient will suppose that the communicator is simply acting bizarrely, trying to run like an antelope or to dig a hole for real when the context is clearly not appropriate.

Tomasello and colleagues argue that the great apes have only limited abilities to imitate and share communicative intentions, and therefore are unable to use iconic gestures (Call & Tomasello 2007; Tomasello 2008).

Yet, like the directive *pushes* described in the present study, reports of iconic gestures by the great apes generally describe them as occurring fairly directly *within* "their normal instrumental context." Because these gestures are thus contextualized, they may be comprehended without necessarily understanding the gesturer's "Gricean communicative intention," but directly through an activated sense of the instrumental action within a context that is relevant to exactly that sort of action. These gestures need not be "quarantined" because they are not – in production or comprehension – fully distinct from the action for which they are iconically expressive.

In addition to work by Tomasello, Call, and colleagues, a comprehensive study by Genty et al. (2009) presumably also failed to observe iconic gestures, although they do not explicitly report one way or the other. Instead, the authors identify 102 different gesture types across several wild and captive groups of gorillas, and based on the consistent observation of overlap, they suggest that the gestures must each be part of a biologically inherited repertoire. One may note, however, that 102 different types of gestures is a lot, and perhaps as a necessary constraint on such a large number, many of the categories seem to include variations on similar kinds of physical motions. For example, several of the gestures (2-*handed grab, 2-handed grab-pull, grab-pull, one-handed grab*, *positioning*, *hand on*, *hands on*, *1-handed push*, *2-handed push*, *touch*) involve touching some unspecified part of another with the palm of the hand and bear a notable similarity to the *pushes* described in the present study. (In addition to *pushes*, Bawang also directed Barney with a variety of *pulls*, *swings*, and *grabs* that were not reported here.) Some of these gestures may have been split by the authors into multiple categories when they just as reasonably could have been included together in a single category, thus indicating a certain amount of arbitrariness to the categorical designations.

Indeed, the 102 different gesture types appear to fill a substantial portion of the full range of actions that are anatomically possible for a gorilla to perform. Especially as many similar gestures were observed in several but not all the populations studied, the overlap could instead be a result of probable action responses to recurring affordances common to gorilla environments and social lives. Further research might distinguish whether these gesture types are truly separate categories and are thus likely to be ritualized, or whether they instead reflect variations on commonly afforded actions, which would lend support to an iconic account.

Whereas most previous work makes a categorical distinction between gesture and instrumental action, the nature of the directive *pushes* described in this study points to a more continuous relationship between them in which the distinction is more a matter of degree. *Push*-like gestures may be created and understood through an activated sense of the full instrumental act (such as a hard, sustained *push*) that is expressed through a weakened or partially-enacted version (a gentle touch). Bawang may have been motivated to cause Barney to move in a particular direction by means of an instrumental act upon him, but, perhaps for socially-minded considerations, she was inclined to inhibit the full act and carry it out in a weakened or partially-enacted form. At other times, particularly when Barney was being less coordinative, Bawang may have become emotionally aroused, leading to less inhibition of the instrumental act and increased application of force upon Barney.

The literature on great ape iconic gesture suggests a variety of social considerations that might lead to the inhibition of instrumental acts. In the present study, for example, Bawang may have had an interest in fostering Barney's locomotive independence, as it would be quite exhausting to have to *push* him everywhere she wanted him to go. Thus she would be motivated to communicate her intentions rather than forcefully carry out the full instrumental act.

In the case of Tanner and Byrne's (1996) report of Kubie and Zura, they note how special circumstances – Zura's ability to escape because of her small size and the intimidating presen of a more dominant silverback – pressured Kubie to be especially tactful and convincing if he wanted to engage Zura in playful interactions. If he were too forceful and unpleasant, Zura could easily have put an end to the bout. And in the case of the iconic gestures produced by Kanzi and Mulika (Savage-Rumbaugh et al. 1986), the inhibition appears to have been for physical, not social reasons. The desired items – nuts and a jar with a twist-top lid – were simply out of physical reach, and so the instrumental action could not be performed. The result in each of these cases is that a gesture is born out of the partial enactment of an instrumental act that is restrained for one reason or another.

5.2 Gesture and sensorimotor simulations

The puzzle remains of how to get from rather simple iconic *pushes* to the full-blown iconic gestures that are considered characteristically human, such as Tomasello's (2008) cheese-sprinkling gesture. How could the so-called iconic gestures of apes be at the origin of human gesture? One possible explanation begins by considering the compatibility of the observed continuity between gesture and action with recent accounts that hypothesize sensorimotor simulations as the essential cognitive process involved in the production of iconic gestures. According to one such view, simulations of action-related thoughts lead to the activation of neural premotor action states, which then has the potential to spread to motor areas (Hostetter & Alibali 2008). This spreading activation comes to be realized as the overt action of iconic gesture.

The idea that iconic gestures are rooted in the simulation of actual instrumental acts is demonstrated in an experiment by Cook and Tanenhaus (2009) in which participants solved the Tower of Hanoi problem and described their solution to a listener. In this problem, a stack of disks is arranged bottom-up from largest to smallest on the leftmost of three pegs, and the goal is to move all of the disks to the rightmost peg, moving only one disk at a time and without ever placing a larger disk on top of a smaller one. Participants performed the task either by physically manipulating a real stack of weights or with a mouse in a computer version of the problem.

When participants described their solution, their iconic gestures were found to correspond to the actual trajectory involved in solving the problem, with differences reflecting the differently afforded constraints of the real-weight versus computer task. Cook and Tanenhaus interpret these analog differences as evidence for the activation of perceptual-motor information that is involved in the actual performance of the task. The instrumental act is simulated, leading to the creation of an iconic gesture that is a direct reflection of this activation.

What are the implications of applying a simulation-based view to the iconic gestures of the great apes? Perlman and Gibbs (in press) consider this question and pose some predictions about the characteristics and qualities of the gestures one would expect to find by the hypothesis. They suggest that the most phylogenetically primitive iconic gestures would be those that manifest from the most imaginatively simple of simulations. Thus, for example, the simulation ought to involve the gesturer's own perspective and body, and not someone else's, let alone the gesturer's body imagined as something entirely different. In addition, the contextual and afforded elements of the simulation ought to be largely present in the gesturer's immediate perceptual experience – the more distant the element, presumably the more difficult it would be to imagine. In sum, primitive iconic gestures

ought to be tightly connected – in form, meaning, and context – to the presently afforded instrumental and attentive actions that are available to the gesturer. And indeed, as we have seen, the most commonly observed iconic gestures are those that are most concrete in form and function, such as tactile gestures used to direct an interlocutor's movement.

Moreover, there is evidence that with increased human enculturation and immersion in language routines, there is an expansion in apes' imaginative ability to engage in mental simulations and mime the imagined actions. For instance, recall the iconic gestures produced by Kanzi and Mulika, notable in how they incorporate the imagined physical manipulation of objects that are not available to immediate tactile experience (Savage-Rumbaugh et al. 1986). Yet, as evident from their description, the simulated objects *are* available to their visual perception. As Kanzi and Mulika perform these gestures, their visual attention is clearly drawn towards the desired objects. One might wonder whether they could produce such sophisticated iconic gestures with the same facility if the objects were located outside of their perceptual purview.

According to the simulation hypothesis, the capacity to create iconic gestures could be considered along the degree of complexity involved in the corresponding mental simulation. For example, a simulated transitive act in which the resulting gesture is directly enacted upon a present object (e.g. Bawang's *pushes* upon Barney) would require less simulative complexity than a simulated act in which the gesture is acted upon an imagined object (e.g. Tomasello's sprinkling-cheese gesture). Indeed, researchers have previously suggested developmental sequences of action-derived gestures through phylogeny and ontogeny that are compatible with the above ideas (Arbib 2002), and similar notions have been applied to apes without enculturation (Savage-Rumbaugh et al. 1977; Tanner et al. 2006) as well as to enculturated apes who show an accelerated sequence (Tanner et al. 2006). Thus, the bridge between Bawang's iconic directive *pushes* and more prototypically human-like iconic gestures may be explained through the development of an increasingly sophisticated ability to engage in sensorimotor simulations.

6. Conclusion

We have made the case that the processes of phylogenetic and ontogenetic ritualization are inadequate as comprehensive explanations for how ape gestures come to be formed from instrumental actions. The directive *pushes* that we have described appear, to a significant extent, to be molded to the physical affordances and social context of the moment of communication and thus reveal the online activation of a particular instrumental action. We offer that multiple processes are involved in

the creation and use of ape gestures, including those operating along different time scales like phylogenetic and ontogenetic ritualization, but critically, one of those processes is the on-line adaptation of action to form spontaneous iconic gestures.

Our focus on gestures within the context of the full scope of more-or-less forceful actions has led to a markedly different conception than commonly assumed of the nature of iconic gestures and the cognitive processes that their creation and use entails. In particular we highlight the consideration of mechanical effectiveness as a variable along a spectrum from action to gesture. In a simulation-oriented view, there is not necessarily a sharp distinction between an iconic gesture and the instrumental act it represents, and accordingly, our data have revealed a notable amount of continuity between Bawang's gestural and instrumental *pushes*.

At the same time, while gesture-action continuity may lie at the origin of ape iconic gesture, it is crucial to consider how iconic gestures may come to be increasingly distinct from contextual elements involved in the real instrumental act. The greatly expanded capability to abstract gestures from their instrumental context is, we suggest, a fundamental cognitive skill that enables the human propensity for iconic gesture. One exciting path for future research is the further investigation of the conceptual and simulative qualities exhibited by the iconic gestures of enculturated and language-taught apes. By examining how these qualities increase in sophistication, we are likely to gain new insights into the nature of human gesture and imagination.

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