Semantics and Pragmatics of Monkey Communication[1]

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Summary.

Rich data gathered in experimental primatology in the last 40 years are beginning to benefit from analytical methods used in contemporary linguistics, especially in the area of semantics and pragmatics. These methods have started to clarify five questions: (i) what morphology and syntax, if any, do monkey calls have? (ii) what is the 'lexical meaning' of individual calls? (iii) how are the meanings of individual calls combined? (iv) how do calls or call sequences compete with each other when several are appropriate in a given situation? (v) how did the form and meaning of calls evolve? Four case studies from this emerging field of 'primate linguistics' provide initial answers, pertaining to Old World monkeys (Putty-nosed monkeys, Campbell's monkeys and Colobus monkeys) and New World monkeys (black-fronted Titi monkeys). The *morphology* mostly involves simple calls, but in at least one case (Campbell's *-oo*) one finds a root-suffix structure, possibly with a compositional semantics. The *syntax* is in all clear cases simple and finite-state. With respect to *meaning*, nearly all cases of call concatenation can be analyzed as being semantically conjunctive. But a key question concerns the *division of labor between semantics, pragmatics and the environmental context ('world' knowledge and context change)*. An apparent case of dialectal variation in the semantics (Campbell's *krak*) can arguably be analyzed away if one posits sufficiently powerful mechanisms of competition among calls, akin to scalar implicatures. An apparent case of non-compositionality (Putty-nosed *pyow-hack* sequences) can be analyzed away if one further posits a pragmatic principle of 'urgency'. Finally, rich Titi sequences in which two calls are re-arranged in complex ways so as to reflect information about both predator identity and location are argued *not* to involve a complex syntax/semantics interface, but rather a fine-grained interaction between simple call meanings and the environmental context. With respect to *call evolution*, the remarkable preservation of call form and function over millions of years should make it possible to lay the groundwork for an *evolutionary monkey linguistics*, illustrated with cercopithecine *booms*.

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1 The rise of primate linguistics[2]

Rich data gathered in experimental primatology in the last 40 years have started to benefit from some analytical methods used in contemporary linguistics. These methods have started to clarify five questions: (i) what morphology and syntax, if any, do monkey calls have? (ii) what is the 'lexical meaning' of individual calls? (iii) how are the meanings of individual calls combined? (iv) how do calls or call sequences compete with each other when several are appropriate in a given situation? (v) how did the form and meaning of calls evolve? This article provides a brief survey of initial results in this emerging field of 'primate linguistics', with special reference to the semantics and pragmatics of monkey calls.

Four case studies provide initial answers to these five questions, pertaining to Old World monkeys (Putty-nosed monkeys, Campbell's monkeys and Colobus monkeys) and New World monkeys (black-fronted Titi monkeys). The *morphology* mostly involves simple calls, but in at least one case (Campbell's *-oo*) one finds a root-suffix structure, possibly with a compositional semantics. The *syntax* is in all clear cases simple and finite-state. With respect to *meaning*, nearly all cases of call concatenation can be analyzed as conjunction. But a key question concerns the *division of labor between semantics, pragmatics and the environmental context ('world' knowledge and context change);* in particular, several case studies make use of a monkey counterpart of implicatures in human language. Thus an apparent case of dialectal variation in the semantics (Campbell's *krak*) can arguably be analyzed away if one posits sufficiently powerful mechanisms of competition among calls, akin to scalar implicatures. An apparent case of non-compositionality (Putty-nosed *pyow-hack* sequences) can be analyzed away if one further posits a pragmatic principle of 'urgency'. Finally, rich Titi sequences in which two calls are re-arranged in complex ways so as to reflect information about both predator identity and location are argued *not* to involve a complex syntax/semantics interface, but rather a fine-grained interaction between simple call meanings and the environmental context. With respect to *call evolution*, the remarkable preservation of call form and function over millions of years should make it possible to lay the groundwork for an *evolutionary monkey linguistics*, illustrated with cercopithecine *booms*.

This article is specifically focused on the application of semantic and pragmatic methods to the analysis of monkey communication, and thus it does not seek to give a balanced view of ethological analyses of this topic, which are for instance surveyed in Zuberbühler 2003, 2009. Importantly, the application of linguistic *methods* to primate calls does not imply that there are non-trivial formal *similarities* between monkey calls and human language; in fact, the same general methods lead to very different substantial results in the two cases.

2 Data collection and analytical methods

2.1 Data collection[3]

Observations and field experiments in primatology have yielded detailed information about vocal communication in primates in general and monkeys in particular (see for instance Zuberbühler 2003, 2009 for surveys). These pertain to the inventory, use, structure, and sometimes phylogeny and ontogeny of various calls, in particular alert calls[4] – with rare cases of apparent dialectal variation (Schlenker et al. 2014). Naturalistic observations make it possible to establish statistical correlations between (i) properties of the situations, such as the presence of predators or encounters between monkey groups, and (ii) calls used in those situations. Field experiments have typically been of two types. In trigger-to-call experiments, the presence of a disturbance is simulated, for instance by way of playback of leopard growls or eagle shrieks, or through the presence of a model leopard or eagle; in

[2] This section recapitulates Schlenker et al. 2016a.
[3] This section borrows from Schlenker et al. 2016a.
[4] The term 'alert call' is sometimes used with a broader meaning than 'alarm call': the latter only pertains to dangers, whereas the former can also be used for other noteworthy events.

call-to-behavior experiments, alert calls are played back and the monkeys' responses are assessed. Note that since calls may be viewed as 'triggers' or as 'behaviors', these two categories are not mutually exclusive; as a result, there is some overlap between the categories in (1)b and (1)c.

(1) **Types of generalizations**
a. Naturalistic observations: correlations between (i) properties of the situation, and (ii) calls used in that situation.
b. Trigger-to-call experiments: causal generalizations of the form: if (i) the situation has property P, then (ii) sequences S_1, ..., S_n of calls may/must be used.
c. Call-to-behavior experiments: causal generalizations of the form: if (i) a sequence S of calls is used, then (ii) the target subjects behave as if the situation had property P.

2.2 Analytical methods[5]

Let us turn to how monkey languages should be studied. In recent work, combined teams of linguists and primatologists have borrowed a key idea from contemporary linguistics: they suggested that monkey call sequences should be studied as formal languages with syntactic rules (pertaining to their form) and semantic rules (pertaining to their meaning). Importantly, from the perspective of formal language theory, it takes *very little* for something to count as a 'language': any set of strings will do. But there is an advantage to treating monkey call sequences as a formal language: it forces one to make precise predictions about the form, use and structure of expressions. Still, from this methodological (and terminological) stance, it does not follow that the specific rules one will uncover are similar to those of human language – for the most part, they don't seem to be (Schlenker et al. 2016a, b).

2.2.1 Human languages as formal languages: syntax, semantics and pragmatics

In linguistics, formal *syntax* seeks to specify rules that predict which strings are well-formed (Chomsky 1957). In the narrow sense, syntax is concerned with the way in which words are combined, but in a broad sense it should include questions of phonology and morphology, which pertain to the organization of sounds and words. For its part, formal *semantics* (following Montague 1970a) sought to specify rules that predict in which situations a syntactically well-formed expression is true. In both fields, the formal approach was integrated into a cognitive one – almost from the start in syntax (Chomsky 1957), and more recently in semantics (Bott et al. 2011, Chemla and Singh 2014).

Importantly for what follows, a key insight of contemporary studies of meaning is that the information conveyed by a sentence does not just derive from its semantics, i.e. from meaning as it is linguistically encoded, but also from pragmatic inferences, which are drawn by reasoning on the speaker's motives for uttering one sentence rather than another (e.g. Schlenker 2016). A well-worn example involves the information conveyed by the disjunction *p or q*. In some cases, *or* appears to be exclusive (*S or S'* is true just in case *exactly one* of *S* and *S'* is true), as in (2)a; but in other cases, it appears to be inclusive (*S or S'* is true just in case *at least one* of *S* and *S'* is true), as in (2)b.

(2) a. I will invite Ann or Mary.
=> usually gives rise to the inference that *I will invite [Ann or Mary but not both]*.
b. I doubt that I'll invite Ann or Mary.
=> usually equivalent to: *I doubt that I'll invite [Ann or Mary or both]*.

How should the meaning of *or* be analyzed, then? While one could posit an ambiguity, a better theory can be devised: the meaning of *or* is inclusive, but a sentence with *or* automatically evokes (or 'competes with') the corresponding sentence with *and*. An interesting result follows: if the speaker is 'maximally informative', and utters a sentence with *or* which is less informative than its competitor with *and*, one can infer that the latter couldn't be uttered – typically because it was false. As a result, in a simple sentence such as (2)a, *or* will overall convey an exclusive meaning. Still, it will retain its bare inclusive meaning in (2)b because, due to the negative expression *doubt*, the sentence with *and* is less informative than that with *or* (e.g. Horn 1972, Schlenker 2016).

[5] The results of this section also appear in Schlenker et al. 2016d, with some differences in formulations.

The key to this analysis is the Informativity Principle stated in (3).

(3) Informativity Principle
If the speaker uttered a sentence *S* which evokes ('competes with') a sentence *S'*, if *S'* is more informative than *S*, infer that *S'* is false (for if *S'* were true the speaker should have uttered it).

In linguistic pragmatics, the Informativity Principle is usually taken to follow from humans' ability to communicate cooperatively and to reconstruct the intentions of language users. But as will be seen in Section 4, the statement in (3) doesn't require such mind-reading abilities, as it is solely based on a relation of competition among possible messages, and differences of informativity among some of them; this will matter when the Informativity Principle is applied to some monkey languages.Specifically, the claim will be that there is 'pragmatics in action' in monkey languages, with rules of competition among calls applied in production and in perception, but this will not entail that monkeys have a theory of mind (but see Crockford et al. 2012 and Schel et al. 2013 for stronger assumptions about chimpanzees).

2.2.2 Monkey call sequences as formal languages

In primatology, observations and field experiments have yielded two important results (e.g. Zuberbühler 2009, Schlenker et al. 2016a):
(i) The species under study arrange discrete calls in constrained ways.
(ii) Some calls are triggered by some situations but not others. Furthermore, field experiments establish that the monkeys themselves capitalize on this correlation and thus derive information from the calls they hear.

The first result establishes that one can study the *syntax* of monkey calls, i.e. the rules by which calls are combined (syntax in a narrow sense) and composed (of sounds and possibly morphemes – phonology and morphology). This falls within a more general program of 'animal syntax', which has given rise to the common claim (Fitch 2010, Berwick et al. 2011) that many animal systems can be analyzed as a sub-class of 'finite-state languages', a simple model which was briefly considered for human language but clearly refuted in the 1950's. Most results in primate syntax are thought to be compatible with this general claim (but see Kershenbaum et al. 2014).

While the project of an 'animal syntax' might be uncontroversial, it might seem surprising to talk of a 'monkey semantics'. First, as mentioned in Section 2.2.1, semantics is concerned with the conditions in which a well-formed message is true. But can one say that monkey call sequences are 'true' or 'false' in certain situations? The issue is terminological: observational and experimental data clearly argue for a bipartition of calls among ‘appropriate’ vs. ‘inappropriate’ ones in a given situation; no matter which terminology one chooses, this means that these calls have a semantics – which is unsurprising since they clearly transmit information. Second, is it legitimate to postulate the existence of a *meaning* when there is no evidence of an *intention* to mean something? Here there is an important discrepancy between the pre-theoretical notion of 'meaning', which involves intentionality and sometimes consciousness, and the technical notion used in linguistics: the latter just *assimilates the meaning of an expression to the bi-partition it establishes among situations in which it is true vs. false*. It is this 'lean' notion of meaning that is employed in the remaining sections (Schlenker et al. 2016a).

While this is the definition of meaning that comes out of linguistics, within primatology there has been much recent debate about the existence in primates of 'functionally referential' signals, defined in Wheeler and Fischer 2012 as being "those signals in which [i] production is **context-specific**, with the relevant contextual feature defining the ‘‘referent’’, and which [ii] elicit specific responses in signal perceivers even **in the absence of the supposed referent**" (but see Scarantino and Clay 2015 for a considerably modified definition of functional reference, much closer to the notion of meaning that semanticists would use). This often seems to be accompanied with the idea that [iii] the contextual feature that triggers the signal should be **external to the caller**, and possibly that [iv] the signal should have a **noun-like denotation**, e.g. pertaining to predator classes (Macedonia and Evans 1993).

From the present perspective, property [ii] is indeed relevant to check that the signal conveys information, but properties [i], [iii] and [iv] are just *not* entailed by a semantic approach. In the studies

surveyed in this article, several general, *non*-context specific calls are analyzed, against [i]; and the meanings posited almost never pertain directly to predator classes, against [iii]. Finally, nothing in approaches from 'primate linguistics' precludes emotional, non-referential meanings – such meanings are certainly not in human language, where 'expressives' have been the object of detailed studies (as seen for instance in Potts 2005).

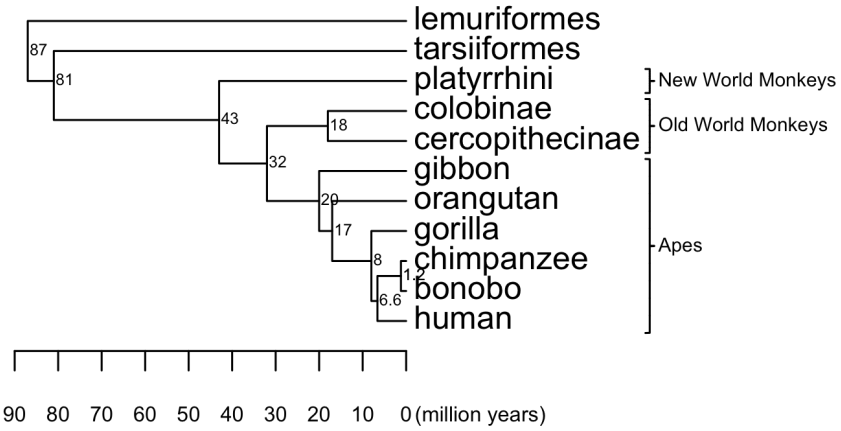
On the other hand, at this point our discussion says nothing of the existence of a monkey *pragmatics*, as the very notion of a pragmatics might presuppose cognitive abilities that go beyond the monkeys' capacities; but as argued in Section 4, there might be evidence for a 'monkey proto-pragmatics'.

2.3 The phylogenetic landscape[6]

This article surveys results from Old World and New World monkeys. As illustrated in Figure 1, in some estimates the most recent common ancestor of Old World monkeys and apes (and humans) lived more than 30 million years ago. The most recent common ancestor of New World monkeys and apes (or for that matter Old World monkeys or humans) lived more than 40 million years ago. These distances alone justify quite a bit of agnosticism concerning the relation between these monkey languages and human language. Furthermore, when similarities are found among systems that are that distant, they may well be due to convergent evolution rather than to common descent.

Of the species reviewed in this article, Putty-nosed monkeys and Campbell's monkeys are part of a subfamily of Old World monkeys called 'cercopithecines' (technically, 'cercopithecini', included in 0 under the larger family of 'cercopithecinae'[7]). Putty-nosed monkeys and Campbell's monkeys have a most recent common ancestor that lived approximately 7.5 million years ago (Guschanski et al. 2013). This article also briefly mentions Black-and-White Colobus monkeys, which are part of another family of Old World monkeys, called 'colobinae'. Colobus monkeys and cercopithecines probably have a most recent common ancestor that lived – very approximately – 18 million years ago (Perelman et al. 2011). Finally, this article discusses the calls of black-fronted Titi monkeys living in South America; since they are New World monkeys, their most recent common ancestor with cercopithecines and Colobus monkeys lived more than 40 million years ago.

Figure 1. Primate phylogeny



Source: Perelman et al. 2011. Figure drawn with Lucie Ravaux's help.

[6] This section borrows from Schlenker et al. 2016a.

[7] Cercopithecinae include cercopithecini and papionini (the latter include macaques and baboons, among others).

3 Generalizations and problems

3.1 Morphology and Syntax[8]

Recent findings about the morphology and syntax of monkey calls include the following. We refer the reader to the source articles for experimental evidence, which includes naturalistic observations and especially field experiments, whose logic was described in (1) in Section 2.1.

(i) There are limited cases that argue for a kind of **morphological composition** within calls. A striking case comes from Campbell's monkeys, a species of Cercopithecines found in West Africa. A typical group includes one adult male and a group of females and juveniles. The male produces loud calls (which are different from female calls), and he plays an important role in predator defense, group spacing and travel coordination. In male Campbell's monkeys, the suffix *-oo* can be added to two roots, *krak* and *hok* (see Ouattara et al. 2009a, Kuhn et al. 2014 for recent discussion); and it is plausible that it modifies the meaning of the root in the same way in both cases (on one theory, *R-oo* indicates that one should be in the same attentional state as if *R* had been uttered – hence a broader meaning; on a competing theory, *R-oo* indicates that there is a weak threat of the type that licenses *R* – hence a narrower meaning). Diana monkeys are a related species of Cercopithecines that often live sympatrically with Campbell's monkeys, with a similar social structure, although the males have very different (and simpler) calls. Interestingly, in female Diana monkeys, the A call has root uses, but it also arguably serves to form the complex calls *LA*, *HA*, and *RA*, which are targeted as units by the operation of repetition, thus yielding *LA LA LA LA* (Veselinović et al. 2014; Candiotti et al. 2012; see also Coye et al. 2016 for field experiments with artificial playbacks, showing that the A suffix provides information about caller identity while the first part of *LA* and *RA* complex calls provides information about the social and physical context.[9])

(ii) There are several cases of **syntactic regularities**, but it is often difficult to know whether they should be attributed to syntax proper or to constraints on call production (or possibly perception), call semantics/pragmatics, or to the fact that the context may change in regular ways as a sequence is uttered. Campbell's monkey males have a *boom* call (revisited in Section 5 from an evolutionary perspective) that seems to have a regular syntax, as it usually appears as a single pair of calls at the beginning of sequences. It also seems to have a regular meaning of non-predation – a meaning which is clear enough to be understood by Diana monkeys, which do not themselves have *booms* (specifically, Zuberbühler 2002 shows that Diana monkeys stop being alarmed by Campbell's predator sequences if these are prefixed with *boom boom*). Importantly, *booms* are produced in a very particular way, which involves filling air sacs, and it is conceivable that there are physiological reasons that explain the syntactic distribution (for instance because both time and energy are required to fill air sacs). It will be seen in Section 4.3 that black-fronted Titi monkey call sequences also display striking syntactic regularities, but in the proposed analysis developed they should be reduced to properties of context change.

(iii) One key question is to determine **what counts as the minimal propositional unit or sentence** (Sauerland 2016). In most cases, there is no strong evidence against analyses that take individual calls to form full-fledged, independent sentences, with a propositional semantics. Two apparent exceptions pertain to *pyow-hack* sequences in Putty-nosed monkeys, and to *snort-roar* sequences in Black-and-White Colobus monkeys.

• Putty-nosed monkeys are also African Cercopithecines living in one-male groups that include several adult females as well as dependent offspring. Besides *booms*, which are not predation-related,

[8] Parts of this section appear in Schlenker 2016b.

[9] In their words, "subjects' responses suggest that the first unit (L or R) allows a receiver to extract information about the social and physical environment, probably by associative learning, while the second unit (A) reveals the caller's identity and may help the receiver to decide how to react given their respective positions in the social network."

male Putty-nosed monkeys have *pyows* and *hacks*. *Pyow* seems to be used as a general alert call, while *hacks* are often (but not only) used in eagle-related environments. Sequences made of a small number of *pyows* followed by a small number of *hacks* were argued to trigger group movement, but this function was not easy to derive on the basis of the individual meaning of the calls, hence the possibility that these behave like idioms in human language (e.g. *kick the bucket*), which are syntactically combinatorial but not semantically compositional (it is presumably because *pyow-hack* sequences do not form tight phonological units that Arnold and Zuberbühler (e.g. 2008) took them to be syntactically rather than morphologically or phonologically complex). Section 4.2 briefly summarizes an alternative analysis in which each call has a constant meaning, and rules of pragmatic competition account for the 'group movement' function.

• Black-and-White (Guereza) Colobus monkeys are African monkeys, with groups that normally consist of one or two adult males, approximately five adult females, with non-adult dependents. Sequences made of a single *snort* immediately followed by *roars* seem to be used as highly underspecified alert calls, unlike their component parts – notably *snorts*, which are indicative of ground mammals when given singly. While the data from field experiments are rather preliminary, they might suggest that *snort-roar* sequences are *less specific* than their component parts. If so, they might have to be treated as a unit rather than semantically composed. But since the *snort-roar* sequence forms a tightly connected acoustic unit (unlike the Putty-nosed *pyow-hack* sequence), it might be that the complexity is phonological rather than morphological or syntactic: on this view, it is a phonological accident (without morphological or semantic consequences) that the *snort-roar* sequence is made of *snort* followed by *roars*, just like in English *irate* is phonologically made of syllables found in *I* and *rate* without thereby being *composed* of these words (see Schlenker et al. 2016a for discussion).

3.2 Semantics and pragmatics[10]

Turning to substantive semantic questions, two theoretical problems were raised by three recent case studies in 'primate semantics'.

(i) First, what is the *meaning of individual calls*? A particularly interesting example is afforded by Campbell's monkeys of the Tai Forest (Ivory Coast; Figure 2). As noted, adult males have non-predation-related call, *boom*. And they use a call *krak* to raise leopard alerts, and *hok* for raptor alerts. But as mentioned in Section 3.1, they also have suffixed calls: *krak-oo* is used for unspecific alerts, and *hok-oo* for non-ground disturbances. The challenge is thus to assign meanings to *boom, krak, hok*, and *-oo*.

But the puzzle gets more complex when one considers Campbell's call use on Tiwai Island (Sierra Leone), where leopards haven't been seen for decades: the Tai calls are used, but *krak* raises unspecific alerts (as does *krak-oo*), rather than leopard alerts. Should one conclude from the Tai vs. Tiwai difference that the meaning of *krak* is subject to 'dialectal' variation – as it is for *pants* in American English (meaning 'trousers') vs. British English (meaning 'underpants')?

(ii) Second, how are the *meanings of individual calls combined?* In semantics, one says that a complex expression is 'compositional' if its meaning is derived from that of its parts. Interestingly, several monkey cases seem to challenge compositionality (Arnold and Zuberbühler 2008, Schlenker et al. 2016a).

–As mentioned, in Putty-nosed monkeys (Figure 2), it is non-trivial to derive the meaning of *pyow-hack* sequences, which trigger group movement, from the meanings of their parts, as *pyows* appear to be general alert calls while *hacks* are often associated with eagle presence. Should *pyow-hack* sequences be analyzed as non-compositional idioms, or can a compositional analysis be proposed?

–A radical compositionality problem arises in black-fronted Titi monkeys (Figure 2). These New World Monkeys belong to the Callicebus family and live in South-Eastern Brazil in monogamous family groups that consist of a pair of reproductive adults and up to four generations of offspring.

[10] The results of this section also appear in Schlenker et al. 2016d, with some differences in formulations.

They have multiple calls, among them the A- and B-calls, which, unlike the other calls discussed in this article, are not loud. Remarkably, with two calls (A and B) re-arranged in various ways, their sequences encode information about both predator type (cat, raptor) and predator location (ground, canopy). Do these sequences have a complex syntax, and should they be treated as very long idioms?

4 Semantic and pragmatic analyses[11]

With respect to the species surveyed here, recent studies have argued that in almost all cases, concatenated calls each contribute their meaning independently from the others, with the result that a sequence is interpreted as the conjunction of its calls; furthermore, no 'dialectal' variation in call meaning is needed. But a key theoretical ingredient, justified in four case studies (Schlenker et al. 2016a), is that *the interpretation of a call or call sequence can be pragmatically enriched by competition with others*. In particular, calls are subject to a version of the 'Informativity Principle' in (3): if a call *C2* is more informative than a call *C1*, then whenever possible *C2* should be preferred to *C1*. For instance, if a raptor shows up, and a raptor call is available, then it should be preferred over an unspecific call; for this reason, the unspecific call may signify the *absence* of a raptor.

It is important to note that this Informativity Principle need not involve an ability to reconstruct conspecifics' intentions: its effects can be obtained as soon as a rule of competition among calls can take into account a relation of informativity. Still, the possible presence of an Informativity Principle in monkey languages and in human raises interesting questions about their (joint or separate) evolutionary history.

4.1 Analyzing Campbell's meanings

Using the Informativity Principle, a uniform analysis of Campbell's calls was proposed in Schlenker et al. 2014 (see Figure 2).

• First, the authors took *krak* to trigger unspecific alerts, and *hok* to trigger non-ground alerts.

• Second, in their analysis of the meaning of the suffix *-oo*, they assumed that if *R* is *krak* or *hok, R–oo* indicates a *weak* alert of the *R*-type. Thus *hok-oo* indicates a weak *(-oo)* non-ground (*hok*) alert – which is more informative than *hok* (since on this analysis the latter can be used for weak as well as for non-weak non-ground alerts). ,

• Third, the authors made crucial use of the Informativity Principle: *hok* competes with other calls, and because *hok-oo* (pertaining to *weak* non-ground alerts rather than to any non-ground alert) is more specific, the meaning of *hok* is enriched to *hok but not hok-oo*: it only applies to aerial (*hok*) non-weak *(not hok-oo)* alerts – hence the raptor uses. Similarly, the unspecific alert *krak* competes with *krak-oo,* but also *hok*. In the end, *krak* can only be used for *serious (not krak-oo) ground (not hok) disturbances* – hence the leopard uses in Tai.

What should be said about the apparent dialectal variation that was noted concerning the uses of *krak* on Tiwai island, used to raise unspecific alerts? Strikingly, this use just corresponds to the basic (unenriched) meaning of *krak*. The question is why this 'bare' meaning fails to be pragmatically enriched on Tiwai. The authors suggested that this enrichment would yield a useless meaning due to the absence of serious ground predators, which might explain why the mechanisms of enrichment are not applied in this case.

4.2 Analyzing Putty-nosed meanings

Turning to Putty-nosed *pyow-hack* sequences, one may treat them as (non-compositional) idioms, memorized as whole units. But this may be taken to be unsatisfying because the *pyow* and *hack* units are separated by pauses, and come in different patterns, with varying numbers of repetitions. An alternative is to posit that these sequences have a weak literal meaning, but that it is pragmatically enriched by an 'Urgency Principle'. This principle mandates that within a sentence, *calls that convey information about the location of a threat come before those that don't* (Figure 2; Schlenker et al. 2015). Specifically, one may take *pyows* to trigger unspecific alerts, and *hacks* to warn of (serious) non-ground, movement-related events. Semantically, then, a *pyow-hack* sequence warns of a non-

[11] The results of this section also appear in Schlenker et al. 2016d, with some differences in formulations. .

ground, movement-related event, e.g. the impending movement of an attacking raptor, or of the (arboreal) monkeys themselves. But crucially, if a raptor were present, *hacks* would convey information about the location of the threat and hence should come before *pyows*. This gives rise to a pragmatic enrichment that explains why *pyow-hack* sequences are indicative of group movement. On this analysis, no idioms need be posited, but competition principles are crucial (see Schlenker et al. 2015 for a more detailed analysis). The Urgency Principle is speculative at this point, but it is interesting to note that it might explain some constraints on alert calls found in other species, notably in birds (Schlenker et al. 2016b, Suzuki et al. 2016, Engesser 2016).

4.3 Analyzing Titi meanings

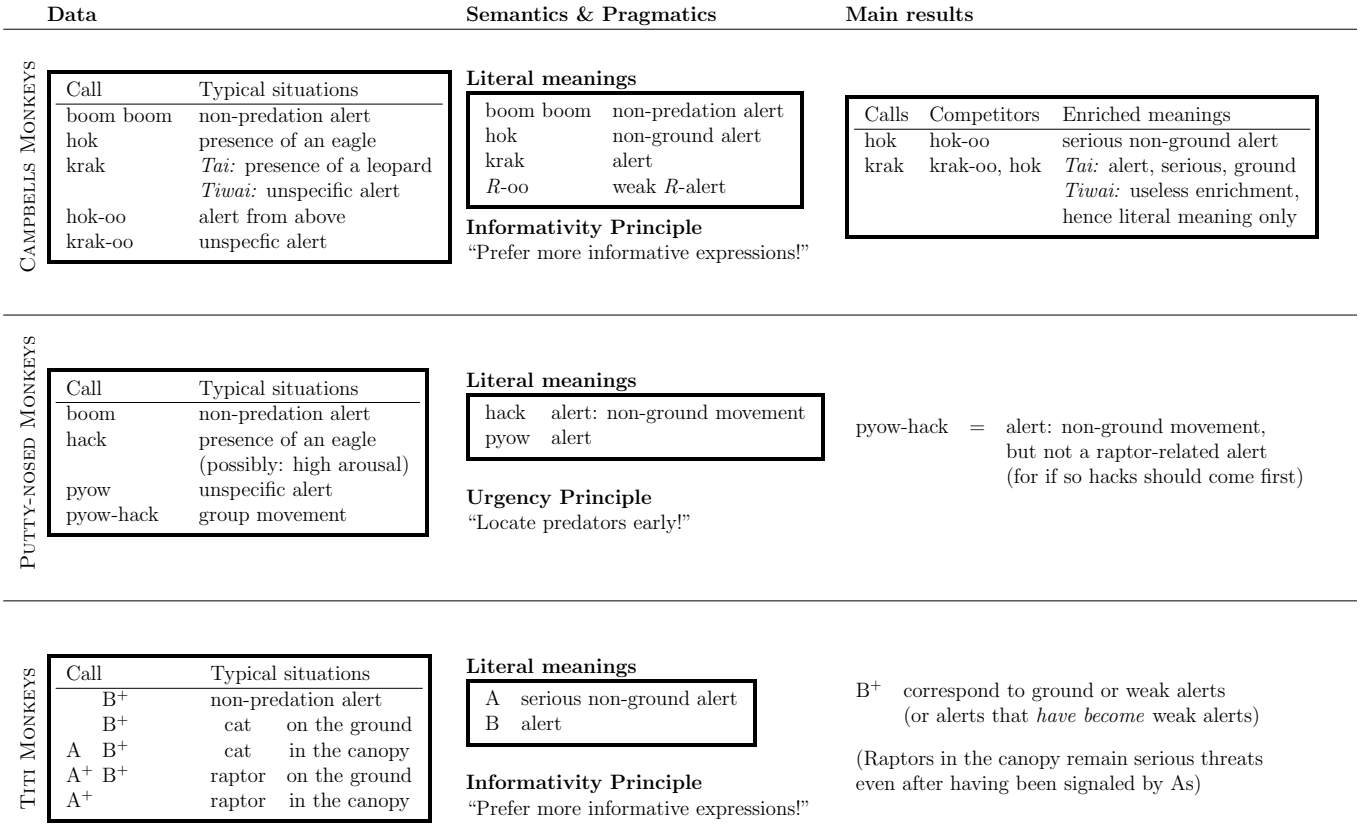
Let us now go back to the puzzle of Titi sequences. Due to their length and slow time course, again, it is unlikely that these sequences are interpreted as idioms because hearers would need to wait for too long for the meaning of the message to be effective. A simpler analysis has been explored, in which each call contributes its meaning independently from the others (Figure 2; Schlenker et al. 2016c). Since the B-call is used in predatory and non-predatory situations alike, one may take it to trigger an unspecific alert. In field experiments, the A-call triggers a 'looking up' behavior, and thus one can posit that it is indicative of *serious non-ground alerts*. These assumptions explain why one finds B^+-sequences (= series of B-calls) in 'cat on the ground' situations, and A^+-sequences in 'raptor in the canopy' situations.

But why does one find A^+B^+ in 'raptor on the ground' situations? A remark about hunting techniques may prove essential: raptors on the ground usually attack by *flying*, hence the serious non-ground alerts A^+. Still, being on the ground isn't a typical hunting position, and after a while the alert stops being serious, which only leaves B as a possibility. In 'cat in the canopy' situations, one finds AB^+ sequences, possibly because a serious non-ground danger is indicated, which then transitions to a weaker danger because a cat becomes less dangerous after detection (Zuberbühler 2009).

While it is only a theoretical possibility at this point, this analysis suggests that the apparent complexity of Titi sequences might reflect the interaction between simple meanings and the evolution of the contextual environment as the sequence is produced, rather than a complex syntax/semantics interface or very long idioms.

As can be seen, a unifying theme of these diverse studies is the precise delineation of the division of labor between semantics, pragmatics and the environmental context – which in the cases surveyed here makes it possible to maintain particularly simple individual meanings and composition rules.

Figure 2. Data and possible theories[12]



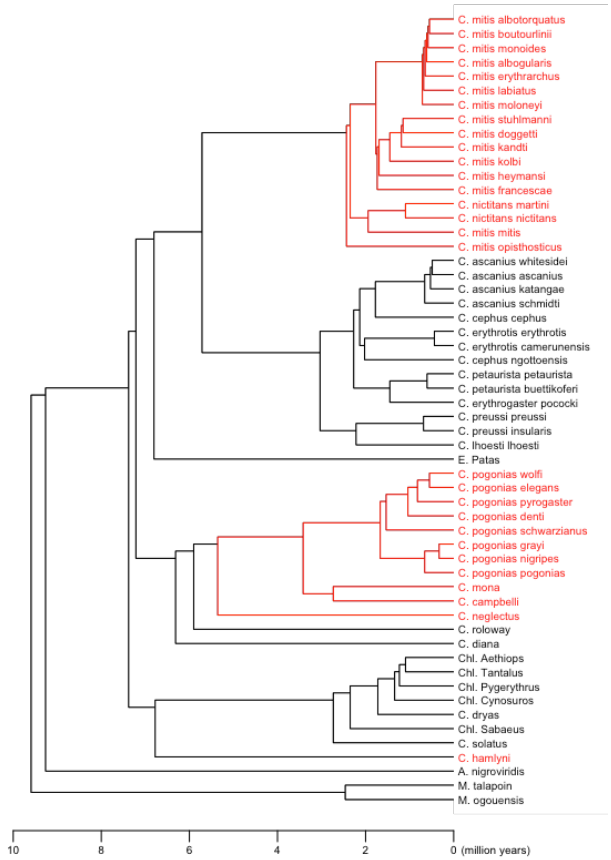
[12] This figure redrawn from Schlenker et al. 2016d.

5 Evolutionary monkey linguistics[13]

While the comparative analysis of monkey calls brings out some common theoretical themes, it also highlights numerous *shared properties* among the calls of different species, both at the level of form and function. Historically, comparative studies of monkey calls were usually conducted to reconstruct phylogenies, with results that often converge with DNA methods (Cap et al. 2008, Gautier 1988). But in the 21st century one can turn the problem on its head and start from established phylogenies to reconstruct the evolutionary history of calls. This promises to offer a window into the evolution of form and meaning in simple systems of primate communication.

Initial results are striking. *Booms* are non-predation-related calls present in many subspecies of cercopithecines, including Campbell's and Putty-nosed monkeys (Figure 3). By inspecting their distribution in phylogenetic trees, one can reasonably infer that they were present in the most recent common ancestor of entire subgroups: *booms* probably existed several million years ago (Schlenker et al. 2016a). Thus while comparative monkey semantics might not directly illuminate the evolution of human language, it could help understand meaning evolution in simpler systems.

Figure 3. Call evolution: the example of *boom*[14]



Phylogenetic tree of cercopithecines (ages taken from Guschanski et al. 2013, updated from Schlenker et al. 2016a), with names in red for species that have *booms*. It seems very likely that the most common recent ancestor of the top red (= mitis) group (which lived about 2.5 million years ago) had *booms*, since all of its descendants do; and similarly for the most recent common ancestor of the middle red group (C. pogonias, C. mona, C. campbelli, C. neglectus), which lived more than 5 million years ago. On the other hand, the evidence is too sparse at the moment to determine whether the most recent common ancestor of all cercopithecines had *booms* approximately 10 millions years ago, in which case *booms* were lost in several subfamilies (roughly half a dozen of times); or whether *booms* developed by convergent evolution in a couple of subfamilies.

[13] This recapitulates results from Schlenker et al. 2016d.
[14] This figure is redrawn from Schlenker et al. 2016a.

6 Primate linguistics and evolutionary linguistics

6.1 Prospects for primate linguistics[15]

On a methodological level, recent research suggests that linguistic methods can help clarify traditional issues about primate communication and raise new ones (these developments could in principle be part of a larger field of 'animal linguistics' [see for instance Yip 2006; Berwick et al. 2011]). The early results surveyed here should be handled with care, as published studies primarily seek to sharpen the theoretical issues and to derive crucial predictions rather than to make definitive pronouncements – which would be ill-advised at this very early stage: it is likely that theoretical conclusions will change drastically as more empirical results are obtained. Still, setting up the relevant theoretical alternatives in a clear way should help orient future investigations towards the most crucial questions. (It should be added that this discussion focused on those few species that gave rise to explicit linguistic analyses, an important selection bias.)

At this point, *syntactic generalizations* are modest and could be handled with very simple finite state grammars. *Semantic analyses* mostly rely on simple propositional meanings, although researchers did posit a non-trivial semantics for the Campbell's suffix *-oo,* and further cases that challenge the propositional nature of elementary units might well be discovered in the future. *Pragmatic analyses* surveyed here are largely based on implicature-like rules of informativity-based competition among calls or sequences, although researchers did explore in the analysis of Putty-nosed semantics the possibility of using competition based on a principle of Urgency.

A key issue for future research is whether the division of labor that was proposed between semantics, pragmatics and the environmental context is on the right track. In particular, the studies surveyed in this article posited rules of pragmatic competition that enrich the meaning of some calls whose core informational content is by itself compatible with a broad range of situations. An alternative is to take these calls to provide instructions about precise actions to be taken, some of which could be appropriate when specific information is available (e.g. 'look up' if a threat comes from above), while others could be appropriate when the information is underspecified (e.g. 'look around'). Further experimental studies should help distinguish among these proposals (see Jäger 2016 and Schlenker et al. 2016b for discussion).

It is also worth noting that the issue of the division of labor among linguistic modules, which has played an important role in recent human linguistics, might turn out to be crucial in monkey linguistics as well – in which case linguists' *know how* could prove particularly useful.

6.2 Evolutionary questions[16]

This survey was cautious not to claim that monkey languages share non-trivial properties with human language. There are important dissimilarities and some very limited similarities between the two systems (Schlenker et al. 2016a, b, Rizzi 2016, Berwick 2016).

• **Morphology and syntax**: word-internal and sentence-internal structure is extremely limited in the species surveyed here (but see Kershenbaum et al. 2014): calls are made of at most two components (e.g. *krak+-oo*), and there is no evidence that sequences have a complex structure. By contrast, human language has arbitrarily complex words (e.g. *anti-dis-establish-ment-ari-an-ism)*, and highly sophisticated syntactic structures (Chomsky 1957). Furthermore, monkey languages display numerous cases of call repetition, which have no equivalent in human language.

• **Semantics**: unlike most human words, call meanings that have been posited so far usually pertain to threats, although this is partly due to a selection bias (for female social calls, see Candiotti et al. 2012, Coye et al. 2016). Call-internal composition seems to exist in Campbell's monkeys (*krak-oo*) and possibly beyond, but remains limited (Schlenker et al. 2016b). There is no real evidence of non-trivial composition of meaning sequence-internally, as each call can be taken as an individual 'sentence', interpreted independently from the others (Sauerland 2016, Schlenker et al. 2016b).

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[15] This section borrows from Schlenker 2016a.

[16] This section borrows from Schlenker 2016a and, to a minor extent, from Schlenker et al. 2016d.

• **Pragmatics**: while there is no clear evidence for an ability to represent communicative intentions in monkeys, an Informativity Principle was postulated which is similar in form to one found in human language, but their evolutionary relationship is unclear.

When monkey languages are better understood, one would need to ask whether any similarities that are found arose by 'convergent evolution' or could result from 'common descent'; it might be too early to tell.

At this point, it is difficult to draw inferences from monkey languages about the evolution of human language. On the other hand, it is possible to approach the simpler question of the 'local' evolution of monkey languages: there are enough diverse species with partly shared call systems that one can hope to gain real insights into their evolutionary history. The development of an 'evolutionary monkey linguistics' would thus seem to us to be a topic of great interest, and it should offer a fertile testing ground for theories of the evolution of meaning (e.g. Skyrms 2010 and Franke and Wagner 2014).

If one is interested in the evolution of human language, one should apply the present methods to the development of an *ape linguistics*, which should serve as a particularly useful point of comparison for human linguistics; and since apes have not just vocalizations (e.g. Clay and Zuberbühler 2011, Crockford et al. 2012, Schel et al. 2013) but also rich gestural inventories (e.g. Genty et al. 2009, Hobaiter and Byrne 2011), both modalities should be relevant for this further project.

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