

Monkey Semantics



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based on collaborative work with

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Plan

■ **Field experiments in primatology**

- have yielded rich data on the form and use of alarm calls...
- which are now ripe for explicit semantic models.

■ **Male Campbell's monkey alarm calls**

- Ouattara et al. 2009a, b showed that these calls display
- 4 words (**boom, krak, hok, wak**), 1 suffix (**-oo**),
 - and possibly a regular semantics (and syntax?)

■ **Two Dialects: Tai forest vs. Tiwai Island**

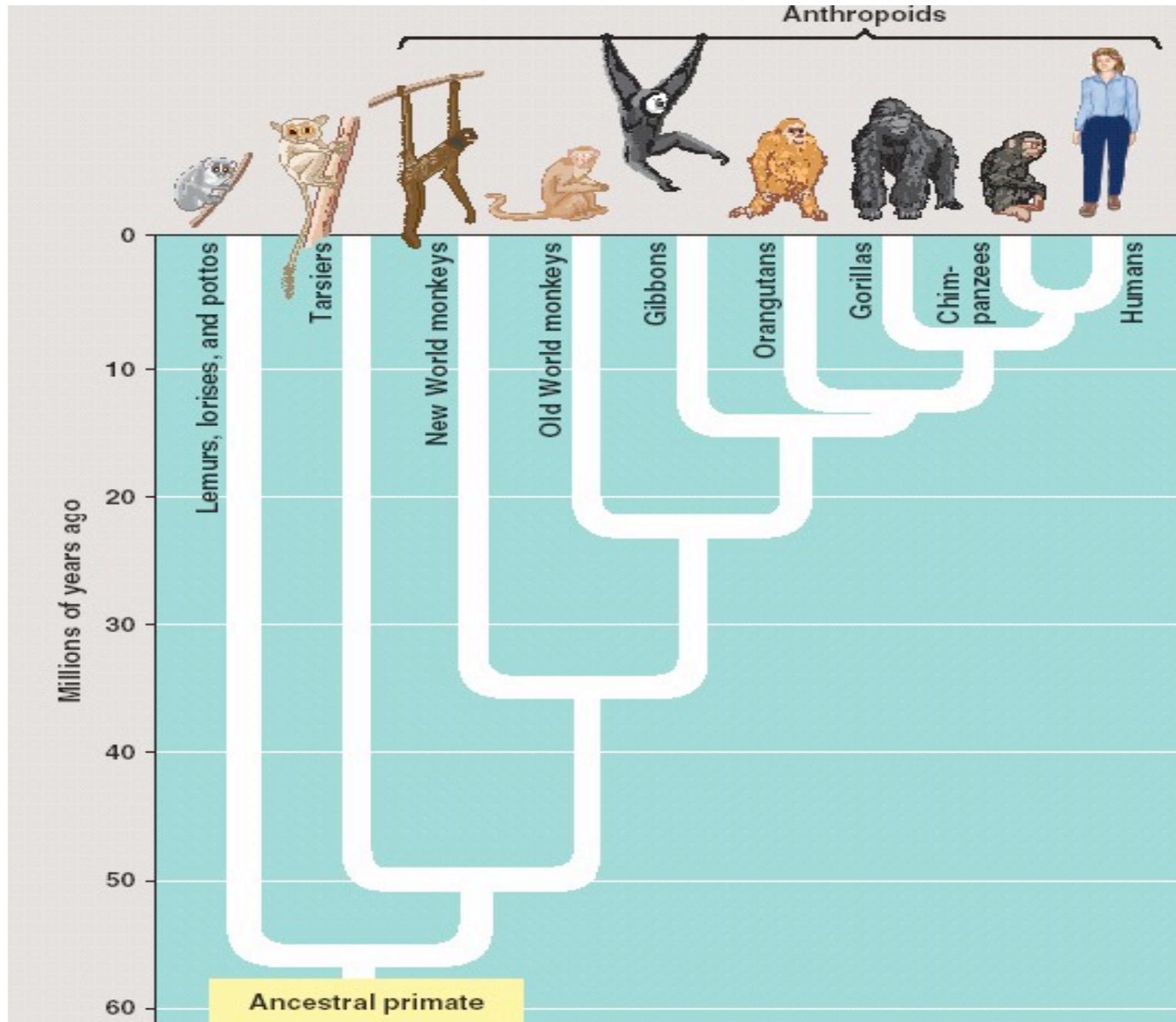
- Leopards are present in Tai and absent from Tiwai, and...
monkeys call differently to eagles on the two sites!

- **Lexicalist analysis:** **krak** = different meanings on 2 sites
- **Pragmatic analysis:** a Strengthening rule fails in one case

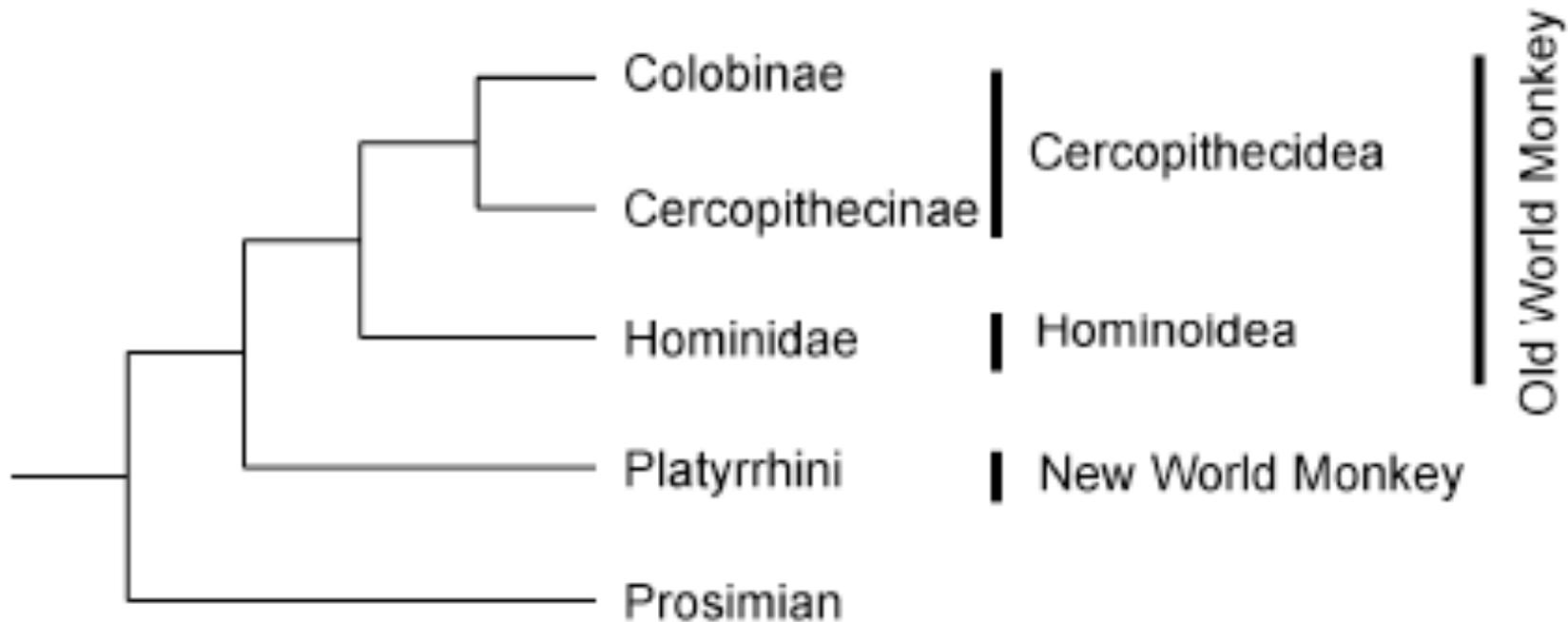
What is Language?

- There is no non-trivial answer to the question 'What is Language':
 - a. a set of well-formed expressions?
 - b. a set of well-formed expressions whose generating rules have designated properties?
 - c. such a set with a semantics? or a semantics and a scalar pragmatics? or a semantics and an intentional pragmatics?
- When one considers human language, the question only becomes more complex, as there are many more modules that interact to produce language as we know it.
- **Replace the question:** 'Does Species X have Language'
with: 'What are the formal properties of the language of Species X' (and how do they compare to other languages)?

Primates



Old World Monkeys



- "Molecular evidence indicates a divergence of Colobinae and Cercopithecinae about 12 mya, while the fossil record suggests a split sometime between 12.5 and 10 mya." (Lambert and Whitham 2012)

Cautionary Note I: Semantics without Reason

■ Semantics proper

Very little is needed to have a semantic system, e.g.

- elementary parts that can be true or false;
- rules to combine them and interpret the result.

■ Pragmatics I: scalar reasoning

Even scalar reasoning doesn't require *so* much:

- a semantics that yields a relation 'is more informative than';
- some optimization to pick the most informative sentence.

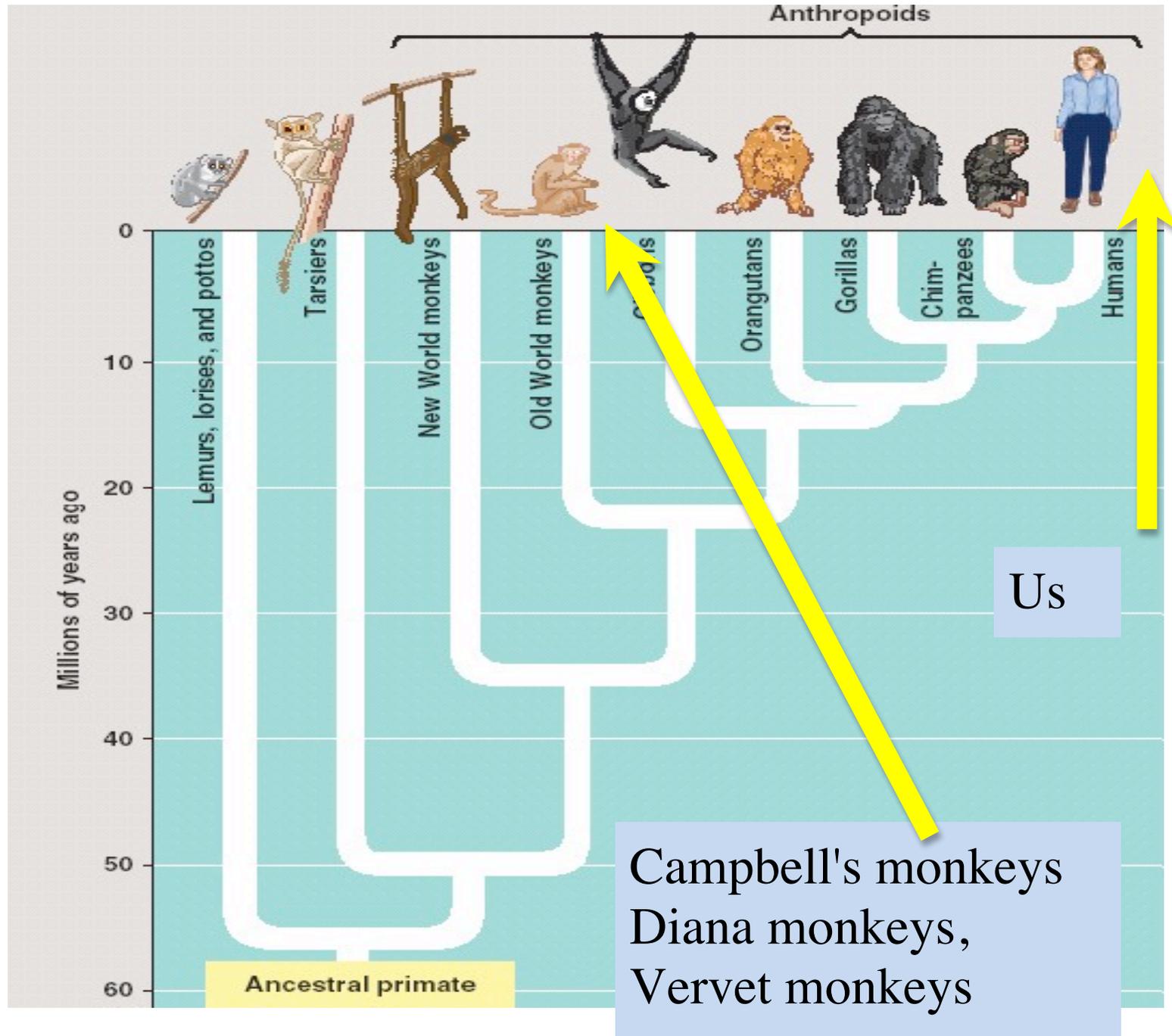
☞ We will be relying on Semantics proper and Pragmatics I.

■ Pragmatics II: intentional pragmatics

- Being truthful...
- Not saying things that the addressee already knows...

Cautionary Note II: Language and Evolution

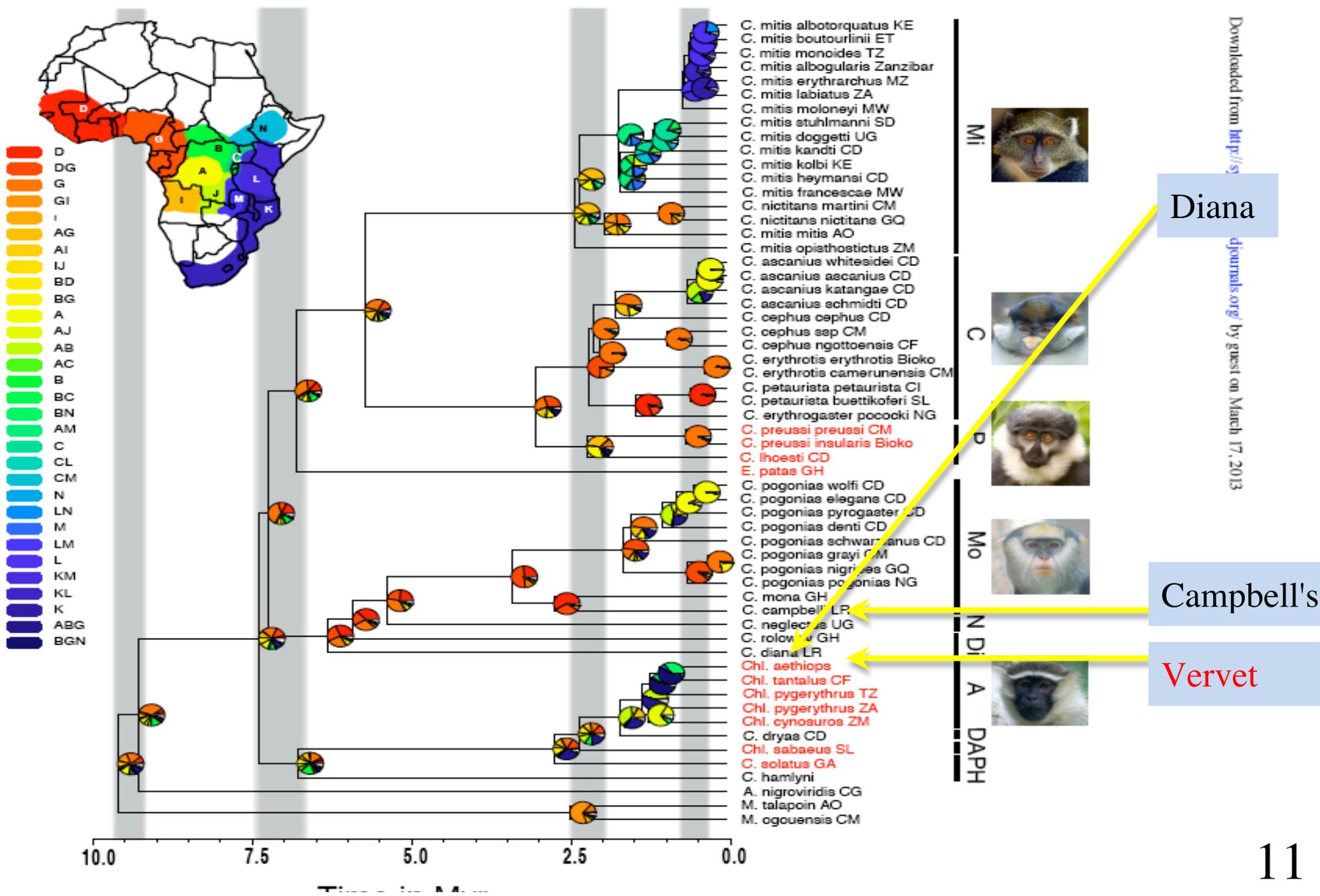
- **Primate languages are often studied to yield insights about language evolution**, e.g. on the debate between "Sign language first" theories = human language used a gestural channel in evolutionary times; "Spoken language first" theories = human language used a vocal channel in evolutionary times.
- **I remain agnostic on this question:** as far as I can tell, the shared properties between monkey languages and human languages do not license any conclusion about their evolutionary origin.
- ***Monkey languages should be studied for themselves*** before leading to evolutionary speculations, which should be based on a detailed understanding of their formal properties.



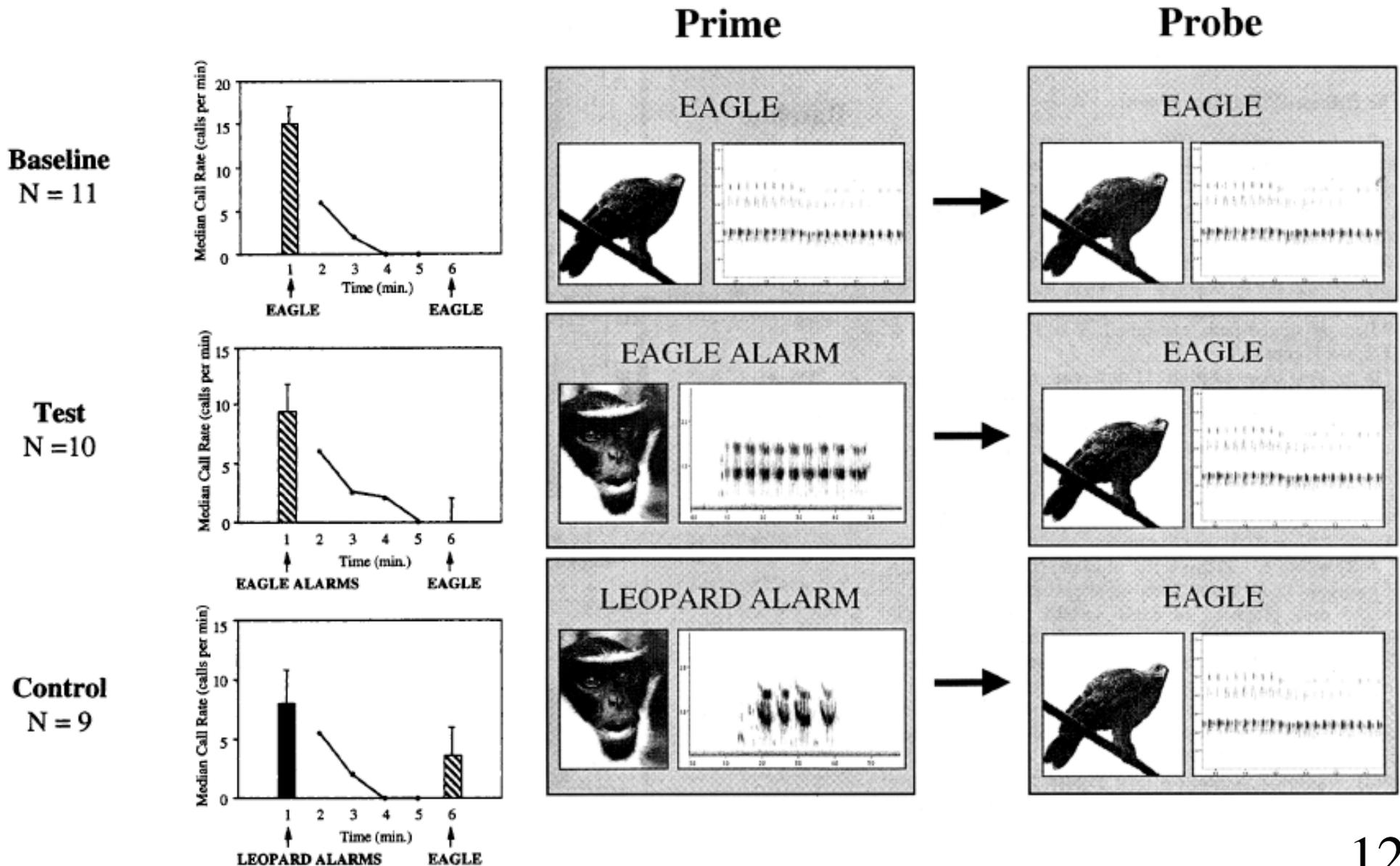
Conceptual Semantics: Diana Monkeys



http://www.environmenttimes.co.uk/news_detail.aspx?news_id=610



Prime-Probe Experiment with Diana Monkeys (Zuberbühler et al. 1999)



'Referential' Calls? Diana Monkeys

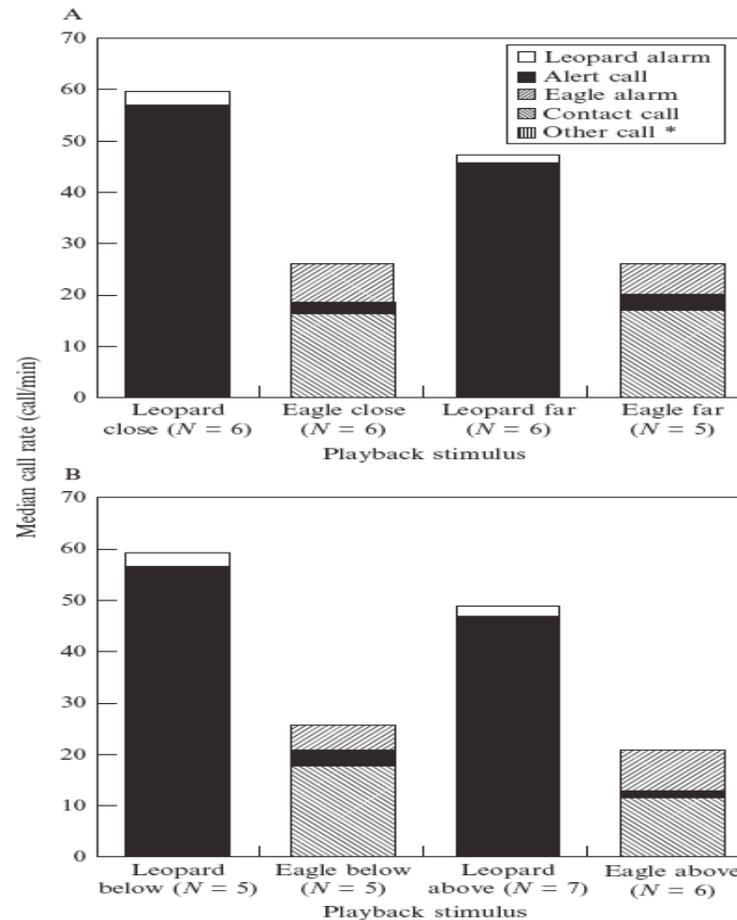
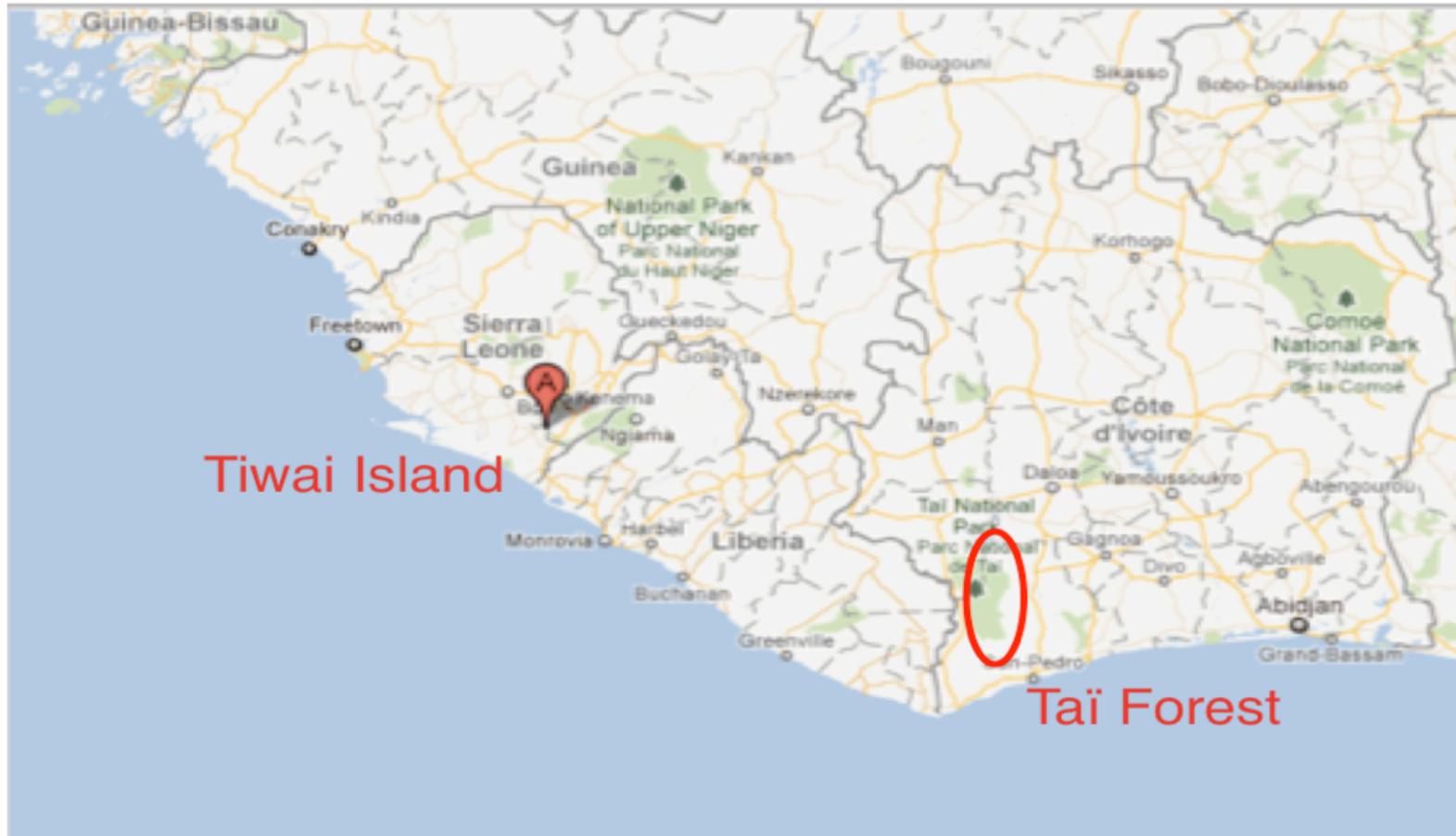


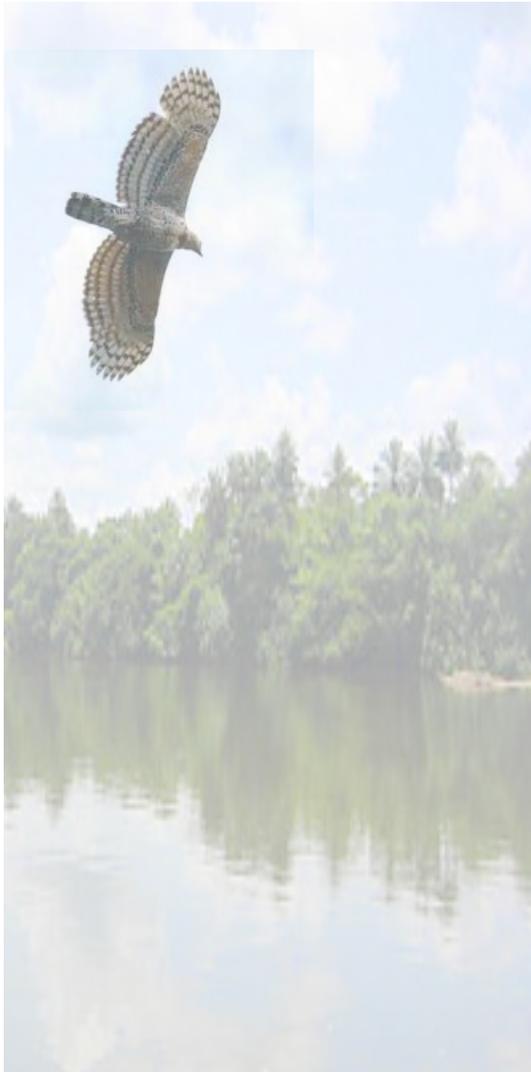
FIG. 5. The acoustic structure of Diana monkey alarm calls is mainly determined by the predator type present, while distance and direction of attack only have minor effects. Box plots depict female vocal behavior in response to leopards and crowned eagles as a function of (A) predator distance and (B) elevation. Bars represent the median number of calls produced in the first minute after onset of the playback stimulus (Zuberbühler, 2000d).

(Zuberbühler 2009)

The Role of Life Experience



No Evidence of Dialectal Variation: Dianas



**Tiwai island
(Sierra Leone)**



**Tai Forest
(Ivory Coast)**

Diana Monkeys in Tai vs. on Tiwai (Stephan and Zuberbühler 2008)

- There is no evidence of specific difference in calling behavior to eagles in Tai vs. Tiwai.
- "At Tai, males discriminate acoustically between their responses to leopards and general disturbances, such as falling trees or fleeing duikers (Zuberbühler et al. 1997), whereas at Tiwai, males also responded regularly to such general disturbances, but these call sequences were not different from the ones given to leopard-related stimuli" (Stephan and Zuberbühler 2008)

[Diana Monkeys in Tai vs. on Tiwai] (Stephan and Zuberbühler 2008)

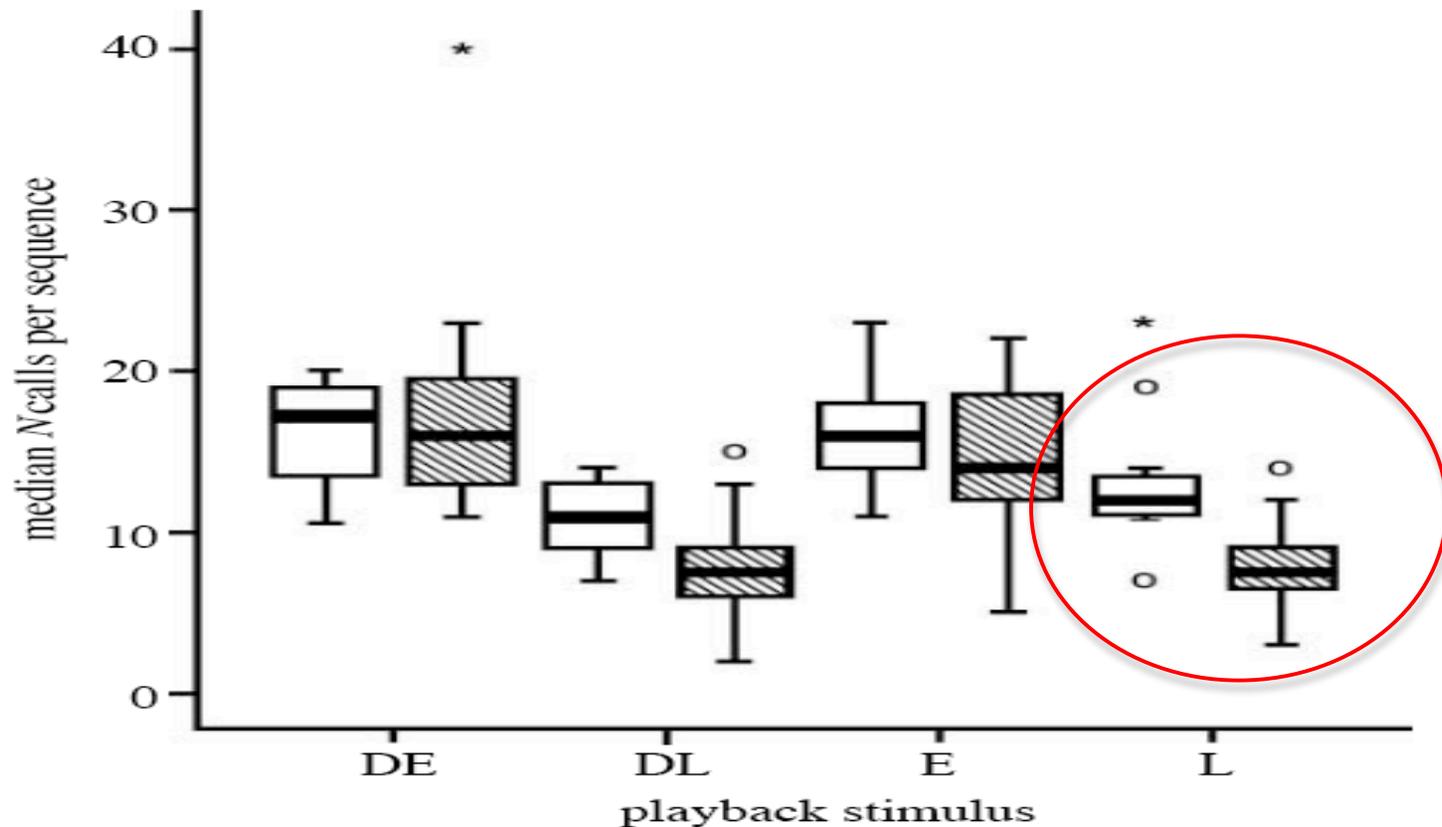
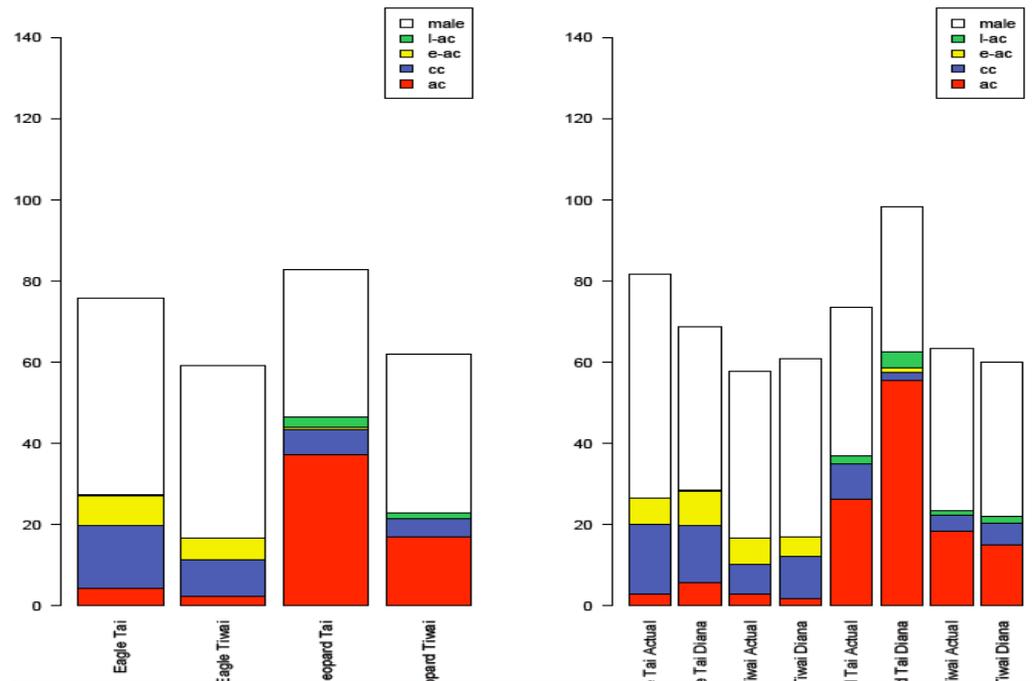


Figure 2. Median numbers of calls per sequence of Tai (hatched boxes) and Tiwai (open boxes) Diana monkeys to playbacks of eagle shrieks (E), leopard growls (L), male Diana alarm calls to eagles (DE) and male Diana alarm calls to leopards (DL). Box plots show median values, quartiles, range and outliers. Circles and asterisks show extreme values, asterisks being more extreme.

Tai vs. Tiwai: Female Diana Monkeys



- **Comment:** (i) There is no obvious difference in (a) the proportion of call types, and (b) the length of sequences in eagle situations in Tai vs. on Tiwai.
- (ii) There might well be differences with respect to leopard situations – as is expected on cognitive grounds.

Raptor-specific vs. General Calls

- **Raptor-specific vs. Ground predator and other threats**
"Interestingly, across species it tends to be the call associated with terrestrial predators that is given in other contexts, whereas the call associated with aerial predators tends to be context-specific ... " (Wheeler and Fischer 2012)
=> lemurs, Capuchin monkeys, tamarins
- **Example: Two species of lemurs (Madagascar)**
Red-fronted lemurs and white sifakas
"both species gave specific alarm calls only in response to raptor playbacks and the corresponding alarm calls, whereas calls given in response to carnivores and the corresponding alarm calls were also observed in other situations characterized by high arousal." (Fichtel & Kappeler 2002).



Capuchin monkeys

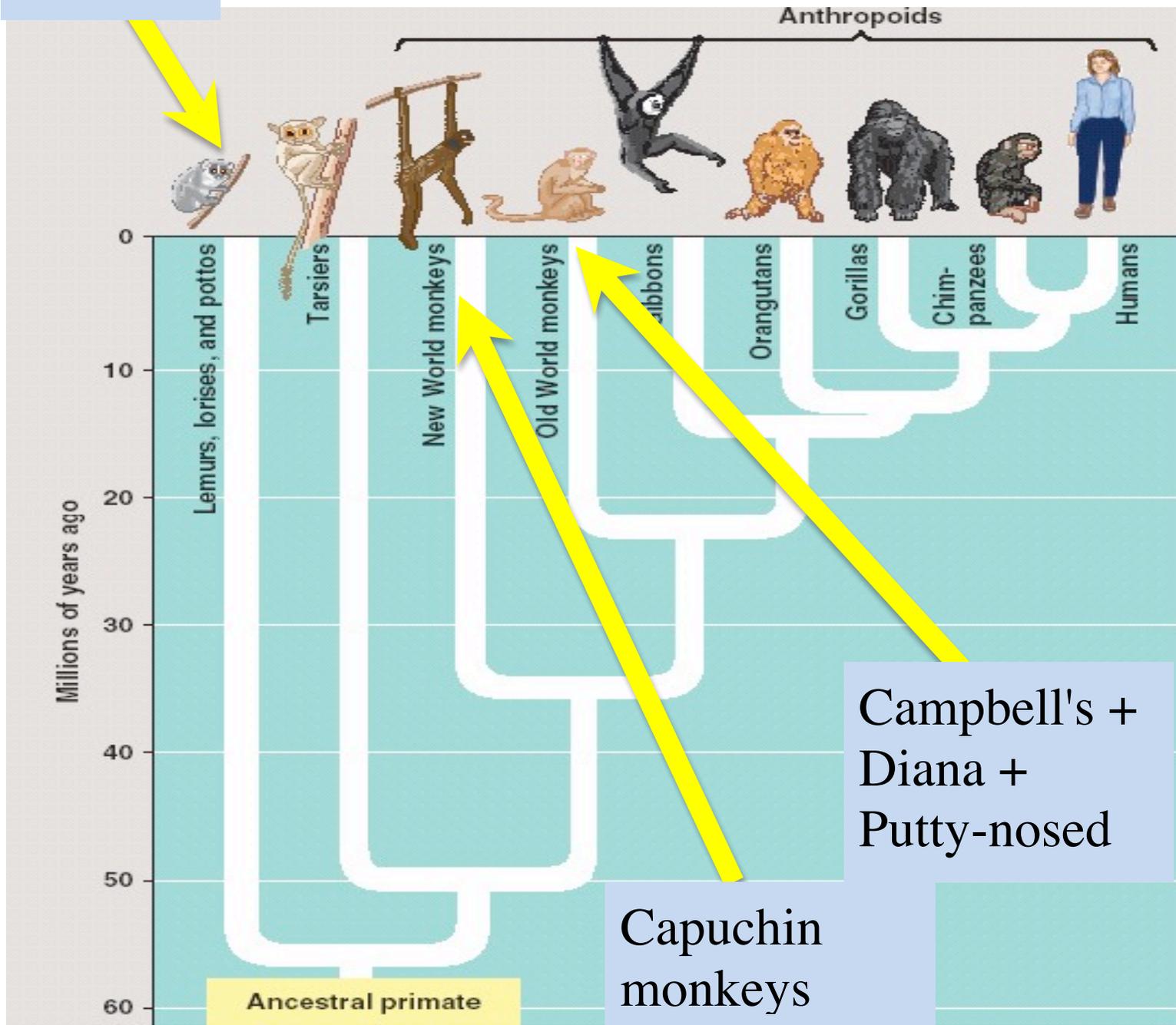


Lemurs



http://upload.wikimedia.org/wikipedia/commons/thumb/2/24/Eulemur_Rufus.JPG/220px-Eulemur_Rufus.JPG
http://ichef.bbci.co.uk/naturelibrary/images/ic/credit/640x395/v/ve/verreauxs_sifaka/verreauxs_sifaka_1.jpg http://en.wikipedia.org/wiki/Tufted_capuchin

Lemurs

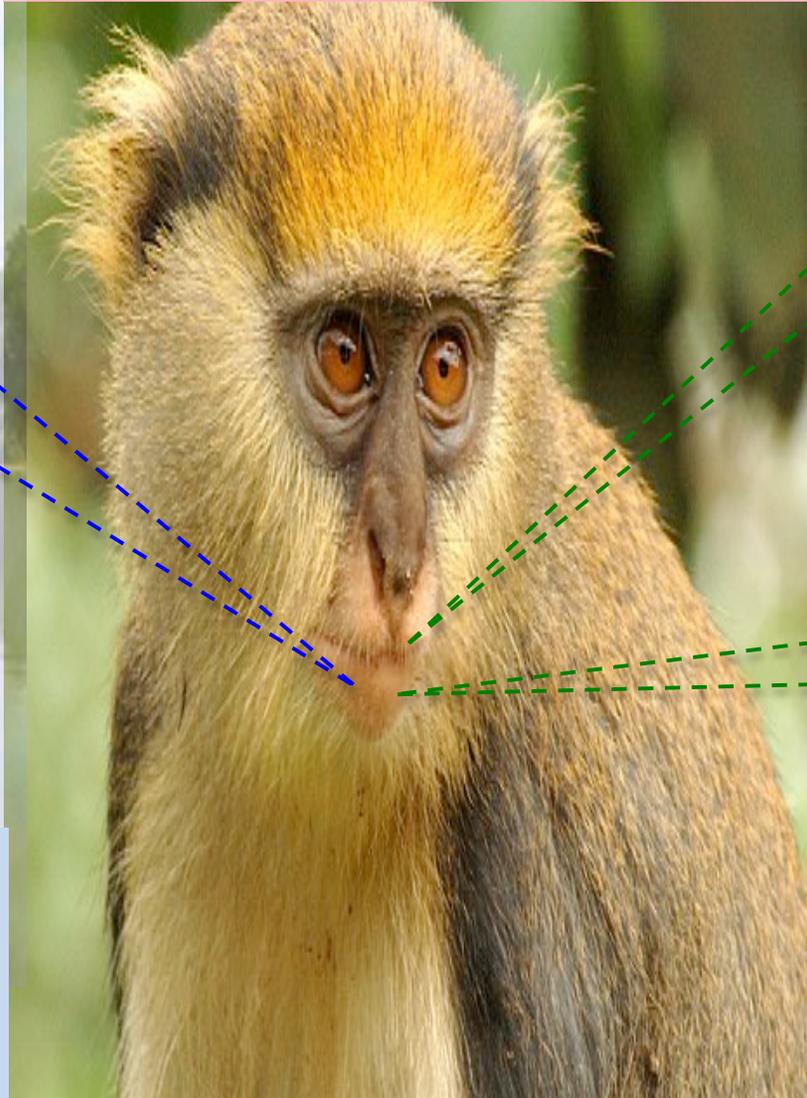


Campbell's Monkeys

krak is used for leopards in
Tai and eagles in Tiwai



krak
hok
krakoo



hok
krakoo

krak
krakoo

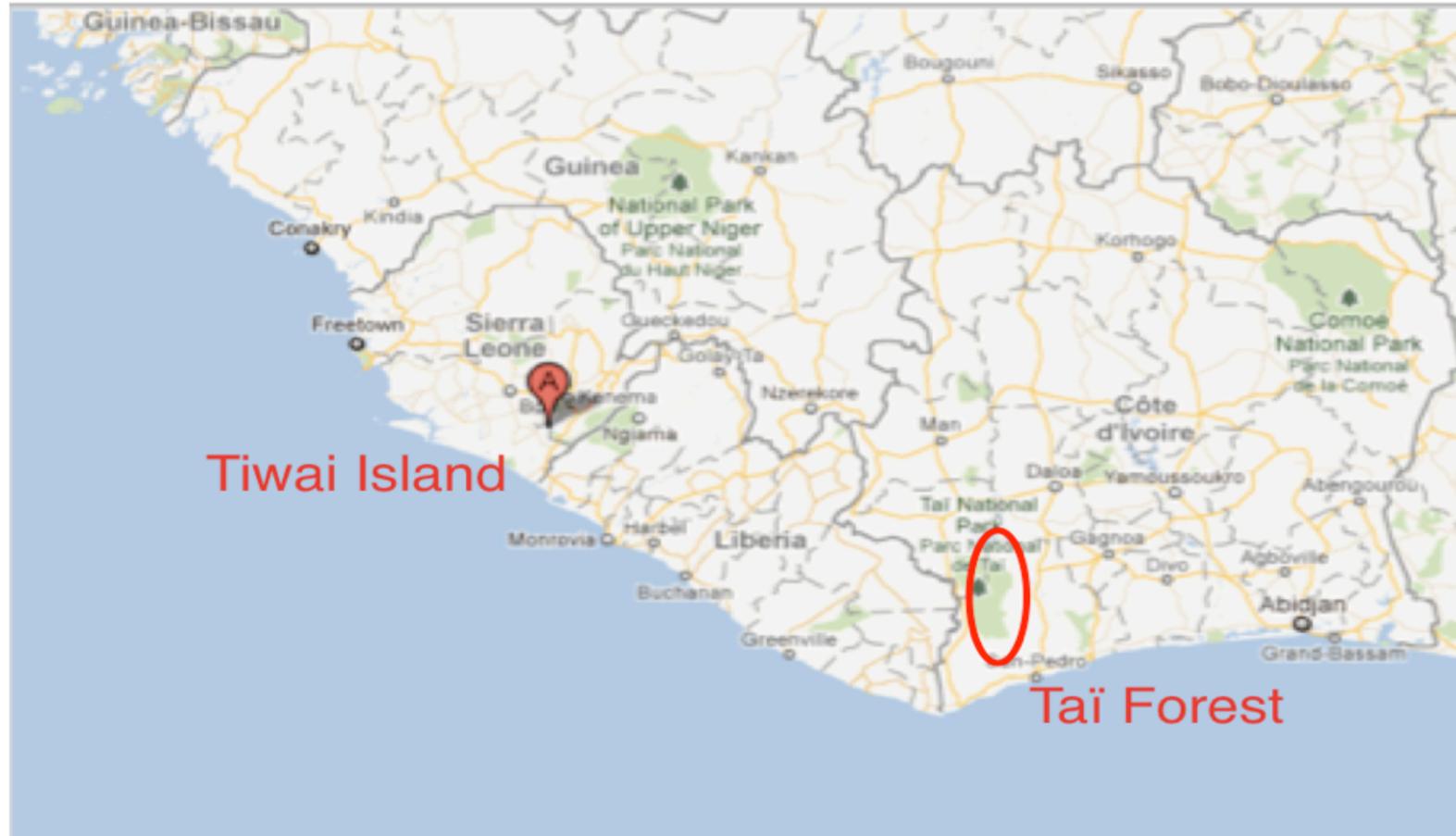
**Tiwai island
(Sierra Leone)**

**Tai Forest
(Ivory Coast)**

Campbell's Monkeys

- They are arboreal.
- Males and females have different calls. Male calls start being used during puberty.
- Male calls can be loud and can be produced with air sacs.
Examples of calls: <http://news.bbc.co.uk/2/hi/science/nature/8405806.stm>





Male Campbell's Monkeys: 3 datasets

- **Tai forest I: data used in Ouattara et al. 2009a, b**
=> natural events and field experiments; transcription by ear (henceforth Tai-K).
- **Tai forest II: new data**
=> field experiments; transcription by ear + spectrograms (henceforth Tai-S).
- **Tiwai island: new data**
=> field experiments; transcription by ear + spectrograms (henceforth Tiwai-K).
- **When we compare Tai and Tiwai, we use Tai forest II + Tiwai data, which were transcribed in comparable ways.**

Male Campbell's Monkey Calls I: Morphology

- Zuberbühler et al. show that Campbell's monkeys have:
 - a. 4 words: **boom**, **krak**, **hok**, **wak**
 - b. 1 suffix: **-oo**
 - c. a syntactic rule: boom always comes at the beginning
 - d. some semantics: **krak** for leopards, **hok** for eagles [in Tai]

■ Roots and affixes

- a. Roots: boom, hok, krak, wak
- b. Bound affixes: -oo

■ Lexicon

- a. Every root is a word.
- b. If R is a root different from *boom*, *R-oo* is a word.

Semantics: Introduction

■ Informal description of the lexical meanings

(except *wak*, *wak-oo*)

a. boom boom: 'this is not a situation of predation'

b. krak-oo: 'there is an alert'

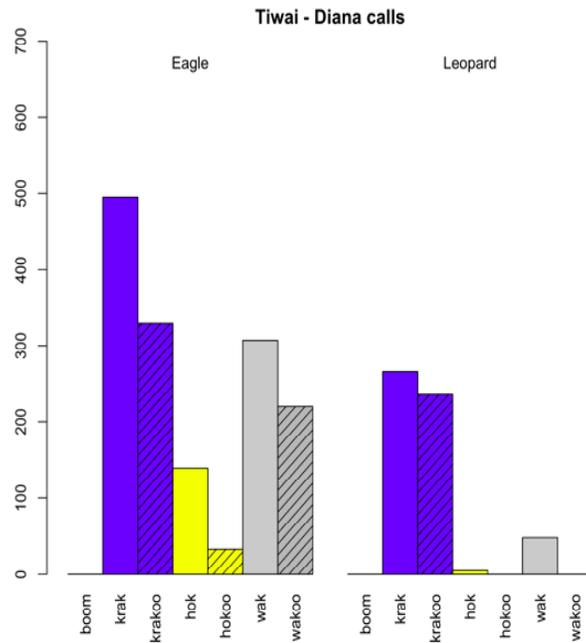
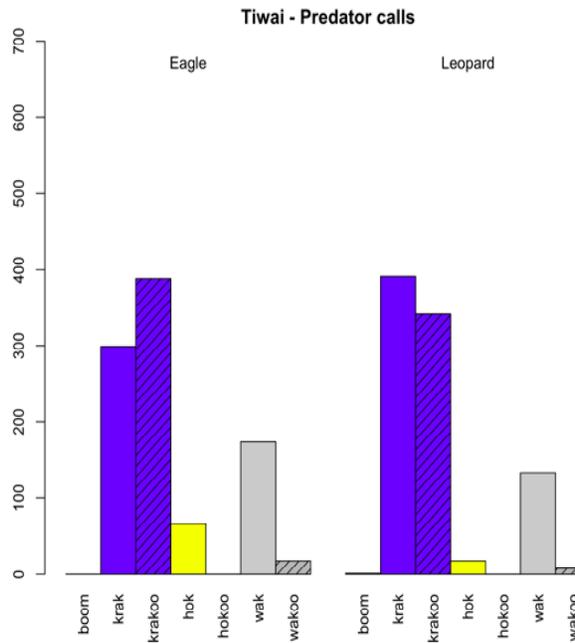
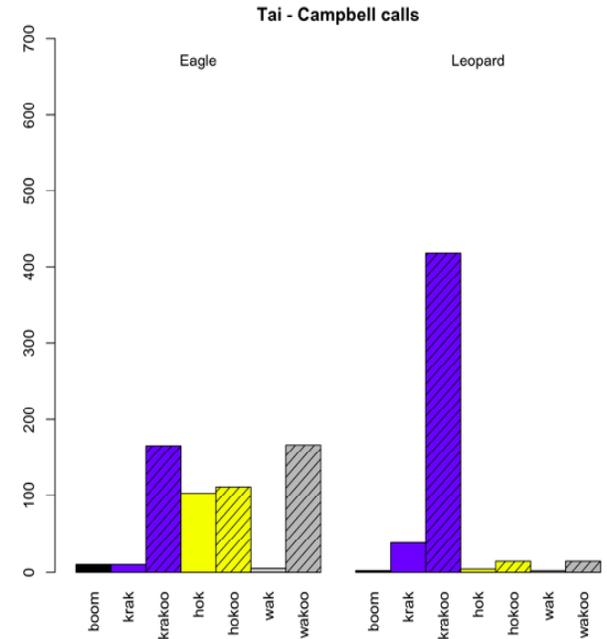
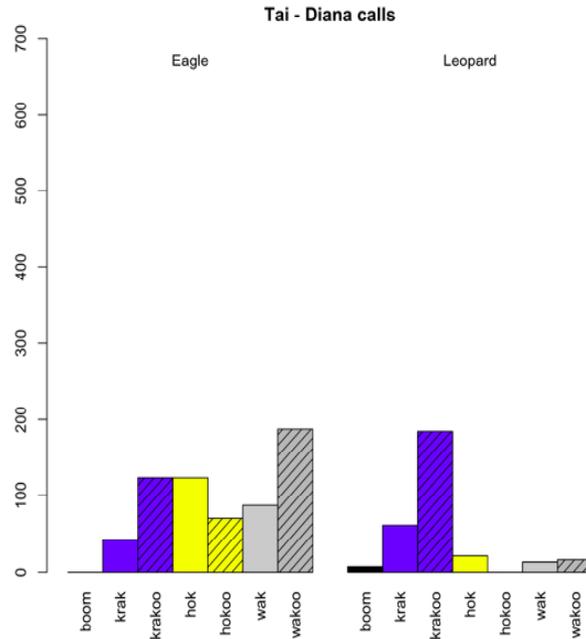
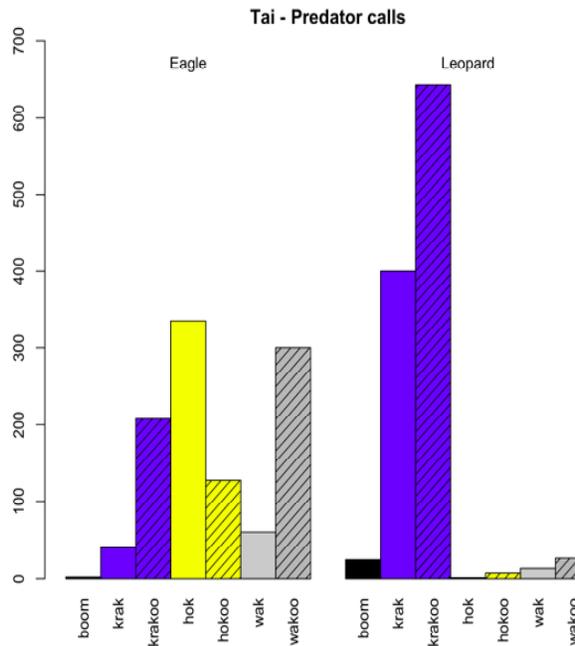
c. hok: 'there is an eagle'

d. hok-oo: 'there is an alert upwards'

e. krak:

(i) 'there is a leopard' (Tai);

(ii) 'there is an alert' (Tiwai)



Number of call sequences per playback situation

		Tai	Tiwai
Eagle	Shriek	24	23
	Diana	12	23
	Campbell	15	
Leopard	Growl	42	18
	Diana	12	16
	Campbell	15	
General Disturbance (tree fall)			17

Boom hok -oo
and compositional semantics

Boom: non-predator-related situations

■ Boom is indicative of non-predation contexts

- a. "Nonpredation events were characterized by the production of two boom calls, which could be given alone (to indicate group movement) or which could introduce subsequent calls (100%, $n = 142$ cases, all eight males). " (Ouattara et al. 2009)
- b. Things are less clear in our other two data sets.

■ # of sequences containing *boom* /total # of sequences

	Tai-K	Tai-S	Tiwai-K
Disturbance			
Cohesion and Travel	13/13	-	-
Eagle	0/43	6/51	0/46
Inter-group	76/76	-	-
Leopard	0/39	16/69	1/34
Tree	53/53	-	4/17

Boom: non-predator-related situations

■ Meaning of *boom* (preliminary)

$I_{M,s}(\text{boom-boom}) = 1$ iff there is a disturbance but no predator in s

■ # of sequences containing *boom* /total # of sequences

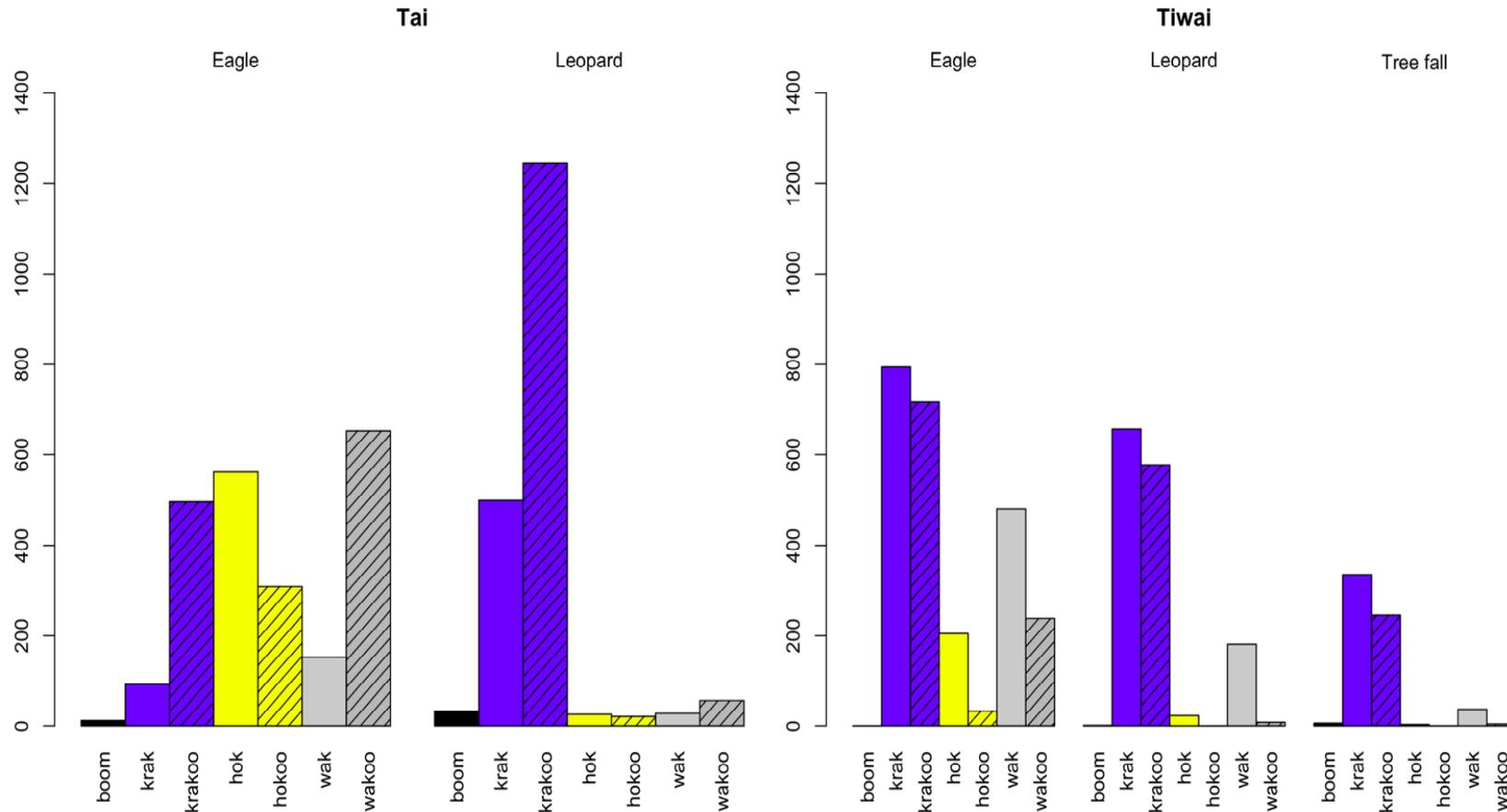
Disturbance	Tai-K	Tai-S	Tiwai-K
Cohesion and Travel	13/13	-	-
Eagle	0/43	6/51	0/46
Inter-group	76/76	-	-
Leopard	0/39	16/69	1/34
Tree	53/53	-	4/17

Hok: aerial predator (?)

■ Meaning of *hok* (preliminary)

$I_{M,s}(hok) = 1$ iff there is an aerial predator in s

■ Hok is indicative of eagles (1st try)



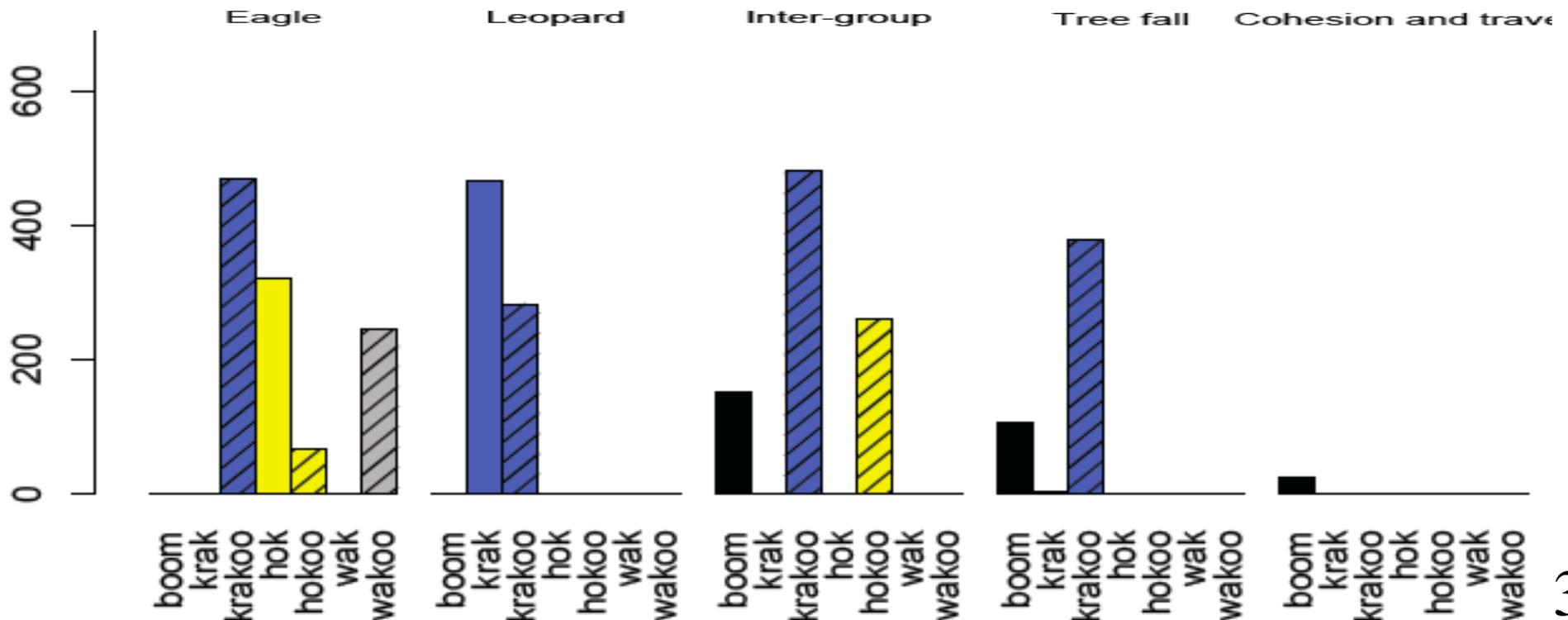
-oo: attenuative/generalizing suffix

■ **Meaning of -oo** (to be revised)

for any root R different from *boom-boom*,

$I_{M,s}(R-oo) = 1$ iff there is a disturbance that licenses the same attentional state as if $I_{M,s}(R) = 1$

■ **Data used in Ouattara 2009a, b (Tai forest)**



Hok-oo: more general non-terrestrial call

- **Meaning of -oo** (to be revised)

for any root R different from *boom-boom*,

$I_{M,s}(R-oo) = 1$ iff there is a disturbance that licenses the same attentional state as if $I_{M,s}(R) = 1$

- $I_{M,s}(hok-oo) = 1$ iff there is a disturbance that licenses the same attentional state as if $I_{M,s}(hok) = 1$,
iff there is a disturbance that licenses the same attentional state as if there is an aerial predator in s
=> look up!

- In the data used in Ouattara 2009a, b (Tai forest), there are quite a few *hok-oo*'s but no *hok*'s in inter-group encounters. (More recent data: very few hok-oo's)

Reminder: Campbell's monkeys are arboreal!

Compositional Semantics

■ Proposal about the semantics

- a. Individual calls have a propositional semantics.
- b. Concatenation is interpreted as conjunction...
- c. ... but each occurrence raises an alarm parameter.

■ Effect of repetitions per time unit (= call rate)

"**krak-oo** series were given more rapidly to predation than non-predation events, **krak-oo** and **krak** series more rapidly to visual than auditory predator detection, and **hok** series more rapidly while counterattacking an eagle than staying put." (Lemasson et al. 2010)

Compositional Semantics

■ Compositional Semantics [time-insensitive version]

Note: we omit parameters M, s unless they play a role

For any alarm level a , for any word w , for any string S ,

a. $[[w]]^a = 1$ iff $I(w) = 1$ and the alarm level is at least a .

b. $[[w S]]^a = 1$ iff $[[w]]^a = 1$ and $[[S]]^{a+1} = 1$

■ Meaning of -oo

$I_{M,s}(R-oo) = 1$ iff there is a disturbance that licenses the same attentional state as if $I_{M,s}(R) = 1$

■ $[[hok-oo]]^0 = 1$

iff $I(hok-oo) = 1$ and the alarm level is at least 0,

iff there is a disturbance that licenses the same attentional state as if there is an aerial predator (and the alarm level is at least 0).

Compositional Semantics

■ Compositional Semantics [time-insensitive version]

Note: we omit parameters M, s unless they play a role

For any alarm level a , for any word w , for any string S ,

a. $[[w]]^a = 1$ iff $I(w) = 1$ and the alarm level is at least a .

b. $[[w S]]^a = 1$ iff $[[w]]^a = 1$ and $[[S]]^{a+1} = 1$

■ $[[\text{hok-oo hok-oo hok-oo}]]^0 = 1$

iff $[[\text{hok-oo}]]^0 = 1$ and $[[\text{hok-oo hok-oo}]]^1 = 1$

iff $[[\text{hok-oo}]]^0 = 1$ and $[[\text{hok-oo}]]^1 = 1$ and $[[\text{hok-oo}]]^2 = 1$

iff there is a disturbance that licenses the same attentional state as if there is an aerial predator and the alarm level is at least 2.

Compositional Semantics

■ Compositional Semantics [time-insensitive version]

Note: we omit parameters M, s unless they play a role

For any alarm level a , for any word w , for any string S ,

a. $[[w]]^a = 1$ iff $I(w) = 1$ and the alarm level is at least a .

b. $[[w S]]^a = 1$ iff $[[w]]^a = 1$ and $[[S]]^{a+1} = 1$

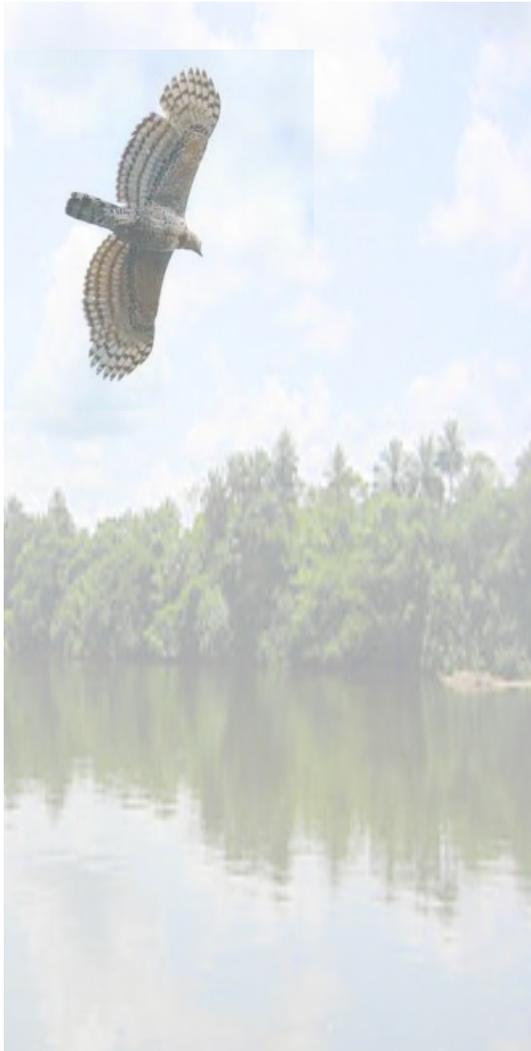
■ $[[\text{boom-boom hok-oo hok-oo hok-oo hok-oo}]]^0 = 1$

iff $[[\text{boom-boom}]]^0 = 1$ and $[[\text{hok-oo hok-oo hok-oo}]]^1 = 1$

iff there is a disturbance but no predator and there is a disturbance that licenses the same attentional state as if there is an aerial predator and the alarm level is at least 3.

Krak
and dialectal variation

Tiwai Dianas react differently to leopards... so?



**Tiwai island
(Sierra Leone)**



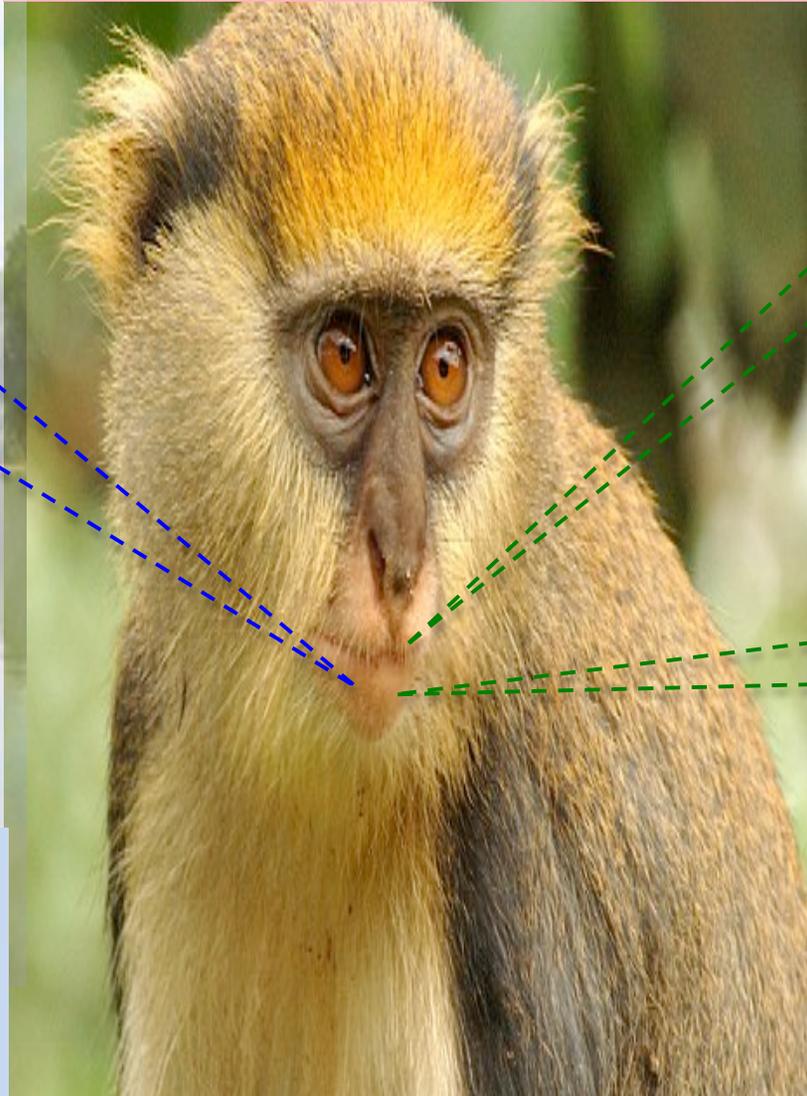
**Tai Forest
(Ivory Coast)**

Tiwai Cambpells react differently to eagles!!

krak is used for leopards in Tai and eagles in Tiwai



krak
hok
krakoo



hok
krakoo

krak
krakoo

Tiwai island
(Sierra Leone)

Tai Forest
(Ivory Coast)

Tiwai Campbells react differently to eagles!!

■ Theory 0 (to be refuted)

(a) The lexical meaning of calls is **entirely innate**.

(b) i. These meanings are only sensitive to the **narrow situation** in which they are used.

ii. The choice of the messages (i.e. truth conditions) uttered is only determined by the narrow situation in which they are used.

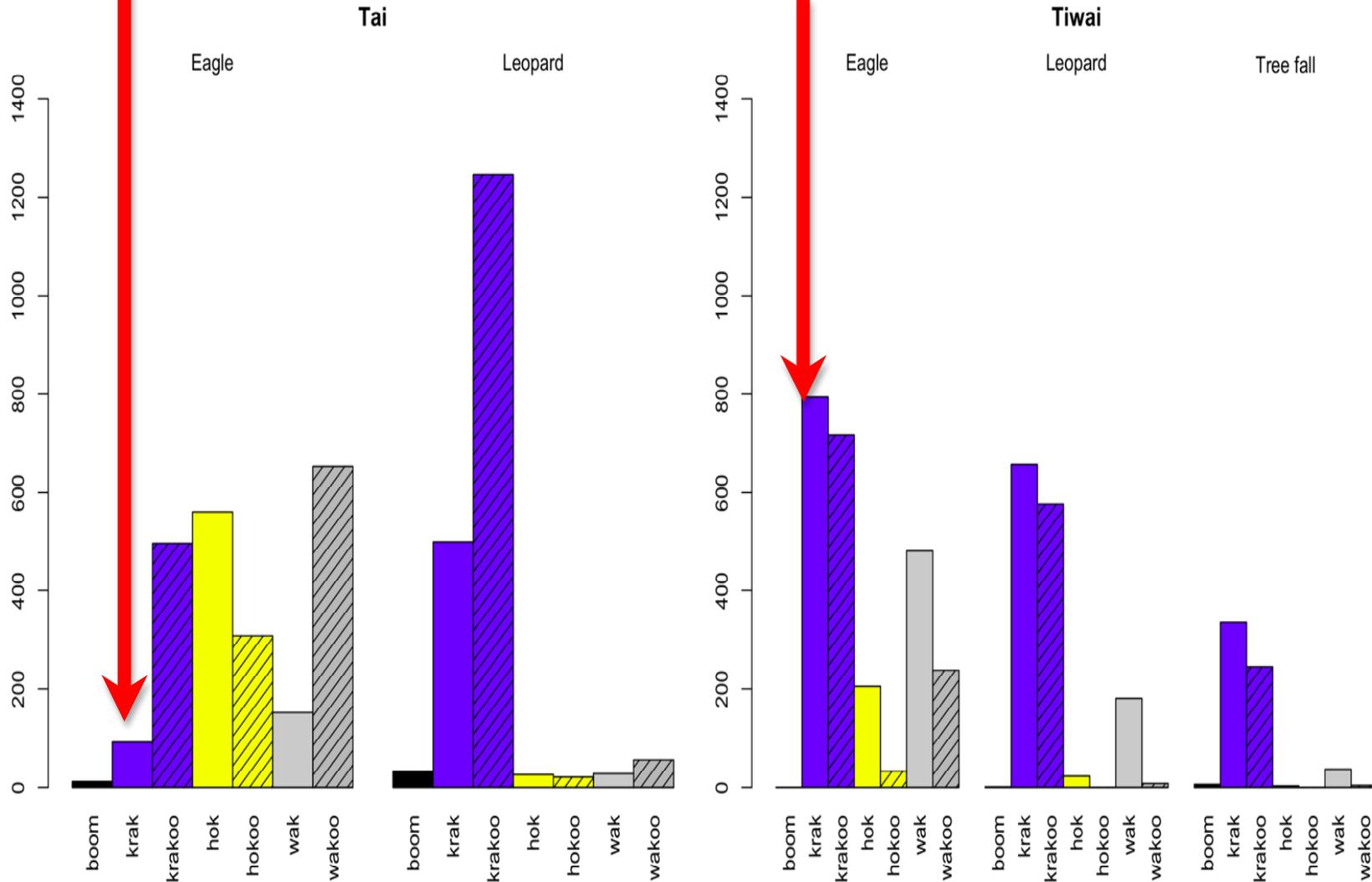
■ Prediction

In eagle situations, the sequences should be similar in Tai and on Tiwai. (No prediction about leopard situations).

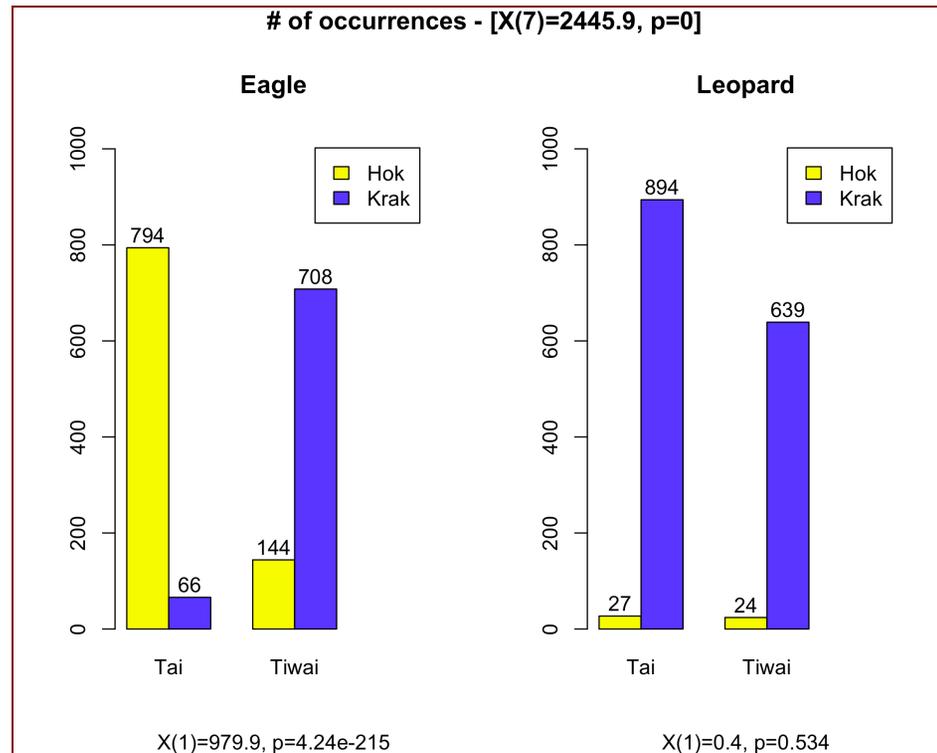
Tai vs. Tiwai: Refuting Theory 0

very few kraks

lots of kraks



Two Dialects



- a. In response to Eagles, the ratio [number of krak's / number of hoks's] is higher on Tiwai than on Tai.
- b. No such difference in leopard situations.

Plot

- a. In Tai, Campbell's monkeys have two main predators: leopards and eagles. On Tiwai, there are no leopards.
 - b. *krak* is used as a leopard alarm call in Tai.
 - c. *krak-oo* is used as a general alarm in Tai and on Tiwai.
- **Theory I: Lexical variation (+ non-innateness)**
 - a. *krak* = leopard meaning in Tai; general meaning on Tiwai
 - b. **Problem:** *krak-oo* in Tai cannot be derived from *krak*.
 - **Theory II: Pragmatic strengthening (+ full innateness)**
 - a. *krak* has a general meaning everywhere, and 'acquires' a leopard-like meaning in Tai by competition with other calls.
 - b. This *predicts* that on Tiwai it should have a general use.

Two Theories

■ Theory I: Dialectal variation

The lexical meaning of *krak* is different in Tai and on Tiwai.

Tai: *krak* = leopard

Tiwai: *krak* = general alert

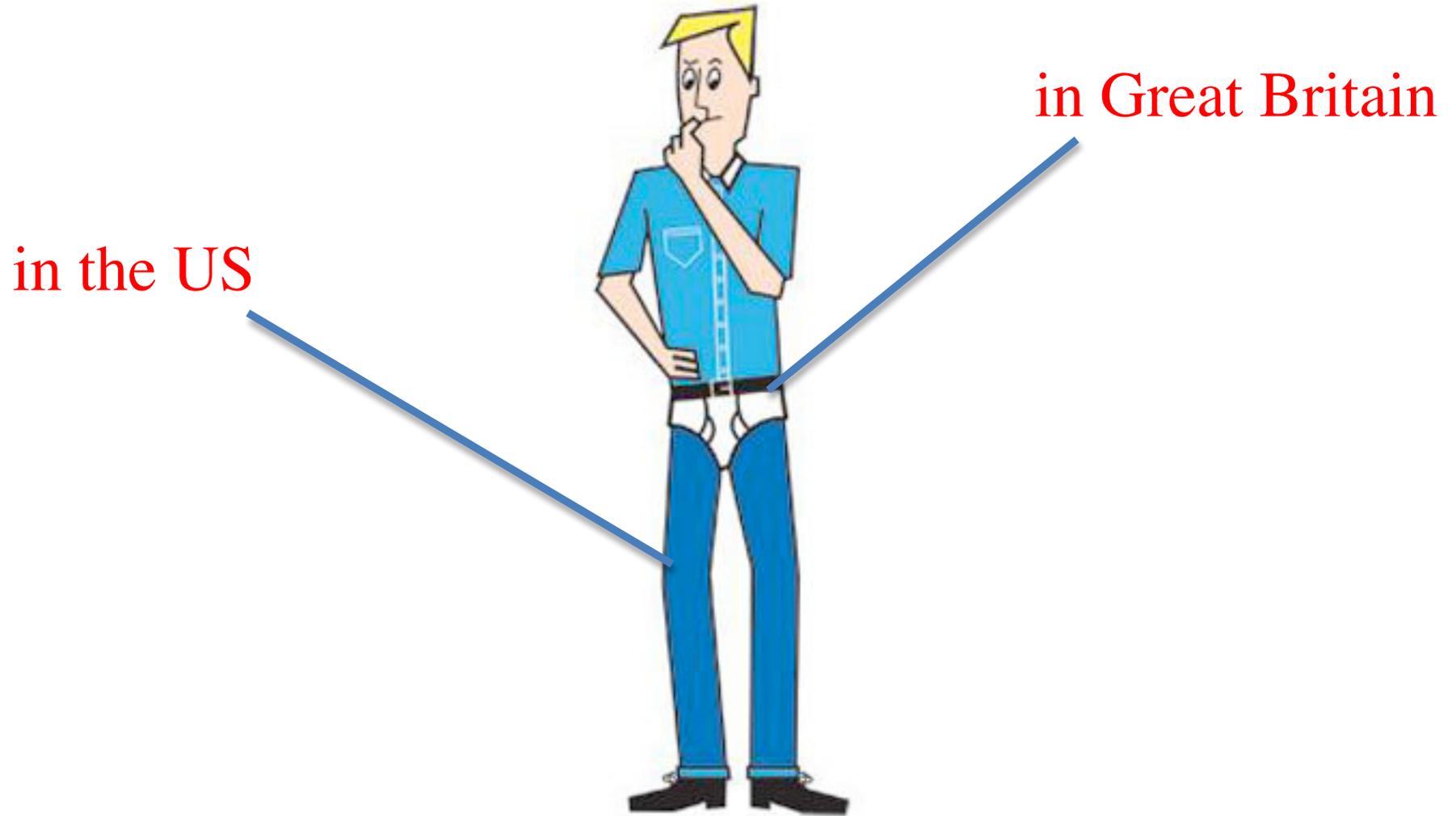
■ Theory II: Context-sensitive strengthening

-The lexical meaning of *krak* is constant across Tai and Tiwai = general alert.

-A rule of strengthening akin to implicatures applies in Tai to yield a meaning of 'serious ground disturbance', hence usually 'leopard'.

-For lack of ground predators on Tiwai, strengthening yields a near-contradiction and isn't used.

'Pants'



http://www.boston.com/bostonglobe/ideas/articles/2011/07/17/if_the_pants_fit/

Theory I: Lexical Variation

■ Innate meanings

-Roots

a. $I(\text{krak}) = 1$ iff there is a disturbance

b. $I(\text{hok}) = 1$ iff there is an aerial predator

c. $I(\text{boom-boom}) = 1$ iff there is a disturbance but no predator

-Affix

d. for any root R,

$I(\text{R-oo}) = 1$ iff there is a disturbance that licenses the same attentional state as if $I(\text{R}) = 1$.

■ Acquired meaning of *krak* in Tai

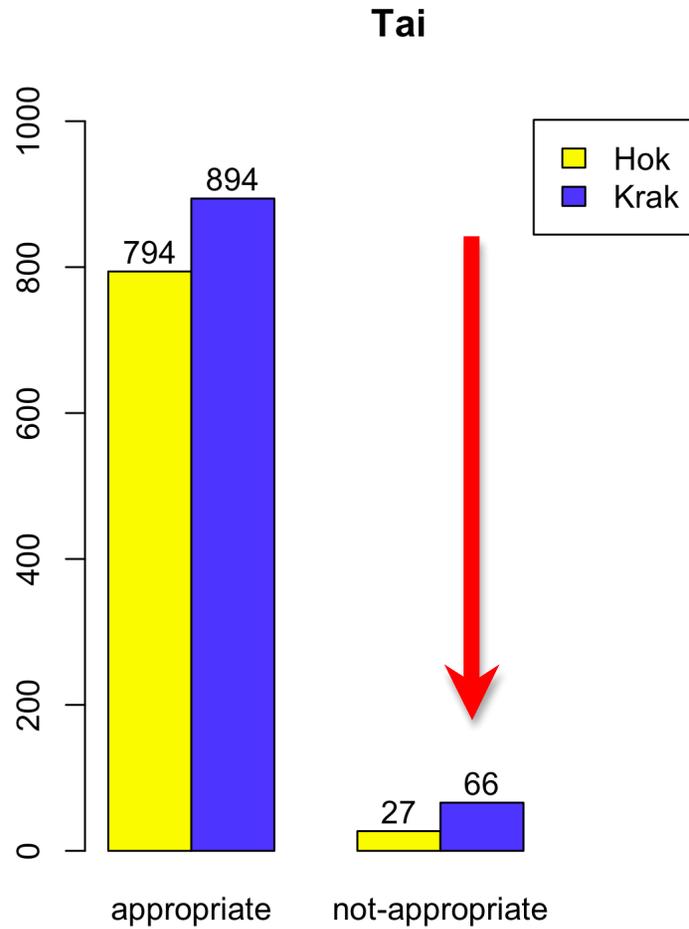
$I_{\text{Tai}}(\text{krak}) = 1$ iff there is a leopard.

Critique of the Lexicalist Theory

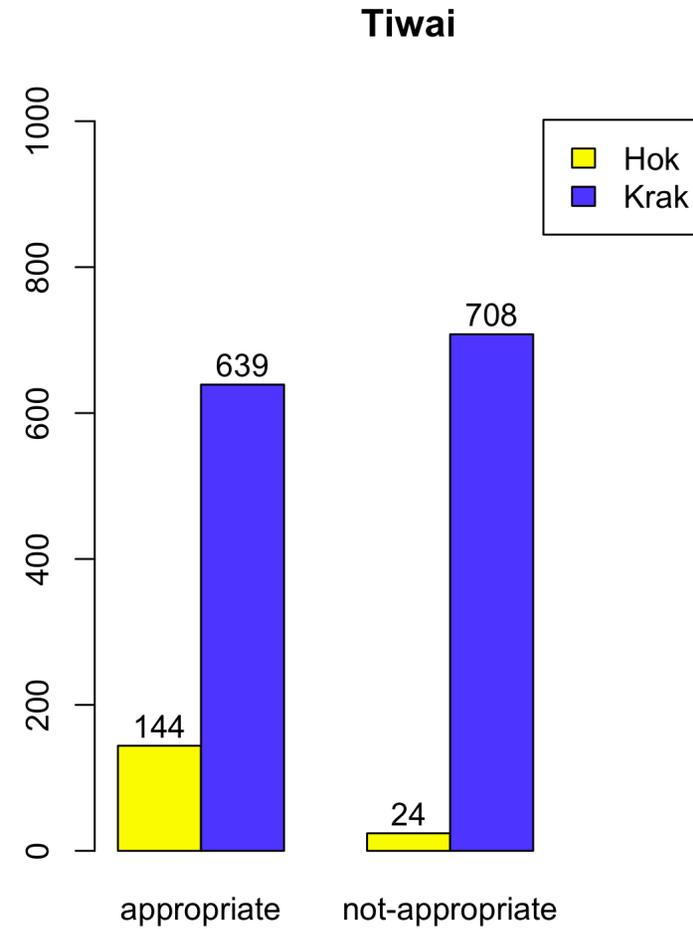
- On the assumption that *krak-oo* is compositionally derived from *krak* + *oo*, **we are forced to posit an ambiguity in the meaning of *krak*.**
- **Even in Tai, *krak* sometimes appears to have the meaning of a general alarm call.**

Critique of the Lexicalist Theory

Uses of Krak and Hok - [X(7)=2445.9, p=0]



X(1)=10.8, p=0.00102



X(1)=86.1, p=1.71e-20

Theory II: Pragmatic Strengthening

■ Competition

a. Pragmatic Scales

{krak, krak-oo, hok, hok-oo} are alternatives to each other

b. Strengthened meanings

For every word w , the strengthened version of w is written as \underline{w} and its meaning is equivalent to

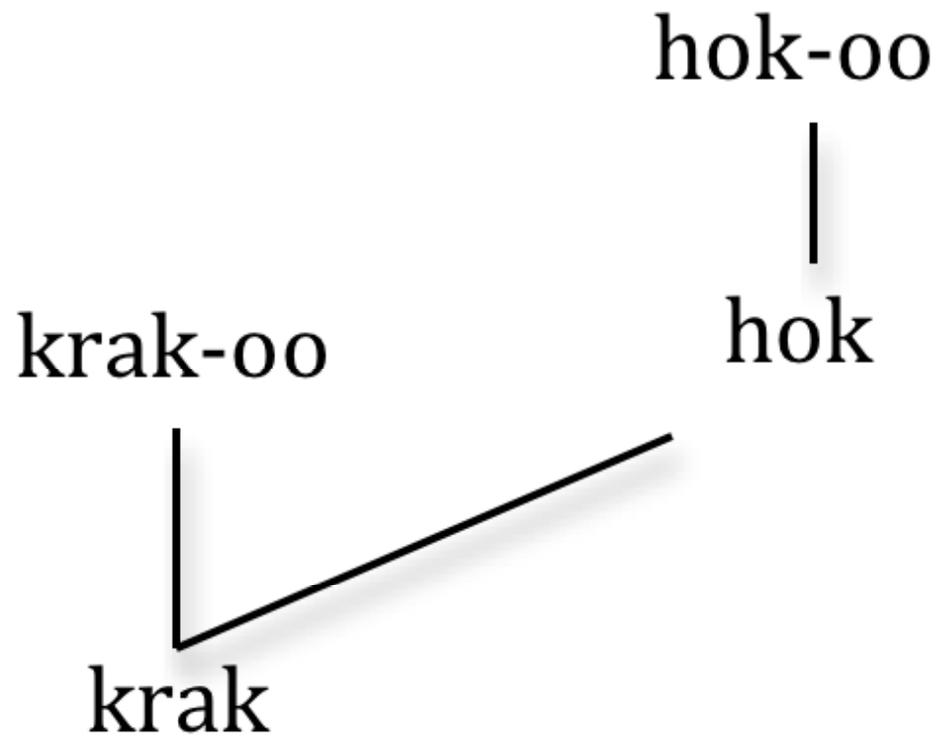
w and not w_1 and not w_2 and ...

where w_1, w_2 are alternatives to w and are more informative (logical stronger) than w .

■ Desired result

krak = krak and not krak-oo and not hok

= disturbance and non-weak and terrestrial



Theory II: Pragmatic Strengthening

■ Meaning of *-oo*

a. Original analysis

For any root R different from *boom-boom*,
 $I(R-oo) = 1$ iff there is a disturbance that licenses the same attentional state as if $I(R) = 1$.

b. Revised analysis (preliminary)

For any root R different from *boom-boom*,
 $I(R-oo) = 1$ iff there is a disturbance which licenses R but is weak among those that license R .

Theory II: Pragmatic Strengthening

■ A Problem: Contradictions!

krak-oo* hok Krak-oo*

■ Solution

–Calls provide information about the speaker's state of mind *at the very moment at which they are uttered*.

–This state of mind can change very quickly: considerable alarm at t , more quiet state at $t+1$, etc.

–Maybe alarm gets 'discharged' as calls get uttered (how? this is not captured in the current model).

■ Meaning of -oo – Time-sensitive Analysis

For any root R different from *boom-boom*, for any time t ,
 $I_t(R-oo) = 1$ iff at t there is a disturbance that is weak among those that license R .

Revised Semantics

■ Lexical Semantics

a. $I_{M,s,t}(\mathbf{kra}k) = 1$ iff at t the caller of s is alert to a disturbance

b. $I_{M,s,t}(\mathbf{hok}) = 1$ iff at t the caller of s is alert to a disturbance whose source is non-terrestrial

c. $I_{M,s,t}(\mathbf{boom-boom}) = 1$ iff at t the caller of s is alert to a disturbance but not of a predator

-Affix

d. $I_{M,s,t}(\mathbf{R-oo}) = 1$ iff at t the caller of s is alert to a disturbance that licenses R and is weak among disturbances that license R .

Revised Semantics

■ Examples

a. $I_{M,s,t}(\text{krak-oo}) = 1$

iff at time t the caller of s is alert to a disturbance that licenses *krak* and is weak among disturbances that license *krak*,

iff at time t the caller of s is alert to a disturbance that is weak among all disturbances.

b. $I_{M,s,t}(\text{hok-oo}) = 1$

iff at time t the caller of s is alert to a disturbance that licenses *hok* and is weak among disturbances that license *hok*,

iff at time t the caller of s is alert to a disturbance whose source is non-terrestrial, and which is weak among those whose source is non-terrestrial

[Revised Semantics]

■ Compositional Semantics [time-sensitive version]

Basic idea: the time parameter can do double duty, playing also the role of the alarm parameter of the 1st model.

For any model M , situation s (whose time of occurrence is $\text{time}(s)$), time t , word w , and string S ,

a. $[[w]]^{M, s, t} = 1$ iff $I_{M, s, t}(w) = 1$ and the alarm level is at least $t - \text{time}(s)$.

b. $[[w S]]^{M, s, t} = 1$ iff $[[w]]^{M, s, t} = 1$ and $[[S]]^{M, s, t+1} = 1$

[Revised Semantics]

■ $[[\text{hok krak-oo}]]^{M, s, 0} = 1$

iff $[[\text{hok}]]^{M, s, 0} = 1$ and $[[\text{krak-oo}]]^{M, s, 1} = 1$,

iff $[I_{M, s, 0}(\text{hok}) = 1$ and the alarm level is at least (0-time(s))]
and $[I_{M, s, 1}(\text{krak-oo}) = 1$ and the alarm level is at least 1-
time(s)],

iff $I_{M, s, 0}(\text{hok}) = 1$ and $I_{M, s, 1}(\text{krak-oo}) = 1$ and the alarm level
is at least 1,

iff at time 0 the caller of s is alert to a disturbance whose
source is non-terrestrial and at time 1 the caller of s is alert to
a disturbance that is weak among those that license *krak* and
the alarm level is at least 1.

Pragmatics

■ Pragmatic Scales

krak, krak-oo, hok, hok-oo are alternatives to each other

■ Strengthened meanings

For every word w , we write as \underline{w} the strengthened version of w , and take its meaning to be given by:

for all situation s and time t ,

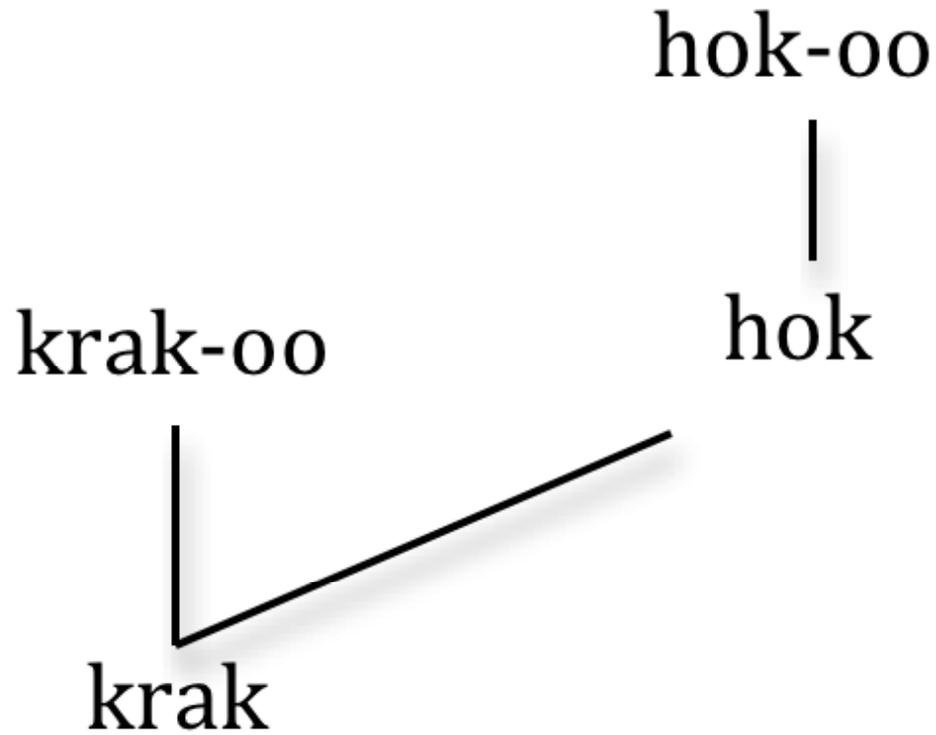
$$[[\underline{w}]]^{M, s, t} = 1 \text{ iff } [[w]]^{M, s, t} = 1$$

and for all $w' \in \text{Alt}(w)$, if w' asymmetrically entails w ,

$$[[w']]^{M, s, t} = 0$$

where $\text{Alt}(w)$ is the set of alternatives of w .

Pragmatics



Pragmatics

- $[[\underline{\text{krak}}]]^{M, s, t} = 1$
iff $[[\text{krak}]]^{M, s, t} = 1$ and
 $[[\text{krak-oo}]]^{M, s, t} = 0$ and
 $[[\text{hok}]]^{M, s, t} = 0$
iff at t **the caller of s is alert to a terrestrial disturbance
which is serious among all disturbances.**

- $[[\underline{\text{hok}}]]^{M, s, t} = 1$
iff $[[\text{hok}]]^{M, s, t} = 1$ and $[[\text{hok-oo}]]^{M, s, t} = 0$
iff at t **the caller of s is alert to a serious aerial
disturbance.**

Tai forest vs. Tiwai island

■ Strengthening avoidance

If at a site M , for every situation s in M , for every time t , $[[\underline{w}]]^{M, s, t} = 0$, one should interpret an utterance of w without strengthening.

■ Tai

Strengthening usually applies \Rightarrow **krak** usually refers to leopards

■ Tiwai

Strengthening doesn't apply \Rightarrow **krak** has its innate meaning of general alert.

Conclusion on Campbell's Calls

- a. Simple morphological structure (and unclear syntax!)
 - boom** is never suffixed;
 - krak, hok, wak** can be suffixed with **-oo**.
- b. It is possible that calls and **-oo** have a regular meaning.
- Apparent dialectal difference between Tai and Tiwai:
 - Theory I:** lexical difference => some lexical acquisition
 - Theory II:** context-sensitive strengthening rule
- **2 arguments for Theory II:**
 - a. If the meaning of **krak-oo** is **compositionally** derived from **krak + -oo**, **krak** must have a general meaning **even in Tai**.
 - b. In Tai, **krak** is (arguably) sometimes a general alarm.

Raptor-specific vs. General Calls

- **Raptor-specific vs. Ground predator and other threats**
"Interestingly, across species it tends to be the call associated with terrestrial predators that is given in other contexts, whereas the call associated with arial predators tends to be context-specific ... " (Wheeler and Fischer 2012)
=> lemurs, Capuchin monkeys, tamarins
- **Example: Two species of lemurs (Madagascar)**
Red-fronted lemurs and white sifakas
"both species gave specific alarm calls only in response to raptor playbacks and the corresponding alarm calls, whereas calls given in response to carnivores and the corresponding alarm calls were also observed in other situations characterized by high arousal." (Fichtel & Kappeler 2002).