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LANGUAGE EVOLUTION: COMPETING SELECTIVE SCENARIOS

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ABSTRACT

The recent blossoming of evolutionary linguistics resulted in a variety of theories that attempt to provide a selective scenario for the evolution of early language. There are scenarios focusing on almost all of the possible uses of human language one can think of: mate choice, mating contract, pair bonding, parent-offspring communication, gossip, rituals, grooming, tool making, and hunting. This is definitely a positive change after the infamous ban of the French Academy of Sciences; however, the overabundance of these theories makes many researchers sceptical towards such theorising. We think, agreeing with the sceptics, that a more rigorous approach is needed towards the construction of such theories. Despite the well-founded scepticism there is no agreement as to what criteria should be used to evaluate the validity of the various competing theories. Here we would like to fill the gap and provide a guideline upon which the various historical narratives can be judged. Some of these criteria follow from our evolutionary stance, some follow from biological and historical constraints, and others follow from common sense and the latest results of game theory. None of these criteria is highly constraining in itself, but we think that taken together these criteria can provide a powerful evolutionary framework to think about the evolution of human language.

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1 Introduction

The issue of the origin of human language always provided a fertile ground for speculation and various alternative theories (see Box 1). “History repeats itself” as the saying goes, and just as a rapid boom of theories and speculations occurred after the publication of Charles Darwin: “The Origin of Species” [11], so as today we can observe an almost rabid increase of alternative theories. However, different people in different times react differently to the same situation. The first boom of theories resulted the infamous ban of the French Academy of Sciences that prohibited any discussion of the issue within academic circles. Today there is less incentive to ban the issue, however today’s scientists are just as puzzled seeing the plethora of alternative theories as their French colleagues might have been back in the XIX century. The main reason why this issue still remains a puzzle and why it provides fertile ground for speculation is that we know very little about the first steps of the evolution of human language, and not just about language but about the relevant anatomy and genetics of humans that first started to use language.

The problem of the origin of language is of course of the utmost importance [9]. This transition happened only in one lineage and is therefore unique, and in this respect has the status of the origin of the genetic code and the emergence of eukaryotic cell [40]. It has led to the emergence of a novel inheritance system [26], which opened up the possibility for cumulative cultural evolution and the beginning of history [41]. Moreover, this novel inheritance system has allowed for the emergence of a much more complex society than anytime before: human society rests on negotiated division of labour and the collaboration of large non-kin groups [18,25].

The normal course for a review like this would be to give a list of the alternative theories and then give a set of criteria upon which these theories can be evaluated. However, in this case it is hardly possible. We know very little about how language evolved, and there is no comparable analogous process in nature. Thus, it is hard to come up with a fool-proof set of criteria that could select the “grain” from the “chaff”, the good theories from the bad. So instead of giving such a set of criteria, we review what we do not know, mostly because this is the only safe way to proceed.

2 What we do not know about the evolution of human language

1. We do not know the exact anatomical changes that paralleled language evolution; moreover we do not know whether these changes (if any) were the cause or the consequence of language evolution.
2. We do not know the context in which language evolved.
3. It follows that we do not know what communication was about.
4. It also follows that we do not know the first words.
5. We do not know what cognitive skills are sufficient and necessary for language to evolve; furthermore we do not know which cognitive skills can co-evolve with language.
6. We do not know what part or what faculty of human language is genetically determined (if any) and what parts are transmitted culturally. It follows that we do not know the exact genetic background of human language.
7. We do not know why our ancestors started to use a conventional communication system instead of the traditional self-reporting signals used by the majority of animals. That is, we do not know the exact selective forces that favoured this

kind of system of communication as opposed to the “traditional” animal communication systems.

8. We do not know why human language is unique, i.e. why none of the other living species has a comparable communication system, despite of the fact that some can learn the rudiments of human language, and despite of the fact that there are contexts in which such system of communication could be beneficial for them.
9. We do not know what neurobiological features of the human brain enable us to acquire and process language so efficiently.

In the light of this lack of knowledge and relevant information it is hardly surprising that the wildest speculations can be put forth about the origin of human language. Not surprisingly this triggered a strong scepticism toward such theorising [2,32]. One might ponder whether the French got it right, after all “Ban the issue till we got enough information!” is a reasonable and obvious reaction. Reasonable it may be, yet it is not the most satisfying solution for a scientist. Thus, here we would like to follow a different course of action and would like to review the possible remedies of the above-mentioned lack of information, the current (sorry) state of our knowledge, and what it could mean for the competing theories. We believe that understanding better what exactly we do not understand is a valuable hint for future research. Given the nature of the review we would like to focus on points 2, 3, 4, 7, and 8 from the above list.

2.1 The context of language evolution

Most of the theories that suggest a given context try to account for the functional role of human language. It is not that difficult to come up with a context in which human language plays a functional role, one just has to look at various contexts of language use today. Accordingly, there is a theory for each such context: mate choice, mating contract, pair bonding, parent-offspring communication, gossip, rituals, competing for status, grooming, tool making, and hunting (see Box 2). So, simply based on the functional roles it is nearly impossible to decide on the usefulness of these theories.

Is there any other piece of information we might be able to use? Luckily, the answer is yes, and this criterion can be suggested from recent game theoretical research. Namely by studying the question of honesty of communication (see Box 3) one can make the following conclusion: an honest communication system using cost-free signals can be evolutionarily stable at the equilibrium either if there is no conflict interest between the participants [39] or if the signal cost is a function of the quality being signalled [38]. Since human language is a conventional communication system, implying that there is no casual relationship between the information content and the form of the signal this latter option can be excluded. While, of course we know that human language is being used in situations in which there is a conflict of interest between participants, we also know that communication under these assumptions is by no means honest. We also know that under these circumstances (i.e. conflict of interest) additional cues, costs and even social institutions are used to bolster the honesty of communication [61]. While the theory so far says nothing about the evolution of such systems of communication, there are a few computer simulations that suggest that honest cost-free communication can evolve only if there is shared interest between the participants [3,29,45]. Of course, this does not exclude automatically all the contexts in which there is conflict of interest, but in such cases the theory should be able to specify those additional cues, costs or

institutions that could reinforce the honesty of communication. Also the theory in such cases must be able to explain how is it possible for conventional communication to “take off from the ground” in a situation potentially ripe for exploitation. All in all, the most obvious and the easiest assumption to defend is the assumption that language evolved in a context in which there was shared interest between participants.

A related question is how this shared interest did arise in the first place. The origin of cooperation is an issue that deserves an article on its own, it is sufficient to say here that there are several (non-exclusive) alternative theories, such as: image scoring, reputation building, punishment of the cheaters, altruistic punishment, ostracising, etc. [28,19,40, 7,48,49]. It is worth noting, however, that some of these theories assume linguistic transfer of information (e.g. reputation building). Thus the task is to find a situation in which shared interest can exist without the help of language.

Actually there are a number of theories that try to account for shared interest [37,53], and there are others that suggest situations with inherently shared interest (such as group hunting), but also there are theories that propose scenarios with conflict of interest (sexual selection, mating contract [13,43]) and do not give any hint about the forces that could reinforce the honesty of the communication system in such context.

2.2 What was communicated?

Even in a given context it is not obvious what was communicated, especially if there was conflict of interest between participants. Some of the theories make explicit statements about the assumed information content of early linguistic communication;

some others leave us in the dark. The suggested information content can be classified into the following categories:

1. Socially important information about the state and behaviour of group members (gossip, status for information, [53,14]).
2. Information about the relevant states of the environment (status for information, hunting theories, [14,34]).
3. Future behaviour (mating contract, [13]).
4. Contact call – information about the proximity of group members (“motherese”, [17]).
5. Social bonding - no information content (grooming, [15])

Finally, there are theories that give no hint at all about the content of communication. Such theories are as follows: mental tool, sexual selection, song theory, group bonding/ritual [4,43,60,37].

Even in case of those theories that give some hints as to the content of communication there are various problems; we consider them in turn referring to the above list: (1) The first situation involves conflict of interest; there is no guarantee for reliable information. (2) This situation can be solved by pointing or by simpler other-reporting signals (like the dance of the bees [42]). (3) This proposal is highly impossible (see the issue of groundedness below). (4) There is no need for complex language (symbolic, referential, etc) to solve this problem. (5) Still something had to be transmitted, what was it?

2.3 First words

We have no information whatsoever about the nature of the possible first words. However, recently there were several attempts to model the evolution of words [56]. These experiments show that one of the crucial criteria of the successful evolution of referent-reference pairs is the so called “groundedness” ([56], see Box.2.). Groundedness implies that the agents playing the “naming game” ([56], see Box.2.) should be able to refer to the referent other than by linguistic means, for example by pointing. Assuming pointing as the most obvious means to refer to things in the environment, this means that the referent should be visible for both participants.

Most of the theories do not bother with groundedness and either boldly propose highly abstract words as the first tokens such as “faithful” or “philander” (gossip [53], “faithfulness” (mating contract [13]) or do not say anything about the possible first words (almost all). Only the motherese and the hunting theories suggest words (“mama” and names of prey animals, respectively) that can be easily grounded in reality. However, in case of motherese this would imply that actually it was the babies and not the mothers who “invented” language! (Also, in many social animals young can call their parents but this has never led to the evolution of symbolic, recursive and socially transmitted system of communication.) So it is reasonable to say that from the point of groundedness hunting theories do the best.

2.4 Selective forces behind language evolution

Most of the theories do not consider the kind of selective forces that could encourage the use of conventional communication in the given context instead of the use of

„traditional” animal signals. The vast majority of contexts put forth to explain language evolution can be found in animals. Mate choice, pair bonding, contact calls, parent-offspring communication all feature prominently in the lives of thousands and thousands of animal species [31], yet none of the evolved a communication system comparable to human language. For example, chimpanzees have fascinating and complex social lives [63], yet they have failed to evolve a complex system of symbolic communication, although arguably they would benefit from gossiping. There is a rich tradition of alliance making/breaking, peace making [63], in general the kind of social life that some would propose as the cradle of language evolution [53]. Also, there are group living mammalian predators capable of coordinated hunting, yet they can solve this problem without any system of symbolic communication. Last but not least, the primary skill for reliable tool making is precise imitation and this is what one can find in humans compared to other primates (see artificial fruit experiments [44]).

All in all, there is not a single theory that would convincingly explain why the given situation required a complex system of symbolic communication instead of the existing much simpler communication systems.

2.5 Why is human language unique?

Given the uniqueness of human language one should be able to explain why other species living under somewhat similar conditions did not evolve language. The fact that no other species evolved the equivalent of human language strongly suggests that human language is a special adaptation. Hurford [35] argues in favour of a similar approach: “... in general, more realistically and more eclectically, for any set of circumstances proposed as individually necessary and collectively sufficient to explain the emergence

of Language, one has to show that this combination of circumstances applies (or applied) to humans and to no other species.”

It is instructive to compare language with other evolutionary transitions. In contrast to multicellularity and eusociality, for example, the genetic code, the eukaryotic condition and natural language seem to be unique evolutionary innovations [40]. Uniqueness must be treated with care in these examples. It just means operationally that we do not know of any successful trials in independent lineages [58]. Researchers tend to assume that unique transitions are ‘difficult’. There are two kinds of difficulty: objective and subjective. An objectively difficult transition is one that was the result of a series of unlikely events in evolution. A transition may be easy for evolution but difficult for us to understand: this is the subjective kind of difficulty. Objective difficulty, by its nature, causes subjective difficulty but not necessarily the other way round. We think that the emergence of language was an objectively difficult transition, but even this can have two sources: one can distinguish between variation-limited and selection-limited difficult transitions, although a transition can be difficult from both aspects at the same time [58]. It seems that, for example the origin of the eukaryotic cell was variation-limited [5]. Whether the same holds for language is open for debate.

Some regard the origin of language as the hardest problem in science [9], partly because three relevant time-scales are interwoven: those of phylogeny, ontogeny and learning (cultural transmission). Given the fact that the chimp and human genomes (setting neutral variation aside) are rather similar [62], one is left with the feeling that relatively few (probably regulatory [57]) genetic changes were involved that affected the language faculty. Primates can learn rather well, which shows that some of the skills are there. History of evolution shows that a particular highly complex organ or behaviour can evolve several times provided that there is strong selection for it (for example:

evolution of the eye, evolution of flight, evolution of sociality, evolution of reproductive division of labour: these examples even offer striking examples of evolutionary convergence [8]). This may suggest that it is the unique context and selective pressure that is responsible for the uniqueness of the human language.

As it happens most of the scenarios do not even consider the issue of uniqueness, or just explain it (away) with a few words (e.g. the “song theory” [60]). This is related to the previous point: namely, the lack of explanation of proper selective pressure. Thus, it still remains a challenge to identify a sequence of selective pressures that could explain both the uniqueness and the gradual evolution of human language.

3 Conclusions

Explaining the evolution of human language is likely to remain a challenge for the coming decades. As we have seen, there is not a single theory that could sufficiently answer all the questions about uniqueness, selective pressure, and groundedness (see Table 1. for summary). Yet some theories do better than the average, capable of providing some answers to at least four out of the six questions. These are the “tool making”, and “hunting” theories [24,34]. It might be a safe bet to say that some combination of these theories could provide a set of selective scenarios that would fit all of our criteria.

It is a striking fact that, although the different scenarios suggest all kinds of selective forces, none of these scenarios has been consistently implemented in a family of models. Given the limitations on experimentation on humans and chimps in all kinds of domains (neurobiology, genetics, etc.), one should really seriously consider implementing the different scenarios in various model-based settings. Ultimately, one should be able to re-enact the emergence of language in artificial worlds, many of which will probably involve robots [16]. The reason for the latter statement is that embodiment offers a unique and probably indispensable way of grounding and somatosensory feedback [20].

We cannot go into assessing the difficulties of such ambitious research projects, we just mention that the tasks that the agents will be subjected to imply a complicated fitness landscape, which is similar to climbing not a hill but a *staircase*: a good capacity for imitation is probably coevolving with the capacity of learning symbols (words), which then opens up the possibility for climbing to the first level of syntax [27].

The only process that has solved the ‘language problem’ is evolution by natural selection. But there is no guarantee at all that just any kind of selection scenario, even if

implemented *in silico* will lead to the origin of such a faculty, partly due to the results of the analysis presented in this review, partly because of what is known as the ‘no free lunches theorem’ [65]. Put simply, the latter says that the efficiency of an evolutionary search process is very much dependent on the problem. Putting constraints on the selective scenarios may constrain the search space to such an extent that simulated evolution will in fact be able to re-enact this fascinating evolutionary transition.

4 Glossary

Conventional communication system: a communication system using conventional signals; i.e. symbols.

Gestural communication: non-verbal communication that should not be confused with sign languages. Gestures are used everywhere in our everyday life, they confer additional information about the motivation, emotional state, feelings of the signaller, and can act as “meta-signals” by altering the meaning of verbal communication.

Groundedness: the ability of the agents to relate the sign with the referent by non-verbal means (for example by pointing).

FLN – the faculty of language in a narrow sense: unique aspects of language.

FLB - language faculty in the broad sense: aspects shared by other faculties or can be found in other organisms.

Major transitions: Radical changes in evolution in the way how heritable information is stored, used and transmitted. It is accompanied by formation of higher level units of evolution. Local interactions and division of labour/combination of functions also play an important role.

Naming game: a game in which agents have to evolve a shared set of conventions to name frequently observed features in their environment.

Other-reporting signals: signals that carry information about the (living or non-living) environment; only a small fraction of animal signals fall into this category, most notably the “dance of the bees” and the alarm calls of vervet monkeys.

Pre-adaptation: an organ/behaviour/morphological feature, selected for some function, is used in a different context for some other function to solve a new ecological/social/cognitive problem; sometimes called “exaptation”.

Selective scenario: a series of adaptive steps in a particular ecological and/or social environment that can result in certain (set of) traits.

Self-reporting signals: signals that carry information about the state, motivation or future behaviour of the signaller; the majority of signals used by animals fall into this category.

Sign languages: symbolic communication system built on visual signs instead of vocal signs. They are the visual equivalents of spoken languages, should not be confused with gestures.

5 BOX 1. Theories of language and language evolution

Theories of language and language evolution can be divided into two paradigms respectively. A nativist vs. empiricist account and a non-adaptationist vs. adaptationist account [55].

The nativist paradigm argues that language capacity is a collection of domain specific cognitive skills that are unique to humans and somehow encoded into our genome. Perhaps the most famous proponent of this approach is Noam Chomsky, who coined the term “language organ” and argued fiercely in favour both of the uniqueness and of the innateness of human linguistic skills [6]. Interestingly Chomsky is in the same camp with most of the biologists on this issue [50,51,40,27,52].

The empiricist paradigm, on the other hand, argues that linguistic performance of humans can be explained with domain-general learning techniques [54].

Non-adaptationist accounts of language evolution rely heavily on the so called “spandrels” [23]. Chomsky again features a prominent role in this debate as the protagonist of the non-adaptationist paradigm. In the latest reformulation of the theory [33], he and his colleagues make a distinction between the so-called FLB and FLN (see Glossary). They argue that while FLB consists of skills that evolved in other animals not just in humans; FLN consists of only one skill: merge, and that this skill is not the result of selection for communication, rather it evolved in a different (unspecified) context and was only co-opted for linguistic use.

The first adaptationist account of human language comes from Darwin himself [12]. As usual it took a long while to pick up the gamut where Darwin left it, but eventually it was Pinker & Bloom [51] who defended in their influential paper the Darwinian account of

language. More specifically, they have argued that language as any of the complex adaptations can be explained only by means of natural selection. This paper catalysed many linguists and biologists to study language and language evolution from the perspective of evolutionary biology and were followed by many influential papers and books [40,27,10,36]. Most recently Jackendoff & Pinker [52] made a forceful defence of the adaptationist paradigm in response of Hauser et al [33].

6 BOX 2. List of alternatives theories put forth to explain the context of language evolution

Language as a mental tool: There is growing interest in viewing language as a mental tool, primarily evolved for the function of thinking and only later co-opted for the purpose of communication [4].

Grooming hypothesis: Dunbar [15] suggested that language evolved as a substitution for physical grooming. The need for this substitution derived from the increasing size of the early hominid groups.

Gossip: Power [53] suggests that menstrual ritual can be a costly signal of commitment; hence participating in such rituals can create female groups of shared interest in which sharing information about the social life of others (i.e. gossiping) can be beneficial.

Tool making: Greenfield [24] argues in favour of a double homology: “a homologous neural substrate for early ontogeny of the hierarchical organisations shared by two domains – language and manual object combination – and a homologous neural substrate and behavioural organisation shared by human and non-human primates in phylogeny.” Based on this homology Greenfield concludes that the most consistent explanation for language evolution is to assume that language evolved in parallel with tool making skills.

Mating contract/ pair-bonding: The core of Deacon’s [13] argument is that: „Group living and male provisioning can occur together only in instances where reproductive access is completely limited and unambiguous, as in the case of social carnivores.” Thus, the increasing size of the early human groups and the need for male provisioning created a need for a “social contract” between males and females.

Sexual selection: Miller's [43] basic argument is that language is a costly ornament that allows females to assess the fitness of a male in the same way as the peacock's tail. According to Miller, language is much more elaborate than what a pure survival function would require, and humans in general talk way too much, and give information away way too often for it to be explained either by reciprocity or by kin selection.

Status for information: Dessalles [14] argues that language evolved in the context of a so-called "asymmetric cooperation" where information was traded for status. Individuals that made relevant "statements" about their environment or about other individuals enjoyed higher status that benefited both the high status individual and the coalition/group of the high status individual.

Song hypothesis: Vaneechoutte & Skoyles [60] in their memetic theory of language argue that "all preadaptation for language production and language understanding were naturally selected for other reasons than language, wherefrom language emerged and evolved rapidly and only recently by a process of cultural evolution." They distinguish two important sets of preadaptations: one is the ability to sing; the others are better representation abilities (thinking, mental syntax).

Group bonding/ ritual: According to the ritual/speech co-evolutionary theory [37] language evolved in the context of inter-group rituals. These rituals emerged on the first place as a kind of "strike-actions" against non-provisioning males. According to Knight, females signalled a "wrong species/sex/time" image to the males to refuse mating this way. Once group-level rituals were established, a "safe" environment was created for further language evolution.

Motherese: Falk [17] suggested that the first words of human language evolved in the context of mother-child communication. According to her, mothers had to put down

their babies in order to collect food efficiently, and their only option to calm down babies was to use some form of vocal communication.

Hunting theories: In their influential paper Washburn and Lancaster [64] argue: “our intellect, interests, emotions, and basic social life – all are evolutionary products of the success of the hunting adaptation.” Later Hewes [34] in his equally influential paper about the gestural origins of language takes up the idea and argues that the probable first use of language was to coordinate the hunting effort of the group.

7 BOX 3. The problem of honesty

There is an ongoing long debate about the honesty of animal communication. The debate centres around the proposition that signals need to be costly in order to be honest [66]. While some models seemed to prove this statement [21,22,39], others were able to show that even under conflict of interest cost-free signals can be evolutionarily stable provided certain conditions are met [1,30,59]. One of the important results is that cost-free signals, in general, are expected to be evolutionarily stable provided that there is no conflict of interest between the communicating parties [39]. In line with this result recent game theoretical investigations strongly suggest that prominent features of human language could arise under shared interest but could not arise under conflict of interest. On one hand, a number of models show that some key features of human language can evolve provided that there is no conflict of interest between the participants [46,47]. On the other hand, Lachmann et al. [38] were able to show that human language can be used honestly even if there is a conflict of interest between the participants. However, no one has been able to show that the key features of human language can evolve under conflict of interest. The problem with conflict of interest situations is that they are very vulnerable to exploitation, which can manifest itself in dishonesty or cheating, which in turn might ruin the signalling system. This logic was confirmed by various computer simulations of a simple communication game [3,29,45]. These simulations show that communication evolves only if there is no conflict of interest between signaller and receiver.

8 BOX 4. The problem of groundedness

Steels and his colleagues [56] studied the formation of word-meaning coupling using agent-based experiments. Agents play the so called “naming” (or guessing) game, during which word-meaning pairs evolve autonomously in a population of agents. The game itself is very simple. It consist a pair of agents: one is the speaker the other is the listener. The speaker “thinks of” an object out of a set of available objects (this set is known to the listener) and gives it a name which gives the highest chance, according to the speaker, that the listener can find out which object was picked by the speaker. If the listener’s understanding is successful then this word-meaning pair is reinforced in both agents, if not then the link is weakened. Steels and his colleagues [56] have identified the following internal conditions (i.e. conditions that the agents should fulfil) in order the game to succeed: (1) agents must be able to engage in coordinated interactions; (2) agents must have parallel non-verbal ways to achieve the goals of interactions (for example pointing); (3) agents must have ways to conceptualise reality and to acquire these conceptualisations, constrained by the semantic concepts expressed in the emerging lexicon and the types of situations they encounter; (4) agents must have ways to recognise word forms and reproduce them; (5) agents must have the ability to discover and use the strongest associations (between words and meanings) in the group. The second and third points are especially noteworthy given that these points imply that abstract concepts (which cannot be pointed at and are not very easy to conceptualise) are highly unlikely to be signalled by the first words.

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Table 1. The properties and the explanatory power of the various theories. We ask the following questions to evaluate the various alternative theories: (1) Selective advantage - Does the theory provide any explanation for the selective advantages that the subsequent small steps offered for the language users? (2) No conflict of interest - Can the theory account for the honesty of early language, that is, is there a shared interest between the proposed communicating parties? (3) Concepts grounded in reality - Can the concepts proposed by the theory grounded in reality? (4) Expressive power - Can the theory account for the power of generalisations unique to human language? (5) Uniqueness - Can the theory account for the uniqueness of human language? (6) Origin of cognitive capacities - Can the theory account for the cognitive abilities necessary for language use? (Mod.: modality; T: thought, V: vocalisation, G: gestures)

	Mod.	first words	topic	#1	#2	#3	#4	#5	#6
1. Language as a mental tool	T	?	?	no	yes	no	yes	no	no
2. Grooming hypothesis	V	?	?	no	yes	no	no	no	no
3. Gossip	V	“faithful”, “philander”	social life	yes	no	no	yes	no	no
4. Tool making	?	?	?	yes	yes	yes	yes	no	yes
5. Mating contract	?	?	social contract	no	no	no	no	no	no
6. Sexual selection	?	?	anything	yes	no	no	no	no	no
7. Status for information	?	?	valuable information	yes	no	no	yes	no	no
8. Song hypothesis	V	?	?	no	no	no	no	yes	no
9. Group bonding/ritual	?/V	?	?	no	yes	no	no	no	no

10.	Motherese	V	"mama"	contact call	no	yes	yes	no	no	no
11.	Hunting theories	G/V	prey animals	coordinati on of the hunt	yes	yes	yes	yes	no	no