Protolanguages that are Semi-Holophrastic

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Abstract. There is an ongoing debate about whether the words in the first languages spoken by humans expressed single concepts or complex holophrases. A computer model was used to investigate the nature of the protolanguages that would arise if speakers could associate words and meanings, but lacked any productive ability beyond saying the word whose past uses most closely matched the meaning that they wished to express. It was found that both words expressing single concepts, and holophrastic words could arise, depending on the conceptual and articulatory abilities of the agents. However, most words were of an intermediate type, as they expressed more than a single concept but less than a holophrase. The model therefore demonstrates that protolanguages may have been of types that are not usually considered in the debate over the nature of the first human languages.

Keywords: Language Evolution, Protolanguage, Synthetic, Analytic, Holophrasis, Iterated Learning.

1 Introduction

Non-human apes do not have the ability to use language, so that ability must have evolved since the human lineage split from that of the other apes. However, it seems unlikely that the first languages that arose had the full complexity of modern human language. Instead it seems more likely that initially languages were very simple, and that humans gained the ability to use more complex language only as a result of further phylogenetic changes.

One of the most distinctive characteristics of modern languages is the complexity of their syntactic structures. Syntax extends the expressiveness of languages, by allowing the meanings of utterances to be related to the structures in which words are used, not just to depend on the words themselves. However, syntax would be of little use unless there already existed meaningful words that could be combined using syntactic rules. Therefore, it seems that humans must have evolved a capacity to associate words with meanings before they evolved the ability to use syntax. Bickerton [3, 4] has termed such pre-syntactic communication systems *protolanguages*.

If we are to determine the nature of these protolanguages, we need to first determine the kind of cognitive abilities humans had immediately prior to their

development. Probably the most relevant evidence for this comes from the cognitive abilities of other apes, and in particular their linguistic capabilities. The human lineage split from that of bonobos and common chimpanzees after the common human-chimpanzee lineage split from the lineages leading to present day gorillas and orangutans. Therefore we can assume that any ability to use language that is common to all non-human great apes was also possessed by the last common ancestor of both humans and chimpanzees [5]. (The alternative is that the ability later evolved separately in gorillas, chimpanzees and orangutans, which seems much less likely.)

Non-human apes do not use anything resembling human language spontaneously in the wild, but several attempts have been made to teach some form of language to captive chimpanzees and gorillas [12, 16, 13, 8]. These studies have shown that while apes have only a very limited ability (if any at all) to use syntactic rules to structure their language, they are much better at learning associations between words and meanings. So long as the words are presented in an appropriate modality (for example using manual gestures, or a lexicographic keyboard) apes can also use the words that they have learned productively, although, unlike humans, they rarely use language spontaneously [16]. When trained apes produce language, rather than choosing the minimal set of words necessary to convey the meaning that they wish to communicate, they appear to simply to use any words relevant to the meaning, without paying attention to whether the whole of the meaning is conveyed, or whether some part of the meaning is conveyed more than once. For example, one trained chimpanzee, Nim Chimpsky, once uttered 'give orange me give eat orange me eat orange give me eat orange give me you' [16, p210]).

We can therefore presume that the last common ancestor of humans and chimpanzees also had such latent abilities, but like modern day non-human apes, did not make use of them. From such a starting point, the only evolutionary change that would have had to have taken place in order for languages to emerge would have been for a tendency to spontaneously use language in the absence of explicit training to have evolved. We could expect that this would have resulted in the emergence of protolanguages with little or no syntax. When speaking, like trained apes, the users of those languages would simply have uttered any words whose meanings were related to the proposition they were trying to express. This paper reports research that used a model of speakers with this kind of language ability to determine what kinds of properties protolanguages emerging in this situation would have had.

The words in the languages spoken by trained apes, are similar to open class words in modern languages, in that they mainly refer to objects such as bananas, or to actions such as tickling. Bickerton [3, 4], Carstairs-McCarthy [6] and Tallerman [15] have argued that the words in protolanguages would have had similar meanings. However, Wray [17, 18] and Arbib [1] have made a quite contradictory proposal, suggesting instead that words in protolanguages would each have expressed a complex holistic meaning, such as '*give us the meat*' [17, p51]. Wray supported her proposal by noting that this kind of word seems to be a natural progression from the kind of communicative signals used by other animals. For example vervet monkeys have an alarm call for eagles, but the meaning of the signal would much better be translated into English as *beware of the eagle*, than as the English word *eagle*, as it can only be used to warn that an eagle is present, and never simply to refer to the concept EAGLE in the abstract, as the English word can.

Previous multi-agent models have been used to study the evolution of human languages [14, 2, 10, 11, 9]. Steels et al [14] simulated the evolution of asyntactic languages in which words could have either holophrastic meanings denoting ranges of values on several different sensory channels, or simple atomic meanings corresponding to a range of values in single sensory channel. However, it seems that a single word with an atomic meaning was usually sufficient to satisfy the communicative needs of Steels et al's agents (which was simply to distinguish a target referent from a context of other objects), so all the most commonly used emergent words consequently had atomic meanings. In other models [2, 10, 9] there was a transition from holistic protolanguages to fully syntactic languages, but in these models the agents had the ability to use syntactic language built in from the very start. It therefore took only a cultural evolutionary process for syntactic languages to evolve. Such models could therefore correspond to a point just after the human capacity for syntactic language had emerged, but before humans had used that capacity to actually create a syntactic language. However, they do not directly address the question of what kind of protolanguage humans lacking an ability to use syntactic language would have spoken.

The model reported here assumes that initially humans tried to use language to express only a limited range of the meanings that were of most importance to them. These meanings might have included concepts such as eating, hunting, and the kinds of animals that early humans ate and hunted. It seems reasonable to assume that initially humans had only a limited ability to remember, articulate or perceive distinct words, as the ability to do any of these things would have come under selective pressure only once language had come into use. It would have been possible for early humans to have used only as many words as the number of distinct sounds that they were able to articulate, but cognitive learning or memory limitations might have further restricted the number of words that they were able to use. Modern human language are able to contain many thousands of perceptually distinct words, because each word is made up of a sequence of discreet phonemes, but it would seem unlikely that the ability to use phonemic language was selected for before protolanguages came into use. The ability to use only a limited number of words was therefore incorporated into the computer model in order to reflect this presumed communicative limitation of early humans.

2 A Model of Protolanguage

The computer model was a very simple expression-induction model [9], which contained ten agents, each of which was able to express meanings by choosing from amongst the words it knew, and to learn new words, and new meanings for words, by observing other agents' use of those words. Each agent was present throughout the whole simulation, so the simulations represented the creolization of a language in a single generation. This contrasts with the work of Dowman [7], which reported an iterated learning model in which protolanguages were passed from generation to generation along a chain of agents, but in which there was only a single agent in each generation. These models incorporate complementary aspects of the process by which

language is passed between individuals in a society, and so any results obtained with one model will be reinforced if similar results are obtained with the other.

Meanings were created at random for the agents to communicate to one another. Each meaning was composed of a small number of individual concepts (four in the case of the results reported in this paper) from a set of ten basic concepts. No constituent concept ever occurred more than once in any complex meaning, and all concepts were chosen with equal probability. Different orderings of the same meanings were not treated as significant.

While this approach clearly neglects many aspects of word meaning, including the role of context and the active role that language users may take in interpreting word meanings, it was sufficient to create a wide range of possible complex propositions that the agents could try to communicate. For example, MAN CHILD ANTELOPE SEE could be taken as a representation of the English phrase *A boy sees an antelope*, although it does not convey as much information as the equivalent English sentence. (In particular tense and number information is absent, and it does not make explicit which semantic role is filled by which participant, or even that it the man that is a child, rather than the antelope.) This form of meaning representation was used to simulate an ability, or a propensity, to express only a limited number of simple meanings, on the assumption that humans would initially have tried to communicate only simple messages.

The agents' limited capacity regarding the number of words they were able to use was simulated simply by limiting the number of distinct words available to the agents in the model. Each word was assumed to be completely distinct, so the agents would never confuse one word with another. Each communicative interaction took place between one randomly selected agent, and one other different randomly selected agent, each agent being selected with equal probability. The speaker would be given a meaning to express, and in response would say one or more words which it associated with that meaning.

In order to learn words in the absence of explicit instruction, people must be able to infer the meaning that a word is intended to convey on at least some of its occasions of use. Therefore, each time a word was used in the simulations, the hearing agent would also observe the meaning that the speaker was trying to express, and would remember that that word had been used to express that meaning. However, the agents were given no indication of which part of the meaning corresponded to which word. Agents would only remember the ten most recent uses of each word, in order to simulate a limited memory capacity, and a preference for updating their internal knowledge of language to reflect recent usage. The agents' knowledge of language therefore consisted of a list of words, and a list of up to ten complex meanings that the agent has observed the word being used to express. (The same complex meaning would be paired with a word more than once if the agent heard the word used to express exactly the same meaning on more than one occasion.)

When agents spoke they simply compared the meaning they were trying to express to the examples of the use of each word that they remembered at that time, so that they could say the words that in the past had been used to express meanings most similar to the target meaning. In order to achieve this, a degree of match was calculated for each word for each of the concepts in the meaning to be expressed, by finding the proportion of meanings that the agent remembered for that word that

contained the concept. These scores were then averaged over each semantic element in the target meaning. For example, if a target meaning contained WOMAN HUNT EAT BIRD, and the agent had previously observed a word being used to express CHILD BIRD NUT WOMAN and NUT BIRD CHILD EAT, then the degree of match would be 0.5, because there are two matches for BIRD, and one each for WOMAN and EAT, out of a total of 8 possible matches. This allowed a score for the similarity of the past uses of each word to the meaning to be expressed to be obtained. These scores could vary from 1 (if the word had only ever been used to express the current meaning) to 0 (if the word had never expressed a meaning containing any of the elements in the meaning to be expressed).

If the agent knew one or more words for which the degree of match was 1, it would say them (up to a limit of three words, so a random choice of three words would be made if ever there were more than three words that matched exactly). Otherwise, if it were able to use a new word for which it had not yet observed any meanings, it would use that word. It would also remember that that word had expressed that meaning, so it would be able to reuse the same word if it ever needed to express the same or a similar meaning in the future. In all other cases, the speaker would just say the three words which received the highest scores (choosing at random in the event of ties).

In each simulation, 125,000 utterances were spoken, so that the there was plenty of time for a coherent language shared by all the agents to emerge. The analysis of the languages that emerged was based on the internal representations of the agents at the end of these simulations. The only parameter that was changed between different simulation runs was the number of distinct words that the agents were able to use, which was varied from only 10 words right up to 500 words.

3 Emergent Languages

A wide range of different types of words emerged in the resulting languages, going well beyond the holophrastic words and the words expressing single concepts that have been the focus of the debate over the nature of protolanguages. Most of the words communicated more than a single concept, but less than a complete proposition.

Table 1 shows the meanings that an agent had associated with two of the words that it knew. This agent was from a simulation in which the agents could use only ten words. The entries in this table indicate the range of meanings that other agents expressed using these words, and they would have provided the basis on which the agent would have chosen which words to say when presented with a meaning to be communicated. Looking at the meanings associated with the first word, we can see that it has been used to express propositions containing all ten basic concepts. It might seem that this word cannot therefore be said to express any single concept, but careful inspection of the meanings reveals that all of them contain the semantic element WOMAN. If this agent heard this word, its observations of its past uses would allow it to reason that the meaning that the speaker was trying to communicate included the meaning WOMAN. The agent would not gain any information about which other concepts were contained in the meaning that the speaker was trying to convey, as no other concept is present in all the entries in the table. Therefore, this word effectively

communicates the single concept WOMAN, and so can be said to have a meaning similar to the English word *woman*. This word therefore supports Bickerton' s [3, 4] claim that the words in prototypes resembled open class items in modern languages.

Table 1. Example Word Meanings when Agents could use only 10 Words.

Meanings Expressed by Word (frequency in brackets)	Description of Word Meaning
HUNT NUT SEE WOMAN (1) CHILD NUT MAN WOMAN (1) MAN CHILD HUNT WOMAN (1) WOMAN BIRD ANTELOPE NUT (1) WOMAN BIRD ANTELOPE HUNT (1) LION HUNT WOMAN CHILD (1) ANTELOPE HUNT NUT WOMAN (1) BIRD LION HUNT WOMAN (1) WOMAN MAN CHILD BIRD (1) WOMAN NUT ANTELOPE EAT (1)	Word denotes WOMAN
BIRD ANTELOPE NUT MAN (1) WOMAN BIRD ANTELOPE NUT (1) WOMAN BIRD ANTELOPE HUNT (1) BIRD SEE ANTELOPE NUT (1) NUT BIRD MAN EAT (2) CHILD BIRD NUT EAT (1) BIRD SEE MAN CHILD (1) NUT LION BIRD EAT (1) MAN BIRD NUT SEE (1)	Word denotes BIRD but carries strong connotations of NUT

The second word in Table 1 is similar, in that it also has a single semantic element that is common to all its observed uses (in this case BIRD). We might therefore consider this word's meaning to correspond simply to the concept BIRD. However, in eight of the ten remembered uses of this word, the meanings it had expressed contained the concept NUT. An agent hearing this word would therefore be able to infer that the intended meaning probably contained the concept NUT in addition to the core meaning BIRD. This word is therefore like many words in modern languages that have strong connotations of concepts that they do not necessarily express. For example the English word *incident* means an event or occurrence, but it strongly suggests the event was in some way undesirable. (This can be seen by comparing the odd sounding *fortunate incident* with the much more normal *unfortunate incident*.) This addition of an extra degree of meaning beyond the single concept which is the core meaning of the word gives this word a small degree of holophrasticity. Most words emerging in simulations in which the agents could use only ten words had meanings of one of these two types.

When agents were able to use 50 words, the meanings of most of the words were of a somewhat different type. Table 2 shows the meanings that an agent had associated with two words emerging in this condition. All the meanings associated with the first word contain both the concept MAN and the concept BIRD, so this word only expresses meanings containing both of those two concepts. This word is therefore partly holophrastic, in that it expresses two concepts instead of one, but is

not completely holophrastic as it does not convey a complete four concept complex meaning. The second word in Table 2 is slightly more holophrastic, as it always expresses both the concept MAN and the concept SEE, but it also carries strong connotations of EAT, as 8 out of the 10 observed meanings contained the concept EAT.

Table 2. Example Word Meanings when Agents could use 50 Words.

Meanings Expressed by Word (frequency in brackets)	Description of Word Meaning
WOMAN BIRD MAN EAT (2) EAT MAN SEE BIRD (2) HUNT SEE MAN BIRD (1) BIRD EAT CHILD MAN (1) NUT ANTELOPE MAN BIRD (1) BIRD WOMAN ANTELOPE MAN (1) MAN LION BIRD CHILD (1) WOMAN SEE MAN BIRD (1)	Word denotes MAN BIRD
EAT MAN NUT SEE (3) HUNT SEE MAN BIRD (1) SEE EAT ANTELOPE MAN (2) MAN BIRD SEE NUT (1) MAN SEE HUNT EAT (1) MAN SEE EAT LION (1) MAN EAT BIRD SEE (1)	Word denotes MAN SEE with strong connotations of EAT

Table 3. Example Word Meanings when Agents could use 100 Words.

Meanings Expressed by Word (frequency in brackets)	Description of Word Meaning
ANTELOPE BIRD HUNT NUT (3) EAT ANTELOPE HUNT BIRD (2) BIRD MAN ANTELOPE HUNT (2) BIRD HUNT ANTELOPE CHILD (1) ANTELOPE LION HUNT BIRD (2)	Word denotes ANTELOPE BIRD HUNT
CHILD HUNT MAN EAT (3) MAN EAT BIRD HUNT (3) HUNT BIRD CHILD MAN (1) CHILD MAN EAT BIRD (1) BIRD HUNT EAT CHILD (2)	Word has strong connotations of CHILD BIRD HUNT EAT MAN but does not denote any concept

When the number of words that the agents could use was increased still further, words with a greater degree of holophrasticity became more common, as shown in Table 3. The first word in this table is of a type common under this condition, which expresses three concepts, but does not convey any information about the final concept in the proposition being expressed. The second word in Table 3 is, however of a quite different type. This word has no meanings common to all its uses, so on hearing this word an agent could not infer that any particular concept had been expressed. This

might appear to make the word communicatively useless, but closer inspection reveals that all of the concepts its expresses come from a set of only five concepts. Therefore, any use of this word carries very strong connotations of all of those concepts, even though each communicated meaning in fact only contains four of them. This word is therefore in some ways highly holophrastic, in that it conveys information about all four concepts in a complex meaning, but it is also in some ways less holophrastic than even a word expressing a single concept, as it does not unambiguously express any single concept.

Fully holophrastic words usually only emerged when the agents were able to use a much larger number of words. Two fully holophrastic words, which expressed only a single four concept complex meaning are shown in Table 4. This is the kind of meaning that the words in protolanguages had, according to the claims of Wray [17, 18] and Arbib [1].

Table 4. Example Word Meanings when Agents could use 500 Words.

Meanings Expressed by Word (frequency in brackets)	Description of Word Meaning
EAT MAN ANTELOPE HUNT (10)	Word denotes EAT MAN ANTELOPE HUNT
HUNT BIRD SEE LION (10)	Word denotes HUNT BIRD SEE LION

Figure 1 shows the relationship between the number of words that the agents were able to use and the degree of holophrasticity of the emergent word meanings. In general, when the agents could use more words, then words with greater degrees of holophrasticity emerged. This should not be surprising, as with only a small number of words, there simply are not enough words available for a separate word to be assigned to each possible fully or partly holophrastic meaning. However, with more words, it is possible to assign a word to many far more specific meanings, allowing a wide range of holophrastic meanings to each be assigned their own words.

Depending on the number of words that the agents could use, words expressing a single concept, a two or three concept partial holophrase, or a fully holophrastic four concept proposition were the most common kind of word. However, because as noted above words can have strong connotations of concepts beyond their core meanings, there is in reality a continuum between words which have atomic meanings and those which have holophrastic meanings. Furthermore, most of the emergent languages contained a mixture of different types of words, so revealing another way in which a language can be intermediate between the type of protolanguage proposed by Bickerton [3, 4] and that envisaged by Wray [17, 18].

Figure 1 suggests that if, when language first arose, humans were able to use only a small number of words, but gradually became able to use more words as the ability to articulate, recognize and remember words came under selective pressure, protolanguage words would initially have had meanings like those in modern languages, but would gradually have become increasingly holophrastic as the number of words that people could use increased. However, clearly the degree of holophrasticity is determined by the number of words relative to the number of concepts that the agents try to communicate, so if instead the complexity of the agents conceptual capacity had increased faster than their communicative ability, there

would have been a change in the opposite direction, from words with holophrastic meanings to ones with meanings increasingly like those of modern words. As both of these abilities may well have evolved in tandem, over many generations of speakers, protolanguages could have gone through stages of being increasingly holophrastic, or increasingly like modern words. There does not seem to be any reason to assume that there could only have been a single type of protolanguage prior to the emergence of fully syntactic language.

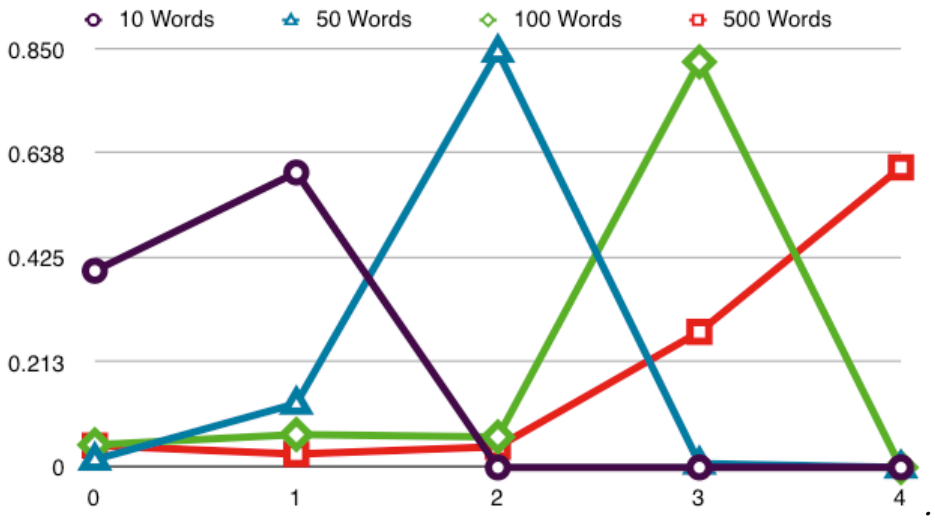

Fig. 1. The proportion of words (y axis) which had a particular number of concepts common to all their uses. These figures are averages over all ten agents in a simulation. As the number of available words increases, so does the frequency of the more holophrastic word types, while the proportion of the less holophrastic types decreases.

4 Conclusions

The research reported in this paper used the evidence we have concerning the cognitive capacities of early humans prior to their use of language to infer what kind of language abilities were most likely possessed by the speakers of the first protolanguages. By creating agents with corresponding language abilities, and simulating conversations between them, it was possible to create a model in which protolanguages emerged as the product of repeated communicative interactions between the agents. These protolanguages had both of the kinds of words that the debate over the nature of protolanguages has focused on, but also had a wide range of words of intermediate levels of holophrasticity. Regardless of whether the details of the model accurately reflect the conditions under which the first protolanguages evolved, the model clearly demonstrates that there is a wide range of potential types

of protolanguage, and any future work addressing the nature of protolanguages should consider the possibility of these types of protolanguages, as well as those in which words express only single concepts or entire holophrases.

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