The Nature of Words in Human Protolanguages

It’s not a Holophrastic-Atomic Meanings Dichotomy

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Abstract

There is an ongoing debate as to whether the words in early pre-syntactic forms of human language had simple atomic meanings like modern words [4, 5], or whether they were holophrastic [43, 44]. Simulations were conducted using an iterated learning model in which the agents were able to associate words with meanings, but in which they were not able to use syntactic rules to combine words into phrases or sentences. In some of these simulations words emerged which had neither holophrastic nor atomic meanings, demonstrating the possibility of protolanguages intermediate between these two extremes. Further simulations show how increases in cognitive or articulatory capacity would have produced changes in the type of words that were dominant in protolanguages. It is likely that at some point in time humans spoke a protolanguage in which most words had neither holophrastic nor atomic meanings.

Keywords: Protolanguage, Synthetic, Analytic, Iterated Learning Model, Co-evolution, Language Evolution
1 Introduction

A controversy exists concerning the nature of the earliest human languages. Most authors agree that modern human languages must have been preceded by a simpler form of language, and that syntactic languages of the type we see today are a more recent development [1, 4, 5, 8, 43, 44]. The kinds of meanings expressed by the words in these early proto-languages is however a matter of considerable debate. Proposals can generally be divided into one of two opposing positions. The first position is that words in proto-languages had atomic meanings roughly comparable to typical words in modern languages, in that they denoted one specific type of entity or action, such as pigs or hunting [4, 5, 8, 38]. The alternative is that each word had a holophrastic meaning (that is a meaning corresponding to a whole proposition), such as ‘let’s hunt for pigs’ [1, 43, 44]. This paper illuminates this debate, by showing under which conditions each type of language would have emerged, and by demonstrating the possibility of types of protolanguage beyond those that have so far been considered.

A simple multi-agent computer model was used to simulate the evolution of protolanguages. The nature of the meanings of the emergent words was determined by the number of distinct words that the agents were able to communicate, and the number of different meanings that they tried to express. Sometimes most of the words had atomic meanings, and sometimes most were holophrastic. However, in many cases most of the emergent words were neither atomic nor holophrastic, but had characteristics intermediate between these two extremes. Furthermore, simulating phylogenetic changes in the communicative and cognitive capacities of the agents during the
simulations showed that these changes could produce a transition either from a language with holophrastic words to one with atomic words, or from a language with atomic words to one with holophrastic ones.

2 Protolanguage

The possibility of an early form of language, without any syntax, was developed in detail by Bickerton [4, 5]. He proposed that the earliest utterances must have consisted of a limited number of words with little or no structure, and that the ability to use truly syntactic language evolved at a later time. Bickerton [4] suggested that grammatical items were largely absent from protolanguage (with the possible exception of more meaning oriented items, such as negators and quantifiers), so protolanguages would have consisted almost exclusively of content words. Furthermore, he proposed that there were no fixed syntactic rules relating, for example, word order to the roles of participants, and no rules dictating items that must be present for a string of words to be a valid utterance, as is the case with modern languages. Protolanguage was therefore effectively ‘a stage in which there was a lexicon without syntax’ [5, p. 51].

Bickerton [4, 5] has proposed that the ability to use protolanguage is still latent in modern humans, and is brought into use when speakers are unable to make use of their modern syntactic language abilities. More specifically, Bickerton proposed that the speech of children under two, speakers of pidgin languages, and of adults who were not exposed to language in childhood relies on the same mechanism as the protolanguage of early humans. He also suggested that this ability is present in other apes, as gorillas, common chimpanzees and bonobos have all successfully been trained to use languages
that resemble the protolanguages used by modern humans,\(^1\) even though they do not use anything resembling protolanguage spontaneously in the wild \[14, 16, 30, 31, 39\].

Wray \[43, 44\] has proposed a radically different kind of protolanguage to that envisioned by Bickerton. She has suggested that words in protolanguages were holophrastic; that is, they corresponded to whole propositions, rather than referring to individual objects or actions as the words in modern languages do.\(^2\) For example a word might mean ‘give us the meat’ or ‘give me some of the meat’ \[43, p. 51\]. Utterances would have no internal structure, so speakers would have to learn a separate word for each different meaning that they wished to communicate. Wray \[43\] notes that it may not have been possible to have a separate word for, for example, every combination of agent, recipient and theme involved in the action of giving. It might therefore have been necessary to use words whose meaning fixed only some of the

\(^1\) It should be noted that apes are unable to articulate the sounds necessary to speak human languages, so the languages they learned used a non-auditory modality: either American Sign Language \[14, 30, 39\], or a pictographic keyboard \[16, 31\]. We should note that the discussions and simulations of this paper are quite neutral as to the modality of language, and are certainly compatible with the proposal that the earliest forms of human language used gestures instead of speech \[1, 18, 19\].

\(^2\) We should that it is not always clear what should be considered a holophrase and what should be considered an atomic meaning. Dowman \[12\] makes a stronger argument than the one presented here, by noting firstly that almost any concept can be reanalyzed into more fundamental components (so puppy could be seen as a holophrase for young dog), and secondly that we can add extra information to any holophrase, so creating a more complex meaning. What we consider to be atomic meanings and holophrases may therefore simply be arbitrary points on a continuum between very general and very specific meanings.
participants in an action, and to have used gestures to communicate those parts of the meaning left unsaid. However, Arbib has suggested that protolanguages could have contained words for very specific meanings, such as ‘Take your spear and go around the other side of that animal and we will have a better chance together of being able to kill it.’ [1, p. 118-119], so long as there was frequently a need to communicate those meanings.

Wray [43, 44] supports her proposal on the grounds that holistic protolanguages are a more natural progression from animal communication systems than are the kind of protolanguage proposed by Bickerton. For example, the alarm calls of vervet monkeys could more accurately be glossed with meanings like ‘Beware of the eagle!’ [43, p. 50] than simply the English word eagle. She also argues that modern human languages contain holophrastic utterances, disguised as compositional ones, which may be traces of an earlier more widespread holophrastic language system. For example, How do you do? could be analyzed as a holophrase meaning ‘I politely acknowledge the event of our initial meeting.’ [43, p. 52]. Bickerton [6] has argued against holophrastic protolanguages on the grounds that it would be difficult to infer the complex meanings expressed by each word, although Wray [43] suggests that at early stages of acquisition children today still learn some phrases as unanalyzed holophrastic chunks, and only later identify all their constituent morphemes.

As protolanguages would have been the earliest form of language, prior to them coming into use there would have been little or no selection pressure for mechanisms to support linguistic communication. Bickerton [4] and Wray [43] therefore both assume that when
protolanguages first arose, humans did not have the ability to use phonological systems in which acoustically distinct morphemes could be made by combining sequences of phonemes. Such combinatorial phonological systems, which are used in all modern human languages (including sign languages [37]), allow languages to contain a huge number of words, but for speakers of those languages to still be able to distinguish each word from all others (except for a relatively small number of homophones). However, if early humans did not have the ability to use such a system, they would have had to make a different non-segmental noise for each word. The number of such sounds which early humans were able to both produce and distinguish would have been determined by their articulatory and perceptual abilities. These abilities would have come under selective pressure once protolanguages had come into use, but both Bickerton and Wray agree that the number of distinct words that humans were able to use would initially have been very limited.

It would seem reasonable to assume that when humans first started to use language to communicate, they did not initially try to communicate the full range of meanings that can be expressed with a modern human language. Instead, it seems likely that early humans initially tried to communicate only a limited number of meanings concerning the topics of most importance to them, perhaps because of a limited cognitive capacity. (We can note that trained apes mainly communicate only about their immediate needs and wants, especially in relation to food [39]. This may well give a good indication of the kind of messages that were conveyed by early human speech.) Both a tendency to communicate only a limited number of meanings, and the ability to use only a limited number of words, were incorporated into the computer model, and the effect of each
type of limitation on the kind of languages that emerged was determined.

3 Iterated Learning Models

Several multi-agent computer models [including 2, 3, 17, 21, 24, 25, 26, 34, 36, 40, 42] have been used to study the emergence of syntax, and therefore give some insight into the possibilities regarding the nature of protolanguages. In most simulations with this kind of model, there was an initial stage in which the languages were asyntactic, and syntactic languages only emerged as the product of a cultural evolutionary process, usually occurring over several generations. The agents in these models each represented a person, and in most of the models each agent observed utterance-meaning pairs produced by other agents. The agents could then use these examples to try to infer the underlying language system that had been used to produce them. They could also use the language system that they had inferred to produce new utterances, which could then be observed by other agents, and in turn be used by them to infer the structure of the underlying language.

In the model of Kirby [24], agents initially used a single word to communicate each meaning (each of which consisted of an agent-patient-predicate triple, such as JOHN, ZOLTAN, HATES). However, as the simulation progressed, agents tried to find syntactic structure in the utterances they had observed, under the assumption that there may be a way to decompose the utterances so that each part of the utterance corresponds to some part of the meaning that it expressed. After the language had been passed between several generations of agents, the holophrases of the initial languages began to be replaced with words whose meanings were atomic (that is they corresponded to an individual semantic element). At this stage we also saw the emergence of words that
had meanings corresponding to two semantic elements, such as: agent=TUNDE and predicate=KNOWS. These words therefore had partly holophrastic meanings, but needed to be combined with another word to make a full sentence. Eventually even these words were replaced with atomic words, so we obtained fully compositional languages, in which all words had simple, non-holophrastic meanings. This model therefore demonstrates one possible route for the evolution of language, in which the initial languages were holophrastic, but in which these languages evolved to be fully syntactic languages through a process of cultural evolution.

The languages evolving in most of the models of this type have, like those in Kirby [24] followed a route from holophrastic protolanguages to syntactic languages, by breaking up holophrastic words into parts, and associating a meaning with each part. This is the route through which Wray [43] proposed that protolanguages developed into syntactic languages. The languages in one model, however, take a different route. Hurford [21] reported a model in which the agents tried to communicate simple atomic meanings, such as ETHEL or RUN, as well as whole propositions. In this model, syntactic language emerged as a result of agents combining words that expressed simple atomic meanings, the opposite of Kirby’s model. These simulations therefore demonstrate two routes for the emergence of syntax, one in which syntactic language develops from holophrastic words, and another in which it develops from atomic words. Arbib [1] and Hurford [21] suggest that both of these routes may have played a role in the transition to syntactic languages.

The iterated learning model reported here is much simpler than either Kirby or
Hurford’s model. While the languages spoken by the first few generations of agents in those models were pre-syntactic languages, all the agents had the capacity to learn and use compositional languages. It was the agents’ ability to search for syntactic patterns in the linguistic data that ultimately led to the emergence of syntactic languages. Therefore the agents were syntactically ready right from the start of these simulations, and only a cultural evolutionary process was needed for a syntactic language to emerge.

The model reported in this paper looked at an earlier stage of language evolution, when humans only had an ability to associate words with meanings, but not to combine those words into sentences with any kind of structure. Syntactic language requires abilities that the agents in the iterated learning model reported here did not have. Firstly, syntax requires the ability to assign words to categories, and to use rules that specify how words can be combined, and what meaning will be represented by each allowable combination of words. However, speaking using a syntactic language also requires another skill, which is the ability to break down the complex meaning that is to be expressed into bits, and to find a valid sentence that expresses all those bits, making sure that all parts of the intended meaning are somehow encoded in the syntactic utterance. Here it is assumed that the ability to associate words and meanings preceded either of these two capacities, which would seem to be reasonable, as the ability to use syntactic rules would be of little use unless there already existed meaningful words that they could be used to combine.

Bickerton’s [4, 5] examples of protolanguages, in particular the speech of trained apes and gorillas, may be one of the best indications of what early forms of human languages
were like. Trained apes appear to simply express any words relevant to the message they are trying to communicate, without paying attention to whether they express the whole of the meaning, or perhaps only some part of it, or whether they express some parts of the meaning many times. For example, Terrace reported that his ASL trained chimpanzee (Nim Chimpsky) once uttered ‘give orange me give eat orange me eat orange give me eat orange give me you’ [39, p. 210], which, although very long for a chimpanzee utterance, was typical in its lack of structure.

Based partly on the evidence from ape language studies, I have assumed that there was a stage in the evolution of language at which humans were able to associate words with meanings, but at which they did not have any more sophisticated strategy for expressing the meaning they wished to communicate than to simply utter one or more words that they associated with the intended meaning. This paper looks at the kind of languages that would emerge among a population of individuals with this kind of speaking ability, and in particular at whether the words in these languages were holophrastic, or had atomic meanings like modern words. This therefore models a stage prior to the emergence of syntax, rather than the development of syntactic language from non-syntactic language, which has been the focus of previous iterated learning models.

**4 A Computer Model of Protolanguage**

The computer model used to obtain the results in this paper was a very simple iterated learning model,³ containing at any one time only two agents, one who was the speaker,

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³ To allow for easy verification and extension of the results, the Java source code is available online at http://ling.ed.ac.uk/~mdowman/protolanguage-model.zip
and another who was the hearer. In most simulations, each utterance could consist only of a single word with no internal structure, so there was no potential to combine several morphemes in order to convey the intended meaning more precisely. Jackendoff [23] proposed that protolanguage went through such a one word stage, although Bickerton [4, 5] seems to believe that even the earliest users of protolanguages were able to use multiple word utterances. An extension to multiple words is described below, which allowed results corresponding to both of these possibilities to be obtained. The agents were also able to use only a limited number of distinct word forms, to simulate a limited capacity for articulating and/or perceiving speech sounds.

The simulations proceeded by randomly selecting a meaning which the speaker would then try to communicate to the hearer by saying one of the available words. The hearer would then remember that word together with the meaning it was used to express.\(^4\) This process was repeated enough times for the hearer to get a good idea of the language. The hearer would then become the speaker, and the process would be repeated with the old hearer using the language it has just learned from the old speaker to speak to a new

\(^4\) We might question how the hearer always comes to know the meaning, given that if the meaning was apparent, there would seem to be no need for the speaker to say a word to express it. However, it would seem that hearers must be able to infer the intended referent of linguistic expressions on at least some occasions of their use if they are ever to learn their meanings. Therefore, we can regard the interactions in the model as corresponding only to those in which the hearing agent is able to infer the intended meaning. In reality hearers are probably sometimes able to infer some part, but not all, of the meaning that a speaker intends to convey, but it was decided that modeling the hearer’s understanding of the meaning in more detail would serve only to complicate the model, without shedding any more light on the phenomenon of interest.
hearer, which initially knew no language. This process models the transmission of language between multiple generations of speakers. The result of most interest will be the nature of the languages that emerge after several generations.  

4.1 Meaning Representations

In order to implement the model, it was necessary to have some way of representing complex meanings such as might be expressed by a holophrastic protolanguage. This was achieved by representing meanings using a number of semantic elements. Each of these corresponded to some object or event about which early humans may have wished to communicate. These meanings could then be put into groups to express a more complex meaning. For example, the elements HUNT, PIG and FOREST would express a meaning such as ‘Hunt pigs in the forest’ and DOG, PIG and SLEEP would express something like ‘Dogs and pigs are sleeping’.

Clearly these collections of semantic elements do not convey as much information as their translations into English (for example they contain no number or tense information, and could possibly have alternative interpretations), but they are sufficient to create a range of complex meanings that the agents can then communicate. We would also expect that the meanings resulting from some combinations of semantic elements would be much more common than others (it may even be difficult to give a coherent interpretation to some of them), and in later simulations I investigate the effects of such

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5 We should note that there is a different kind of computer model, closely related to the iterated learning model, in which several agents exist throughout the whole simulation, and gradually negotiate a common language (for example [2, 32, 35]). By producing similar results with such a single generational model, Dowman [11] showed that the multi-generational property of the model reported here was not critical.
a frequency bias. However, in most of the simulations all possible combinations of the semantic elements occurred with equal probability, as modeling variation in the frequency of meanings was considered to be an unnecessary complication. We should also note that the order of the semantic elements makes no difference, thus DOG, PIG, SLEEP is treated no differently to PIG, SLEEP, DOG.

These same representations are used both to represent meanings in the world, and for the agents' internal representations of meanings. However, this is not a claim that early humans thought or represented meanings using this kind of logical representation; it is simply a convenient representation that is easy to implement in a computer model. I would expect to achieve substantially the same results using other semantic representations, such as first order predicate logic, or purely analogical representations.\(^6\) The crucial characteristic that the meaning representations must have is that there must be some variation in the degree of similarity between different complex meanings. This is the case with the system used here, as meanings can differ in terms of the number of semantic elements that they share.

4.2 Agent’s Choice of Words

So far the specification of the model is complete, except that no explanation has been given for how an agent decides which word to use to communicate each of the meanings with which it is presented. Put simply, each time an agent speaks, they use the word whose past uses have been most similar to the current meaning. More precisely, for each word they know, they look at all the meaning elements in each meaning that

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\(^6\) Some support for this claim is provided by Dowman [11], where qualitatively similar results where obtained using more complex four-element meanings.
they have previously heard it being used to express, and work out the proportion of those meanings that match one of the elements in the current meaning. For example, if the current meaning is EAT, HOUSE, PIG, and the agent has previously heard a word used to express EAT, HOUSE, DOG one time and HUNT, FOREST, PIG two times, that word would have a degree of match of 4/9. This is made up of two matches (EAT and HOUSE) for the first previously heard meaning, and one match (PIG) twice over for the two occurrences of the second previously heard meaning, out of a total of nine potential matches. Degrees of match can therefore range from 1, for words that have only ever been used to express the current meaning, to 0, for words that have never expressed a meaning containing any of the elements of the current meaning.

Where a word has a degree of match of one to the current meaning, the agent will always choose that word. However, if no current word is an exact match, then the agent will use a new word that they have so far neither heard nor used themselves, so long as there is another word available, given the limited number of words that they are able to use. Whenever they use a new word, they will remember it and the corresponding meaning in the same way as if they had heard it from another agent, so that they will be able to use it to express the same or similar meanings in the future. (This is the only situation in which agents remember their own productions.) If there is no new word available (which will be the case most of the time) then the agent will use the word that has the highest degree of match to the current meaning. Whenever more than one word has an equal degree of match, one of those words will be selected at random. This word choice mechanism was chosen because it is simple, but is still consistent with the limited evidence we have about the mechanism that speakers of protolanguages used to
select words (see section 3). However, clearly it is only one of a wide variety of word choice mechanisms that could reasonably have been considered, and future work in which agents use different word choice mechanisms might result in the emergence of different types of protolanguages.

5 Emergent Languages

The iterated learning model was used to simulate the emergence of several different languages. In all the cases reported in this section, the meanings the agents tried to communicate were concatenations of three semantic elements randomly chosen from a set of ten. This allowed for 120 distinct meanings, each of which was equally likely to be chosen. Each agent produced 1,000 utterances, each of which was heard by the agent in the next generation, and each simulation proceeded over 10 generations. The only parameter that was changed between these simulations was the number of words that the agents were able to use, which was set at a range of different values, therefore resulting in a variety of different types of language emerging. While in most cases only results from a single run are reported, all the simulations reported in this paper were performed multiple times, and significant variations between runs are noted where appropriate. However, as the argument made in this paper is of a qualitative not a quantitative nature, qualitative descriptions of the kinds of words that emerge seem to be more appropriate than a detailed quantitative investigation of the properties of the computer model.

5.1 Emergence of Languages in which Words have Atomic Meanings

In the first simulations, the number of words that the agents could use was set to be 10, equal to the number of semantic elements. All the agents used all ten of these words, and Table 1 shows for three words the meanings that were expressed with each by the
last agent in the simulation. These words, which are typical of those emerging in this condition, appear to have meanings similar to modern day nouns and verbs. That is, whenever each of these words is used, one semantic predicate is always present: EAT in the first case, FIGHT in the second and DOG in the third. As so many other semantic elements occur together with these words, hearing one of them gives little information about any other aspect of the meaning that the agent is attempting to express, and so the information conveyed by such words corresponds only to one semantic element. To a third party observer who did not have direct access to the agents’ internal representations of the language, it would appear that the meaning of these words was simply that semantic element. Therefore we could gloss these words as English eat, fight and dog.
Table 1. Some Examples of Words in a Simulation with 10 Semantic Elements and 10 Distinct Words

<table>
<thead>
<tr>
<th>Meanings Expressed by Word (frequency in brackets)</th>
<th>Description of Word Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOREST, PIG, EAT (12) EAT, DOG, GATHER (10) FOREST, GATHER, EAT (11) HUNT, EAT, PIG (11) FIGHT, PIG, EAT (6) GATHER, EAT, PIG (7) HOUSE, EAT, GATHER (9) DOG, FIGHT, EAT (7) EAT, HUNT, FIGHT (11) GATHER, EAT, FIGHT (10) GATHER, EAT, SLEEP (13) DOG, EAT, PIG (4) GATHER, HUNT, EAT (4)</td>
<td>Word denotes EAT</td>
</tr>
<tr>
<td>SLEEP, FIGHT, EAT (8) SLEEP, FIGHT, GATHER (8) EAT, FIGHT, HOUSE (13) RIVER, HOUSE, FIGHT (9) FOREST, RIVER, FIGHT (9) FOREST, PIG, FIGHT (10) HOUSE, FIGHT, GATHER (13) FIGHT, DOG, SLEEP (9) RIVER, SLEEP, FIGHT (10) FOREST, FIGHT, HOUSE (7) FIGHT, SLEEP, HOUSE (7) FIGHT, GATHER, FOREST (8) SLEEP, FIGHT, FOREST (5) EAT, FIGHT, FOREST (4)</td>
<td>Word denotes FIGHT</td>
</tr>
<tr>
<td>DOG, RIVER, FOREST (7) PIG, FOREST, DOG (10) RIVER, DOG, PIG (17) EAT, DOG, FOREST (10) DOG, FOREST, GATHER (5) DOG, PIG, FIGHT (7) FOREST, DOG, FIGHT (6) FIGHT, RIVER, DOG (10) FOREST, SLEEP, DOG (5) SLEEP, DOG, RIVER (5)</td>
<td>Word denotes DOG</td>
</tr>
</tbody>
</table>

Most of the words emerging in simulations in which ten words were available were similarly used only when one particular semantic element was present, including all of the words in the simulation from which these examples were taken. Clearly using these words individually as the agents in this simulation did does not allow the full content of
the meanings to be conveyed, but it is perhaps as good a language as could be achieved
given the limited number of words available. In most simulations in this condition, there
were also a few (usually one or two) words whose meanings did not correspond to a
single semantic element. We return to the nature of these words below in section 5.3.

5.2 Emergence of Languages in which Words are Holophrastic

A second simulation was conducted in which the number of distinct words that the
agents could use was increased to 150. In this case all of the agents used 120 of these
words, and examples of the meanings that the final agent expressed using three of these
words are given in Table 2. We can see that each of these words expresses a whole
complex meaning, and so each is holophrastic. In fact, each word emerging in this
simulation (and in all other simulations in which there were at least as many words as
meanings) expressed a different complex meaning. The other 30 words were never used,
as no further semantic distinctions remained to be distinguished, this language being
sufficiently powerful to convey all the intended meanings unambiguously.

Table 2. Some Examples of Words in a Simulation with 10 Semantic Elements and
150 Distinct Words

<table>
<thead>
<tr>
<th>Meanings Expressed by Word (frequency in brackets)</th>
<th>Description of Word Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLEEP, PIG, HUNT (5)</td>
<td>Word denotes events or objects containing all the elements SLEEP, PIG and HUNT</td>
</tr>
<tr>
<td>PIG, HOUSE, FIGHT (9)</td>
<td>Word denotes events or objects containing all the elements PIG, HOUSE and FIGHT</td>
</tr>
<tr>
<td>FOREST, FIGHT, HUNT (10)</td>
<td>Word denotes events or objects containing all the elements FOREST, FIGHT and HUNT</td>
</tr>
</tbody>
</table>
5.3 *Languages with Words Intermediate between Holophrastic and Atomic Words*

If words which denote a single semantic element develop when there are the same number of words as semantic elements, and holophrastic languages develop when there are at least as many words as complex meanings, what kind of language will emerge when the number of words available falls between these two limits? Will we get a mixture of holophrastic and atomic words? A simulation in which the agents could use 50 distinct words was conducted in order to investigate this.

Each agent in this simulation used all 50 words, and the meanings expressed by a selection of the words used by the last agent are given in Table 3. The first word clearly has a holophrastic meaning, like those in the previous section. The second word at first appears to be an atomic word, in that, like those words emerging in the first simulation, it is only used when one particular semantic element is present (in this case RIVER). However, we can see that it is not used with anywhere near the full range of available semantic elements, as the only other semantic elements in the meanings it expressed were FOREST, HOUSE and FIGHT. This word is therefore restricted to expressing the meaning RIVER in the context of at least two of the meanings FOREST, HOUSE and FIGHT. It therefore has some degree of holophrasis, and so this places this word at an intermediate position between a fully holophrastic word and one with an atomic meaning. Truly atomic words, which always expressed a single semantic element, but which also expressed meanings containing all of the other semantic elements, did occur when there were more words available than there were semantic elements, but generally only when the number of available words was only slightly more than the number of semantic elements.
Table 3. Some Examples of Words in a Simulation with 10 Semantic Elements and 50 Distinct Words

<table>
<thead>
<tr>
<th>Meanings Expressed by Word (frequency in brackets)</th>
<th>Description of Word Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLEEP, FOREST, GATHER (7)</td>
<td>Word denotes events or objects containing all the elements SLEEP, FOREST and GATHER</td>
</tr>
<tr>
<td>FOREST, RIVER, HOUSE (5)</td>
<td>Word denotes RIVER, but only in relation to FOREST, HOUSE or FIGHT</td>
</tr>
<tr>
<td>HOUSE, RIVER, FIGHT (8)</td>
<td></td>
</tr>
<tr>
<td>FOREST, RIVER, FIGHT (6)</td>
<td></td>
</tr>
<tr>
<td>SLEEP, HUNT, EAT (13)</td>
<td>Word denotes events or objects containing both of the elements SLEEP and EAT</td>
</tr>
<tr>
<td>SLEEP, EAT, RIVER (11)</td>
<td></td>
</tr>
<tr>
<td>PIG, EAT, SLEEP (8)</td>
<td></td>
</tr>
<tr>
<td>EAT, GATHER, SLEEP (11)</td>
<td></td>
</tr>
<tr>
<td>SLEEP, FIGHT, EAT (6)</td>
<td></td>
</tr>
<tr>
<td>SLEEP, DOG, EAT (9)</td>
<td></td>
</tr>
<tr>
<td>FOREST, SLEEP, EAT (6)</td>
<td></td>
</tr>
<tr>
<td>GATHER, SLEEP, PIG (10)</td>
<td>Word denotes events or objects containing both of the elements SLEEP and PIG, but only in relation to GATHER, DOG or HOUSE</td>
</tr>
<tr>
<td>PIG, DOG, SLEEP (10)</td>
<td></td>
</tr>
<tr>
<td>PIG, SLEEP, HOUSE (5)</td>
<td></td>
</tr>
<tr>
<td>DOG, HUNT, HOUSE (5)</td>
<td>Word denotes meanings containing three of the elements DOG, HUNT, HOUSE and EAT</td>
</tr>
<tr>
<td>HUNT, EAT, DOG (6)</td>
<td></td>
</tr>
<tr>
<td>EAT, DOG, HOUSE (12)</td>
<td></td>
</tr>
<tr>
<td>HOUSE, HUNT, EAT (5)</td>
<td></td>
</tr>
</tbody>
</table>

We should perhaps note that even most of the words emerging in the first simulation had this kind of slightly holophrastic characteristic to a small degree, as most of them did not express the full range of semantic elements. (This is the case with all three words in Table 1.) However, we might analyze some words in modern languages as having this kind of property, as often the choice of word we use to express some concept depends on its context. For example, in English *cow* and *beef* both refer to the same animal, but we always use one word when it’s alive, and another when we eat it. We might therefore analyze *beef* as expressing the semantic element *COW*, but only in the context of the semantic element *FOOD*. 
The third and fourth words in Table 3 were only used to express meanings containing two specific elements (SLEEP and EAT in the first case, SLEEP and PIG in the second). The first of these two words could do so in combination with any of the other semantic elements except for HOUSE, so we can characterize it as expressing meanings combining the concepts SLEEP and EAT, but not conveying any further information. The fourth word can only express its combined SLEEP and PIG meaning in the context of GATHER, DOG or HOUSE, so limiting its domain of use to expressing the meaning SLEEP and PIG in relation to a limited range of other meanings. Both of these words are therefore partly holophrastic, but the second one more than the first, and both of them are more holophrastic than the second word in the table.

The final word in Table 3 does not always express any particular semantic element, and so represents another distinct word type. This word might seem to be of limited communicative use, as when it is used we cannot be certain that the meaning the agent is trying to communicate contains any particular semantic element. However, this word always expressed meanings combining three elements out of DOG, HUNT, HOUSE and EAT. When an agent hears this word, it can therefore narrow down the intended message to a small range of closely related meanings. Words of this kind, which we can also regard as being partly holophrastic, only emerged occasionally when there were 50 distinct words available, but were common in simulations in which the number of available words was reduced. (Sometimes, however, the range of semantic elements contained in the meanings expressed by this kind of word was more than the four present in this case.)
A small number of words of this kind emerged in most simulations in which there were only ten words, besides those words with atomic meanings. This should not be surprising as, as each complex meaning contains three semantic elements. Therefore, if we have eight words that always express one element, then one of those words can always be used in response to any complex meaning. Hence there may be limited opportunities to use words which express the two remaining semantic elements, and so the final two words are likely to express a non-atomic meaning instead.

The frequency of each type of word depended on the number of words available. In the simulation from which the words in Table 3 were taken, there were 10 holophrastic words, 35 words containing two fixed semantic elements, four words containing one fixed element, and one word containing no fixed elements at all. In general when the agents were able to use a smaller number of distinct words, the languages became less holophrastic, and as the number of available words increased towards 120, they became more holophrastic. For example, when the simulation was repeated with only 20 distinct word forms available there were no holophrastic words, 12 words contained two fixed semantic elements, four contained one fixed element, and four contained no fixed elements at all. When there were 90 distinct word forms available there were 62 holophrastic words, 27 with two fixed elements, one with a single fixed element, and none with no fixed elements at all.

5.4 Emergence of Languages in which there are Fewer Words than Semantic Elements

So far we have reported simulations in which the number of available words was the same as the number of semantic elements, intermediate between the number of semantic elements and the number of complex meanings, or greater than the number of complex
meanings. This leaves one further possibility to be considered. What would happen if
the agents’ communicative ability was so impoverished that they could not even
produce one distinct word for every semantic element. (Alternatively we could state this
as, ‘What if agents had so many semantic elements available that there were more than
the number of available words?’, although in the simulations it was in fact the number
of available words that was varied, not the number of semantic elements.)

To investigate this possibility, one more simulation was conducted in which the number
of distinct words that the agents could communicate was only five. Three of the words
emerging in this simulation always contained one semantic element, and hence had
atomic meanings. Of the other two words, one used any three of the other seven
semantic elements, and so could be said to denote meanings covering the full range of
those elements, but excluding those meanings conveyed by the semantic elements that
had their own words.

However, the meanings expressed by the final word contained 9 of the semantic
elements, excluding only one of the elements that had its own word. This word
therefore at first appears to have little communicative use, as on hearing it an agent
would seem to be able to infer very little about the meaning that the speaker had
intended to convey. However, closer inspection of the meanings expressed by this word
show that they all contain at least two of the elements EAT, GATHER and PIG, and so
in fact this word does express a reasonably constrained range of meanings, and
represents another type of word that is distinct from those discussed above. In some
ways it appears to be partly holophrastic, as its meaning must be described in terms of
two semantic elements, instead of just one like the atomic words, but because there is not even one semantic element that is common to all its uses, it is also in some ways very un-holophrastic.

5.5 Frequent and Infrequent Meanings

One assumption that has been incorporated into all the simulations reported so far has been that all complex meanings are equally likely to be expressed by the agents. However, this is clearly not a very realistic assumption, as we could expect that early humans would have had a frequent need to express meanings corresponding to commonly encountered situations, while many other meanings would be expressed rarely, if at all [43]. Therefore the model was modified slightly so that five randomly chosen complex meanings were expressed much more frequently than any of the other meanings. (50% of the time, one of these meanings was chosen, while the other 50% of the time a meaning was selected from the full set of possible meanings.) Table 4 shows all of the meanings that were expressed by two of the words used to express frequent meanings in a simulation in which the agents were able to use 50 distinct words. (The other parameters were the same as those in previous simulations.)

**Table 4. Words Expressing Frequent Meanings.**

<table>
<thead>
<tr>
<th>Meanings Expressed by Word (frequency in brackets)</th>
<th>Description of Word Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>HUNT, PIG, DOG (7)</td>
<td>Word denotes events or objects relating to DOG, but only the context of HUNT, PIG or SLEEP</td>
</tr>
<tr>
<td>DOG, HUNT, SLEEP (102)</td>
<td></td>
</tr>
<tr>
<td>SLEEP, DOG, PIG (4)</td>
<td></td>
</tr>
<tr>
<td>DOG, RIVER, PIG (108)</td>
<td>Word denotes events or objects containing both of the elements DOG and RIVER, but only in relation to PIG or SLEEP</td>
</tr>
<tr>
<td>RIVER, SLEEP, DOG (4)</td>
<td></td>
</tr>
</tbody>
</table>

These words clearly express a small range of meanings closely related to the single complex meaning. However, apart from one meaning being much more frequent than
the others, the structure of these words is not greatly different to some of those emerging in the previous simulations. In this simulation the other words that expressed frequent meanings were very similar, also expressing just one or two closely related meanings in addition to the frequent meaning, although sometimes fully holophrastic words expressing only the frequent meanings emerged.

When the agents were able to use only 10 words, there were no meanings elements common to all the uses of most of the words that expressed frequent meanings, but all (or occasionally almost all) the uses of those words contained two of the elements in the frequent meaning. However, for a few of the words containing the frequent meaning there was one meaning element common to all uses. When the agent could use 150 words, then each word was fully holophrastic, as before. Making some meanings especially frequent therefore seems to have had little effect on the nature of the emergent languages. The words containing the frequent meanings tend to express only a limited range of very closely related meanings, but in the simulations overall we can still observe the full range of word types reported above.

6 Coevolution of Agents and Protolanguages

The previous results give insight into the conditions under which different kinds of protolanguage would have emerged, focusing on a point in evolutionary history at which humans’ cognitive capabilities were such that they communicated only a limited number of meanings, and at which they were only able to use a limited number of distinct words. However, over a period of time the number and complexity of meanings that humans tried to communicate would presumably have increased, as would have their capacity for articulating and distinguishing word forms. The iterated learning
model was therefore extended so that phylogenetic changes affecting the agents’ communicative abilities, or the complexity of the meanings that they tried to communicate, could be modeled.

In the new version of the model, one of these abilities was changed slowly and gradually. After every ten generations, either the number of distinct words that the agents could use, or the number of semantic elements from which the meanings that they tried to communicate were constructed was increased by one. We would then expect the protolanguages to rapidly adapt to the new extended capacities of the agents, and so the model was expected to show coevolution of the agents (phylogenetic evolution) and of the languages that they spoke (cultural evolution).\(^7\) Coevolution has previously been simulated by other iterated learning models (for example [7, 27]), but no such models have focused on protolanguage.

6.1 *Evolving Communicative Capacity*

In the first simulation in which phylogenetic evolution of the agents took place, the model was identical to that used in the previous simulations, and had the same parameters, except that the number of distinct words that the agents could use was

\(^7\) Deacon [10] discussed the coevolution of languages and human language capacity in depth, and concluded that, because cultural evolution can operate over much shorter timescales than phylogenetic evolution, it will primarily be languages that adapt to humans’ language abilities, rather than humans’ language abilities to languages. In this model, there was no opportunity for languages to influence phylogenetic evolution, as the phylogenetic changes that the agents underwent were fixed from the outset. The model was therefore constrained to modeling a slow rate of phylogenetic change of language capacity, to which languages could then rapidly adapt, and is therefore in line with Deacon’s arguments regarding co-evolution.
started at one, and raised by one every ten generations. The simulation was conducted over 1300 generations, so at the end of the simulation the agents were able to use 130 distinct words. In this simulation, the number of semantic elements was kept constant throughout, so there were always ten semantic elements and hence 120 distinct meanings.

Figure 1 displays the results of the simulation, showing the proportion of words that had either one, two, all three, or no semantic elements common to all the meanings that they were used to express. We can see that each of these types of word was dominant at some point during the simulation. Initially the very limited number of words meant that no words could be used only for expressing meanings containing one particular semantic element, so all words had no semantic elements common to all uses. However, as the number of words rose, we rapidly came to a point where most words had atomic meanings (that is they had one semantic element common to all uses).

As the number of available words rose still further, these atomic words began to be replaced\(^8\) by partly holophrastic words, which were always used to express meanings containing two fixed elements. Finally, these words were eventually replaced by completely holophrastic words that expressed only a single complex meaning comprised of three fixed semantic elements. After generation 1200, there were enough words for each complex meaning to be expressed with a separate word, so all words

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\(^8\) We should note that while it is convenient to talk of words being ‘replaced’, in fact it was the words’ meanings that changed. While we appear to see the replacement of one type of word by another, the original words were usually still present, but came to express a different kind of meaning.
become holophrastic, and there were no further changes in the frequency of each word type beyond this point.

After each phylogenetic change (an increase in the number of words that the agents were able to use), the newly available word was usually used immediately by the next agent, so the protolanguages adapted quickly to the new characteristics of the agents. There was then generally little or no change in the meanings expressed by each word until the next phylogenetic change, which is why parts of the graph have a step like shape, with changes appearing only every ten generations. These simulations demonstrate that if the complexity of the meanings that the agents try to express remains fixed, but the agents communicative capacity gradually increases, we can expect to see a move towards increasingly holophrastic protolanguages.

6.2 Evolving Conceptual Complexity

The second possibility to be investigated was what would happen if the complexities of the meanings that the agents tried to express increased. A second simulation was therefore conducted, starting with the agents trying to express meanings containing ten different semantic elements, and being able to use up to 120 words, thus corresponding to a point close to the end of the last simulation. The number of available words was this time kept constant throughout the simulation, but every ten generations a new semantic element was added, thus increasing the complexity of meanings that the agents tried to communicate. This simulation was also conducted over 130 generations, so there were 140 semantic elements at the end of the simulation, allowing 447,580 distinct complex meanings. The other parameters of the simulation remained the same as before, with each agent expressing 1,000 randomly chosen complex meanings.
Figure 2 shows the results of this simulation. Again we see that a different type of word was dominant in each part of the simulation. At first the words were holophrastic, which should be expected given that the conditions at the start of this simulation were identical to those close to the end of the last one. However, as the number of semantic elements increased, the frequency of this kind of word decreased very rapidly, and they were largely replaced by words that were only partly holophrastic, in that there were two semantic elements common to all the meanings that they expressed.

As the number of meanings rose yet further, there were not enough words even for this level of holophrasis, so these words came to express a range of meanings that had only one semantic element in common, and which were therefore similar to the atomic words found in today’s languages. Towards the end of the graph, we start to see the emergence of an increasing number of words for which there are no elements at all that are common to all uses. This is because the number of semantic elements approaches, and then becomes greater than the number of words, so there are no longer sufficient words for each to exclusively express even a single semantic element. When simulations are continued beyond this point, this kind of word eventually becomes dominant.

In this simulation we see a complete reversal of the sequence in the previous simulation, with a move from holophrastic words, to those with two common elements, to those with only a single common element to those with no common elements at all. We can therefore conclude that if the communicative ability of the agents is fixed, but the complexity of the meanings that they try to communicate increases, we should expect to
see a movement towards languages that are less and less holophrastic.

6.3 Simultaneous Evolution of Communicative and Conceptual Capacity

While the previous simulations have demonstrated the consequences of an increase in the number of words that agents are able to use, or in the complexity of the meanings they try to communicate, in reality it seems likely that both of these capacities evolved in parallel. Therefore what kind of protolanguage should we expect to see evolve under these circumstances? The above simulations suggest that this will depend on the relative rates of evolution of these two capacities. If communicative ability evolves more rapidly than conceptual capacity, we would expect a move towards more holophrastic protolanguages, while if conceptual capacity evolves more rapidly than communicative ability, we should expect a move towards less holophrastic protolanguages. As these two abilities likely evolved at different rates at different points in the course of human evolution, there may well have been multiple transitions between holophrastic protolanguages and protolanguages where the words had atomic meanings.

7 Multiple Word Utterances

One criticism that could be made about the simulations reported up to this point is that the agents always uttered only a single word per utterance. The reason for conducting simulations in this way was that the aim was to simulate the earliest stages of human language, and as single word utterances are simpler than multiple word ones, they likely preceded them. However, one piece of evidence that might seem to stand in opposition to this assumption is the language abilities of trained apes. Common chimpanzees and bonobos sometimes use several words together in one utterance [14, 16, 31, 39], so it’s clear that they have the cognitive capacity to do this, even though they do not use language in the wild. This ability could have evolved since the chimpanzee lineage split
from that of early humans, but that seems unlikely given that gorillas, whose lineage is separate from the common human-chimpanzee one, have similar abilities [30]. It therefore seems likely that the ability to use this kind of protolanguage in response to training was present in the common ancestor of gorillas, chimpanzees and humans.

However, even if we assume that the same cognitive ability that allows chimpanzees and gorillas to use multiple word utterances was also present in early humans, it is not clear that the first human proto-languages would necessarily have contained multiple word utterances. Chimpanzees and gorillas only use multiple word utterances in response to training by humans in which they are shown many multiple word examples. The fact that they are able to use multiple word utterances in response to such training does not mean that the first languages that arose as a result of some change in the human phenotype would have been as complex as this. Chimpanzee and gorilla language demonstrates that species can extend their language abilities beyond those they would use naturally in response to training, but the languages that arose spontaneously among early humans might have had quite different characteristics.

The above argument is intended to support the validity of the simulations reported up to this point. We cannot, however, be certain that the first protolanguages consisted only of single words. Therefore the validity of the model would be seriously in question if similar results could not be obtained when the agents used multiple words to express each meaning, rather than a single word. The model was therefore extended so that the agents could use multiple words utterances.
7.1 Extension of the Model to Multiple Word Utterances

A small modification was made to the model, so that the maximum number of words that the agents used to express each meaning could be varied. In the results reported below this was always set at three. When agents spoke they would calculate the degree of match between each word they knew and the meaning they were trying to convey. If a word was an exact match, then it would be used, and the utterance would consist only of this single word. Otherwise, if the agent was able to produce a new word distinct from all those it had heard before, then it would use a new word to express the meaning, and it would remember the word-meaning pair as though it had heard it from another agent. So far the model is the same as for when each utterance consisted of only a single word. However, when no word was an exact match, the agent would say the maximum number of words that it was allowed to use in an utterance, choosing those words with the highest degree of match. (If there was more than one word with an equal degree of match, then the agent resolved the uncertainty over which words to use by choosing at random out of those words with equal degrees of match.) The hearing agent would then associate each of these words with the current meaning, just as if it had heard three separate utterances all paired with that meaning. This is the only difference between this version of the model and the original one.

7.2 Languages Resulting from Multiple Word Utterances

The initial simulations, in which the number of semantic elements was ten, and the number of available words was either 10, 50, 90 or 150, were repeated using the new model. The results are shown in Table 5, and were broadly similar to those obtained in the initial simulations, with both atomic and holophrastic words emerging, as well as words that were intermediate between these two types.
Table 5. Types of Word Emerging with Multiple Word Utterances.

<table>
<thead>
<tr>
<th>Number of Words Available</th>
<th>Number of Words of Each Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(types defined by the number of semantic elements common to all uses)</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>50</td>
<td>3</td>
</tr>
<tr>
<td>90</td>
<td>6</td>
</tr>
<tr>
<td>150</td>
<td></td>
</tr>
</tbody>
</table>

When there were 10 words available, seven of the emergent words had atomic meanings, although these words could only express six distinct semantic elements, as there were two words that expressed EAT. The main difference between these words and the atomic words emerging in the previous simulations is that these words could be used with the full range of semantic elements, so they were in fact even more like the words seen in modern languages. One more word was close to an atomic word, in that in 268 of its 290 uses it expressed HUNT, but there were three more meanings, all including both DOG and FISH that accounted for the final 22 uses of this word. Finally, one word was used with all ten elements, and another with nine of the elements, but for these words there were no semantic elements common to all or almost all uses. These words therefore appear to be quite communicatively useless, and may simply have been added to utterances to provide an extra word when there were less than three words that were appropriate given the current meaning. We can see that in general these results were consistent with the initial simulations, and that as before, with only ten distinct words available, most words have atomic meanings.

In the next simulation, 50 distinct words were made available for the agents to use. In this case nine of the emerging words had atomic meanings and 38 were partly
holophrastic. The other three had no common semantic elements, but instead expressed meanings containing elements that were all from a subset (either five or six elements) of the full set of semantic elements. As with the initial simulation in which 50 words were available, the emergent words were a mix of different types, but in this case several atomic words emerged, but no fully holophrastic ones, which is the opposite of what happened in the previous simulation.

Increasing the number of available words to 90 did however result in languages with the full range of word types, but there were usually far fewer fully holophrastic words (and more words with two fixed elements) than when each utterance consisted of only a single word. This can be explained if we think about the process by which agents choose words to say. Because they now choose the three best matches, instead of a single match, they are likely to use fully holophrastic words to make up the second or third word when no better match is available. However, this will result in the agent in the next generation associating those fully holophrastic words with a new meaning, so they will no longer be fully holophrastic. Despite this factor, even if simulations in this condition are continued for as many as 100 generations, several holophrastic words are usually present at the end of the simulation.

In simulations with 90 words available, the other semantic elements present in words in which one semantic element was fixed, were always from a set of only three semantic elements. (If the choice of semantic elements was restricted any further, then the word would be fully holophrastic.) Therefore even these words displayed quite a high degree of holophrasticity, and were not really that similar to most words in present day
languages, because they expressed the fixed semantic element only in relation to a small range of other concepts. We should also note that the number of words with two common semantic elements was much greater than the total number of different combinations of two semantic elements (there being 45 such possibilities). There therefore tended to be more than one word expressing most combinations of two semantic elements, but for each such word, the third semantic element was usually restricted to a distinct subset of elements.

Finally, when there were 150 words available, 120 fully holophrastic words emerged as before. In this case an exact match could be achieved for every meaning, so each utterance consisted of a single word. The simulations in this condition were therefore no different to those conducted using the original model.

8 Discussion

The simulations reported above have produced a wide range of different types of protolanguages, demonstrating that holophrastic protolanguages and protolanguages in which the words have atomic meanings are not the only possibilities. We might, however, have doubts about how effective these languages would be for communication. Would language have to reach a certain level of complexity or precision before it was useful? Wray suggests that the kind of protolanguage envisioned by Bickerton would be of little communicative use: ‘A language that lacks sufficient lexical items and grammatical relations can only hint at explicit meaning, once more than one word at a time is involved.’ [43, p. 48-49]. ‘To make the language useful, it must be able to reliably convey a message from speaker to hearer in its own right.’ [43, p. 49].
Hurford [22] takes a somewhat different view: ‘A large vocabulary of “one-word” descriptive symbols could have been very useful, even without, or before, the advent of syntactic rules for combining them into an even more useful recursive communication system.’ Jackendoff also supports the view that that an impoverished language capacity is better than none at all, noting that ‘a baby’s needs are much easier to understand when (s)he has a few dozen words than when there are no words at all.’ [23, p. 275]. Further support for the utility of impoverished linguistic systems comes from second language learners. Anyone who has ever lived in a country where they do not speak the native language is likely to have discovered that knowledge of only a single word is often extremely beneficial in negotiating many everyday situations. These arguments seem to lead to the inevitable conclusion that a protolanguage with a very impoverished vocabulary of atomic words would be better than no protolanguage at all.

Above it was argued that modern languages do contain holophrastic expressions, so there is evidence for the utility of at least some kinds of holophrastic word. Some authors (for example [33]) have considered how many words would be needed to make a viable holophrastic protolanguage. However, it would seem that a single holophrase would be useful whenever the need arose to express the meaning that it represented, so a protolanguage with just a single holophrase would seem to be better than none at all. I would therefore argue that all the kinds of words emerging in the above simulations would have been useful to early humans, with the exception of those few words whose meaning could not be related to any subset of semantic elements. However, Hoefler [20] presents an interesting theoretical analysis that suggests that even a language
languages emerging in the simulations were clearly limited in their expressive power, there does not seem to be any reason to argue that a particular kind of protolanguage is implausible simply because its expressive power is much less than that of modern languages.

It is interesting to note that the languages would appear to have a different structure to an observer who could only see how they were used in the world (E-language) compared to an observer who could inspect the internal representations in the minds of the speakers (I-language). To an observer with access only to E-language who observed the use of an atomic word, it would seem that the agents had determined that the word was only used to convey meanings containing one particular semantic element. However, in the I-language representation no such abstraction is made – there is simply a list of all the meanings that have previously been expressed using the word. An agent hearing an atomic word could narrow down the intended meaning to be one of those meanings, all of which contain the semantic element that appears to be the word’s meaning, but they need not assign a special status to that element in order to use the language effectively. This suggests that people or animals (such as trained apes) who appear to be able to learn nouns and verbs, could have simply memorized all the situations in which those words can be used, without actually determining their true meaning.

which had only a single word that was not tied to any particular meaning could be useful. On hearing the word, a person could use context to recover the intended meaning, and so communication could be achieved even if the signal did not itself convey any specific meaning at all.

10 The terms E-language and I-language were introduced in [9].
One theory concerning the evolution of language that is inconsistent with the scenario presented here is the song hypothesis [13, 28, 29, 41]. This theory proposes that language developed by exaptation\(^\text{11}\) of a previously evolved capacity for music (and more specifically singing). Music could initially have been used as part of a courtship ritual or to enhance group identity, much as it is used today by song birds (and also by humans). Song would therefore have initially communicated a limited number of holophrastic meanings, which could be seen as a form of holophrastic protolanguage in itself. However, at a later stage humans may have developed the capacity to learn to associate a much wider range of meanings with song, which would have led to the development of protolanguage proper.

The ability to combine musical notes (which may have developed into phonemes) in sequences, would have allowed speakers to form a large number of distinct signals, far more than the limited number available in the simulations reported above. This would have allowed for much more extensive and therefore more expressive holophrastic protolanguages. In this case the limit on the number of holophrases that could exist in a language would probably not be due to limits on articulatory and perceptual ability, but rather to learning and memory capacity. Only holophrases that occurred frequently enough for children to have had a chance to learn them could have formed part of a sustainable language. Therefore, if the song hypothesis is correct, the limited number of examples available to language learners (the language bottleneck [25]), would have had

\(^{11}\) *Exaptation* is an evolutionary process in which a new use is found for a mechanism or structure that was originally selected for on the basis that it fulfilled a different function [15].
a greater impact on the nature of protolanguages than the number of distinct signals that learners were able to use.

This paper does not aim to address the question of what came after protolanguage, nor what sort of phylogenetic adaptations would be needed to allow for a transition to syntactic language. Clearly this would depend to some extent on the kind of protolanguage that was present when the transition to syntactic language took place, and whether that transition was gradual (as proposed by, for example K. Smith [33]) or sudden (as proposed by Bickerton [4, 5]). If holophrastic words were present at this time, then the mechanism proposed by Wray [43] and Kirby [24], whereby holophrases are broken down into meaningful segments, might have played a role in the transition to syntactic language. Alternatively, new words with atomic meanings could have been introduced to the language, in which case we might expect the now redundant holophrastic words to no longer be used, and so be lost from the language.

As noted above, Hurford [21] and Arbib [1] suggest that the transition to language may have incorporated aspects of both of these two routes. Another possibility is that when the ability to use syntactic language emerged, words whose meanings were initially fully or partly holophrastic could have undergone a process of semantic drift so that they came to have atomic meanings. Finally, if all the words in protolanguages had atomic meanings at the time syntactic language developed, then it would seem most likely that these words were straightforwardly incorporated into a syntactic language. However, making a more definite statement about how protolanguages developed into syntactic languages may depend on first gaining a better understanding of the nature of
protolanguages.

9 Conclusion

This paper has demonstrated that protolanguages could have contained words that were neither atomic nor holophrastic, and has revealed the conditions under which these kinds of words would have emerged. Future discussions of early human language should consider the possibility that protolanguages did not contain only atomic words or only holophrastic ones. Protolanguages may have contained a mixture of both types of word, as well as words that were intermediate between these two extremes. Furthermore, increases in conceptual and communicative capacities could have produced different types of protolanguage at different points in human prehistory.

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Britain Annual Meeting, Newcastle upon Tyne, 31 August 2006.


Figure 1. Change in Frequency of Each Type of Word as Communicative Ability Increased
Figure 2. Change in Frequency of Each Type of Word as Semantic Complexity Increased