A theory of glossogenesis

by Charles William Kastner, Houston, Texas, U.S.A.

We present a theory of glossogenesis, i.e. a theory of the origin of language, based on the following ideas: 1) on the road to present-day human language, man developed a series of protolanguages[1] of gradually increasing complexity, 2) there exists within human language a well-defined hierarchy of syntactic structures, with higher level structures dependent on all lower level structures, 3) the above-mentioned hierarchy is linear, so that one can define the nth protolanguage to be the language containing the nth syntactic structure in addition to all n-1 syntactic structures above it in the hierarchy, 4) the hierarchy of syntactic structures can be deduced from the physical world, 5) the selection process at work involved competing, hostile groups speaking different protolanguages or the same protolanguage with different levels of proficiency, 6) a group speaking one protolanguage had better survival chances than a rival group speaking the same protolanguage with less proficiency or a less complex protolanguage within the same environment, everything else being equal, 7) as one approached modern human language in the hierarchy, the selection advantage for the individual with greater linguistic proficiency became increasingly important. The above-mentioned hierarchy is shown to lead to mathematical structures from category theory.

The theory is testable in that it predicts that simulations of language evolution must generate syntax elements in a certain order. It also provides a broad explanation for the evolution of human culture as reflected in the material record, providing an explicit timeline for the development of syntax structure. This timeline indicates that language developed slowly, starting with the ability to associate words with objects about 1.5 million years ago.

Studies of great apes in the wild over the last 40 years have given us a riveting portrait of what early human life may have been like.[2,3,4,5] One aspect of our history in particular has remained obscure, however, and that is how we made the transition to human language.[6,7] We present here a glossogenesis theory based on natural selection that uses the overall setting provided by wild ape studies as a social and environmental backdrop, adding one essential new ingredient: the ability to ground symbols denoting physical objects, by which we mean the ability to name things with spoken language. This new ingredient is not far-fetched, given the variety of chimpanzee and other primate vocalizations and their semantics, and particularly in light of the ability of vervet monkeys to emit different alarms for leopard, snake and eagle.[8,9,10,11,12]

One key assumption of the theory is that natural selection can operate on a group level, an hypothesis that has proponents among evolutionary biologists.[13,14] It also makes two major assumptions about early human society: that humans socialized in well-defined groups and that rival groups competed with one another violently. In fact, the second assumption is really only used in the model in the development of two syntax structures corresponding to the numerical concepts one and two, and it may be that other scenarios that selected for these concepts can be found that do not require the existence of hostile groups. In any event, there is precedent among primates for such groups. Chimpanzees in particular live in small groups inhabiting established territories with habits and technologies so distinguished from those of neighboring groups that to speak of chimpanzee *culture* is appropriate.[15] Chimpanzees are also known to raid other groups and attack their members.[16] A likely group size for early humans may have been from 50 to 150 individuals, although this size of course grew with time.[17]

For each syntax structure presented below we will do the following: 1) define what it means, 2) discuss why it requires the structures above it, 3) discuss the horizontal extension of the syntactic structure, that is, the evolution of meaning within the protolanguage, 4) apply a statement in the protolanguage to a scenario in which the survival rate of the population or individual that can utter it is enhanced, and 5) discuss the selection advantages of the new structure.

We have strictly applied the following criterion in distinguishing between the horizontal extension of a structure and vertical extension to a new structure: no protolanguage is allowed to depend on the horizontal extension of a less complex protolanguage. For example, nowhere in the theory do we presume the ability to count to three, since two is the highest structure related to number. Further counting is a horizontal extension of two.

An informal notation is adopted using the idea of an *operator*. Within each syntax structure after *symbol* an operator is introduced whose meaning defines that syntax structure. The term *operator* is used to emphasize that the new syntax acts on something to bring out something new. The operands, i.e. the things operators act on, in all cases represent symbols, which we will define presently; they are written α, β. We call an operator that operates on one symbol a unary operator, and an operator that operates on two symbols a binary operator.

Symbol

symbol is a language comprised only of symbols. A symbol is a spoken word which refers to a thing in the real world and which has meaning even when that thing is absent from the context of usage.

Horizontal Extension: We assume that over time speakers were able to agree on a symbol for any physical object, and ignores the issue of how such symbols were grounded. However, at the time when *symbol* was the only protolanguage, it is likely that new symbols would only arise if they had immediate natural selection implications for the group. The first symbols may have been alarm cries analogous to those of vervet monkeys.[18]

The horizontal extension of *symbol* happens in all subsequent protolanguages. Indeed, as the hierarchy of protolanguages is traversed, most dependent sub-protolanguages continue to expand horizontally. The process of adding *symbols* to the language must have been continually refined, so that beyond the *classification* protolanguage, one can imagine symbols being added quite readily.

Usage Scenario: "Tiger," in the presence of a tiger.

Although we don't mention them further here, all utterances given in all usage scenarios are assumed to be accompanied by gesturing and other cues such as tone and volume of voice, and so on. The complex non-verbal communications systems in primates and the copious amount of information they convey stand in stark contrast to the meager information content of early language.

Selection Advantage: Obvious.

Negation

Operator: ! is a unary operator indicating the absence of the physical object referred to by the symbol upon which it acts.

Valid statements in the *negation* language consist of all valid statements from *symbol*, which are just symbols α, β, and so on, plus statements using the operator **!,** such as $!\alpha$, $!\beta$ and so on. In general, each protolanguage includes all valid statements from the preceding protolanguage and adds the new statements made possible by its operator, including compositions of the new operator with previous operators. These compositions are not part of the horizontal extension of the protolanguage since the meanings of the component operators are known and so the composite operator is immediately meaningful.

Other Required Structures: *negation* is obviously meaningless without *symbol.*

Horizontal Extension: In the *negation* and all subsequent protolanguages, the *!* operator means no or not.

Usage Scenario: "Not tiger," when a tiger warning has already been issued, but turns out to be false.

Selection Advantage: The original warning will cause a panic, which can be exploited by other predators. Calling off the warning allows for a return to normal vigilance.

Singularity

Operator: *singular* α is a unary operator that indicates there is exactly one instance of the physical object referred to by the element of *symbol* it acts on.

Other Required Structures: *singular* is obviously meaningless without *symbol,* but it also requires *negation*, since it is predicative, meaning that it says something about a subject, and a predicate only has meaning if the concept of the truth or falsity of a predicate is available, i.e. only in *negation* and subsequent protolanguages. Without the concept of the truth or falsity of a predicate, any predicate would have to be universally applicable and therefore could not be used to characterize a subject in a meaningful way.

Given a symbol β, suppose we have a singularity operator without *negation*. In order for this operator to be well defined, that is, in order for a speaker to know when to use this operator, it must have meaning in all situations in which a speaker encounters the object referred to by β, and those situations include more than one object referred to by β. Otherwise, if we assumed that *singular* only had meaning when a single object were present, then in order for the speaker to have a criterion for when to use the operator, *symbol* would need to contain at least two kinds of β, one for a single instance of the object referred to by β and one for multiple instances of the object referred to by β. Clearly that could not happen: two such betas could not arise before *singular*, since their meaning requires the functionality of *singular*. In other words, it is the job of the *singular* operator to expand the symbolic world; it is not up to *symbol* to spontaneously evolve. So what happens when there is more than one object referred to by β? The putative *singular* operator without *negation* in that case is not defined and the speaker has no criterion for deciding whether or not to use the operator, which makes the operator meaningless.

In order for *singular* to be always properly defined, we need *negation.* Now when a speaker encounters an object or objects referred to by β, he or she can use the *singular* operator when there is one object, or the negation of the *singular* operator when there is more than one. To indicate that there are no objects referred to by β, the speaker of course can use $!\beta$.

The requirement that *negation* precede *singularity* is analogous to the requirement in classical recursion theory that the primitive recursive function α be defined before any primitive recursion predicate function can be defined.[19] The function $\alpha(x)$, defined as 1 if x is 0 and otherwise as 0, fills the role of negation.

Horizontal Extension: None.

Usage Scenario: “Single enemy,” when a single enemy is present.

Selection Advantage: A single enemy can be overcome by a group of speakers. The advantage is that this weakens the rival population and lessons competition for food resources.

Duality

Operator: *dual* α is a unary [sic] operator that indicates there are exactly two instances of the physical object referred to by the element of *symbol* it acts on.

Other Required Structures: *dual* is obviously meaningless without *symbol* and it clearly also requires *singular*. The reason that *duality* is required as a separate syntax structure is that it is required by the following structure, *similarity*.

Horizontal Extension: *duality* extends horizontally as counting: first there is a symbol for three instances of an object, then four instances, and so on.

Usage Scenario: “Two enemies,” when two enemies are present.

Selection Advantage: Two enemies can be overcome by a group of several speakers. The advantages of this are the same as given above for a single enemy. One can imagine that a member of the population who hears this may react differently depending on sex, age, size, and so on.

Similarity

Operator: *similar* α,β is a binary operator that indicates there is some perceived similarity between the two instances of the physical objects referred to by the elements of *symbol* it acts on. One or both of the objects referred to may be understood by pointing or by gazing; these forms of non-verbal communication are observed in other primates.[20,21,22]

Other Required Structures: *similar* is obviously meaningless without *symbol,* but it clearly also requires *duality*, since making a statement that things are alike requires that two objects be brought to mind simultaneously. It also requires *singularity,* since specific solitary instances of α and β are initially involved, but *singularity* is inherited from *duality*.

Note that a demonstrative pronoun is not required as a syntax structure here because that meaning must be supplied by pointing. Demonstrative pronouns arise as a horizontal extension of *reflexive verb*, since it is not until then that the implied reference back to the speaker makes sense.

Note also that *similar* requires *symbol,* but it does not necessarily require known symbols. This operator was undoubtedly used as new symbols were being established.

Horizontal Extension: Eventually *similar* operates in situations where neither symbol operated on refers to a specific instance of a thing.

Usage Scenario: "[this] bug like [that] bug!" when the second bug is known by everyone to be good to eat and non-biting, and the speaker knows the first bug to also be good to eat and non-biting.

Selection Advantage: Obvious.

Classification

Operator: *class_x* α is a unary operator that indicates that the thing referred to by the *symbol* it acts on has quality x, where x represents any quality or attribute.

Other Required Structures: *class_x* is obviously meaningless without *symbol.* To see why *similarity* is necessary, assume it is not necessary. If a speaker of *classification* only knows *duality*, then the only way he can classify things is by number. But that's something he can already do, as a speaker of *duality*. He must know *similarity* so that he can group things together in his mind based on their being alike in some way.

As in the case of *similar*, *class_x* requires *symbol,* but it does not necessarily require a known symbol. The object referred to may be understood by context.

Horizontal Extension: *class_x* from the beginning says what kind of thing a thing is and that includes things that can be classified by an intransitive action. In this regard it is worth noting that some modern languages such as Chinese do not clearly distinguish between adjectives and intransitive verbs.[23] At any rate, there would be no way to distinguish in *classification* between *hot* and *boiling*, for example, since all usage is predicative. Of course, in subsequent protolanguages the ability to distinguish the quality from the action related to the quality was developed.

Usage Scenario: "Good plant!" when the speaker wants to convey that a plant is good for a given ailment.[24] Here the quality referred to is the quality of being beneficial.

Selection Advantage: Obvious.

Comparison

Operator: *more_class_x* α, β is a binary operator that indicates that the physical objects referred to by the symbols upon which it acts differ from one another in terms of degree with respect to a given classification *class_x*. It means that the first operand has more of the quality denoted by *class_x* than the second operand.

Other Required Structures: *more_class_x* clearly requires *classification.* As was the case in *classification*, *more_class_x* requires *symbol,* but it does not necessarily require known symbols. The objects referred to may be understood by context.

Horizontal Extension: The quality x in *more_class_x* initially was probably only the quality of being good; in other words, initially *more_class_x* meant *better.* Gradually, more differentiating qualities were referred to, such as sharpness in the usage scenario below.

Usage Scenario: "[This] rock sharper than [that] rock."

Selection Advantage: Being able to differentiate things by degree allows speakers to store more detailed knowledge about what works and what doesn't work to their advantage.

Sequence

Operator: *first* α is a unary operator that indicates that the object referred to by the symbol upon which it acts occurs before some other object as perceived by the speaker, with respect to time or space.

Other Required Structures: *first* requires *comparison,* for the following reason. *first* as applied to space is really identical to *more_class_x*, where x is the quality of being close or near in space and the second operand is understood from context . As an example from English, consider *The apple tree is the first tree in the row of trees that extends to the south from the road*.

The reason that *sequence* is required as an independent syntax structure is that it is required by subsequent structures; otherwise, it could be considered a horizontal extension of *comparison*.

Horizontal Extension: In the beginning, *!first* was understood as *last*. Later, *sequence* extended horizontally to the ordinals *second*, *third*, and so on. The degree of extension is the same or less than the degree of extension of the cardinals, which occurs in *duality*. In addition to ranking with respect to space or time, the operator was extended to allow ranking with respect to any quality, for example the quality of being good or fast. Included in this extension is the superlative, which denotes first rank of at least three things, as in the ranking best, better, good, or fastest, faster, fast.

The speaker cannot distinguish at this point between time and space. The usage scenario below illustrates a sequence in time.

Usage Scenario: "Impala first, spear last," when the speaker has thrown a spear at an impala running across his field of vision. He aims his throw at the current position of the impala and when the spear lands there, the impala is no longer at that position.

Selection Advantage: The author remembers as a boy the first few times he tried to throw a ball at a receiver running across his field of vision: the ball always landed behind the receiver. The ability to throw ahead of the receiver so that the ball hits him as he runs is not innate, but requires a conscious, i.e. verbally based, effort, at least in order to quickly acquire the ability. This ability has obvious selection advantages for speakers who hunt using a spear or rock trying to hit a running animal. [25]

Elapsed Time

Operator: *earlier_class_x* α is a unary operator that indicates that the object referred to by the symbol upon which it acts was in a state characterized by the quality x at some point in time earlier than when the operator is used.

Other Required Structures: *earlier_class_x* clearly requires *sequence* and also *classification*. It must be an independent structure because it is the first structure to distinguish time from space, and subsequent structures require that capability.

Horizontal Extension: *earlier_class_x* has little horizontal extension. Eventually the state quality x may be dropped and the operator used adverbially.

Usage Scenario: "Earlier impala sleeping," when the speaker finds matted grass after seeing an impala from a distance and going over to investigate.

Selection Advantage: The speakers become better hunters if they are consciously aware of the habits of their prey. In the above scenario, they might come back another day and see if the impala return.

Transitive Verb

Operator: *action_x* α,β is a binary operator that indicates that the object referred to by the first symbol upon which it acts performed an action x on the object referred to by the second symbol. α or β might be understood by context.

Other Required Structures: *action_x* clearly requires *symbol*, but it also requires *elapsed time*. We will give a lengthier explanation than usual for this, since at first glance it may seem counterintuitive, especially if one considers that by the time *transitive verb* is reached considerable time may have elapsed since the introduction of *negation*, the first syntax structure which unambiguously distinguishes human language from other native primate languages.

The idea that the meaning of a verb could be established by an innovative speaker of *duality* who mimics or performs an action for an audience must be rejected. Context would already convey the meaning intended by the verb and so the verb could neither take hold nor even have a reason for being. Another reason that such a scenario does not work is that the speaker would have had to have at least spoken *sequence,* because the source of the action begins acting before the receiver begins receiving the action and a speaker must understand this before discovering the concept of subject and object (α and β). But even here we fall short, for the following fundamental reason.

The receiver of the action of the verb undergoes a change of state due to that action; for example, in the case of the verb *hit*, he goes from being untouched to touched, or unhurt to hurt, or sleeping to awake, as the case may be. Or take the example of the verb *kill*; here the receiver goes from the live state to the dead state. Any transitive verb one can think of also has this effect of changing the state of the receiver of the action: *kiss, push, trick, eat, throw, pull, tear, break*, and so on. The *elapsed time* structure provides the mechanism for expressing this change of state, via *earlier_class_x*, *!earlier_class_y,* where in the latter statement *!earlier…*means *later* and the quality y is the negation of the quality x in the former. Without this understanding of change of state, *transitive verb* cannot be discovered, just as *similarity* cannot be discovered without an understanding of *duality*.

One final reason that *action_x* requires *elapsed time*: *action_x* only makes sense as a past tense when it is first introduced. As we've mentioned, context makes usage of the transitive to describe concurrent action unworkable at this stage of the hierarchy. This is consistent with the fact that a transitive verb brings about a state change in the receiver: in order for the receiver to be in the new state, the action of the verb has to take place before the speaker speaks. So in *transitive verb*, what speakers were really saying was *kissed, pushed, tricked, ate, threw, pulled, tore,* and *broke.* Since no syntax structure before *elapsed time* distinguishes between time and space, *transitive verb* cannot be before *elapsed time* in the hierarchy.

Horizontal Extension: *action_x* instances originally had to be expressed in terms of the instrument used to perform the action, possibly accompanied by all or part of *earlier_class_x, !earlier_class_y.* So, for example, *speared* was used before *killed*.

Since *sequence* is available at this level, at some point two *action_x* statements were chained together to describe two events in order, and then three statements, and so on.

After the introduction of *cyclic time*, *transitive verb* extends to different time contexts and to verbs of emotion, etc.

Usage Scenario: "Rock cut skin," when the speaker brings up the fact that he just cut an animal skin with a rock, in order to point out a new application for a sharp rock.

Selection Advantage: The selection advantage of the above usage scenario is clearly less immediate than in the earliest structures. This reflects a trend for successive syntax structures to have selection advantages that are more and more systematic. Originally, language served to immediately save lives and was used chiefly in life and death situations. Over time, it increased survival rates by improving survival processes, so that its use was not only for life and death situations, but also for referring to situations that had long-term implications for the survival of the group.

The selection advantage of *transitive verb* is that it allows a more elaborate description of processes that work for survival, so that these can be preserved, and it facilitates the discovery of new survival processes because existing processes that work have been better described and understood.

Reflexive Verb

Operator: *action_x_on_self* α is a unary operator that indicates that the object(s) referred to by the symbol upon which it acts performed an action x on himself/herself/itself/themselves.

Other Required Structures: *action_x_on_self* clearly requires *transitive verb*. However, it cannot be a horizontal extension of *transitive verb* because it is required by the next syntactic structure in the hierarchy, *cyclic time*. This is a point worth discussing here.

We first point out that before *reflexive verb* a verbalized concept of identity is not available. In *transitive verb* there is nothing in the language that allows for a speaker to refer to himself or herself, or for a speaker to refer to another object as referring to itself. The word *I* does not exist yet, because nothing has allowed it to exist. It is possible for *action_x* to be used with the speaker understood by context to be the one who carried out the action, but that does not mean that the speaker has a concept of herself as a separate identity, nor does it mean that other speakers will interpret the fact that the speaker carried out the action as meaning that the speaker has an identity. In the speaker's mind the focus is on the action and the receiver of the action, but not on herself as the initiator of the action, because nothing in *transitive verb* allows her to refer to herself using words. If no speaker has a concept of his or her own identity, no particular thing can have an identity in a speaker's mind either, because the concept of identity does not exist.

We also point out that in order for the concept of future to emerge, it is necessary for there to be an external time marker undergoing periodic motion that serves as a time reference, such as the sun or moon. Without a time marker, there would be no way to associate an event with a time, and no way to project a certain amount into the future, because there would be no metric for such a projection. In the discussion below, we refer to two separate events at two different times. We assume the two events both occur during daylight hours and that they are separated by less than a few hours.

Now we are able to discuss the discovery of *cyclic time*. The speaker knows how to think backwards in time from *time elapsed*, so she first thinks backwards. She must remember some remarkable event in the past that she witnessed, which she can do because she speaks *reflexive verb*, and associate with that event the position of the sun, her time marker, at that time. She can make that association if the sun hurt her eyes, for example, again because she speaks *reflexive verb*. In effect, she must now transport herself into her previous self for an instant to that event and from that point in time and space think of herself in her current state, noting the current position of the sun and realizing that the position of the sun has continuously evolved from its position at the time of the event to its current position. Finally, having understood the forward-moving nature of time, it dawns on her that she can project from her current state to the future some amount, and extrapolate to get the position of the sun at that future time. Once this mapping from sun position to events in time is understood, the cyclical aspect of the sun's motion is also readily understood.

Clearly the process just described requires that the speaker understand that the person who witnessed the remarkable event and the person reflecting on that event are one and the same, that is, that she have a concept of her own identity, which as we've argued first arises in *reflexive verb*.

Horizontal Extension: *reflexive verb* extends horizontally in many ways. As argued above, a speaker's sense of identity is established here. Also, it becomes apparent that other speakers also have identities which can be addressed with language. This shift in consciousness must have generated an explosion of verbal communication. Before *reflexive verb* language was strictly declarative, the only form of discourse being declarations in sequence, which were limited by the syntax available in *transitive verb* --- repetition was the main form of linguistic interaction between speakers. In *reflexive verb* it became possible to ask for information from others, because they were thinking beings, too, with whom a convention could be established for exchanging information. Dialogue, in which speakers may explicitly refer to themselves and their interlocutors, could now take place. Furthermore, language was now a conscious act, which means it could be consciously, that is deliberately, developed. It is no exaggeration to liken this abrupt change in human communications to a phase transition in a physical system, in which a system undergoes a transition from a disordered to an ordered state due to an infinitesimal change in some physical quantity upon which the system depends.

In *reflexive verb* many new forms of expression are possible. The question words *what*, *where*, *who*, *which* and *how*, personal pronouns such as *he*, *she*, *you*, *we*, possessive markers such as *my*, *your*, *mine*, clearly all of these can now be discovered and used. Also, the demonstratives *this*, *that*, *these*, and *those* make sense because they refer indirectly to the speaker, who now has an identity. Relative clauses such as *that I threw* in *the rock that I threw* are also possible after questions and demonstratives have been introduced. After relative clauses, the definite and indefinite markers *the* and *a* too make sense.

Representative art is now possible, since speakers can be aware in some dim sense of the essence of *symbol*.

Usage Scenario: "Hit myself," when the speaker hits himself with a sharp rock and explains to others what happened.

Selection Advantage: In *reflexive verb* selection operates to a significant extent on the individual as well as the group level. Although selection on the individual level undoubtedly occurred in previous protolanguages, in *reflexive verb* interpersonal relations have a much stronger verbal component than before. This allows an intelligent speaker more opportunity to stand out in complex social situations, which results in better chances of reproductive success. On the group level, the advantage that the drastically improved communications made possible in *reflexive verb* is obvious.

Cyclic Time

We now describe the hierarchy's next ten structures, each of which we will later show to be closely analogous to a corresponding structure already described, namely the structure occurring ten steps back in the hierarchy. The selection advantages of these new structures are obvious.

In *cyclic time* speakers discover the meaning of units in time by reference to something that repeats itself over and over at regular intervals in time.

We have already discussed the mechanism for discovery of *cyclic time* while discussing *reflexive verb*, where we argued that *cyclic time* requires *reflexive verb*. From that discussion it is clear that along with *cyclic time* emerges the concept of the present as well as the future, so that speakers now understand past, present and future. Therefore, all time-related verbal markers can now occur, although not all at once since there is a dependence among them. Verbs of volition now make sense, too, because the speaker has a concept of the future and the ability to anticipate verbally, and likewise imperatives are now possible. Time units *day*, *month, year*, and fractions of *day* also arise here.

The reason *cyclic time* must exist as a separate syntax structure is that it is required by the next structure, *implication*.

Implication

implication is a syntax structure characterized by the if-then construction. We argue that *cyclic time* must be available in order for *implication* to emerge.

In order for *implication* to establish itself, there must be a belief that given a certain set of circumstances, the consequences of those circumstances are similar whenever that certain set of circumstances happens again. Such a belief can only arise if it is seen over and over as a pattern. Here is an example.

Let us call A a circumstance and B an event for the sake of simplicity; in general, A and B each could be either a circumstance or an event. Now consider the following pattern in time: AB*************AB*********AB************AB…, where the ************** indicate arbitrary events and circumstances not including A, and the three dots at the end indicate the pattern repeats itself an arbitrary number of times.

If the pattern is repeated enough, then it will be held that given A, B will follow as inevitably as it follows that if the sun is currently rising, it will later be at high noon, provided *cyclic time* is spoken.

One might argue that the mere repetition of AB in itself might be sufficient to cause one to understand that given A, B will always follow, without *cyclic time*; one could imagine for example a rat in a cage with constant lighting being conditioned to respond to a stimulus. The point to be made here in response is that we are trying to show where in the hierarchy the understanding that B follows A can be explicitly expressed with language. Let us look at the problem more closely: suppose there are many such rats in the above-mentioned controlled environment and that these rats speak *reflexive verb,* which we assume is a necessary condition for the discovery of *implication.* If *cyclic time* were not available, then the rats could not say that B *always* follows A, because this implies that they have a concept of something happening over and over, now and in the future. From *elapsed time* they can express order in time, but without *cyclic time* they don't have a notion of the present or future, since in *reflexive verb* the action of all expressions involving time starts and ends at some point in the past. In *reflexive verb* they could say B always *followed* A, which strictly refers to the past and does not involve *implication*.

There is an interesting question that arises from the rats discussion above, namely whether the notions of present and future time could have been discovered without discovering the cyclic aspect of time; the question is interesting because *implication* might be discovered with these notions alone. If A and B were both events, and B followed A at regular intervals, then the rats could use the AB cycles to discover *cyclic time* by the mechanism we've already described: A and B would be analogous to two points on the sun's trajectory. We want to consider what might happen if the intervals between A and B were aperiodic. According to our arguments above, the discovery of *cyclic time* relied on the speaker realizing that the position of the sun had moved in a predictable fashion from one point to another during the time separating a memorable past event and the present. If the only thing that can be said about the relation in time between A and B is that they are ordered, then it is not possible to predict when B will occur, given A. So even if there are events A and B corresponding to the past event and the present, respectively, and even if the speaker happens to notice the corresponding position in time of both A and B, there is no way for him to establish a rule for measuring distances in time based on the distance in time between the past event and the present. Without such a metric, the idea of projecting into future time cannot occur to him, and without an understanding of future time, the present has no meaning, being a bridge between past and future time. We conclude that understanding the cyclic aspect of time goes hand in hand with understanding present and future time and therefore is indispensable for the discovery of *implication*.

The horizontal extension of *implication* includes the question *why*, the concept of causality, and conditional modalities in verbs, as in *if you had listened to the crow, you would have known the rain was coming*. Verbs of cognition such as *to know* are also possible now for the first time.

AND

AND is a syntax structure that includes the two logical operators AND and OR. They emerge together because a AND b is the same as !(!a OR !b) and likewise a OR b is the same as !(!a AND !b). In logic, the operators negation, AND and OR form what is called an adequate set of connectives, which means that any truth function can be represented by a statement whose variables are acted upon by a combination of those connectives; some other adequate sets are {negation, OR}, {negation, AND}, and {negation, implication}.[26] The essence of the *AND* structure is that speakers now have an intuitive understanding of the concept of an adequate set of connectives.

Obviously, these operators require *implication* in order to have meaning. They could be considered to be a horizontal extension of *implication*, but once again they must be a separate structure because they are required by the next structure, *equality*. Regarding their origin, one can use arguments similar to those used for *implication* based on *cyclic time*.

Equality

equality is a syntactic structure which allows one thing to be thought of as equal or equivalent to another in some sense. Looking back, we notice that *similarity* is a structure that goes in the direction of *equality*; this is the first obvious hint of the parallels between structures to be found throughout this article.

The new syntax is given by the binary operator *equivalent_x* α, β, meaning α is equivalent to β with respect to a classification x. This operator requires *AND* as we shall now show, and therefore was not possible before now.

We recall that *more_class_x* β, γ, the *comparison* operator, indicates that β has more of the quality denoted by *class_x* than γ (we changed symbols from α, β used in the above discussion of *comparison* to β, γ here temporarily in order to avoid a conflict with the primitive recursive function described below). Combining this operator with *implication* and *AND*, we get

if(!*more_class_x* α,β AND !!*more_class_x* α,β) then *equivalent_x* α,β.

In words: if α doesn't have more of the quality x than β and it doesn't have less, then it has the same amount, i.e. α is equivalent to β with respect to the quality x. This procedure for defining equality is analogous to the procedure for defining equality as a primitive recursive function $x = y$, which defines two numbers to be equal by first defining the primitive recursive absolute value $|x - y|$, and then uses a form of negation of the absolute value. The definition of the absolute value is $|x - y| = (x \dot{-} y)+(y \dot{-} x)$, where the binary operator $\dot{-}$ is defined by $x \dot{-} y = x - y$ if $x > y$, and 0 otherwise. The definition of equality is then $\alpha(|x - y|) = \alpha((x \dot{-} y)+(y \dot{-} x))$, where $\alpha(x)$ is defined as 1 if x is 0 and otherwise as 0.

A natural context in which such a thought process would occur is in the cutting and playing of two reeds as musical instruments; in this case the quality x is the length of the reeds: if they are the same length, they give the same tone, which is <u>much</u> more pleasing than if the tones are slightly different, outside of a very small tolerance. By cutting different lengths related in a certain manner consonant intervals could be generated, for which humans appear to have a universal preference.[27] This context appears so natural that the author holds that *equality* was in fact discovered this way, under the assumption that our preference for consonant intervals did not develop *after* the discovery of *equality*. Other contexts, such as the sizing of spear tips to fit stone spearheads, seem to lack the motivation for such exactness or they lack such a sensitive gauge for measuring convergence on an exact value; weighing things using a balance scale is another possibility, but that appears to be premature at this point in the hierarchy.

The horizontal extension of *equality* is extremely rich. As indicated, music starts here. The question of what something is or is not can first be asked in this structure. Abstract concepts such as love and courage can be synthesized. Epistemology and the beginnings of science, from history to Euclidean geometry to physics, are now possible.

Equivalence Class

equivalence class is a mathematical structure. Several definitions emerge with it at once: binary relation, equivalence relation, equivalence class, partition, set, subset, and element. These definitions are possible because *equality* allows new concepts to be defined using existing syntax structure.

Provisionally, we say a set is a collection of things called elements. A subset of a set S is a set containing none, some or all of the elements of S. A null set contains no elements. Given a non-null set S containing elements A, B, C, …, a binary relation on S is a set whose elements are ordered pairs (A, B) of elements of the set S. A binary relation R on a set S is an equivalence relation if the following three statements hold for all elements A, B and C of S:

1. if (A, B) is an element of R, then (B, A) is an element of R.
2. if (A, B) and (B, C) are elements of R, then (A, C) is an element of R.
3. (A, A) is an element of R.

An equivalence class is defined in terms of equivalence relation, as follows. Given a set Z with an equivalence relation defined on it, there is a theorem that says that Z can be partitioned in a unique way into subsets based on the equivalence relation.[28] These subsets are disjoint, meaning that every element in Z is in exactly one of the subsets. Each subset is called an equivalence class; the decomposition of the set into equivalence classes is called a partition. The theorem also says the converse is true; in other words, given a partition of a set, a unique equivalence relation on that set is determined.

For example, given the set Z = {1,2,3,4,5} partitioned into three equivalence classes as follows {1}, {2,4,5}, {3}, the corresponding equivalence relation is given by R = {(1,1), (2,2), (3,3), (4,4), (5,5), (2,4), (4,2), (2,5), (5,2), (4,5), (5,4) }.

Now we return to the definition of set and say a set is something we construct by the procedure indicated above: starting with a collection of things, we define an equivalence relation on the collection, and that makes our collection of things a well-defined set.

To show that the above-mentioned definitions are possible at this stage of the hierarchy, we justify them as follows. The definition of set, first in its provisional form as a collection, makes use of *sequence* to build the set one by one from its constituent elements in any order we choose; subset also uses *sequence* in the same way. The definition of null set requires *negation*. Ordered pairs in the definition of binary relation come from *sequence* and *duality*. The conditions required for an equivalence relation use syntax from *implication* and *AND*. The above-mentioned theorem makes use of *implication*, *comparison*, *AND* and *singularity* in its statement and proof. Finally, the names of these concepts, as all words, come from *symbol*.

equivalence class is required as a separate structure because the concept of set is required by the following structure, *function*.

Function

function is a mathematical structure. A function relates one set to another, a source set to a target set, by associating with each element of the source set exactly one element of the target set. The source set of a function f is called the domain of f, and the target set is called the codomain. Other names for function are mapping, transformation, operator, and map. A function f from the set A to the set B is often written

f

$$A \rightarrow B$$

For each element a in the domain A, f assigns an element b = f(a) in the codomain B.

A careful definition of a function f says that it is a set whose elements are ordered pairs (x, f(x)), where x ranges over the entire domain of f, subject to the condition that given an x, f(x) is a single element of the codomain of f. We are able to speak of sets and elements here because of *equivalence class* and of ordered pairs again because of *sequence* and *duality*. Also, the *subject to the condition* in the definition comes from *implication*. The word *entire* comes from *sequence*: we build these ordered pairs starting from the first and ending at the last element in the domain according to any order of our choosing. Lastly, we note that *single* comes from *singularity.*

The horizontal extension of function includes monomorphism, epimorphism, isomorphism, endomorphism, and automorphism, all of which are functions having special properties with respect to domain and codomain. For example, an endomorphism is a function for which A and B are the same set.

In physics, Kepler's laws, force, Newton's laws, and Maxwell's equations can all occur here, as well as thermodynamics, statistical mechanics, optics, and so on.

Function Composition

function composition is a structure needed by the next structure, *category*. Given sets A, B, and C, and a function ϕ from A to B and a function ω from B to C, we define the function $\zeta = \omega \circ \phi$ from A to C to be given by first applying ϕ, then ω. *function composition* is actually a function, since it takes two functions and maps them to a single function.

function composition is the glue that holds category theory together. [29] Practically anything of interest in category theory can be drawn up as a diagram with arrows between objects, where the arrows represent functions. Many interesting cases arise when there is more than one sequence of arrows available to get between two given sets in a diagram. In such cases, when more than one arrow is involved in such a sequence, functions are being composed.

In theory our speakers could still only be counting to two if there had been no horizontal extension in *duality* at all. Using A, B and C appears to violate our principle of not allowing any structure to rely on the horizontal extension of a less complex structure. We get around this problem by noticing that we can speak only of two objects in this case, so C must be either A or B.

The horizontal extension of composition involves chaining three functions together to get a new function, then four, and so on.

Category

A *category* **C** is a set of things A, B, C, D, E … called objects, and a set of function-like things called morphisms or arrows that go from object to object. A category is subject to the following two conditions: [30,31,32]

1. Composition of morphisms is defined, and is associative, which means that given morphisms ω from A to B, ϕ from B to C, and ζ from C to D, the following holds: $(\zeta\circ\phi)\circ\omega = \zeta\circ(\phi\circ\omega)$.
2. For each object A in **C** there exists an identity morphism 1_A such that, given morphisms κ from A to B and λ from C to A, we have $1_A \circ\lambda = \lambda$ and $\kappa \circ 1_A = \kappa$.

Morphism is a generalization of the concept of function. A morphism distinguishes itself from a function in that it is allowed to have no ordered pairs at all, although we still give it a domain and codomain; the name arrow reflects this generalization.

An object refers to anything at all, a fish, a sack of potatoes, a set, anything, as long as 1. and 2. above hold. Object, morphism, and category all arise together in this structure.

Categories are pervasive throughout mathematics; in fact, it is possible to describe all of mathematics using category theory, a point we will touch upon later. To give an example of a category with supreme importance in mathematics and physics, we shall define what a group is and show how that definition makes a group a category. The theory of groups is a major component of modern algebra.

First, we define a binary operation on the set G informally as an operation that takes two elements of G and maps them to an element of G; a more formal definition would require the concept of a product so that we could define a binary operation as a function from the product GxG to G. A set G with a binary operation * is a group if the following hold:

1. There is in a unity element 1 within G such that, for all g in G, 1*g = g*1 = g.
2. For all g in G, there exists an element h in G such that h*g = g*h = 1.
3. The binary operation * is associative.

A group is a category containing one object, G. We take as morphisms the elements of G with both domain and codomain G, and we define composition of morphisms to be the binary operation *. The elements of G as morphisms do not have ordered pairs associated with them.

Groups provide a natural framework for expressing symmetry. They were an absolutely indispensable tool in 20th century physics, well before they were interpreted as categories. The horizontal extension of category includes special and general relativity, quantum mechanics, quantum field theory and string theory.

Within category theory itself, an important horizontal extension of category is topos, which is used in the categorical development of set theory and logic.[33]

Functor

functor is a map between categories. If C and D are categories, a functor F from C to D is a map that assigns to each object A in C an object F(A) in D and to each morphism f:A->B in C a morphism F(f):F(A)->F(B) in D such that:

1. $F(1_A) = 1_{F(A)}$.
2. $F(\zeta \circ \phi) = F(\zeta) \circ F(\phi)$.

In other words, a functor maps objects to objects and morphisms to morphisms so that objects in the target category are related to one another by morphisms in the same way they are in the source object. In this fashion functors preserve structure. It may occur that the target category is much simpler, in which case the functor must forget some of the structure of the source category.

There are many examples of non-trivial functors.[34] For physicists the most interesting example of functors are topological quantum field theories, which relate as categories the world of general relativity on the one hand and quantum theory on the other.[35] The existence of topological quantum field theories, established by Witten in the late 1980's, is further evidence of the profound links between mathematics and physics.[36]

Natural Transformation

natural transformation is a mapping between functors. If S and T are functors from the category C to the category D, a natural transformation is a map τ: S(A) -> T(A) which assigns to each object A in C a morphism in D such that given a morphism f: A->B in C, $T(f)\tau_A = \tau_B S(f)$. In other words, the following diagram "commutes":

$$\begin{tikzcd} S(A) \arrow[r, "\tau_A"] \arrow[d, "S(f)"'] & T(A) \arrow[d, "T(f)"] \\ S(B) \arrow[r, "\tau_B"] & T(B) \end{tikzcd}$$

A *natural transformation* preserves structure between two functors that map between the same two categories, C and D.

category and *functor* were originally defined in order to define *natural transformation*, which itself was motivated by connections between topology and algebra.[37] The horizontal extension of *natural transformation* appears to include n-categories.[38]

It appears that as of the year 2003 we find ourselves in *natural transformation*, since no applications of natural transformations as yet have led to new physics.

Generalizations

0	Negation	Cyclic Time
1	Singularity	Implication
2	Duality	AND
3	Similarity	Equality
4	Classification	Equivalence Class
5	Comparison	Function
6	Sequence	Function Composition
7	Elapsed Time	Category
8	Transitive Verb	Functor
9	Reflexive Verb	Natural Transformation

Table I

Table I summarizes our results so far. The generalizations we now describe have in common that they account for variation with time; this is more clearly manifested in the early structures.

negation is generalized by *cyclic time*. The negation operator applied twice is the same as the identity operator, at least until intuitionistic logic is discovered. Both *negation* and *cyclic time* behave cyclically.

singularity is generalized by *implication*. In *singularity* there are two operators, *singular*, and *!singular,* which together allow exactly two propositions in the physical presence of the object referred to by any operand; one of the propositions must be true and the other false. *implication* allows propositions with variable truth values to be considered using its operands. *singularity* gives speakers an inkling of nature of the boolean constants true and false, and propositional logic; *implication* gives speakers an inkling of the nature of boolean variables and first order logic.

duality is generalized by *AND*. *duality* is discovered by combining two invocations of *singular*. *AND* is discovered by combining two implications. *duality* makes possible a static picture of two things. *AND* makes possible a variable picture of two ideas. These operators extend their predecessors in an analogous way: *duality* gives meaning to the idea of a numerical successor function that leads to the natural numbers, while AND gives rise to the concept of a complete set of logical connectives, which allows for an arbitrary formula in first order logic.

similarity is generalized by *equality*. For its discovery, *similarity* requires two separate invocations of *singularity* to first isolate the operands and then the use of *duality* to relate them; likewise, *equality* requires two boolean variables from *implication* as well as *AND* for its discovery. *similarity* results from a one-time evaluation; *equality* results from a sequence of evaluations.

classification is generalized by *equivalence class*. *classification* uses *similarity* to determine how to group things. Likewise, *equivalence class* requires *equality*, without which the concept of equivalence relation is impossible; *equivalence class* determines how to group things unambiguously.

comparison is generalized by *function*. The *comparison* operator *more_class_x* selects one of two things on the basis of *classification*, thus relating one thing to another in an integral sense; *function* maps one thing to another on the basis of *equivalence class*, relating one thing to another in a structural sense.

sequence is generalized by *function composition. function composition* combines two functions to yield a new function, whereas *sequence* combines two comparisons to yield a new comparison. To explain the latter, consider the usage scenario "impala first, spear last" given above. Translated into operator notation, this reads *more_class_x* α β, *!more_class_x* β α, where α and β refer to impala and spear, respectively, and x is the quality of being near in a temporal sense to the time when the spear was thrown --- viewed from the point in space where the spear landed. The scenario could also be translated as "impala before spear," which is effectively a comparison in itself. Both *sequence* and *function composition* extend horizontally in parallel with the horizontal extension of *duality*.

elapsed time is generalized by *category*. *earlier_class_x* α represents an evolution in time of α; "earlier impala sleeping" says something about the impala at an earlier time which may or may not still hold at the time of the utterance. A category can be used to model the evolution in time of a dynamical system; in such a category the objects represent states of the system and the morphisms represent transitions between states.

The subject of a *transitive verb* takes its object from one state to another, the two states being *earlier_class_x*, !*earlier_class_y*, where *y* is !*x,* as mentioned above. So in "rock cut skin," the animal skin earlier was in the uncut state and later was in the cut state.   By themselves *earlier_class_x* and !*earlier_class_y* each implicitly contain the same information, but from a different viewpoint. *functor*, which generalizes *transitive verb*, maps from one category to another category. The two categories are analogues of the initial and final states of the receiver of the transitive verb's action. As discussed above, a topological quantum field theory is a functor relating a category that models the world of general relativity to a category that models the world of quantum theory. In terms of structure given by morphisms between objects, these two categories contain the same information by the definition of functor.

The subject of a *reflexive verb* takes itself from one state to another. We now consider the state of the "giver" of the action of the verb as well as the state of the receiver, before and after the action takes place. The reflexive aspect of the verb equates the giver with the receiver, and therefore the transitive aspect of the verb takes the both the giver and the receiver of the action from one state to another. A *natural transformation* is a mapping from one functor to another, whereby each of the two functors act on one category and relate it to a second category. Again the two categories can be thought of as analogues of the initial and final states of the receiver of the verb's action. The functors are analogues of the transitive action of the verb, which takes the receiver of the action from initial to final state. The natural transformation, which links equivalent structure within the functors, is the analogue of the reflexive aspect of the verb.

Language Evolution Timeline

Only a few protolanguages have been discovered in times of recorded history: the three protolanguages of category theory in 1945 by MacLane and Eilenberg, and the notion of equivalence class in the 19th century. Since earlier protolanguages evolved in prehistory, we must look at material culture specimens to determine approximate dates for them. We shall do that for a few protolanguages and then use those dates to put together a very rough overall timeline.

First, we look for a latest possible date for *equality*. Any musical instrument capable of producing tones requiring the notion of an exact interval can be considered to be evidence for *equality*. Flutes found in the Henan province of China dating from 8000 to 9000 years ago have this quality; one of the flutes even has a correcting hole that brings it into a better tuning.[39] An older flute from the Geissenkloesterle cave in southern Germany, dating from roughly 37,000 years ago, has been shown in a reconstructed model to play the notes C, D, F and B melodically, so that multiples of the half-step interval of the chromatic scale were clearly deliberately produced.[40,41] It is possible as well that stone tools were used as musical instruments in the manner of a xylophone at still earlier times.[42]

There are several things which would indicate competence in *cyclic time*: 1) representations of the sun at different positions in the course of a day, 2) representations of cycles of the moon, 3) seasonal behavior clearly planned for in advance, such as agriculture, and 4) structures such as the boulders of Stonehenge which show knowledge of the solstice or equinox. The earliest such evidence is that of bone carvings found in Europe from roughly 30,000 years ago that points to an awareness of the lunar cycle according to Marschack.[43] However, we know from the evidence for *equality* that *cyclic time* was spoken sometime before roughly 37,000 years ago.

reflexive verb is the first protolanguage in which symbolic art is likely to emerge. A pair of recently found engravings in ochre from the Blombos cave of South Africa, shown in Figure 1, suggests that such art may go back at least as far as 77,000 years, but this is open to interpretation since the engravings are abstract and may have no meaning.[44] The author suspects that the two engravings contain the same number of diagonal lines in one direction, eight, and so at least might be interpreted as a representation of the number eight, especially if other such engravings were found. In the spirit of Marschack, he further suspects that the two engravings represent the same thing, namely the trajectories of the moon and the sun over a one-month period with the skyline in the middle, whereby the new moon trajectory breaks the symmetry of the representation in a single segment as it approaches the sun. If the latter interpretation were correct, the engraving would correspond at least to *cycle.* Speculations aside, the first firm evidence of symbolic art is from the Upper Paleolithic in Europe, about 35,000 years later.[45]

sequence would be reflected in material culture as an object which required at least two steps to make, the steps being in a particular order. The Mousterian stone tool tradition, which began roughly 200,000 years ago, produced such objects.[46] In fact, the distinguishing characteristic of the Mousterian technique was precisely that it was a multistep process: first a stone core was shaped, from which stone was "peeled off" subsequently piece by piece, and then each of these individual pieces of stone was finished into a tool itself. This tradition appears early in North Africa, South Africa, Northwest Europe and Mediterranean France, perhaps independently.[47]

In order to find traces of *duality* we look for something involving two distinct aspects that were deliberately produced. We find this in the stone tool technique preceding the Mousterian called the Acheulean, which began roughly 1.5 million years ago in East Africa.[48] It differs from the Oldowan tradition that preceded it in that the finished stones had two distinct faces, as opposed to being of haphazard shape as finished stones were in the Oldowan tradition, which began roughly 2.5 million years ago.

From the above observations we establish the rough timeline shown in Figure 2, which shows the appearance of syntax structures as a function of time. Note that since we have taken conservative dates for each point in the above curve, revisions are expected to shift the points corresponding to *equality* and all protolanguages before *equality* to the left. Of course, the plot in Figure 2 does not mean to imply that there was a single group that started in *duality* whose direct descendants made it all the way to *equality*. One can easily imagine that syntax structures were independently discovered by different groups, as may be reflected in the Mousterian tool traditions just mentioned.

From Figure 2 one concludes that humans have been using language for at least 1.5 million years. Such a time span is long enough for substantial changes to have occurred in the human brain and vocal tract due to selection based on language proficiency in both speech and syntax.[49,50] In Figure 3 we speculate what the plot in Figure 2 might look like as more evidence becomes available, shifting the points corresponding to *reflexive verb*, *cycle* and *equality* to the left. Figure 4 shows a plot of hominid brain size as a function of time; it is apparent that brain size increases in a way that qualitatively matches our plot in Figure 3. In particular, there is an explosive growth period in the last 200 thousand years, which one would expect from the increased importance of language for both group survival and individuals' reproductive success within the group as higher syntax structures were employed.

In Figure 5 we have plotted, in addition to the points of Figure 3, three exponential functions fitted to the endpoints *duality* and *natural transformation*, *sequence* and *natural transformation*, and *reflexive verb* and *natural transformation*, respectively; from the plot it is clear that the latter two fits give a better approximation to the data than the first fit, and they would for any reasonable shift to the left of points corresponding to *sequence*, *reflexive verb*, *cyclic time* and *equality*. In fact the shifted points in Figure 3 were positioned so as to illustrate that the strange dependence on time that we see in Figure 2 may have to do with the population size of the speakers of a given syntax structure. One could imagine that the discovery of *reflexive verb* gave a competitive advantage over other groups and allowed for a larger population size and more complex social interactions and structures, which in turn allowed for greater selection of individuals with more language ability and so led to greater brain size, which in turn, coupled with the now increased population size, hastened the discovery of the next syntax structure, *cyclic time*, which in turn allowed for an even larger population size, and so on, in a positive feedback loop. This process may have culminated in the so-called Upper Paleolithic Revolution, a term associated with an explosion of new behaviour beginning about 35-40 thousand years ago (kya) in Europe which is reflected in innovative tool forms, sculptured stone and bone, personal decoration, evidence of activities requiring long-term planning and strategy, more structured living environments, cave art, and so on.[51] Evidence indicating that this revolution may have started at least 35,000 years earlier in Africa has begun to emerge.[52]

It is worth considering whether there are mechanisms other than increased speaker population size that might explain the time behaviour of Figure 2. One possibility is that the later syntax structures are by nature easier to discover and for that reason they occurred in more rapid succession; this appears counterintuitive and unlikely. Perhaps the above-mentioned feedback loop took place without population growth, fueled only by ever-increasing cognitive ability; this is possible, but then it would be necessary to explain why population size did *not* increase because more cognitive ability naturally leads to a higher population size, and furthermore this would weaken the feedback loop since higher population size *certainly* increases the likelihood that a new syntax structure would be discovered, all else being equal. Another possibility is that there is simply a gap in the archaeological record and that we must shift many of the higher syntax structure points hundreds of thousands of years to the left; this doesn't seem likely, since stone tools are well represented in the archaeological record going back 1.5 million years over a wide geographical area and, if higher syntax structures were reached hundreds of thousands of years earlier than the current evidence suggests, there is no easy way to explain why we have not found corresponding stone tool evidence similar to that found in Europe dating from roughly 40 kya onward.

On the other hand, there is some evidence in the archaeological record for increased population in the Upper Paleolithic in Europe.[53] More extensive evidence comes from human origins studies based on genetics, which have indicated that it is necessary to assume a low effective hominid population, on the order of 10,000, over the last 2 million years in order to account for the gene distribution in living humans.[54] They have also indicated that an explosion in effective population occurred at some time in the past, and that a likely time for such a population explosion appears to be between 50,000 and 100,000 years ago.[55] This evidence lends some weight to the conjecture that the time behavior of Figure 2 may be related to speaker population size; by the same token, Figure 2 appears to reinforce the genetic evidence for low effective population and a sudden population expansion between 50,000 and 100,000 years ago. Implicit in the above argument is the assumption that if the effective population used in the population genetics studies increases, so does the speaker population size and vice versa; the argument also only makes sense if the low effective population long-term was not due in large part to extinction and recolonization of populations, which allow for large breeding populations to leave a small effective population trace.[56]

Population size is a crucial aspect of the human origins debate centered on whether *homo sapiens* emerged as a new species, unable to breed with other hominids, within the last 200,000 years. How this article bears on that debate is a question best left to experts in paleontology, archaeology, and population genetics.[57]

Predictions of the Glossogenesis Model

The glossogenesis theory described here makes two main predictions, which are testable.

1. No computer simulation of glossogenesis starting from nothing more than the ability to ground symbols can arrive at the concept of one before arriving at the concept of negation, nor similarity before duality, and so on. The linearity of the theory precludes skipping steps.
2. It is possible for a simulation to start from the ability to ground symbols and from there arrive at negation, and from there singularity, and so on.

Regarding the archaeological record, the theory does predict a time order in which certain material culture specimens can occur. Unfortunately, since the possibility of new finds can never be excluded and since the material culture does not tell us whether two different specimens were made by speakers of related or unrelated languages, one cannot with certainty validate or invalidate the theory using such time order arguments. However, the archaeological record can be interpreted broadly in terms of the theory with no apparent contradictions, as we’ve shown above.

There is some slim evidence that there existed a single common ancestral human language of some form based on the widespread occurrence of a few common words, among them the form *tik meaning *one* or *finger*, and *pal meaning *two*.[58] The theory cannot predict that there was one such single common language, since two or more languages could in theory have emerged in isolation and arrived at *equality* independently, but if there was only one, then obviously *tik would have arisen in *singularity* and **pal* in *duality*. Evidence for common parentage of existing or reconstructed languages of course must be weighed on a statistical basis, and certainly the present theory can be useful in quantifying the likelihood that language families are related and in determining where they may have diverged in the syntax hierarchy. Other corroborating evidence for the existence of such relations would likely come from genetics studies and the archaeological record.[59]

Computer Simulations of the Glossogenesis Model

It is beyond the scope of this paper to discuss simulation details, but it is worthwhile to underscore a few key points. First of all, a simulation of this model must do two things. It must on the one hand show that it is possible to go from protolanguage to protolanguage starting from *symbol*, and the other hand it must show that a group has a better survival rate or an individual is reproductively more successful by virtue of language proficiency. The latter is simple once the former has been achieved.

A general feature of simulations of this model is that speakers must recognize patterns of behavior in response to threat and opportunity which lead to the success of the individual and the group. In effect they must also be able to generate initially a random symbol when such a pattern is recognized and use that symbol until or unless they hear two other speakers generate a different symbol in response to the same pattern, in which case that symbol must be adopted.

It is clear that a connectionist approach is appropriate here for simulating the linguistic behavior of speakers, which means that associated with every speaker in each of two groups of speakers there must be a neural network. The speakers themselves would be actors in a world simulation that starts from initial conditions and is continually updated by small time increments. The simulation might be in an abstract world or it might represent the real world; an abstract world would be preferable if machines of pure intelligence were the desired result of the simulation. In a real world simulation, during each update speakers may be hunting, foraging, running or climbing trees when avoiding predators, sleeping, grooming and so on. Other parts of the environment would include a variety of edible plants, predators, and prey. All animals would of course be simulated so that they act according to their behavior in the wild. The important thing is that a diversified environment be simulated, with a rich variety of rewards and penalties, the understanding of which allows for altered behavior through new syntax structure. A starting point for such an environment is provided by the great ape field research mentioned above.

Surveying current simulations of glossogenesis, one sees that a common approach has been to assume that certain meanings exist a priori.[60, 61] The point of the simulation is then for speakers to associate symbols with those meanings. Such an approach, although it has merits, obviously will not work as is for this model. A more appropriate approach for this model is that of simulations in which progress has been made in simulating the formation of meaning in social situations.[62, 63]

Non-bootstrapped Language Acquisition

Extensive research has been done in the area of human-animal communication, especially human-primate communication, but not exclusively.[64,65] The exploits of Washoe the chimpanzee[66], Koko the gorilla,[67] Chantek the orangutan,[68] Kanzi the bonobo[69] and others clearly indicate that all of them have a grasp of *symbol*, some of them can count,[70] and some of them have even shown some understanding of the concept of self and of time, although none has shown an understanding of *implication* or *AND*. In all cases, horizontal extension is very limited when compared with human linguistic performance. It is interesting to note that the results of the mirror test[71], which purports to establish whether a primate recognizes himself in the mirror, may depend on the rearing and training of the subject.[72]

The implications of this article on interpretations of the above-mentioned research are limited due to the fact that glossogenesis theory tries to account for a bootstrap process in the sense that new syntax structure must be discovered without outside aide, whereas animal language learning through human intervention is not a bootstrap process. So, for example, it might be possible to teach a primate *singularity* without teaching him *negation*, or *duality* without teaching him *singularity*, but glossogenesis has nothing to do with this form of syntax acquisition and so in this context is irrelevant. That said, it may be that a distinction can be made between partial and full language competence, where full competence refers to competence in the current and all preceding protolanguages. Although such a distinction may be blurry, it could be helpful in determining what methods of teaching syntax lead to the best linguistic performance of animals.

The above arguments also hold for child language development in humans, which likewise is not a bootstrap process. In particular, children with learning disabilities may be responsive to teaching methods that focus on mastering the structures in order.

Further work

This article poses a number of questions, such as why a hierarchy of syntax structures leading to higher mathematics should exist in the first place, and why it should start particularly at *symbol*. It is also puzzling that there is no apparent structure analogous to *symbol* itself --- it is left out of Table I because there is no place to put it. The fact that the structure is linear suggests an answer to these questions. Just as we started from *symbol* in this article and went on to more complex structures, one might also consider examining whether one can also develop the theory in the opposite direction, i.e. toward less complex structures. It turns out that this approach is viable and leads to the conclusion that the two columns of Table I are part of a much larger structure, as discussed in a separate article.[73]

I hereby confirm that the above paper is a work in progress which I have created independently.

______________________________________ __________________________

Charles Kastner date

This instrument was signed before me on this _____ day of _____________, 2003, by Charles Kastner, TX driver license 14399159.

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