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4

Linguistic Theory, Explanation and the Dynamics of Language[1]

PETER W. CULICOVER, ANDRZEJ NOWAK, AND WOJCIECH BORKOWSKI

1 Introduction

A central concern of linguistic theory is the nature of linguistic explanation, as exemplified by this conference. The goal is to gain as deep an understanding as possible of why human languages have certain properties and lack others. At the same time, we wish to understand better the limits of linguistic explanation. For example, are all apparent syntactic phenomena explained in terms of properties of the syntactic component of a grammar, or are some explicable in terms of the mappings between syntax and semantics, between syntax and phonology, between syntax and pragmatics, in terms of processing complexity, in more abstract computational terms, or otherwise?[2] It seems to be that in seeking to identify the status of one type of explanation, especially in the case of syntax where many different factors are simultaneously realized in a single string of words and morphemes, it is

[1] For stimulating discussion and helpful comments regarding this work we are indebted to Sarah Thomason, Michael Broe, Brian Joseph, audiences at the University of Illinois, Michigan State University, the University of Rochester, Keio University and the University of Stuttgart, and an anonymous reviewer. Naturally we are responsible for any errors. This work is part of a more extended collaborative project on the dynamics of language between the Center for Cognitive Science at The Ohio State University and the Center for Complex Systems at the University of Warsaw. Some of the material in this paper appears in a more elaborated form in a longer piece (Culicover, Nowak, and Borkowski 1999) and in Culicover and Nowak (2003). We gratefully acknowledge the James F. Mcdonnell Foundation for their support of this research.

[2] For some recent investigations of such questions, see the papers in Culicover and McNally (1998).

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essential to keep in mind the possibility that certain phenomena may properly fall under other mechanisms.

As our basic point of departure here, we adopt the sometimes (strangely) controversial proposition that human languages are *learned*, contrasting it with the view that knowledge of language is basically wired into the human mind/brain in some almost completely specified form and is rapidly refined through parameter setting in the course of language acquisition. Moreover, we take seriously the idea that language exists in a social context.

It is often proposed that the properties that languages may or must have are not accidental, but are in effect projections of the Language Faculty. This is certainly true to some extent, but we wish to argue here that there are, in principle, at least, other ways in which languages can get to be the way they are that does not directly reflect the Language Faculty. These other ways have to do with the dynamics of language, in particular language change, language learning, and language processing. We will focus here just on the first, although we believe that a good case can be made for the others as well. Moreover, we will suggest that at least in the case of language change, some explanations may be located entirely outside of the Language Faculty.[3]

2 Gaps

2.1 Gaps and the Language Faculty

The close study of the grammars of natural languages that has been pursued over the past forty-odd years has revealed that many if not most of the logically possible languages do not exist. We call these missing languages gaps. Linguistic theories have sought to account for some of the gaps by appealing to the structure of the Language Faculty. On such an approach, particular logically possible properties and correlations of properties are unattested because they are not allowed by the Language Faculty. They are biologically impossible, and their non-existence is explained in much the same way as are the non-existence of flying pigs or talking dogs. So the precise characteristics of the gaps may reveal something important about the Language Faculty.

This is in fact the standard approach that one takes when asymmetries are observed in some typological database. One of the earliest cases is Bresnan's (1970) account of the fact that if a language has *wh*-movement it is always to the left. The gap in this case consists of languages that have *wh*-movement to the right. Bresnan proposed that there is a node COMP that is universally a left sister of S, and that *wh*-movement is movement to this position. In recent years, many typological asymmetries have been tied to structural asymmetries such as these; see Kayne (1994) for development of the idea that there is in fact a universal asymmetry in branching structure, where all branching is binary and to the right, and all movement is to the left.

There are also gaps of a more specific nature. To take just one example, Zwart (1994) shows that not all of the possible orderings of three or four verbs in verbal clusters in West Germanic are possible. Let 1, 2, 3 and 4 represent the verbs in a syntactic structure, where 1 is the highest verb in the structure, 2 the second highest, and so on. An ordering such as 1-2 represents the surface order of the verbs in a main clause. While many orders are possible, Zwart shows that what apparently never occurs is *2-1-3. We will focus more closely on this example in section 2.4 in our discussion of the explanation of how such gaps might come about.

We stress that we have no quarrel with the methodology of seeking explanations for gaps in terms of linguistic structure, and in fact to reject this methodology would be irrational. We wish to suggest, however, that gaps may in principle reveal not just the structure of the Language Faculty, but also the structure of *social networks* of human beings in which linguistic knowledge is communicated. In fact, we will show that the way in which knowledge is communicated in such social networks makes it virtually inevitable that some combinations of properties will not appear. The combinations that do and do not appear are not necessarily predictable in terms of the linguistic content of the properties in question, although linguistic considerations may be relevant.

2.2 A Computational Simulation

In previous work, Nettle (1999) has shown through a computational simulation that the spatial distribution and particularly spatial clustering of languages can be attributed to interactions among speakers in the social network, assuming the Dynamic Theory of Social Impact (Nowak et. al. 1990; Latané 1996; Levenshtein et. al. 1992). We have replicated his results, and extended the approach to the clustering and correlation of linguistic features.

In our computational simulation, the social network is represented by a square matrix of k rows and k columns. Each of $k \times k$ locations can be occupied by an individual agent, so if all the locations are occupied there are $N=k \times k$ individuals. Each individual agent A is characterized in addition to

[3] There is a prominent line of research in historical linguistics that takes this view. See Thomason and Kaufman (1988).

its location in the matrix by the values of three linguistic features, and additionally by a strength parameter. The strength parameter describes how influential each individual is in inducing change in other individuals.

Each linguistic feature can have one of a discrete set of values. In the simplest case the value is a binary variable with values of 0 and 1. The linguistic features are assumed to be independent of one another. That is, there is no relationship between the values of different features.

The simulation proceeds according to the so-called Monte Carlo dynamic. An individual agent *A* is randomly selected from the matrix. For the chosen individual a specified number (p) of interaction partners are drawn randomly from a distance not greater than d cells from the agent, where p and d are chosen for the particular simulation. If the limiting distance d is equal to one, then only cells adjacent to the cell occupied by the agent can be selected as the interaction partners. The selection of interaction partners is independent for each agent so it is possible that a specific partner can be selected more than once.

For each of the linguistic features (independently of the two other features) the following procedure is repeated: for each value of the feature the social pressure to adopt this feature is computed by adding the strength of all the interaction partners (that were drawn in this round of simulation). If an agent has the value 1 for some feature, for example, and if enough of its neighbors have 0, then in the course of interaction with its neighbors, the 1 will be changed to 0 for this agent. Precisely how sensitive each agent is to external influence, which neighbors are potential interlocutors, and so on, are parameters of the simulation that can be adjusted.

Another parameter of the simulation model is whether or not there is self-influence. If self-influence is chosen, the agent is treated as one of the interaction partners and the strength of the agent is added to the value of influences of the appropriate value of the feature.

It is also possible to introduce noise into the simulation. If the value of noise is greater than 0 then the noise is added to the sum of the pressures from the interaction partners.[4]

In sampling the values of its interaction partners, an agent adopts the feature value that received the highest score. If two or more values have the same score then the value is chosen randomly from among them. After the values of all the three features have been updated for a given agent (the interaction partners are the same for all the three features of an agent), a new agent is randomly drawn. A simulation step corresponds to choosing N

[4] The noise is calculated as a random number drawn from a flat distribution (0..1) multiplied by the maximum strength of the individuals (to normalize it to the strength of individuals in the simulation) and multiplied by 4.5.

agents, so every individual is updated approximately once in a simulation step. Since the random drawings are independent of each other, some individuals may not be chosen in a given step and some possible interaction partners are not drawn at all in the course of the simulation.

We give a very simple illustration of a single iteration to show roughly how the simulation works.[5] For simplicity we have a 3x3 matrix consisting of nine agents. We assume that the features are binary valued, so that there are eight possibilities. A random distribution of feature values has a chance of realizing all possible combinations at least once; we generated such random distributions until this distribution occurred. The initial state is shown in Figure 1.

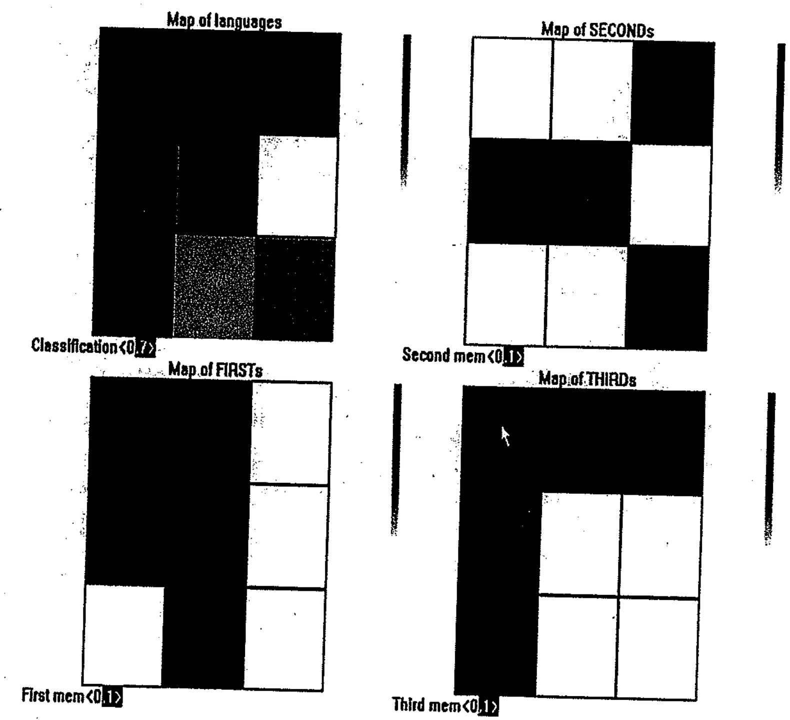


Figure 1. Simple Initial State

[5] The probabilistic nature of the simulation means that it is impossible to replicate precisely the course of change given the same starting configuration, so the example that we give is only illustrative.

The upper left image is a composite that represents the three feature values of each of the agents, using the gray scale. The individual feature values are shown in the 'Map of FIRSTs', 'Map of SECONDs' and 'Map of THIRDs'; they are either black (which we refer to as '+') or white (or '-'). The strengths are assigned randomly, and are shown in Figure 2.

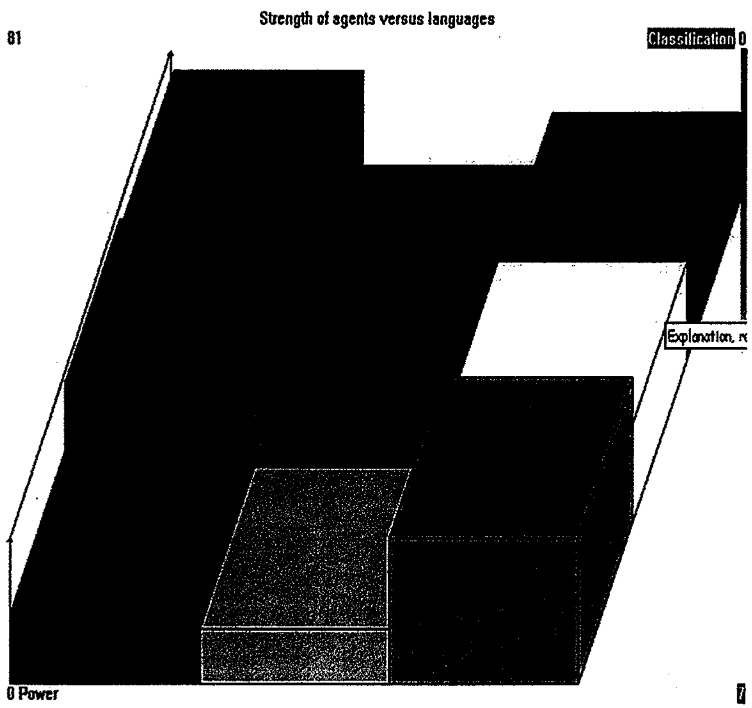


Figure 2. Strengths of Agents

On a single iteration, each agent interacts with those in its neighborhood and independently changes its values for each feature if the external influence is sufficiently strong. The result of doing so for one iteration in this example is shown in Figure 3.

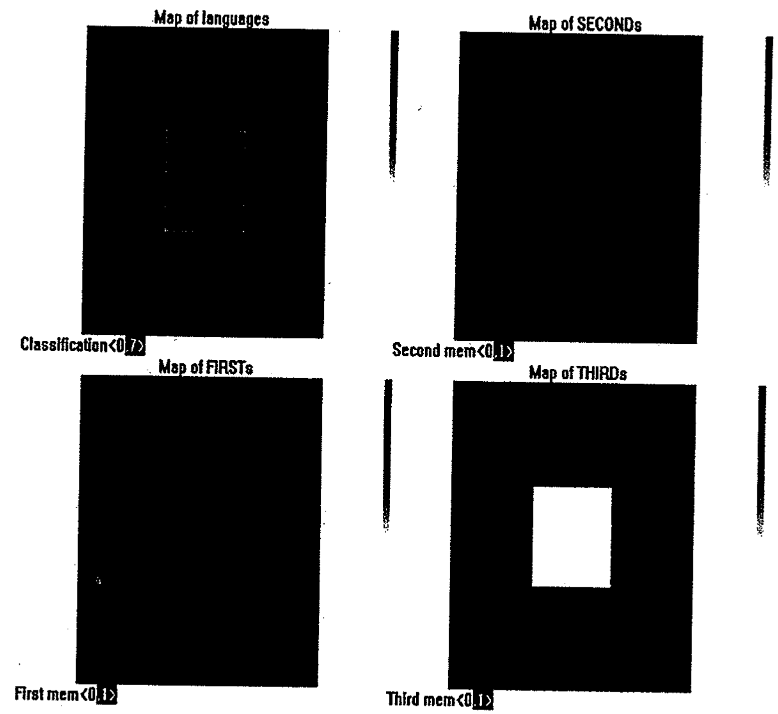


Figure 3. Result of Single Iteration

We can track the behavior of each agent for each feature by examining the result of a single iteration. For example, the agent in the middle row and middle column has the values +,+,- for the three features at the start. Looking just at the first feature, we see that four of its neighbors have the value + and four have the value -. The agent itself has the value + for this feature, and this is included in the calculation. So there are five +'s and four –'s, and the agent remains unchanged for this feature as we might expect. In the case of the other two features, however, the values of the neighbors outnumber that of the agent, and it should change its values, but doesn't. Recall that the agent does not interact with each neighbor once on this iteration, but with some neighbors that share its values more than once. Moreover, some agents are not chosen on every iteration. In the short run this means that an agent may resist change for a while, but in the long run the agent will eventually sample enough of its neighbors to change its values.

This simulation model is applicable to a wide range of socially transmitted attributions. In our computational simulation of language change, we interpret the simulation as modeling the distribution across the network of logically independent linguistic properties over time. The network consists of interactions and social relationships between individuals. There are linguistic communications across this network that pass between individuals. A language learner acquires knowledge of language by interacting with (a subportion of) this network, and by acquiring the linguistic features of the individuals with which it interacts, with some suitable weighting based on proximity, frequency of contact, social mobility, and so on.

Crucially, the Social Impact Theory that underlies this model presumes that the content of the linguistic features (or other social transmitted attributions) has nothing to do with the particular configuration of features displayed by a given agent or group of agents at any point in time. Agents change their feature values strictly as a function of the feature values of the agents that they interact with, and the strengths of the agents. While this presumption is extremely simplistic, and may well be controversial when the feature values in question correspond to social attitudes, it is fully consistent with prevailing views on how knowledge of language is transmitted from a community to its children. In brief, the children acquire the prevailing linguistic features of the community in which they live.

2.3 How Gaps Arise

For the purpose of the simulation we suppose that there are three two-valued features, which define eight distinct languages. Gaps occur when certain feature combinations are not attested. Our simulation shows that gaps may arise over the course of time, as the values of pairs of the features become strongly correlated. To take a very simple example as an illustration, suppose that there are two two-valued features that define four languages, as in (1):

(1) [+F1,+F2] [-F1,+F2] [+F1,-F2] [-F1,-F2]

If the geographical distribution of [–F2] becomes sufficiently restricted, it may fail to overlap with [+F1]. When this happens, one of the languages, namely [+F1,-F2], ceases to exist. Such a situation may occur simply as a consequence of the social structure, and in itself tells us nothing interesting about the relationship between [+F1] and [-F2].

Figure 4 shows the random distribution of feature values for three linguistic features in a population of 900 (=30x30). The upper left hand image shows the distinct languages as intensities on the gray scale. The other images show the distribution of + (black) and - (white) values for the three features FIRSTs, SECONDs and THIRDs.

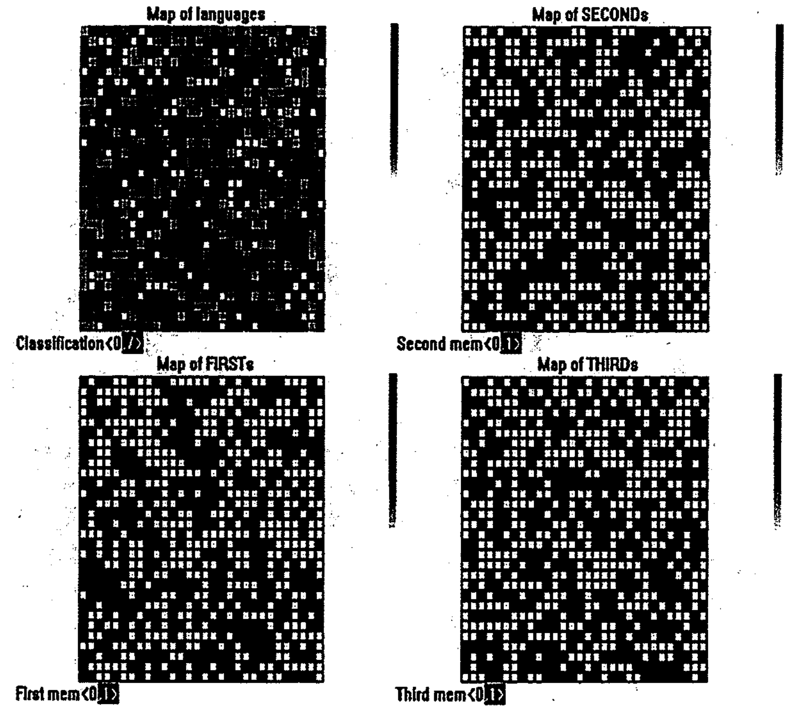


Figure 4. Initial Random Distribution of Feature Values

The initial population of each of the eight languages is shown in the histogram in Figure 5. As can be seen, the languages are distributed more or less evenly over the entire population, as would be expected from a randomized assignment of feature values.

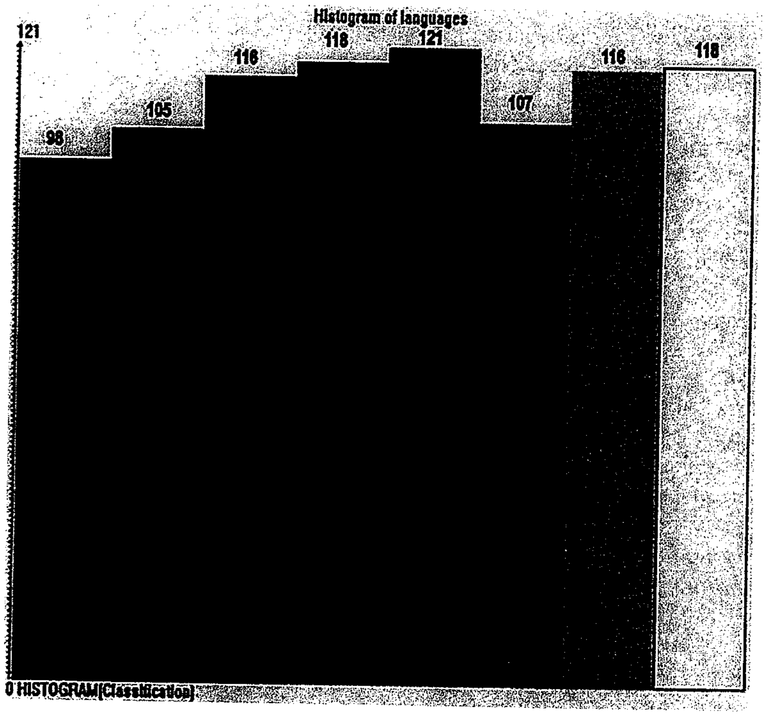


Figure 5. Initial Population of the Eight Languages

The picture at step 69 is shown in Figure 6.

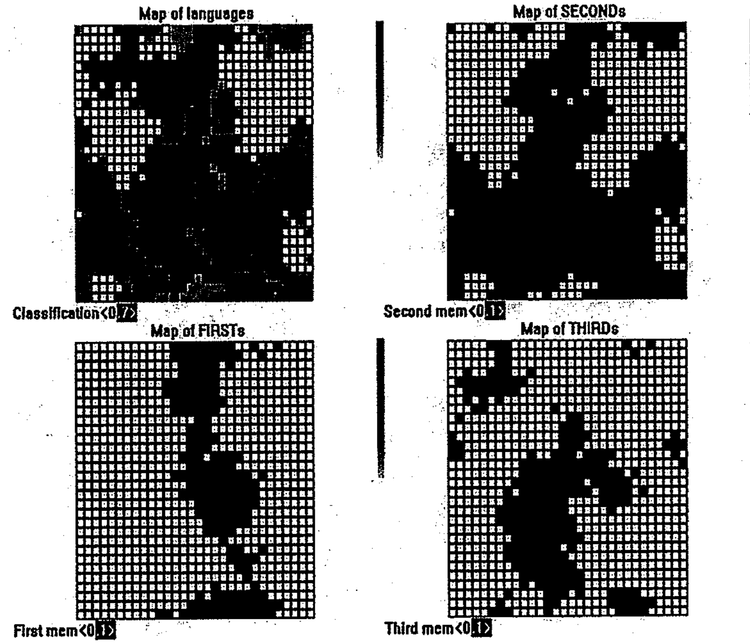


Figure 6. Distribution of Languages and Features at 69th Step

We have omitted additional intermediate steps in displaying the simulation for reasons of space. After 150 steps the distribution of languages and features is as in Figure 7.

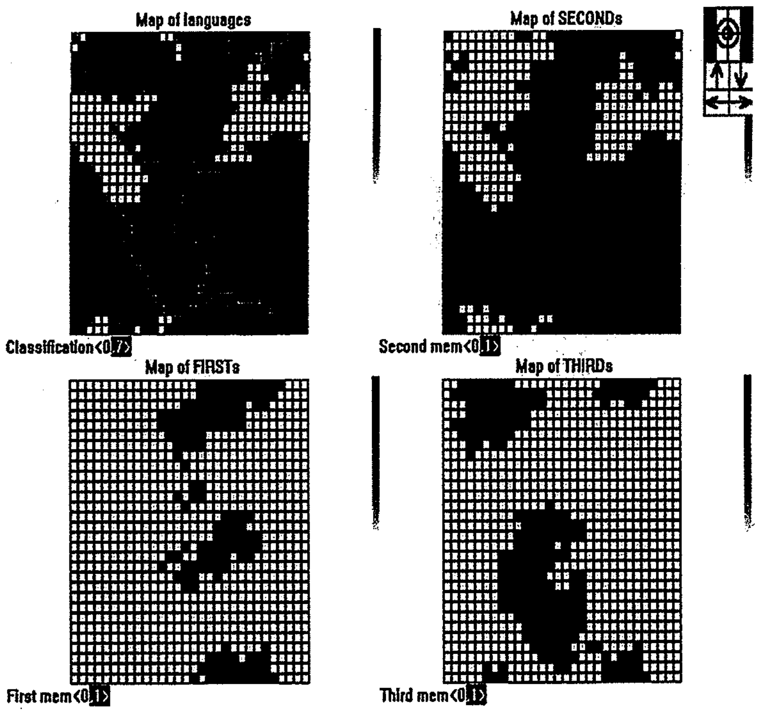


Figure 7. Distribution of Languages and Features at Step 150

It is clear from the images that there is significant clustering of feature values, and of feature value combinations, i.e. languages. The histogram in Figure 8 shows the population levels of the eight possible languages. Note that the third language (from the left) and the seventh language have entirely disappeared.

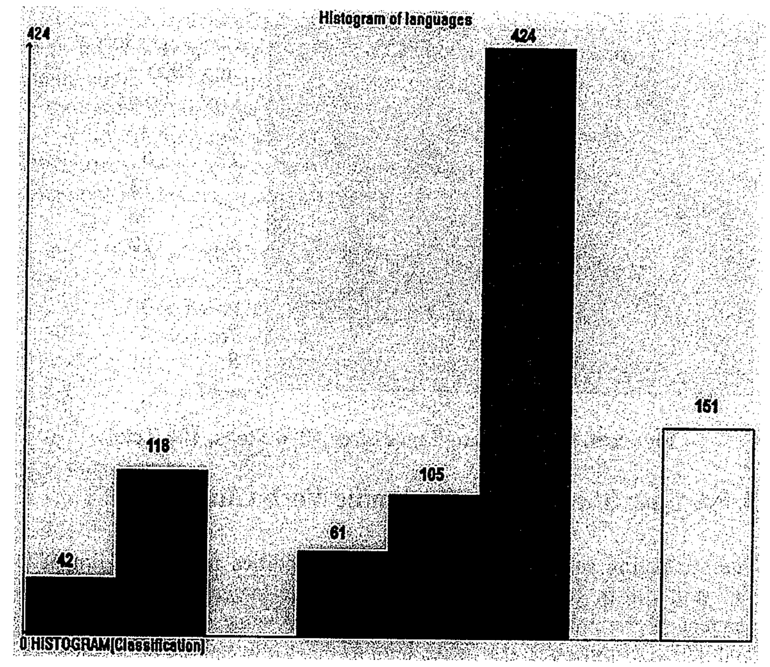
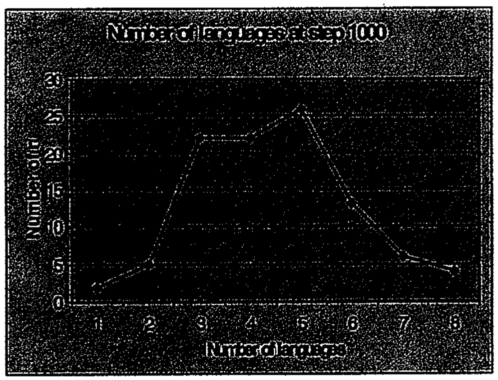


Figure 8. Population of Languages after 150 Steps

The loss of languages illustrated in this particular instance of the simulation is not unique. It is a consequence of the particular assumptions made in the simulation about how individuals interact in the network. Running the same simulation under the same parameters *p* and *d* yields a different pattern of features and languages each time; in most cases at least one language is lost. As an illustration, we repeated this simulation 100 times. The following chart shows the number of times a given number of languages remained after 1000 simulation steps. The results are also summarized in terms of number of languages lost.



Languages lost at step 1000

Lost	Trials
0	4
1	6
2	13
3	26
4	22
5	22
6	5
7	2
8	0

Figure 9. Loss of Languages after 1000 Steps, 100 Trials

2.4 A Case Study: West Germanic Verb Clusters

The simulation suggests that the actual possibilities realized in linguistic variation will in general display a subset of the logical possibilities, independent of grammatical considerations. Feature values that are in a minority relative to other feature values tend to die out in non-equilibrium situations. The question of why it is that a particular feature value is in a minority is an independent question, and one of great importance. It may certainly have a linguistic as well as a sociological basis. Nettle (1999) shows that built-in biases against certain linguistic properties will produce clustering when coupled with the differential effects of social status and the dynamics of the social network model. Nettle characterizes properties with inherent bias as follows (1999: 112): they are hard to acquire, which causes languages to change away from them. In the context of current linguistic theorizing, this idea is a powerful one. It suggests that non-existing linguistic properties are in principle a consequence both of the social structure, and also of learnability, in some sense related to complexity of computation.[6] In effect, this is markedness, which takes us back to some essential insights of Chomsky's *Aspects*.

The linguistically interesting question is what constitutes computational complexity in the domain of grammar and language acquisition. We hypothesize that where there is grammatical structure, the logical possibilities

[6] See also Hawkins (1994) and Briscoe (2000).

in which the structure is more transparent, in the sense of correspondence with conceptual structure (CS), will be more highly favored, other things being equal.[7] Those possibilities that are minimally transparent will be rare if they exist at all, simply for this reason.

With this in mind we return to a consideration of the order of verbs in Continental West Germanic verb clusters, as described by Zwart (1994). The possibilities are summarized in Table 1.

1-2	Standard Dutch; dialects
2-1	Standard Dutch; dialects
1-2-3	Standard Dutch; High German
1-3-2	Standard Dutch; High German
*2-1-3	
2-3-1	West Flemish[8]
3-1-2	Dutch
3-2-1	Frisian; High German
4-3-2-1	Dutch
4-1-2-3	Dutch
1-4-2-3	Dutch
Others	

Table 1. West Germanic Verb Clusters

The set of possibilities clearly cannot be subsumed under a single ordering parameter that applies to sisters in a phrase marker. Zwart's solution is to assume that there is basically a single underlying ordering in a binary branching structure, 1-[2-[3-..., and that there are various leftward movements to designated positions.[9] These movements are constrained by grammatical factors, so that not all imaginable orderings occur. The major gap is that of *2-1-3.

Let us consider an alternative perspective, which is that the correct representation of the knowledge of the possible clusters can be expressed in terms of linear properties of the sequence of verbs. It is certainly true that even in theory of parameter setting, the learner must extract generalizations about the possible sequences prior to setting the parameters. Let us suppose that the relevant features are simply the relative orderings of pairs of verbs in the sequence. In a three-verb sequence, the features are 1>2, 2>3, and

[7] For discussion, see Culicover (1999) and Culicover and Nowak (2003).

[8] This order occurs only when V1 is an auxiliary verb (Zwart 1995). Zwart attributes the order to topicalization of the VP of which V2 is the head and V3 the head of the complement.

[9] Recall that 1 refers to the highest V in the structure, 2 to the next highest, and so on.

1>3 where one does not follow from the other two. These features will produce eight possible combinations, as shown in Table 2.

Language	P1	P2	P3	Sequences
D	1-2	2-3	(1-3)	1-2-3
G	2-1	2-3	1-3	*2-1-3
A	1-2	3-2	1-3	1-3-2
E	2-1	3-2	(1-3)	3-2-1
F	1-2	2-3	(3-1)	1-2-3
B	2-1	2-3	3-1	2-3-1
C	1-2	3-2	3-1	3-1-2
H	2-1	3-2	(3-1)	3-2-1

Table 2. Verb Clusters Generated by Simulation

All possible orders are produced by these three features, including the unattested *2-1-3. For languages A, F, E and H the value of P3 is irrelevant since 1-2 and 2-3 imply 1-3, and 3-2 and 2-1 imply 3-1. For the sake of the illustration we may take the feature P3 to be completely determined by the other two features when there is redundancy, recognizing that this is an unprincipled assumption.

Let us now consider the simulation. Suppose that there are in fact these three features, and that the unattested *2-1-3 is possible and actually exists at some point in a dialect of the language, but is relatively weakly attested; perhaps there is a functional bias against it. Figure 10 displays the development of a typical language group after 775 steps.

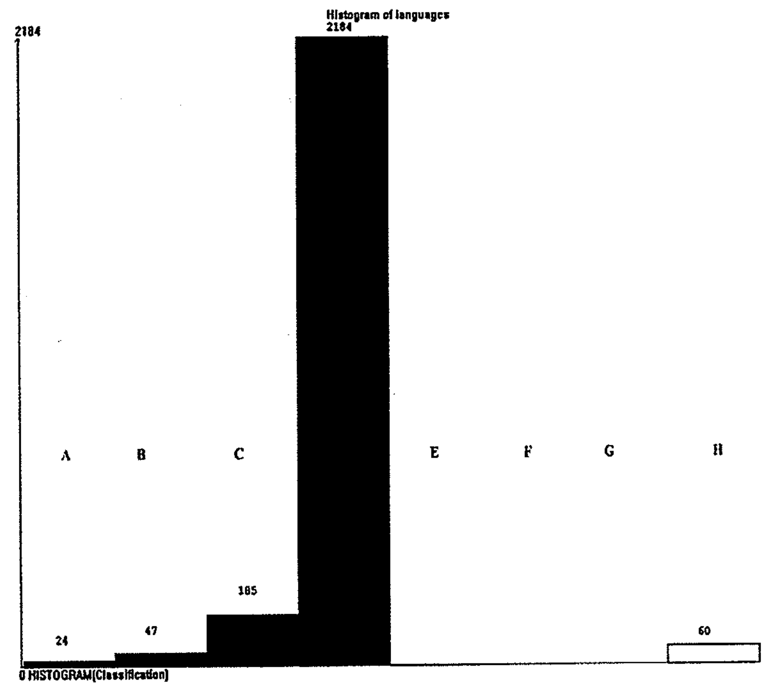


Figure 10. Histogram, Step 775

We can see that at this point there is one majority language (Language D), and there are three other more or less alive languages (B, C and H), three non-existent languages (E, F and G), and one that is very weak (A). Let the languages in the histogram be as defined above in Table 2. On this view, the non-existent *2-1-3 is not ruled out in principle, it simply does not exist as a consequence of the behavior of the network.

It is apparent that there is no linguistic content in this simulation, and we have chosen to name the languages in such a way that the simulation would illustrate the point. We do not claim to have explained the West Germanic data, and in fact Zwart's account could well be the correct one from a theoretical perspective. The point is simply to show that the non-existence of a particular combination of properties, in this case *2-1-3, is not *necessarily* linguistically interesting. Even if there are linguistic factors at play, it would be a mistake to conclude that the nonexistence of a particular combination of properties signifies that this combination is impossible for some deep principled reason. It may simply be, as suggested earlier, that this combination of features is possible but highly dispreferred, and hence dies out under pressure from more favored alternatives.

So we must consider the question, is there any way to predict which of the languages will in fact go extinct? In this simulation model there is no way to do these, because the three features and their values are equipotent. But, suppose that we add the further condition that a language property that is computationally more complex than its competitors in the set will be dispreferred. In the case of word order in West Germanic verb clusters, we may reasonably hypothesize that the processing of a head and its complement is facilitated by adjacency and consistent canonical order.[10] In the case of the order *2-1-3, the head of 2-3 is 2. The head 2 is not adjacent to 3, which may constitute a processing burden, perhaps a special instance of LOCALITY, or MINIMUM DISTANCE or MINIMUM LINK or RELATIVIZED MINIMALITY, all of which plausibly have a computational basis. Since the head 1 intervenes between 2 and 3 and is to the right of its (split up) complement, there is an additional burden with respect to the identification of 1 as the head of *2-3. Our suggestion is that while this particular state of affairs is not grammatically impossible, it is highly marked for computational reasons, and will be dispreferred by the language learner. It remains, of course, to provide an explicit characterization of relative computational complexity, a challenge that would take us far beyond the bounds of the present study.

3 Correlations

The appearance of gaps in the set of languages is an extreme case of a more general property of the simulation model, which is that feature values correlate. In other words, the model evolves over time so that there is a tendency for one feature value to appear when another appears. However, the correlation is not usually 100%, so that the opposite pattern may also occur, although less frequently.

In a random initial state the level of correlation between features is zero. Since the value of a feature for an individual is determined by the interactions between that individual and its interaction partners, over time all of the feature values of an individual tend to become more highly correlated with those of its interaction partners. An illustration of the history of correlation in a particular simulation is given in Figure 11.

[10] We leave open the question of whether or not there is a universal canonical order.

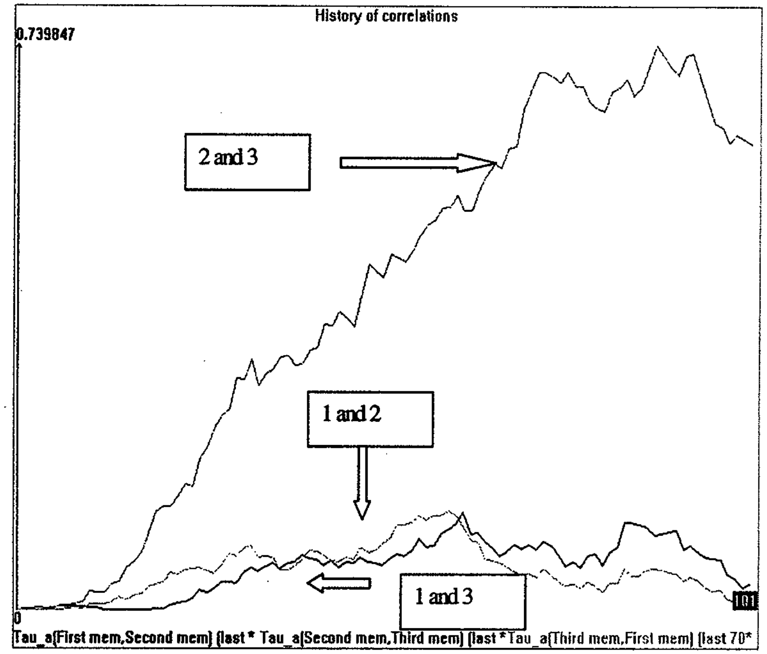


Figure 11. History of Correlations over 100 Steps

As can be seen, features F2 and F3 correlate increasingly closely over the course of the simulation, while features F1-F3 and F1-F2 do not.

It is instructive to observe the kind of pattern that is associated with such correlation. In Figure 12 we see the space for F2 and F3 after 100 steps.

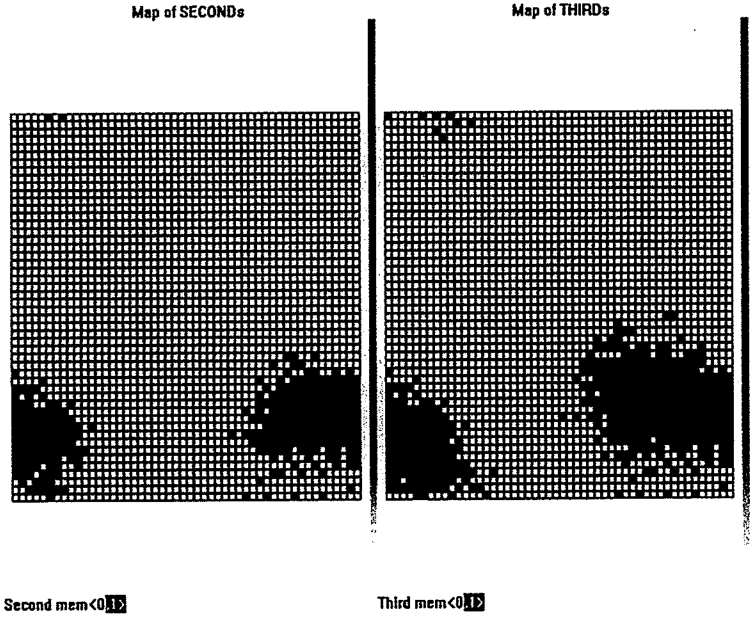


Figure 12. Features 2 and 3 after 100 Steps

The visual evidence reveals the tendency for F2 and F3 to have the correlated values, even though there are exceptions. The statistical correlation data confirms this observation. Such tendencies may have a linguistic interpretation along the lines of some Greenbergian universals (Greenberg 1963). Consider one chosen more or less at random, for example, Universal 4: With overwhelmingly greater than chance frequency, languages with normal SOV order are postpositional.[11] Let F2 be [+/-postpositional], and let F3 be [+/-OV]. Figure 12 can be understood as an illustration of the situation in which most SOV languages are postpositional, although some are not; we illustrate in Figure 13.

[11] Similar universals are:
UNIVERSAL 9: With well more than chance frequency, when question particles or affixes are specified in position by reference to the sentence as a whole, if initial, such elements are found in prepositional languages and, if final, in postpositional.
UNIVERSAL 17: With overwhelmingly more than chance frequency, languages with dominant VSO order have the adjective after the noun.

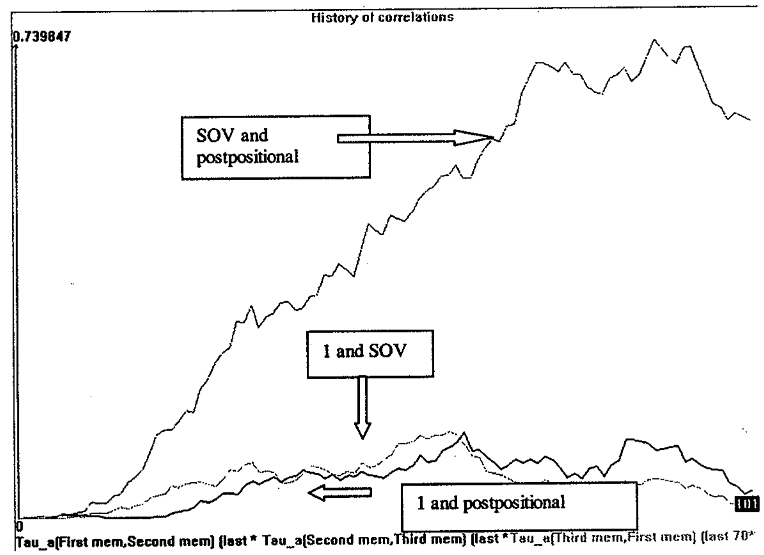


Figure 13. Hypothetical Correlation between SOV and Pre/Post-Position

While it is almost certainly true that there are other sorts of explanations for some implicational universals of this type, the possibility cannot be ruled out that at least some are due simply to the correlation of features through the interaction of the network.

4 Future Perspectives

We have argued that it is possible in principle to attribute to the social network such phenomena as gaps in the set of languages, and the tendency for certain properties to co-occur in languages. It is almost certainly the case that the intrinsic content of the features also plays an explanatory role as well in each of these categories of phenomena. The point is simply that there are at least two potential sources of explanation. This observation at first glance appears to complicate the task of the theorist, who is no longer able to posit without further investigation that the distributional patterns of linguistic phenomena reveal something interesting about the language capacity. But it does sharpen up to some extent our notion of what it means for something to count as an explanation of some linguistic phenomenon.

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5

Explaining Infixation

JOHN HAIMAN

1 Introduction

Ever since Bopp first proposed the idea in his Sanskrit grammar of 1816, we have recognized one source of bound grammatical morphemes: they are simply words that have been worn down by frequent use. Perhaps we do not always know exactly *which* words, but in principle, erosion offers a possible diachronic explanation for all prefixes and suffixes. Manifestly however, such an account is not available, even in principle, for the origins of infixes: morphemes that break up minimal morphemes. In this paper, I will try to justify a 'natural' explanation for the origins of infixation in Khmer (and, possibly, other Mon-Khmer languages).

I will call any explanation for a grammatical fact a NATURAL one (as opposed to FORMAL) when it crucially refers to something outside of the structural system wherein that fact occurs. Assuming the autonomy of grammar, all appeals to 'meaning' constitute (attempts at) natural explanations for grammatical facts. Assuming separation of levels or modularity within a grammar, appeals to syntax or phonology constitute attempts at natural explanations for morphological facts, and so on. Natural explanations may be synchronic or historical.

We turn now to the grammatical fact under review here, infixation. Why is it rare? What does its rarity explain? And why, in spite of everything, does it occasionally happen anyway?

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