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Editors

Signed and Spoken Language: Biological Constraints on Linguistic Form

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Signed and Spoken Language: Biological Constraints on Linguistic Form

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Editors: U. Bellugi/M. Studdert-Kennedy

Until recently, nearly all that was known about language had come from the study of spoken languages. But now new research into signed languages has revealed that there are primary linguistic systems, passed down from one generation of deaf people to the next, which have been forged into autonomous languages and are not derived from spoken languages. Thus, for the first time, we can examine the properties of communication systems that have developed in alternate transmission systems, i. e. in visual-gestural channels.
A group of psychologists, linguists, neurologists, and biologists met in Berlin in March, 1980 to review the progress of this new work, in particular with regard to the structure of language, its acquisition, related cognitive processes, and the complicated set of constraints that have been linked together to shape language. What emerges are new views and new directions for research within the broadened perspective afforded by languages in different modalities.

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Capacity Constraints on the Properties of Signed and Spoken Language

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Abstract. I explore the possibility that there exists a "core language" on which there are no capacity constraints. Rather, I suggest that the computational machinery evolved just to service the requirement of turning prelanguage forms (e.g., sets of propositions) into language. Apparent limitations on spoken language are seen as reflecting the use of core language by other cognitive mechanisms or by the limitations of the device which selects the prelanguage forms.

INTRODUCTION

The classical way of talking about competence and performance in language assumes that performance is limited by capacity constraints. King (10) and others expressed it by analogy with the performance in mental arithmetic. In this case, memory limitations impose severe restrictions upon the size of the numbers we can manipulate although in principle our "competence" is to handle numbers of indefinite length. In practice, with paper and pencil, the size of numbers which could be multiplied together successfully is limited by boredom rather than by ability.

With spoken language, analogous constraints are held to apply. Theoretically, the grammar of the language possesses a property

of indefinite recursiveness which is thus the potential of the speaker's competence. In practice, however, performance with spoken language is limited to one center embedded sentence owing to limits in "working memory" which cannot store enough pointers. A comment typical of workers in the area is the following from Fryer and Marshall (7): "..our finite wind and memory capacity ensure that many sentences which are strictly within our formal competence will never be uttered or comprehended..." A comment such as this makes it clear that language as seen as something which, locked in the mind of man, finds itself straining against arbitrary limitations.

In this debate we assume a number of components. First we have the dichotomy between mechanisms which are language specific and those which are more generally cognitive. In general, the former are seen as specifically human; the status of the latter is usually left in doubt. Second, from a linguistic point of view we can identify three stages in the language stream: roughly, the propositional, the syntactic, and the phonetic. The position of "semantics" in such a framework varies from theory to theory; the present scheme is intended to be neutral with respect to these. From the point of view of the underlying psychological processes it is possible to make a rough division into the same three parts. Note that for present purposes whether processing at the three stages is strictly serial is not at issue.

A part of the mental cognitive apparatus will be referred to here as a General Problem Solver (GPS). This device can intervene in language processing in the course of acquisition and in the stable state. We can see there to be a range of possibilities as a function of the level of contribution of the GPS to language. Note that in the course of language acquisition, both the GPS and the linguistic device (LD) will be operating. Some of the child's "hypotheses" about language structure will be due to the GPS and others will be due to the linguistic device. Equally there will be processes whereby utterances can be produced or comprehended which are largely or entirely the responsibility of the GPS. There seems to be no need for these to be

equivalent in production and comprehension. The "perceptual strategies" of Bever (2) would be candidates for GPS-driven comprehension processes. Equivalent processes in speech production would include the incorporation of clichés into the speech stream and, I will suggest, certain kinds of elaboration. Note also that the interaction of the linguistic device and GPS in the course of learning a specific language will give rise to structures or processes which are uniquely linguistic (not being shared by non-linguistic functions) while not being universal, since they will be specific to the language learned. The form of the competence-performance debate can be expressed in terms of this framework. At one extreme the linguistic mechanisms would have responsibility for all language performance with the GPS actually playing no role. Any performance constraints would then be seen as caused by uneven development of the linguistic device. Thus, the potential of the syntactic component might be limited by inadequacies in the processes corresponding to the phonological component. (Note that this account is intended to be neutral with respect to issues of the "psychological reality" of linguistic structures. See Bresnan (4) and Chomsky (5) for some recent views on this issue which is also sometimes couched in competence-performance terms. Some authors, e.g., Morton (14), prefer a tripartite distinction.) The view discussed in the opening paragraph would take the linguistic device as fully responsible for language but reliant on non-linguistic computational machinery for its execution. The latter create the limitations.

In the current paper I wish to explore a contrary and extreme position which I shall first state briefly and then will attempt to elucidate and justify. Finally I will try to meet some possible counterarguments.

Hypothesis 1. There are no properties of core language which are the results of processing capacity constraints. (It will follow that it is unlikely that any capacity constraints affect the structure of sign language.)

It is clear that some of the cognitive devices involved in the production and perception of language have limited capacity either in respect to storage or processing power. If H1, above, is to be sustained, then we would require H2.

Hypothesis 2. Inasmuch as there exist mechanisms responsible for language with capacity limitations, then the capacity of these mechanisms will be that required to understand and produce core language.

The first two hypotheses say nothing of the structure of core language. The simplest view of language structure is that it has evolved successfully in response to particular needs. We can express this in some way such as H3.

Hypothesis 3. If we regard spoken language as the means of communicating propositions and sequences of propositions, then the structure of core language is such as to allow the expression of any sequence of propositions which might be in need of expression.

For any other view of language, the latter hypothesis would have to be changed appropriately. I take it that all views of the production of spoken language will involve the aspect of communication and that the things to be communicated will include elements from some structures best described in terms different from those used to refer to language itself. I use the term proposition as a means of referring to the whole range of such possibilities. The elements would be such as to lead to imperative and question forms as well as declaratives. Let us imagine that such propositions are derived from knowledge structures (including a representation of the current world) by a mechanism we can call a "conceptualizer" (cf. Kempen (8)). This mechanism presents sets of propositions to the language-responsible mechanisms for conversion into some linear form.

Note that the view of language will have to be restricted in certain ways. If we are to take a biological/evolutionary framework, then we seem obliged to treat as primary those aspects of language use which are within range of the evolutionary process. This would seem to exclude written language and the use of language for formal purposes (logic, mathematics, linguistics, etc.). In the limit, these restrictions will be applied in order to sustain the position. That is, we will end with a definition of language such that it will be the case that its structure is unaffected by capacity limitations. The circularity of this procedure would be ended by examining the result which would be a partition of the conventional material of language into a core language together with various elaborations. Note that the core language would have built into it what are currently regarded as performance limitations. In addition, a large part of what is now considered to be language competence would come to be seen as the use of the core language devices and elaboration of the core language codes by mechanisms which are part of other cognitive systems such as the GPS. The analysis which follows will not approach this goal and the reader is invited to suspend his a priori judgments. As an illustration of the way in which the GPS might be used, we could imagine that judgments of grammaticality involve the GPS looking at the output from the linguistic processes and trying to infer the principles underlying its operation. A sentence would be called grammatical if it could be derived using these principles. Such judgments would be as reliable as the beliefs of the GPS.

A BIOLOGICAL OVERVIEW

Let me now restate this position from a standpoint within a biological/evolutionary framework. The hypotheses appear to involve the following substantive claims:

Claim 1. - Language evolved in proto-man as a vehicle for the communication of propositions. (The teleological flavor of this formulation is for expository purposes only. The details of the evolutionary process are immaterial.)

Claim 2. - The complexity of the sets of propositions which the conceptualizer can produce is limited. This limitation might

be an intrinsic property of the knowledge structures or might arise as a consequence of the way these are retrieved.

Claim 3. - Language has evolved in such a way as to allow the appropriate mechanisms to linearize any form presented to it by the conceptualizer.

Claim 4. - The computational devices required to sustain the operations of the language mechanisms evolved in a way as to allow these mechanisms to function properly. Thus, according to this position, there would not be any limitations on the normal operation of the language mechanisms, as defined by C.3.

Claim 5. - The peripheral speech mechanism has imposed no constraints on the structure of language. The Hypothesis of Optimal Adaptation is accepted, viz, "The speech signal is optimally adapted to human speech recognition and vice versa" (Marcus (12)). The speech recognition system constructs some internal code which maps onto the listener's knowledge structures.

Claim 6. - The mechanisms responsible for converting the input code into propositional form are of the same complexity as those responsible for speech production and operate at the same rate, either by virtue of being identical with the latter or by virtue of parallel evolution.

Claim 7. - The computational devices necessary to sustain these mechanisms have evolved to allow them to function without impediment. (cf. Claim 4).

Examination of Some of the Claims

The claims are perhaps not exhaustive. In some cases they are no more than the faintest hint of the profound implications of the position I am testing. These implications should be followed through as far as necessary to sustain the position. The implausibility of the consequent theory in relation to more orthodox views should not perturb us provided that it is productive

and internally consistent. All the orthodox views seem to be regarded as ludicrous by holders of other orthodox views.

Claims 4 and 7

Taken together these claims specify that the computational devices necessary to sustain the operation of the language mechanisms have evolved to allow the latter to function without restriction. Consider the alternative position: there are limitations of short-term memory or processing speed or processing power which restrict the proper operation of the language mechanisms. What might these be? Let us look at the notion of memory, using information processing concepts which are in currency (1,6,13).

a) A "working memory," with a capacity of, e.g., five pointers, restricts the degree of center-embedding which can be handled.

b) An input acoustic buffer, such as pre-categorical acoustic store (PAS), with a duration of, e.g., 1/2 second, might indirectly limit the clause length which can be comprehended by the listener.

c) A response buffer, which enables the motor program to operate efficiently, limits the length of phrase which can be uttered (e.g., by limiting the scope of intonation contours).

If such claims are intelligible, their relevance would be that these limitations restrict the structure of language. In other words, our language would be more efficient if, for example:

a) we possessed a working memory which could handle 7 instead of 5 items;

b) if the useful persistence of pre-categorical acoustic store were 750 ms instead of 500 ms;

or

c) if the output buffer could handle 2.2 s worth of motor code instead of 1.7 s.

The plausibility of these claims may be challenged for two reasons. First, there is no evidence that normal adult variation in such functions (as usually measured) has any effect whatsoever on the nature of the language mechanisms. Thus,

conceptual system would never hand on a propositional structure with an embedded S. The occurrence of embedding in language is then to be attributed to the operation of the GPS which may have evolved some fast-operating procedures to allow it to intervene in speech production by elaborating upon elements in the propositions. It would be such operations which would be limited by capacity constraints rather than operations of the language mechanisms.

Language and Thought

Intuitively we seem to be able to think with a speed and complexity which outstrips our ability to speak. Quite literally, we cannot say all that we think. This seems to indicate that the conceptualizer cannot be serviced adequately by the language systems. If this were indeed the case it would seriously weaken the argument above concerning the relationship between the linguistic mechanisms and the computational machinery which serves it. I remarked on the plausibility of supposing that the latter had evolved sufficiently to serve the former. On a parallel argument it would be surprising if the linguistic mechanisms were inadequate for their purpose. However, it seems to me that such limitations of speech arise when we attempt to introspect upon and verbalize our thought processes rather than in the course of communicating. Our thought processes, particularly in the solution of everyday problems, can operate perfectly well without the use of language mechanisms. If we try to speak at the same rate, then the conceptual system produces the bottle-neck, not the language mechanisms. Note here that Klein (personal communication) has shown that while 7-year old children are capable of solving complex moral dilemmas in the course of discussion, they cannot subsequently derive and explain the reasons for their solutions. Adult skills in this respect seem to be trainable and perhaps are associated with other skills such as problem solving. We would not, then, I imagine, want to ascribe the acquisition of such skills to expansion of the peripheral capacities with a consequent elaboration of language structure.

Limitations in Speech Comprehension

In the main I suppose that any breakdown in speech comprehension can be attributed to a listener encountering at least one of the following adverse conditions:

a) Poor signal-to-noise level.
b) The speaker's use of unfamiliar vocabulary or unexpected or unusual pronunciation.
c) The speaker producing utterances which presupposed background knowledge which was, in fact, not shared by the listener. This is what David Routh has termed "pragmatic opacity."

Only the last could conceivably be attributed to capacity limitations, and even here it seems clear that the limitation again arises at the level of the propositional system rather than in any capacity limitations in the language mechanisms. There would also be problems with propositional structures which had been formed as a result of the intervention of the GPS in the production stream. Multiple center-embedding would be the best example of this. Of course, not all interventions of the GPS would lead to problems. Furthermore, which kinds of GPS elaboration give rise to difficulties would depend upon the particular language. Kimball (9) gives examples from Japanese and English. Japanese differs from English in that main clauses are verb final and relative clauses precede their antecedents. If we start with a main clause (corresponding to the main or only proposition in "core language"): "The man saw the girl" and modify the subject noun, we get in English:

The man the dog the cat bit hit saw the girl.

In Japanese, the surface structure of the equivalent sentence would be (roughly):

cat bite dog hit man girl see,

with markers distinguishing the main subject, subordinate clause subject, and object. The result is comprehensible and acceptable, unlike the English version. On the other other hand, the Japanese equivalent of the sentence:

The man knows that the girl said that Bill wants Sam to leave.

comes out center-embedded and unacceptable.

It is possible, then, for us to produce utterances which are of such a degree of complexity that they cannot be comprehended (see also (3)). My argument is that such utterances will always be found to be outside the scope of what I called "core language" in the first section of the paper. Indeed, from a biological point of view it would be strongly nonadaptive if it were possible to produce an unintelligible structure in core language. In advanced societies, such utterances might be seen as worthy of priests, kings, politicians, or philosophers. In proto-man, using language to communicate about the immediate environment, about the lessons of the day's activities and plans for tomorrow, excursions beyond this core could well have been seen as signs of illness.

A RESTATEMENT AND SOME ALTERNATIVES

The position I have been discussing, then, is that the language mechanisms evolved in response to a need to communicate propositions. The mechanisms are as complex as they need to be in order to handle the propositional structures handed to them, and the necessary computational machinery has evolved in parallel. Language structure, then, the product of these mechanisms, is equally unconstrained by the processing machinery. The constraints in spoken language, as compared with theoretically possible languages, arise from the limited demands of the propositional system. Here we must consider two major alternatives to the position I have been exploring. These alternatives are that language is imposed from outside or that language is discovered by each infant.

Language as Imposed

An extreme version of an alternative position would regard language rather as something imposed on the nervous system from the outside. Thus we could image a group of roving scientists from another galaxy looking for organisms whose behavior they might modify. Furthermore, it would be required that they themselves have an unrestricted language and a description of it

which they attempt to impose upon species they encounter.[1] In man the capacity restrictions of his general purpose information processing systems lead to a reduced form of the language although enough is retained to permit him to reconstruct the form of the original (as an activity of the GPS in linguists). It will be seen that this alternative does allow the question in the conference title to be posed much as we can properly pose the question of the influence of capacity limitations on the structure of sign language in nonhuman primates.

Language as Discovered

An alternative way of preserving the notion of the independence of language from man is to imagine that man discovered or discovers language. This is the standard behaviorist position; that there is no phylogeny, only ontogony. In this case we have each individual child discovering language - not just his native language, the version he will speak, but language itself. This is, of course, a popular view of language with a certain kind of behavioral psychologist, but not one which I am inclined to take seriously.

A more plausible alternative is that mankind has discovered language, language, that is, as a property of the universe. Their understanding of this object is limited by the computational properties of their nervous system. An analogy might be with the way in which mankind has discovered the properties of number. If one believes that numbers exist apart from man, that is, are Platonic forms, rather than having been invented, then we can see how theories of number in all but a few persons are greatly impoverished owing, presumably, to some limitations in our ability to compute with abstract objects.

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[1] For the technically minded we could image the limitations of their nervous system (or some functional equivalent) to be circumvented by their ability to extrude directly and automatically representations of interconnected propositions or deep structures which are to be communicated. The resulting excrescence would be automatically ingested at the appropriate times and converted into the appropriate code to feed the language mechanisms. The only restrictions on sentence length or complexity would be those dictated by such mundane factors as the food supply or the life-span of the organism.

Hints for a Research Program

Something of the position being discussed here has precedent. A number of people have proposed that some of the arbitrary bits in transformational theory could be accounted for by appeal to capacity limitations. What I am suggesting as possible is that a large portion of language may be due to non-language mechanisms and as such better described in a different fashion from that used for core language. Ideas about the nature of the two contributions could be discovered by comparing clear extreme cases. Thus, "literary" writing could be seen as a case of the greatest contribution by the GPS. The communicative abilities of the apes would represent a pure form of GPS (albeit reduced from the human potential) with no contribution from a linguistic device. And there may exist a type of early brain damage whereby language is acquired but without the contribution of a GPS. In the latter case, care must be taken to distinguish between a GPS as a formal and consciously controllable, problem solving apparatus, and GPS as a general property of the central nervous system.

SIGN LANGUAGE

In the position I have been discussing, the major limitations on the form of language have to do with the way in which propositions are presented to the linguistic device. Now it is also the case that the eating/breathing apparatus is used for language output, and we can reasonably assume (though we should remember it is an assumption) that language has always been output using speech. The influence of vocal output on the evolutionary process has not been considered. It is possible that it shaped the nature of the linguistic device itself by requiring it to produce a linear output. This influence could have reached deeper into the production chain and shaped the nature of the conceptualizer and, perhaps, of human consciousness. In this case we would expect to find that speech was a more efficient means of expression than sign. As Klima and Bellugi say:

"If speech is specially selected, if sound constitutes such a natural signal for language, then it is all the more striking

how the human mind, when deprived of the faculty that makes sound accessible, seizes on, perfects and systematises an alternate form to enable the deeper linguistic faculties to give explicit expression to ideas." ((11), p. 315).

The evidence is that the rate of "expression of ideas," so far as we can tell, is the same in sign as in speech. This is inconsistent with the idea of the breathing/eating system imposing constraints upon the linguistic device and perfectly consistent with the idea that it is the conceptualizer which is responsible for the limitations. If this is the case we should not be surprised if only single messages can be signed at once, with all cases of apparent parallelism being found only under special circumstances - such as in poetic form or as a mixture of sign and gesture.

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