

FROM HAND TO MOUTH: SOME CRITICAL STAGES IN THE EVOLUTION OF LANGUAGE

Horst D. Stekalis
*Department of Anthropology,
Livingston College, Rutgers University
New Brunswick, New Jersey 08903*

Stevan R. Harnad
*Department of Psychiatry
CMDNJ-Rutgers Medical School
Piscataway, New Jersey 08854*

THE TRANSLATABILITY THESIS

In the evolution of linguistic behavior, as in the evolution of other traits, the actual sequence of events often proceeds by accretion and overlay upon prior developments such that a purely synchronic consideration of the end product can be considerably misleading as to its lineage; i.e., how it got that way. Although the actual optimal route taken in evolution may sometimes seem somewhat circuitous with respect to the final stage if the latter is considered in isolation, it need not appear that way if antecedent conditions are taken into account.

An indisputable fact about language is that it is currently a phenomenon intimately and almost inextricably linked to the medium of speech. Almost all language is spoken language. Most orthographies are derived from phonology, or are at least one-to-one with the words of a spoken language, and even in the brain, linguistic functions seem to be closely bound with, if not identical to, speech functions. In fact, it is virtually impossible to find a medium-neutral general term for the function in question, because “language,” “linguistic,” “glossogony,” and so on, are all etymologically linked to (the) “tongue.” However, capitalizing upon a general diachronic trend in the “evolution” of word meanings — namely, a gradual change away from “iconicity” toward “arbitrariness”⁴³ will use the term language, ignoring its etymological speech-origins, to denote *a general system for encoding and communicating propositional information by arbitrary, syntactically-concatenated symbols which* (and this is the most important definiendum) *can provide a translation* (not necessarily one-to-one) *of anything that anyone can say in a natural language* (with “natural language” here standing for our intuitions as to what we are all capable of saying or writing). A *proposition* is an intentional claim or a prediction about what is the case; i.e., a description or an explanation of something.

The purpose of the “translatability” criterion, which is certainly a particularly strong one, is to settle unequivocally questions of the type “does organism X have language” or “is Y a language.” Should such a question arise, the critical test would be whether, given enough time and attention, a translation of, say, Plato’s *Cratylus*, could be accomplished by or for X in Y. It is a linguistic truism that there is no such thing as a “primitive” language. Any existing natural language can do anything any other one can. We simply extend this as a conjecture about all possible languages.*

*We suspect that our translatability criterion is equivalent to Katz’ “effability hypothesis” as expressed in this It is particularly interesting that attempts to provide counterexamples to the translatability criterion are doomed by their very effability! A revealing illustration is

SERIAL MOTOR PRAXIS

Our strategy in the present attempt to reconstruct language phylogeny will be to focus upon certain critical transitions that may already be familiar but that either have not yet been linked with language evolution explicitly or have not been fully appreciated in that specific context. For example, we feel that it is neither irrelevant nor a coincidence that both speech and motor dominance are co-lateralized in the same, left, hemisphere, or that tool-fashioning and use, which many authors attempted to link somehow with speech, partake of this same asymmetry. It is likewise significant that gestural signaling with the emancipated forelimbs of hominoids would provide the most direct link between these two species of complex lateralized praxis.

Any human language must take the form of serial motor activity. First of all, we have no way of generating complex outputs in "parallel." Most behavior is serial in time, one chunk at a time.²² Nor are we efficient parallel processors, especially with respect to propositional information. What a computer can direct an output device to throw on a whole page at once, we (and indeed the computer too) must "read" sequentially, item by item.²⁹ So, as input/output devices, and also as central processors, we are constrained to temporal-sequential activity. In this connection, Lashley²² predicted that "analysis of the nervous mechanisms underlying order in the

provided by Kiparsky's attempt in the discussion section following Keenan's paper in this volume.⁵⁸ In English the comparative "he is smarter than she is" allows an option not present in all languages. The default provides an implicit "than she is smart" in this case, but one could also have said "he is smarter than she is beautiful." The argument is that in some languages this option is not available, and the comparative is constrained to a single dimension. One could not even say "the building is wider than it is tall" in such languages.

But of course a powerful and rather illuminating rebuttal is possible. There are, in fact, two ways of translating the English message into a language which has the constrained comparative. Let us call one translation "internal" and the other "external." Each provides a profound explication of the power of effability and the scope of translatability.

The "internal" translation would run something like this: "The degree to which the house is wide is greater than the degree to which the house is tall." This involves no problem for the dimensional constraint (degree/degree) and it also shows how plastic the internal resources of a language really are, in terms of what is readily effable. Faced with a situation in which we would use our "heterodimensional" comparative, speakers of a language with a "homodimensional" comparative would, of course, immediately and quite naturally use the kind of circuit just mentioned. Did anyone seriously think that they would be stopped mute in their tracks, or, more absurd still, that they would display some sort of Whorfian agnosia for the real world state of affairs corresponding to a heterodimensional comparison? "How can buildings be taller than they are wide?" or some nonsense like that!

The "external" means is still more enlightening, for it is the very means to which Kiparsky or Keenan must resort in intimating to us the putative limitation of a language. The critical point is that, in the case of natural languages, "meta-linguistic" statements are every bit as linguistic as are "object-linguistic" ones. So one could just as easily go to the native speakers with the homodimensional comparative and tell them (much as Kiparsky and Keenan tell us). "Listen, you have a kinky sort of comparative here, it can only do so-and-so, while in other languages it can do so-and-so." Would the native stare with bewildered receptive aphasia (or such intimations? Of course not. He would understand at once. Nor would a sudden new dimension of cognitive experience be opened up for him upon the realization of the new syntactic horizons vouchsafed by languages other than his own. He would simply nod and acknowledge that others say what he says and knows in a different way. But know it he does, and say it he can. QED.

more primitive acts may contribute ultimately to the solution even of the physiology of logic.” Thus, in many respects the story of the evolution of language must begin with the evolution of serial motor activity and its nervous control.

A quick inventory of the principal organs of serial motor activity in primates yields the following: [1] The muscles of the eyes and head; these have their work pretty much cut out for them, as they have crucial responsibility in orienting toward incoming visual, auditory, and olfactory information, as well as performing their parts in species-typical behaviors such as feeding and aggression. [2] The muscles of the limbs; in quadrupedal primates, these are primarily dedicated to locomotion as well as components of species-typical behavior. [3] The vocal apparatus; this is involved in species-typical vocalizations, principally of an emotive sort [4] The facial musculature; this, too, is involved in species-typical emotional expression.

Of the above motor candidates for taking on a linguistic function, [3] the vocal apparatus is certainly the least “busy” in terms of being occupied by other duties. Furthermore, vocalization is much more versatile than the other semi-employed contender, facial expression, especially in the relatively “deadpan” prosimians. Vocalization, however, has one critical shortcoming: it hasn’t any relevant experience: its normal function is far-removed from what would be demanded of a motor organ that was to take on the role of producing language.

ENCEPHALIZATION

Of course, at this point we are no longer discussing the motor end organs themselves, but the brain which controls them. What does it mean to say that the vocal apparatus “lacks experience” relevant to language? It means that the neural control of the vocal activity of nonhuman primates is somehow not adapted to the kind of activity involved in language. These vocalizations are controlled by evolutionarily primitive regions of the brain which are involved in stereotyped species-typical communicative behaviors and emotion.^{32,38} They lack the requisite independence from affect to assume other duties. Furthermore, they are not particularly disposed toward learning. Although there is evidence for some minimal conditionability of monkey vocalization under certain conditions,³² previous attempts to shape chimpanzee vocalizations have been unsuccessful overall.¹³ Primate calls are a relatively restricted and predictable set for a particular species, and even if they depend upon experience for acquisition,³⁵ the amount of variation in the final product is negligible compared to the variety of learned complex behaviors of which the limbs, the most qualified candidates of all, are capable. In short, the neural control of vocalization lacks the requisite plasticity, both in terms of available repertoire, prior experience, and modifiability by experience.

In contrast, the limbs are relatively better qualified. They are adapted to operating on the environment and being guided by feedback from it. They have, and display, a much wider range of variability in their activities than does vocalization, or any of the other candidates. Their only drawback is that they are already fully employed. In quadrupedal primates they can hardly be spared for outside work unless some of them, at least, are released from their full-time duties. Furthermore, in these lower primates the limbs are not totally independent agents. They are primarily under the control of those previously mentioned areas of the brain which are involved in stereotyped behavior and affect. These limbic and associated brain-stem nuclei govern the programming of holistic, patterned species-typical behaviors.²⁷ They cannot subserve the kind of fine tuning of complex motor activity that only neocortical mediation can provide.

The process of increasing control of function by the neocortex is called *encephalization*. and fully quadrupedal limbs, besides being otherwise occupied, are not very advanced in this respect. Much better qualified are the forelimbs of hominoids, with their specialization for prehensile and manipulative functions.^{1,33} Extrapyramidal control, characteristic of lower primates, is now supplemented by neocortical, pyramidal mediation for skilled precision movements.³⁶ This permits increased flexibility in voluntary sequencing, fine control of the digits, manipulative proficiency, and a plasticity to experience, all characteristic of increased motor encephalization.

MOTOR DOMINANCE

Relieved from doing double duty with the hindlimbs in locomotion, the emancipated hominoid forelimbs still exhibit a basic duplication of function, in that there are two of them, and for many reasons these must be prepared to be equipotential.^{18,61} There is no evidence for anything like “cerebral dominance” in these organisms, nor extant primates, who are equally skilled in manipulation with either arm even in their most skilled acts.⁴⁸ There is a tendency (probably not a genetic one) for an individual monkey or ape to display relatively stable hand preferences under unbiased circumstances.^{3,6,20,30} However, these preferences are easily reversed by experience,⁴⁹ and vary randomly in being left or right for individuals in a population; so they are probably idiosyncratic, rather than genetically transmitted.

The first evidence for a “nonrandom” distribution of handedness comes with tool- and weapon-use by Pleistocene *Australopithecus*.⁵ Middle paleolithic tools associated with *Homo erectus* from Choukoutien, China, show that the majority were chipped by right-handers.³⁷ A similar conclusion has been reached³⁷ on the basis of the few arm and hand bones known of Neanderthal man. The latter’s skull displays further evidence of cerebral asymmetry, as does that of *Homo erectus*.²⁴ Precise origins of these first asymmetries can only be conjectured, but it would seem most parsimonious to assume that they were related to the evidence itself, namely that functions requiring sophisticated asymmetric *use* of the forelimbs,³⁷ such as the power and the precision grip,³⁴ particularly in skilled sequential acts requiring bimanual coordination, must encephalize asymmetrically. This means that the tool- and weapon-use of contemporary chimpanzees,^{19,47} who do not seem to display consistent laterality, is not the kind that demands asymmetric encephalization.

Gross movements of the forelimbs can be initiated by either side of the brain in monkeys, and only fine movements of the digits are under exclusive contralateral control.²¹ Apparently, unlike in man,⁸ nothing that contemporary nonhuman primates do with their hands, gross or fine, demands any differentiation between the motor control regions on the two sides. Concerning the origins of laterality, then, it seems reasonable to suppose that it was the degree of elaboration of learned asymmetric movement sequences that tilted the balance, and it was early man’s critical reliance on these new behaviors as a means of survival that consolidated the gain.

COUPLING

Next something must be said about “coupling” in the nervous system. We have suggested that it is unlikely that the pressures for asymmetry issued simply from unimanual weapon use; however, it seems reasonable to expect that a population that

already favors the right in the context of skilled bimanual use would favor it also in the simpler unimanual function. In general, unless some antagonism can be demonstrated, it seems reasonable to suppose that there was some kind of coupling between the two tendencies. By coupling is meant either a partially shared substrate or a synergy between two functions. One of the most striking examples of the latter kind of coupling in the nervous system is that of "turning tendencies."¹⁷ Local activity on one side of the brain has, besides its specific function, the effect of turning the organisms attention, responsiveness, and sometimes even his body toward the side opposite the activated region. Local activity and contraversive turning are coupled.

From the existence of coupling one might be led to expect a mutual facilitation if the coupled functions are compatible. For example, if local activity in the brain occurred at a time when there was need for attention to contralateral space, then one would expect the latter performance to be improved. Experiment, in fact, supports this.¹⁸ Conversely there may be situations in which coupling produces interference and there is evidence for this too.¹⁰

In the studies just cited it happens that the coupled functions investigated were verbalization, hand use and contralateral turning. Verbalization and the processing of verbal materials induce a detectable rightward turning tendency in man. They are also compatible with concurrent, sequential arm-tapping and dowel-balancing with the left hand, but interfere with these tasks on the right. The mediating factor is, of course, the fact that language functions are predominantly lateralized in various regions of the left cerebral hemisphere in man. Facilitation occurs when the coupled functions are compatible with the task, such as the detection of verbal materials in the right field, but interference occurs when they are incompatible, such as in the attempt to concentrate on tapping or dowel-balancing with the right hand at the same time as speaking. These tasks are performed better when divided between hemispheres through the use of the left hand.

To return now to early hominids with their newly developed asymmetric hand use, we claim that the pressures for asymmetric use resulted not only in increased elaboration in the left hemisphere for right-hand skills, but that the control of coordination and sequencing of all skilled bimanual performance also lateralized to the hemisphere controlling the more specialized hand. There is evidence that this is the case in contemporary man,^{16,26} whose left hemisphere is specialized for organizing the performance of patterned limb-movements while the isolated right hemisphere is proficient only in directing axial movement.⁸ Unimanual specialization became coupled with dominance for bimanual coordination, and finally the dominant hemisphere came to assume the programming of all forms of complex serial praxis.

THE ALLEGORY OF THE ROOMS

We now come to a stage in language evolution with respect to which this paper does not purport to suggest hypotheses, namely, the stage of language-specific environmental pressures. We do not know what these pressures were, although we venture to doubt certain attempted explications. Concerning the relation between tool-use and language, there have been three kinds of suggestion, of which we espouse only the last, which is the weakest.

I. The first kind of suggestion has been that language is somehow a prerequisite for tool-making and hunting. It is not at all apparent to us why this should be so. Tool-making and hunting are certainly not themselves verbal activities, although it is undeniable that they, like virtually all other human skills, have profited, both in terms of their exercise and their transmission, from the existence of language.

However, australopithecines did not do the kind of sophisticated big-game hunting for which some have claimed language to be essential⁵¹ (cf. Ref. 23). Further more contemporary artisans are celebrated as the principal exponents of the so-called “nonverbal” functions.²⁵ So it seems improbable that the critical pressures for language were in the service of either of these activities. (cf. Refs: 17,67,68)

2. The second kind of suggestion has been that there is an important analogy between tool-fashioning-and-use and language; that they somehow have a common cognitive mechanism. In this view, language is simply an elaboration of the function. We do not see this analogy, except for the fact that. Both seem to be planned, skilled motor-sequential activity. The latter fact is-certainly important, and we will make use of it below to explain motor continuities, but it is surely not sufficient to account for the specific origins of language, nor to account for those critical cognitive characteristics in which language differs from all other forms of planned sequential behavior (cf. Ref. 69).

It seems to us that the source for insights as to language-origins is more likely to be in the dialogue between man and man than between man and tool, and to this end we propose a simple paradigm for the state of affairs which does telescope the kind of cognitive capacity which we feel is unique to language. One is to imagine two organisms out of sight from one another in two rooms with identical contents, identically located, consisting of more-or-less familiar objects. A third party enters one of the rooms and displaces one of the subjects. The task of the observing organism is to signal to his counterpart in the other room what has been done, so that the counterpart can do the same. The critical properties of this scenario are that the objects and the act of displacement can be *any whatsoever* with which the organism is familiar (i.e., can and has perceptually discriminated) and the information to be conveyed to his counterpart must not be conveyed iconically (i.e., by imitation). We feel that this paradigm comes closer to mirroring the competence that language uniquely confers, and we see nothing in the skills of tool-use or hunting that resembles it in any significant way (cf. Ref. 70).

3. The third and weakest suggestion seems more plausible, although it leaves a good deal still to be accounted for; namely, that it is difficult to-imagine a hominid with the cognitive capacity to fashion tools and artifacts of the kind that have been found^{11,67} who did not also have the capacity for linguistic communication. This is not to imply that he would need language to do what he does, or that language is in any important sense *like* what he does, but simply that one would expect language too to go hand in hand with such cognitive sophistication. The compellingness of this last suggestion is increased by what is known about the cognitive and communicative capacities of contemporary apes,^{28,46} and particularly by the recent experiments on the acquisition of gestural and other symbolic communication systems by chimpanzees.^{40,41,43}

GESTURES AND PROPOSITIONS

None of the factors cited, however, seem to Constitute necessary and sufficient conditions for language-origins, so that will have to remain an acknowledged gap in this sequence as we are tracing it. Some minor links, however, do suggest themselves. First, the motor state of affairs we have sketched makes it seem highly unlikely that language would have begun in the vocal mode. For one thing, vocalization is at this stage still largely under the control of the limbic system and there is no reason it

should not be. The advanced encephalized end-organ of choice at this juncture is surely the forelimb. Furthermore, to return for a heuristic moment to our allegory of the rooms, it seems reasonable to expect that an immediate *imitational* solution to such a problem would have preceded the linguistic one. Therefore, all one need do is remove the partition between the rooms, and the task is easily accomplished.

Now, to proceed from this simplified version by a series of approximations to the full-blown paradigm of the rooms, one may suppose that the imitative act could by degrees become less iconic as it came more into use. Whole acts could become progressively as short-circuited as circumstances and experience would allow.⁵³ Pointing, and more and more approximate and arbitrary icons, could replace the full-blown pantomime; and as these arbitrary sequences came increasingly to be relied upon as communicating information in their own right (rather than by obvious immediate iconic correspondence with their immanent referents), a gesturer may well be held *accountable* for what he has signaled. That is, his signal could be construed as a *claim*, and not just a direct interaction with objects which it would make no sense to deny or disbelieve. In this way, a proposition could be born.

This is not to say that “deception” is the origin of propositionality. There is certainly deception in nonpropositional intentional contexts, such as hiding or withholding food, and so on. Furthermore, in the room allegory it is not the act itself which is the proposition.. Initially, a gestural act may just be a short-circuited iconic sequence, which it would make no sense to deny as long as it continues to retain some isomorphism with its referent and the referent is present for verification. What makes an act a proposition is the possibility of misleading, of claiming something false. Once a communicative act can give intentionally misleading information, it is a proposition.

So as soon (in the allegory of the rooms) as the gestures are divorced from their immediate referents and are intended and relied upon to transmit information about those referents, *propositionality* is involved. But let this not be taken to mean that *language*, in the sense we have earlier defined it in this paper, is necessarily involved yet. A gestural propositional system may still not be able to sustain a translation of everything which can be said in a natural language. It may be restricted to certain contexts and simply never used in others. Its users may simply not be inclined to exploit its full potential. Yet there seems to be something very arbitrary about restrictions of this sort. One feels, as with the sophisticated tool-maker, that if he can do that much, then he ought to have the brains to go all the way. And perhaps that is in fact the reason for the rapid explosion of artifacts that occurred in that putative period in the Upper Pleistocene when language is believed to have flourished.¹¹ Once begun, it is hard to imagine the function staying within bounds. At that point, only motivation had to be selected for; i.e., motivation to communicate propositional information, and the rest could be transmitted — one would like to say by “word of mouth,” but at this stage it is only by “sight of hand.”

Now what of those hands which were doing this gestural signaling? There were two of them; were they both gesturing? On the basis of contemporary evidence from sign language of the deaf,^{44,53} one can conclude that both were indeed used, and perhaps asymmetrically. However, the “leading hand,” in the sense not merely of setting the pace, but of governing the planning and sequencing of the gestures, was surely the right, or more appropriately, the control regions for complex serial praxis in the left hemisphere.⁵⁹ There is evidence, also from contemporary deaf signers, that left-hemisphere damage causes sign-language aphasia, just as it causes aphasia for speech. So we suggest that the programming of gestural language came to be assumed by the hemisphere already dominant for praxis.

THE ADVENT OF SPEECH

Now we come to the limitations of sign-language. There is still the problem of the partition between the rooms in our allegory. This is not just an arbitrary stipulation. It is meant to allow for the absence of the referent, particularly if it is in the past or the future, as well as for what one may conceivably wish to express while the all-important eyes and hands are otherwise occupied. So certain intrinsic limitations of a gestural language immediately suggest themselves. Not only are gestures of no use in the dark, or across partitions, or when the hands or eyes are otherwise busy, but they are slow and inefficient. So we propose that as the dramatic potentialities of language became manifest, and it became more and more critically relied upon, gesture-specific shortcomings began to intrude: at night, across distances, when several people were communicating, when crucial information had to be communicated rapidly, or when the hands were not free. One can almost hear the grunts of frustration!

And there, too, was the obvious solution. Language was already present, and increasingly exploited and depended upon. Now was the time for a relatively unoccupied fellow traveler to get into the act, and language became coupled with vocalization. Since gestures were already quite arbitrary by this time, there was no reason why they should not be supplemented by vocalization to further differentiate and extend them. This coupling may first have been only an incidental suprasegmental intensity marker for gesture¹² due to limbic intrusions into communicative acts,⁵⁴ but as it became increasingly relied upon for differentiating meaning and remedying the shortcomings of gesture, control of vocalization underwent encephalization, and, in accordance with the pattern of coupling and accretion described so far, the most natural locus for the neocortical control of speech was again the left side, colateralized with its linguistic and praxic precursors.†

Furthermore, this allowed for a very felicitous division of labor, because the more limbic emotive and iconic vocalizations, which could potentially interfere with that necessarily affect-free medium,‡ speech,² could be segregated to the minor hemisphere for continued participation in emotional expression,⁷ music,⁹ and other nonverbal activities.⁶² The elaboration of speech-specific mechanisms on the left then proceeded, not only with the development of neocortical control of rapid voluntary articulatory sequencing, but also with specialization of speech-specific central auditory mechanisms.^{50,31,65,66} Cognitive bifurcations in the service of verbal ideation also appeared and were duly lateralized.^{62,25}

From there it was only a matter of time until it became apparent that it was in fact gesture which was now the excess baggage, and that last relic of iconicity could drop out, to leave only the vestigial coupling between speech and gesture which we still display today.^{15,4,14}

† Lateralization is not an evolutionarily unprecedented solution for the neural control of complex learned vocalization, as Nottebohm has shown in passerine songbirds.⁵⁶ In man there is the added advantage that the corresponding receptive sensory system, audition, is not very busy either, both peripherally and centrally,⁵⁷ compared to vision. And there may already exist in primates a tendency toward lateralization of auditory function⁶³ as well as anatomical asymmetries in auditory regions.^{64,24}

‡ Neither the contemporary preoccupation with so-called "nonverbal communication." or "total communication" (cf. Tanner, Ref. 60). nor the otherwise valid concern for the iconic aspects of communication^{43,53} are pertinent here. The uniqueness of *linguistic* communication (refer to our definition of "language" above) is quite distinct from these, and even if it is often complemented by them, the evolutionary question is how it is that we came to rely so heavily upon *linguistic* communication as a species.

REFERENCES

1. BISHOP, A. 1964. Use of the hand in lower primates. *In* Evolutionary and Genetic Biology of Primates. I. Buettner-Janusch. Eds. Vol. 2:133-225. Academic Press. New York. N.Y.
2. BRONOWSKY, J. S. 1969. Human and animal languages. *In* To Honor Roman Jakobson. Vol. 1: 374-394. Mouton. The Hague. The Netherlands.
3. COLE, J. 1957. Laterality in the use of the hand, foot, and eye in monkeys. *J. Comp. Physiol. Psychol.* 50: 296-299.
4. CONDON, W. S. & L. W. SANDER. 1974. Neonate movement is synchronized with adult speech: interactional participation and language acquisition. *Science* 183: 99-101.
5. DART, R. A. 1949. The predatory implemental technique of *Australopithecus*. *Amer. J. Phys. Anthropol.* 7:1-38.
6. FINCH, G. 1941. Chimpanzee handedness. *Science* 94: 117-118.
7. FLOR-HENRY, P. This annal.
8. GESCHWIND, N. 1975. The apraxias: Neural mechanisms of disorders of learned movement. *American Scientist* 63: 188-195.
9. GORDON, H. W. 1974. Auditory specialization of the right and left hemispheres. *In* Hemispheric Disconnection And Cerebral Function. M. Kinsbourne & W. L. Smith, Eds. Charles C Thomas. Springfield. Ill.
10. HICKS, R. E. 1975. Intrahemispheric response competition between vocal and unimanual performance in normal adult human males. *J. Comp. Physiol. Psychol.* 89(1): 50-60.
11. ISAAC, G. L. This annal.
12. JAYNES, J. This annal.
13. KELLOGG, W. N. 1968. Communication and language in the home-raised chimpanzee. *Science* 162:423-427.
14. KENDON, A. 1970. Movement coordination in social interaction: Some examples described. *Acta Psychologica* 32: 100-123.
15. KIMURA, D. 1973. Manual activity during speaking. I. Right-handers. 2. Left-handers. *Neuropsychologia* 11:45-50 & 51-55.
16. KIMURA, D. & Y. ARCHIBALD. 1974. Motor functions of the left hemisphere. *Brain* 97: 337-350.
17. KINSBOURNE, M. 1970. The cerebral basis of lateral asymmetries in attention. *Act. Psychologica* 33: 193-201.
18. KINSBOURNE, M. This annal.
19. VON KORTLANDT, A. 1968. Handgebrauch bei freilebenden schimpansen. *In* Handgebrauch und Verständigung bei Affen und Frühmenschen. B. Rensch, Ed. Verlag Hans Huber Bern and Stuttgart.
20. KRUPER, D. C., B. E. BOYLE & R. A. PATTON. 1966. Eye and hand preference in rhesus monkeys (*Macaca mulatta*): *Psychonom. Sci.* 5(7): 277-278.
21. KUYPERS, H. G. J. M. 1973. The anatomical organization of the descending pathways and their contributions to motor control especially in primates. *In* New Developments in EMG and Clinical Neurophysiology. J. E. Desmedt, Ed. Vol. 3:38-68.
22. LASHLEY, K.S. 1951. The problem of serial order in behavior. *In* Cerebral Mechanisms In Behavior- L A. Jeffress. Ed. John Wiley & Sons. New York. N.Y.
23. LAUGHLIN, W. S. 1968. Hunting: An integrating biobehavior system and its evolutionary importance. *In* Man The Hunter. R. B. Lee & I. De Yore, Eds. Aldine. Chicago, Ill.
24. LE MAY, M. This annal.
25. LEVY, J. This annal.
26. LOMAS, J. & D. KIMURA. 1975. Intrahemispheric interaction between speaking and sequential manual activity. *University of Western Ontario Res. Bull.* 314. January.
27. MACLEAN, P. D. 1973. A triune concept of the brain and behavior. *In* The Clarence M. Hincks Memorial Lectures. 1969. T. J. Boag & D. Campbell. Eds. Part I: 6-66. University of Toronto Press. Toronto, Canada.
28. MENZEL, E. & M. JOHNSON. This annal.
29. MILLER, G. A. 1956. The magical numbers seven, plus or minus two: Some limits on our capacity for processing information. *Psych. Rev.* 63(2): 81-91.
30. MILNER, A. D. 1969. Distribution of hand preferences in monkeys. *Neuropsychologia* 7: 375-377.

Steklis, Horst D & Stevan R Harnad: 1976.
From Hand to Mouth: some critical stages in the evolution of language.
In Stevan Harnad, Horst D Stekalis & Jane Lancaster, *Origins and Evolution of Language and Speech*,
New York Academy of Sciences, New York, USA.
pp445-455.

31. MORSE, P. This annal.
32. MYERS, R. This annal.
33. NAPIER, J. R. It. 1960. Studies of the hands of living primates. Proc. Zool. Soc. London. 134: 647-657.
34. NAPIER, J. R. 1962. The evolution of the hand. Scientific American 207(6): 56-62.
35. NEWMAN, J. D. & D. SYMMENS. 1974. Vocal pathology in socially deprived monkeys. Developmental Psychobiol. 7(4): 35 1-358.
36. NOBACK, C. R. & N. MOSKOWITZ. 1963. The primate nervous system: Functional and structural aspects in phylogeny. In Evolutionary and Genetic Biology of Primates. J. Buettner-Janusch. Ed. Vol. I: 131-177. Academic Press. New York, NY.
37. OAKLEY, K. P. 1972. Skill as a human possession. In Perspectives on Human Evolution. S. L. Washburn & P. Dolhinow. Eds. Vol.2: 14-50. Holt Rinehart & Winston, Inc. New York, N.Y.
38. PETERS, M. & D. PLOOG. 1973. Communication among primates. Ann. Rev. Physiol. 35: 221-242.
39. PHILLIPS. C. G. 1971. Evolution of the corticospinal tract in primates with special reference to the hand. Proc. 3rd Int. Cong. Primatol. 2: 2-23. Karger. Basel, Switzerland.
40. PREMACK, D. This annal.
41. RUMBAUGH, D. This annal.
42. SARNO, J. E., L. PECK SWISHER & M. TAYLOR SARNO. 1969. Aphasia in a congenitally deaf man. Cortex 5(4): 398-414.
43. SEBEOK, T. A. This annal.
44. STOKOE, W. This annal.
45. TERRACE, H. This annal.
46. VAN LAWICK-GOODALL, J. 1968. A preliminary report on expressive movements and communication in the Gombe Stream chimpanzees. In Primates: Studies in adaptation and variability. P. C. Jay, Ed.: 313-382. Holt Rinehart & Winston, Inc. N.Y.
47. VAN LAWICK-GOODALL, J. 1970. Tool-using in primates and other vertebrates. In Advances in the Study of Behavior. R. A. Hinde, Ed.: 195-249. Academic Press. New York, N.Y.
48. WARREN, J. M. 1976. Handedness and cerebral dominance in monkeys. In Lateralization in the Nervous System. S. R. Harnad, R. W. Doty, L. Goldstein, J. Jaynes & G. Krauthamer, Eds. Academic Press. New York, N.Y.
49. WARREN, J. M. & A. NONNEMANN. This annal.
50. WARREN, R. This annal.
51. WASHBURN, S. L. & J.S. LANCASTER. 1968. The evolution of hunting. In Man the Hunter R. B. Lee & I. De Vore. Eds.: 293-303. Aldine. Chicago, Ill.
52. WYKE, M. 1971. The effects of brain lesions on the learning performance of a bimanual coordination task. Cortex 7: 59-72.
53. BELLUGI, U. This annal.
54. ROBINSON, B. This annal.
55. KATZ, J. J. 1976. This annal.
56. NOTTEBOHM, F. 1976. Asymmetries in neural control of vocalization in the canary. In Lateralization in the Nervous System. S. R. Harnad, R. W. Doty, L. Goldstein, J. Jaynes. and G. Krauthamer, Eds. Academic Press. New York, N.Y.
57. MARIN, O. This annal.
58. KEENAN, E. This annal.
59. KIMURA, D. and Y. ARCHIBALD. 1974. Motor functions of the left hemisphere. Brain 97: 37 1-384.
60. TANNER, N. Discussion paper. This annal.
61. CORBALLIS, M. C. 1974. The left -right problem in psychology. The Canadian Psychologist. 35(1): 16-33
62. HARNAD, S. R. 1973 Interhemispheric division of labour. Presented at: Bucke Soc. Conf. on Transformation of Consciousness. Montreal. Ms.
63. DEWSON, J. H. 1976 Preliminary evidence of hemispheric asymmetry of auditory function In monk . In Lateralization in the Nervous System. S. R. Harnad, R. W. Doty, L. Goldstein, J. Jaynes. and G. Krauthamer, Eds. Academic Press. New York, N.Y.

Steklis, Horst D & Stevan R Harnad: 1976.
From Hand to Mouth: some critical stages in the evolution of language.
In Stevan Harnad, Horst D Stekalis & Jane Lancaster, *Origins and Evolution of Language and Speech*,
New York Academy of Sciences, New York, USA.
pp445-455.

64. YENI-KOMSHIAN, G. H. & BENSON, D. A. 1976. Anatomical study of cerebral asymmetry in the temporal lobe of humans, chimpanzees and rhesus monkeys. Submitted for publication.
65. LIBERMAN, A. This volume.
66. MARLER, P. This volume.
67. MARSHACK, A. This volume. *Science* 192: 387-389.
68. MONTAGU, A. This volume.
69. REYNOLDS, P. This volume.
70. MASON, W. A. & HOLLIS, J. H. 1962. Communication between young rhesus monkeys. *Anim. Behav.* 10(3-4): 211-221.