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On Explaining Language

The development of language in children can best be understood in the context of developmental biology.

Eric H. Lenneberg

Many explanations have been offered for many aspects of language; there is little agreement, however, on how to explain various problems or even on what there is to be explained. Of course, explanations differ with the personal inclinations and interests of the investigator. My interests are in man as a biological species, and I believe that the study of language is relevant to these interests because language has the following six characteristics. (i) It is a form of behavior present in all cultures of the world. (ii) In all cultures its onset is age correlated. (iii) There is only one acquisition strategy—it is the same for all babies everywhere in the world. (iv) It is based intrinsically upon the same formal operating characteristics whatever its outward form (*1*). (v) Throughout man's recorded history these operating characteristics have been constant. (vi) It is a form of behavior that may be impaired specifically by circumscribed brain lesions which may leave other mental and motor skills relatively unaffected.

Any form of human behavior that has all of these six characteristics may likewise be assumed to have a rather specific biological foundation. This, of course, does not mean that language cannot be studied from different points of view; it can, for example, be investigated for its cultural or social variations, its capacity to reflect individual differences, or its applications. The purpose of this article, however, is to discuss the aspects of language to which biological concepts are applied most appropriately (*2*). Further, my concern is with the development of language in children—not with its origin in the species.

The author is professor of psychology and neurobiology at Cornell University, Ithaca, New York.

Predictability of Language Development

A little boy starts washing his hands before dinner no sooner than when his parents decide that training in cleanliness should begin. However, children begin to speak no sooner and no later than when they reach a given stage of physical maturation (Table 1). There are individual variations in development, particularly with respect to age correlation. It is interesting that language development correlates better with motor development than it does with chronological age. If we take these two variables (motor and language development) and make ordinal scales out of the stages shown in Table 1 and then use them for a correlation matrix, the result is a remarkably small degree of scatter. Since motor development is one of the most important indices of maturation, it is not unreasonable to propose that language development, too, is related to physical growth and development. This impression is further corroborated by examination of retarded children. Here the age correlation is very poor, whereas the correlation between motor and language development continues to be high (*3*). Nevertheless, there is evidence that the statistical relation between motor and language development is not due to any immediate, causal relation; peripheral motor disabilities can occur that do not delay language acquisition.

Just as it is possible to correlate the variable language development with the variables chronological age or motor development, it is possible to relate it to the physical indications of brain maturation, such as the gross weight of the brain, neurodensity in the cerebral cortex, or the changing weight proportions of given substances in either gray or white matter. On almost all counts, language begins when such maturational indices have attained at least 65 percent of their mature values. (Inversely, language acquisition becomes more difficult when the physical maturation of the brain is complete.) These correlations do not prove causal connections, although they suggest some interesting questions for further research.

Effect of Certain Variations in Social Environment

In most of the studies on this topic the language development of children in orphanages or socially deprived households has been compared with that of children in so-called normal, middle-class environments. Statistically significant differences are usually reported, which is sometimes taken as a demonstration that language development is contingent on specific language training. That certain aspects of the environment are absolutely essential for language development is undeniable, but it is important to distinguish between what the children actually do, and what they can do.

Table 1. Correlation of motor and language development (*3*, pp. 128–130).

Age (years)	Motor milestones	Language milestones
0.5	Sits using hands for support; unilateral reaching	Cooing sounds change to babbling by introduction of consonantal sounds
1	Stands; walks when held by one hand	Syllabic reduplication; signs of understanding some words; applies some sounds regularly to signify persons or objects, that is, the first words
1.5	Prehension and release fully developed; gait propulsive; creeps downstairs backward	Repertoire of 3 to 50 words not joined in phrases; trains of sounds and intonation patterns resembling discourse; good progress in understanding
2	Runs (with falls); walks stairs with one foot forward only	More than 50 words; two-word phrases most common; more interest in verbal communication; no more babbling
2.5	Jumps with both feet; stands on one foot for 1 second; builds tower of six cubes	Every day new words; utterances of three and more words; seems to understand almost everything said to him; still many grammatical deviations
3	Tiptoes 3 yards (2.7 meters); walks stairs with alternating feet; jumps 0.9 meter	Vocabulary of some 1000 words; about 80 percent intelligibility; grammar of utterances close approximation to colloquial adult; syntactic mistakes fewer in variety, systematic, predictable
4.5	Jumps over rope; hops on one foot; walks on line	Language well established; grammatical anomalies restricted either to unusual constructions or to the more literate aspects of discourse

There is nothing particularly surprising or revealing in the demonstration that language deficits occur in children who hear no language, very little language, or only the discourse of uneducated persons. But what interests us is the underlying capacity for language. This is not a spurious question; for instance, some children have the capacity for language but do not use it, either because of peripheral handicaps such as congenital deafness or because of psychiatric disturbances such as childhood schizophrenia; other children may not speak because they do not have a sufficient capacity for language, on account of certain severely retarding diseases.

There is a simple technique for ascertaining the degree of development of the capacity for speech and language. Instead of assessing it by means of an inventory of the vocabulary, the grammatical complexity of the utterances, the clarity of pronunciation, and the like, and computing a score derived from several subtests of this kind, it is preferable to describe the children's ability in terms of a few broad and general developmental stages, such as those shown in Table 1. Tests which are essentially inventories of vocabulary and syntactic constructions are likely to reflect simply the deficiencies of the environment; they obscure the child's potentialities and capabilities.

I have used the schema described to compare the speech development of children in many different societies, some of them much more primitive than our own. In none of these studies could I find evidence of variation in developmental rate, despite the enormous differences in social environment.

I have also had an opportunity to study the effect of a dramatically different speech environment upon the development of vocalizations during the first 3 months of life (*4*). It is very common in our culture for congenitally deaf individuals to marry one another, creating households in which all vocal sounds are decidedly different from those normally heard and in which the sounds of babies cannot be attended to directly. Six deaf mothers and ten hearing mothers were asked, during their last month of pregnancy, to participate in our study. The babies were visited at home when they were no more than 10 days old and were seen biweekly thereafter for at least 3 months. Each visit consisted of 3 hours of observation and 24 hours of mechanical recording of all sounds made and heard by the baby. Data were analyzed quantitatively and qualitatively. Figure 1 shows that although the environment was quantitatively quite different in the experimental

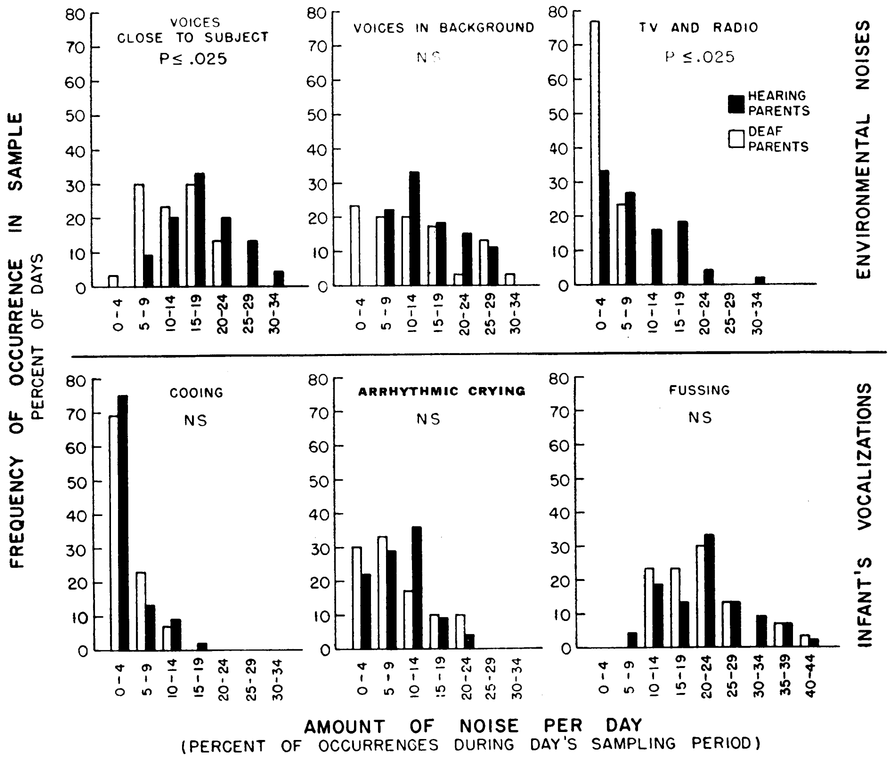

Fig. 1. Frequency distributions of various noises. The basic counting unit is individual recording days.

and the control groups, the frequency distributions of various baby noises did not differ significantly; as seen in Fig. 2, the developmental histories of cooing noises are also remarkably alike in the two groups. Figure 3 demonstrates that the babies of deaf parents tend to fuss an equal amount, even though the hearing parents are much more likely to come to the child when it fusses. Thus the earliest development of human sounds appears to be relatively independent of the amount, nature, or timing of the sounds made by parents.

I have observed this type of child-rearing through later stages, as well. The hearing children of deaf parents eventually learn two languages and sound systems: those of their deaf parents and those of the rest of the community. In some instances, communication between children and parents is predominantly by gestures. In no case have I found any adverse effects upon the language development of standard English in these children. Although the mothers made sounds different from the children's, and although the children's vocalizations had no significant effect upon attaining what they wanted during early infancy, language in these children invariably began at the usual time and went through the same stages as is normally encountered.

Also of interest may be the following observations on fairly retarded children growing up in state institutions that are badly understaffed. During the day the children play in large, bare rooms, attended by only one person, often an older retardate who herself lacks a perfect command of language. The children's only entertainment is provided by a large television set, playing all day at full strength. Although most of these retarded children have only primitive beginnings of language, there are always some among them who manage, even under these extremely deprived circumstances, to pick up an amazing degree of language skill. Apparently they learn language partly through the television programs, whose level is often quite adequate for them!

From these instances we see that language capacity follows its own natural history. The child can avail himself of this capacity if the environment provides a minimum of stimulation and opportunity. His engagement in language activity can be limited by his environmental circumstances, but the underlying capacity is not easily arrested. Impoverished environments are not conducive to good language development, but good language development is not contingent on specific training measures (*5*); a wide variety of rather haphazard factors seems to be sufficient.

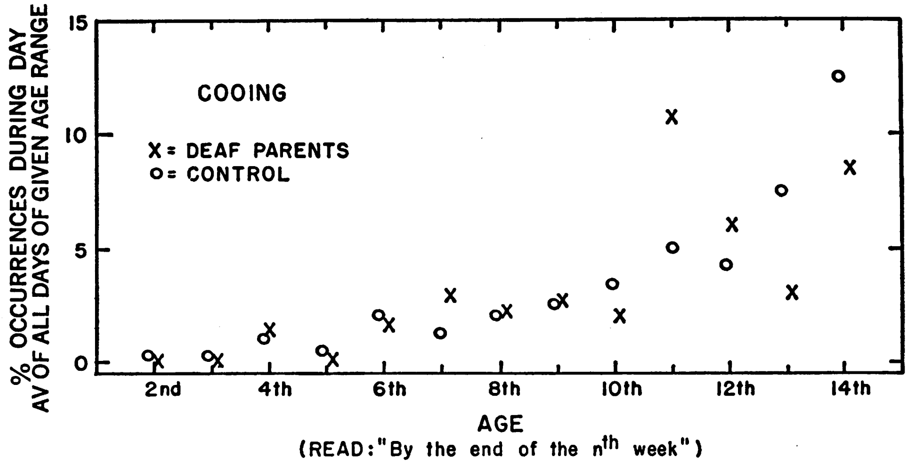

Fig. 2. Each baby's day was divided into 6-minute periods; the presence or absence of cooing was noted for each period; this yielded a percentage for each baby's day; days of all babies were ordered by their ages, and the average was taken for all days of identical age. Nonaveraged data were published in (*4*).

Effect of Variations in Genetic Background

Man is an unsatisfactory subject for the study of genetic influences; we cannot do breeding experiments on him and can use only statistical controls. Practically any evidence adduced is susceptible to a variety of interpretations. Nevertheless, there are indications that inheritance is at least partially responsible for deviations in verbal skills, as in the familial occurrence of a deficit termed congenital language disability (*2*, chapter 6). Studies, with complete pedigrees, have been published on the occurrence and distribution of stuttering, of hyperfluencies, of voice qualities, and of many other traits, which constitute supporting though not conclusive evidence that inheritance plays a role in language acquisition. In addition to such family studies, much research has been carried out on twins. Particularly notable are the studies of Luchsinger,

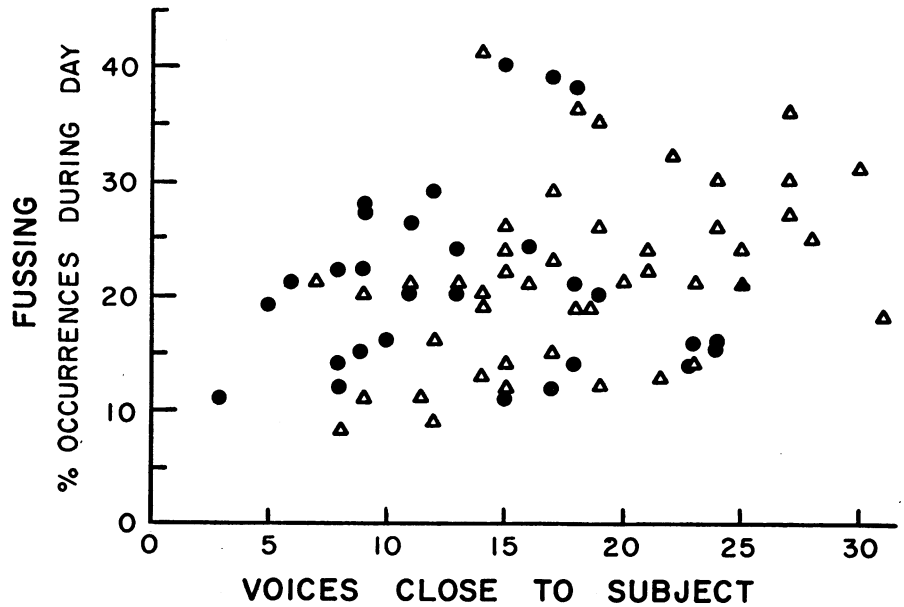

Fig. 3. Relation between the amount of parents' noises heard by the baby and the amount of fussing noises made by the baby. Each symbol is one baby's day; (solid circles) deaf parents; (triangles) hearing parents.

who reported on the concordance of developmental histories and of many aspects of speech and language. Zygosity was established in these cases by serology (Fig. 4). Developmental data of this kind are, in my opinion, of greater relevance to our speculations on genetic background than are pedigrees.

The nonbiologist frequently and mistakenly thinks of genes as being directly responsible for one property or another; this leads him to the fallacy, especially when behavior is concerned, of dichotomizing everything as being dependent on either genes or environment. Genes act merely on intracellular biochemical processes, although these processes have indirect effects on events in the individual's developmental history. Many alterations in structure and function indirectly attributable to genes are more immediately the consequence of alterations in the schedule of developmental events. Therefore, the studies on twins are important in that they show that homozygotes reach milestones in language development at the same age, in contrast to heterozygotes, in whom divergences are relatively common. It is also interesting that the nature of the deviations—the symptoms, if you wish—are, in the vast majority, identical in homozygotes but not in heterozygotes.

Such evidence indicates that man's biological heritage endows him with sensitivities and propensities that lead to language development in children, who are spoken to (in contrast to chimpanzee infants, who do not automatically develop language—either receptive or productive—under identical treatment). The endowment has a genetic foundation, but this is not to say that there are "genes for language," or that the environment is of no importance.

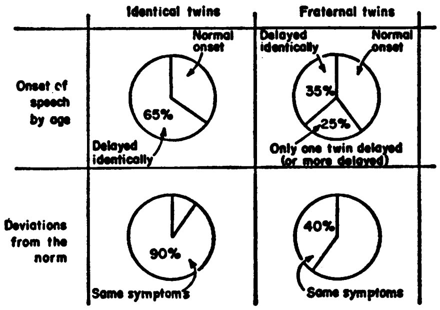

Fig. 4. The onset of speech and its subsequent development tend to be more uniform among identical twins than fraternal twins.

Attempts To Modify Language Development

Let us now consider children who have the capacity for language acquisition but fail to develop it for lack of exposure. This is the case with the congenitally deaf, who are allowed to grow up without either language or speech until school age, when suddenly language is brought to them in very unnatural ways. Before this time they may have half a dozen words they can utter, read, write, or finger-spell, but I have known of no profoundly deaf child (in New England, where my investigations were conducted) with whom one could communicate by use of the English language before school age.

When deaf children enter an oralist school, lipreading and speech become the major preoccupation of training. However, in most children these activities remain poor for many more years, and in some, throughout life. Their knowledge of language comes through learning to read and write. However, teachers in the oral tradition restrict expression in the graphic medium on the hypothesis that it interferes with lipreading and speech skills. Thus, exposure to language (i) comes much later in these children's lives than is normal, (ii) is dramatically reduced in quantity, (iii) is presented through a different medium and sensory modality, and (iv) is taught to the children rather as a second language is taught, instead of through the simple immersion into a sea of language that most children experience. The deaf children are immediately required to use grammatically correct sentences, and every mistake is discussed and explained to them.

The results of this procedure are interesting but not very encouraging from the educational point of view. During the early years of schooling, the children's spontaneous writings have a very unusual pattern; there is little evidence that the teachers' instruction in "how to compose correct sentences" is of any avail. Yet, careful analysis of their compositions shows that some subtleties of English syntax that are usually not part of the grammar taught in the school do make their appearance, sometimes quite early. There can be no question that the children do not simply imitate what they see; some of the teachings fall by the wayside, whereas a number of aspects of language are automatically absorbed from the written material given to the children.

There are other instances in which efforts are made to change a child's language skills by special training, as in the mildly retarded, for example. Many parents believe that their retarded child would function quite normally if somebody could just teach him to speak. At Children's Hospital in Boston I undertook a pilot study in which a speech therapist saw a small number of children with Downe's syndrome (mongolism) for several hours each week, in an effort to speed up language development. Later, two graduate students in linguistics investigated the children's phonetic skills and tried to assess the capacities of each child for clearer enunciation. Throughout these attempts, it was found that if a child had a small repertoire of single words, it was always possible to teach him yet another word, but if he was not joining these words spontaneously into phrases, there was nothing that could be done to induce him to do so. The articulatory skills were somewhat different. It was often possible to make a child who had always had slurred speech say a specific word more clearly. However, the moment the child returned to spontaneous utterances, he would fall back to the style that was usual for him. The most interesting results were obtained when the retarded children were required simply to repeat well-formed sentences. A child who had not developed to a stage in which he used certain grammatical rules spontaneously, who was still missing the syntactic foundations and prerequisites, could not be taught to repeat a sentence that was formed by such higher rules. This was true even in sentences of very few words. Similar observations have since been made on normal children (*6*), with uniformly similar results; normal children, too, can repeat correctly only that which is formed by rules they have already mastered. This is the best indication that language does not come about by simple imitation, but that the child abstracts regularities or relations from the language he hears, which he then applies to building up language for himself as an apparatus of principles.

What Sets the Pace of Language Development?

There is a widespread belief that the development of language is dependent on the motor skills of the articulating organs. Some psychologists believe that species other than man fail to develop language only because of anatomical differences in their oral structures. However, we have evidence that this is not so.

It is important that we are clear about the essential nature of language. Since my interests are in language capacities, I am concerned with the development of the child's knowledge of how language works. This is not the same as the acquisition of "the first word." The best test for the presence and development of this knowledge is the manner in which discourse is understood. In most instances, it is true that there is a relation between speech and understanding, but this relation is not a necessary one (*7*).

By understanding, I mean something quite specific. In the realm of phonology, understanding involves a process that roughly corresponds to the linguists' phonematization (in contrast, for example, to a "pictographic" understanding: phonematization results in seeing similarities between speech sounds, whereas pictographic understanding would treat a word as an indivisible sound pattern). In the realm of semantics, understanding involves seeing the basis on which objects are categorized, thus enabling a child to name an object correctly that he has never seen before. (The child does not start out with a hypothesis that "table" is the proper name of a unique object or that it refers to all things that have four appendages.) In the realm of grammar, understanding involves the extraction of relations between word classes; an example is the understanding of predication. By application of these tests, it can be shown empirically that Aunt Pauline's favorite lapdog does not have a little language knowledge, but, in fact, fails the test of understanding on all counts.

A survey of children with a variety of handicaps shows that their grasp of how language works is intimately related to their general cognitive growth, which, in turn, is partly dependent on physical maturation and partly on opportunities to interact with a stimulus-rich environment. In many retarding diseases, for example, language development is predicted best by the rate of advancement in mental age (using tests of nonverbal intelligence). In an investigation of congenitally blind children (*8*), we are again finding that major milestones for language development are highly correlated with physical development. A naive conception of language development as an accumulation of associations between visual and auditory patterns would be hard put to explain this.

Brain Correlates

In adults, language functions take place predominantly in the left hemisphere. A number of cortical fields have been related to specific aspects of language. The details are still somewhat controversial and need not concern us here. It is certain, however, that precentral areas of the frontal lobe are principally involved in the production of language, whereas the postcentral parietal and superior temporal fields are involved in sensory functions. These cortical specializations are not present at birth, but become only gradually established during childhood, in a process very similar to that of embryological history; there is evidence of differentiation and regulation of function. In the adult, traumata causing large left-sided central cortical lesions carry a highly predictable prognosis; in 70 percent of all cases, aphasia occurs, and in about half of these, the condition is irreversible (I am basing these figures on our experience with penetrating head injuries incurred in war).

Comparable traumatic lesions in childhood have quite different consequences, the prognosis being directly related to the age at which the insult is incurred. Lesions of the left hemisphere in children under age 2 are no more injurious to future language development than are lesions of the right hemisphere. Children whose brain is traumatized after the onset of language but before the age of 4 usually have transient aphasias; language is quickly reestablished, however, if the right hemisphere remains intact. Often these children regain language by going through stages of language development similar to those of the 2-year-old, but they traverse each stage at greater speed. Lesions incurred before the very early teens also carry an excellent prognosis, permanent residues of symptoms being extremely rare.

The prognosis becomes rapidly worse for lesions that occur after this period; the young men who become casualties of war have symptoms virtually identical with those of stroke patients of advanced age. Experience with the surgical removal of an entire cerebral hemisphere closely parallels this picture. The basis for prognosticating operative success is, again, the age at which the disease has been contracted for which the operation is performed.

If a disturbance in the left hemisphere occurs early enough in life, the right hemisphere remains competent for language throughout life. Apparently this process is comparable to regulation, as we know it from morphogenesis. If the disease occurs after a certain critical period of life, namely, the early teens, this regulative capacity is lost and language is interfered with permanently. Thus the time at which the hemispherectomy is performed is less important than the time of the lesion.

Critical Age for Language Acquisition

The most reasonable interpretation of this picture of recovery from aphasia in childhood is not that there is vicarious functioning, or taking over, by the right hemisphere because of need, but rather that language functions are not yet confined to the left hemisphere during early life. Apparently both hemispheres are involved at the beginning, and a specialization takes place later (which is the characteristic of differentiation), resulting in a kind of left-right polarization of functions. Therefore, the recovery from aphasia during preteen years may partly be regarded as a reinstatment of activities that had never been lost. There is evidence that children at this age are capable of developing language in the same natural way as do very young children. Not only do symptoms subside, but active language development continues to occur. Similarly, we see that healthy children have a quite different propensity for acquiring foreign languages before the early teens than after the late teens, the period in between being transitional. For the young adult, second-language learning is an academic exercise, and there is a vast variety in degree of proficiency. It rapidly becomes more and more difficult to overcome the accent and interfering influences of the mother tongue.

Neurological material strongly suggests that something happens in the brain during the early teens that changes the propensity for language acquisition. We do not know the factors involved, but it is interesting that the critical period coincides with the time at which the human brain attains its final state of maturity in terms of structure, function, and biochemistry (electroencephalographic patterns slightly lag behind, but become stabilized by about 16 years). Apparently the maturation of the brain marks the end of regulation and locks certain functions into place.

There is further evidence that corroborates the notion of a critical period for primary language acquisition, most importantly, the developmental histories of retarded children. It is dangerous to make sweeping generalizations about all retarded children, because so much depends on the specific disease that causes the retardation. But if we concentrate on diseases in which the pathological condition is essentially stationary, such as microcephaly vera or mongolism, it is possible to make fairly general predictions about language development. If the child's mental developmental age is 2 when he is 4 years old (that is, his I.Q. is 50), one may safely predict that some small progress will be made in language development. He will slowly move through the usual stages of infant language, although the rate of development will gradually slow down. In virtually all of these cases, language development comes to a complete standstill in the early teens, so that these individuals are arrested in primitive stages of language development that are perpetuated for the rest of their lives. Training and motivation are of little help.

Development in the congenitally deaf is also revealing. When they first enter school, their language acquisition is usually quite spectacular, considering the enormous odds against them. However, children who by their early teens have still not mastered all of the principles that underlie the production of sentences appear to encounter almost unsurmountable difficulties in perfecting verbal skills.

There is also evidence of the converse. Children who suddenly lose their hearing (usually a consequence of meningitis) show very different degrees of language skill, depending on whether the disease strikes before the onset of language or after. If it occurs before they are 18 months old, such children encounter difficulties with language development that are very much the same as those encountered by the congenitally deaf. Children who lose their hearing after they have acquired language, however, at age 3 to 4, have a different prospect. Their speech deteriorates rapidly; usually within weeks they stop using language, and so far it has proved impossible to maintain the skill by educational procedures [although new techniques developed in England and described by Fry (*9*) give promise of great improvement]. Many such children then live without language for a relatively long time, often 2 to 3 years, and when they enter the schools for the deaf, must be trained in the same way that other deaf children are trained. However, training is much more successful, and their language habits stand out dramatically against those of their less fortunate colleagues. There appears to be a direct relation between the length of time during which a child has been exposed to language and the proficiency seen at the time of retraining.

Biological Approach: Defining Language Further

Some investigators propose that language is an artifact—a tool that man has shaped for himself to serve a purpose. This assumption induces the view that language consists of many individual traits, each independent of the other. However, the panorama of observations presented above suggests a biological predisposition for the development of language that is anchored in the operating characteristics of the human brain (*10*). Man's cognitive apparatus apparently becomes a language receiver and transmitter, provided the growing organism is exposed to minimum and haphazard environmental events.

However, this assumption leads to a view different from that suggested by the artifact assumption. Instead of thinking of language as a collection of separate and mutually independent traits, one comes to see it as a profoundly integrated activity. Language is to be understood as an operation rather than a static product of the mind. Its modus operandi reflects that of human cognition, because language is an intimate part of cognition. Thus the biological view denies that language is the cause of cognition, or even its effect, since language is not an object (like a tool) that exists apart from a living human brain.

As biologists, we are interested in the operating principles of language because we hope that this will give us some clues about the operating principles of the human brain. We know there is just one species *Homo sapiens*, and it is therefore reasonable to assume that individuals who speak Turkish, English, or Basque (or who spoke Sanskrit some millennia ago) all have (or had) the same kind of brain, that is, a computer with the same operating principles and the same sensorium. Therefore, in a biological investigation one must try to disregard the differences between the languages of the world and to discover the general principles of operation that are common to all of them. This is not an easy matter; in fact, there are social scientists who doubt the existence of language universals. As students of language we cannot fail to be impressed with the enormous differences among languages. Yet every normal child learns the language to which he is exposed. Perhaps we are simply claiming that common denominators must exist; can we prove their existence? If we discovered a totally isolated tribe with a language unknown to any outsider, how could we find out whether this language is generated by a computer that has the same biological characteristics as do our brains, and how could we prove that it shares the universal features of all languages?

As a start, we could exchange children between our two cultures to discover whether the same language developmental history would occur in those exchanged. Our data would be gross developmental stages, correlated with the emergence of motor milestones. A bioassay of this kind (already performed many times, always with positive results) gives only part of the answer.

In theory, one may also adduce more rigorous proof of similarity among languages. The conception of language universals is difficult to grasp intuitively, because we find it so hard to translate from one language to another and because the grammars appear, on the surface, to be so different. But it is entirely possible that underneath the structural difference that makes it so difficult for the adult speaker to learn a second language (particularly one that is not a cognate of his own) there are significant formal identities.

Virtually every aspect of language is the expression of relations. This is true of phonology (as stressed by Roman Jakobson and his school), semantics, and syntax. For instance, in all languages of the world words label a set of relational principles instead of being labels of specific objects. Knowing a word is never a simple association between an object and an acoustic pattern, but the successful operation of those principles, or application of those rules, that lead to using the word "table" or "house" for objects never before encountered. The language universal in this instance is not the type of object that comes to have a word, nor the particular relations involved; the universal is the generality that words stand for relations instead of being unique names for one object.

Further, no language has ever been described that does not have a second order of relational principles, namely, principles in which relations are being related, that is, syntax in which relations between words are being specified. Once again, the universal is not a particular relation that occurs in all languages (though there are several such relations) but that all languages have relations of relations.

Mathematics may be used as a highly abstract form of description, not of scattered facts but of the dynamic interrelations—the operating principles—found in nature. Chomsky and his students have done this. Their aim has been to develop algorithms for specific languages, primarily English, that make explicit the series of computations that may account for the structure of sentences. The fact that these attempts have only been partially successful is irrelevant to the argument here. (Since every native speaker of English *can* tell a well-formed sentence from an ill-formed one, it is evident that some principles must exist; the question is merely whether the Chomskyites have discovered the correct ones.) The development of algorithms is only one province of mathematics, and in the eyes of many mathematicians a relatively limited one. There is a more exciting prospect; once we know something about the basic relational operating principles underlying a few languages, it should be possible to characterize formally the abstract system *language* as a whole. If our assumption of the existence of basic, structural language universals is correct, one ought to be able to adduce rigorous proof for the existence of homeomorphisms between any natural languages, that is, any of the systems characterized formally. If a category calculus were developed for this sort of thing, there would be one level of generality on which a common denominator could be found; this may be done trivially (for instance by using the product of all systems). However, our present knowledge of the relations, and the relations of relations, found in the languages so far investigated in depth encourages us to expect a significant solution.

Environment and Maturation

Everything in life, including behavior and language, is interaction of the individual with its milieu. But the milieu is not constant. The organism itself helps to shape it (this is true of cells and organs as much as of animals and man). Thus, the organism and its environment is a dynamic system and, phylogenetically, developed as such.

The development of language in the child may be elucidated by applying to it the conceptual framework of developmental biology. Maturation may be characterized as a sequence of states. At each state, the growing organism is capable of accepting some specific input; this it breaks down and resynthesizes in such a way that it makes itself develop into a new state. This new state makes the organism sensitive to new and different types of input, whose acceptance transforms it to yet a further state, which opens the way to still different input, and so on. This is called epigenesis. It is the story of embryological development observable in the formation of the body, as well as in certain aspects of behavior.

At various epigenetic states, the organism may be susceptible to more than one sort of input—it may be susceptible to two or more distinct kinds or even to an infinite variety of inputs, as long as they are within determined limits—and the developmental history varies with the nature of the input accepted. In other words, the organism, during development, comes to crossroads; if condition A is present, it goes one way; if condition B is present, it goes another. We speak of states here, but this is, of course, an abstraction. Every stage of maturation is unstable. It is prone to change into specific directions, but requires a trigger from the environment.

When language acquisition in the child is studied from the point of view of developmental biology, one makes an effort to describe developmental stages together with their tendencies for change and the conditions that bring about that change. I believe that the schema of physical maturation is applicable to the study of language development because children appear to be sensitive to successively different aspects of the language environment. The child first reacts only to intonation patterns. With continued exposure to these patterns as they occur in a given language, mechanisms develop that allow him to process the patterns, and in most instances to reproduce them (although the latter is not a necessary condition for further development). This changes him so that he reaches a new state, a new potential for language development. Now he becomes aware of certain articulatory aspects, can process them and possibly also reproduce them, and so on. A similar sequence of acceptance, synthesis, and state of new acceptance can be demonstrated on the level of semantics and syntax.

That the embryological concepts of differentiation, as well as of determination and regulation, are applicable to the brain processes associated with language development is best illustrated by the material discussed above under the headings "brain correlates" and "critical age for language acquisition." Furthermore, the correlation between language development and other maturational indices suggests that there are anatomical and physiological processes whose maturation sets the pace for both cognitive and language development; it is to these maturational processes that the concept differentiation refers. We often transfer the meaning of the word to the verbal behavior itself, which is not unreasonable, although, strictly speaking, it is the physical correlates only that differentiate.

Pseudo-Homologies and Naive "Evolutionizing"

The relation between species is established on the basis of structural, physiological, biochemical, and often behavioral correspondences, called homologies. The identification of homologies frequently poses heuristic problems. Common sense may be very misleading in this matter. Unless there is cogent evidence that the correspondences noted are due to a common phylogenetic origin, one must entertain the possibility that resemblances are spurious (though perhaps due to convergence). In other words, not all criteria are equally reliable for the discovery of true homologies. The criteria must pass the following two tests if they are to reveal common biological origins. (i) They must be applicable to traits that have a demonstrable (or at least conceivable) genetic basis; and (ii) the traits to which they apply must not have a sporadic and seemingly random distribution over the taxa of the entire animal kingdom. Homologies cannot be established by relying on similarity that rests on superficial inspection (a whale is not a fish); on logical rather than biological aspects (animals that move at 14 miles per hour are not necessarily related to one another); and on anthropocentric imputation of motives (a squirrel's hoarding of nuts may have nothing in common with man's provisions for his future).

Comparisons of language with animal communication that purport to throw light on the problem of its phylogenetic origins infringe on every one of these guidelines. Attempts to write generative grammars for the language of the bees in order to discover in what respect that language is similar to and different from man's language fail to pass test (i). Syntax does not have a genetic basis any more than do arithmetic or algebra; these are calculi used to describe relations. It may be that the activities or circumstances to which the calculi are applied are in some way related to genetically determined capacities. However, merely the fact that the calculus may or may not be applied obviously does not settle that issue.

The common practice of searching the entire animal kingdom for communication behavior that resembles man's in one aspect or another fails test (ii). The fact that some bird species and perhaps two or three cetaceans can make noises that sound like words, that some insects use discrete signals when they communicate, or that recombination of signals has been observed to occur in communication systems of a dozen totally unrelated species are not signs of a common phylogeny or genetically based relationship to language. Furthermore, the similarities noted between human language and animal communication all rest on superficial intuition. The resemblances that exist between human language and the language of the bees and the birds are spurious. The comparative criteria are usually logical (*12*) instead of biological; and the very idea that there must be a common denominator underlying all communication systems of animals and man is based on an anthropocentric imputation.

Everything in biology has a history, and so every communication system is the result of evolution. But traits or skills do not have an evolutionary history of their own, that is, a history that is independent of the history of the species. Contemporary species are discontinuous groups (except for those in the process of branching) with discontinuous communication behavior. Therefore, historical continuity need not lead to continuity between contemporary communication systems, many of which (including man's) constitute unique developments.

Another recent practice is to give speculative accounts of just how, why, and when human language developed. This is a somewhat futile undertaking. The knowledge that we have gained about the mechanisms of evolution does not enable us to give specific accounts of every event of the past. Paleontological evidence points to the nature of its fauna, flora, and climate. The precursors of modern man have left for us their bones, teeth, and primitive tools. None of these bears any necessary or assured relation to any type of communication system. Most speculations on the nature of the most primitive sounds, on the first discovery of their usefulness, on the reasons for the hypertrophy of the brain, or the consequences of a narrow pelvis are in vain. We can no longer reconstruct what the selection pressures were or in what order they came, because we know too little that is securely established by hard evidence about the ecological and social conditions of fossil man. Moreover, we do not even know what the targets of actual selection were. This is particularly troublesome because every genetic alteration brings about several changes at once, some of which must be quite incidental to the selective process.

Species Specificities and Cognitive Specialization

In the 19th century it was demonstrated that man is not in a category apart from that of animals. Today it seems to be necessary to defend the view (before many psychologists) that man is not identical with all other animals—in fact, that every animal species is unique, and that most of the commonalities that exist are, at best, homologies. It is frequently claimed that the principles of behavioral function are identical—in all vertebrates, for example—and that the differences between species are differences of magnitude, rather than quality. At other times, it is assumed that cognitive functions are alike in two species except that one of the two may have additionally acquired a capacity for a specific activity. I find fault with both views.

Since behavioral capacities (I prefer the term cognition) are the product of brain function, my point can well be illustrated by considering some aspects of brain evolution. Every mammalian species has an anatomically distinct brain. Homologies are common, but innovations can also be demonstrated. When man's brain is compared with the brain of other primates, extensive correspondences can be found, but there are major problems when it comes to the identification of homologies. Dramatic differences exist not only in size but also in details of the developmental histories; together with differences in cerebrocortical histology, topography, and extent, there are differences in subcortical fiber-connections, as pointed out by Geschwind (*13*) most recently and by others before him. The problem is, what do we make of the innovations? Is is possible that each innovation (usually an innovation is not a clear-cut anatomical entity) is like an independent component that is simply added to the components common to all the more old-fashioned brains? And if so, is it likely that the new component is simply adding a routine to the computational facilities already available? Both presumptions are naive. A brain is an integrated organ, and cognition results from the integrated operation of all its tissues and suborgans. Man's brain is not a chimpanzee's brain plus added "association facilities." Its functions have undergone reintegration at the same pace as its evolutionary developments.

The identical argument applies to cognitive functions. Cognition is not made up of isolated processes such as perception, storing, and retrieval. Animals do not all have an identical memory mechanism except that some have a larger storage capacity. As the structure of most proteins, the morphology of most cells, and the gross anatomy of most animals show certain species specificities (as do details of behavioral repertoires), so we may expect that cognition, too, in all of its aspects, has its species specificities. My assumption, therefore, is that man's cognition is not essentially that of every other primate with merely the addition of the capacity for language; instead, I propose that his entire cognitive function, of which his capacity for language is an integral part, is species-specific. I repeat once more that I make this assumption not because I think man is in a category all of his own, but because every animal species must be assumed to have cognitive specificities.

Conclusion

The human brain is a biochemical machine; it computes the relations expressed in sentences and their components. It has a print-out consisting of acoustic patterns that are capable of similar relational computation by machines of the same constitution using the same program. Linguists, biologists, and psychologists have all discussed certain aspects of the machine.

Linguists, particularly those developing generative grammar, aim at a formal description of the machine's behavior; they search mathematics for a calculus to describe it adequately. Different calculations are matched against the behavior to test their descriptive adequacy. This is an empirical procedure. The raw data are the way a speaker of a language understands collections of words or the relationships he sees. A totally adequate calculus has not yet been discovered. Once available, it will merely describe, in formal terms, the process of relational interpretation in the realm of verbal behavior. It will describe a set of operations; however, it will not make any claims of isomorphism between the formal operations and the biological operations they describe.

Biologists try to understand the nature, growth, and function of the machine (the human brain) itself. They make little inroads here and there, and generally play catch-as-catch-can; everything about the machine interests them (including the descriptions furnished by linguists).

Traditionally, learning theory has been involved neither in a specific description of this particular machine's behavior nor in its physical constitution. Its concern has been with the use of the machine: What makes it go? Can one make it operate more or less often? What purposes does it serve?

Answers provided by each of these inquiries into language are not intrinsically anatagonistic, as has often been claimed. It is only certain overgeneralizations that come into conflict. This is especially so when claims are made that any one of these approaches provides answers to all the questions that matter.

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Drug Safety: Experimental Programs

Problems and solutions of the past 10 years are critically reviewed.

Gerhard Zbinden

On 6 November 1958 J. Lehman, chief of the division of pharmacology of the Food and Drug Administration (FDA), addressed the research and development section meeting of the Pharmaceutical Manufacturers Association at Sea Island, Georgia. Although Lehman's views on the subject were well known, through his work with his colleagues at FDA (*1*), rumor had it that new and far-reaching official rules for testing drug toxicity were about to be proclaimed. For those who had feared the introduction of minimum standards, the spokesman of FDA provided no cause for immediate concern. Although he did pronounce certain rules for the toxicologic evaluation of experimental drugs he made it clear that these were only meant as flexible guidelines (*2*). An abstract of Lehman's 1958 talk was published in a journal with limited distribution. The concept became generally known after Lehman spoke at a joint American Medical Association, Society of Toxicology Symposium on 17 June 1963, when copies of his projected slides were made available and gained wide distribution. To this day, Lehman's unofficial rules have decidedly shaped the industry's and FDA's approach to toxicity testing.

The 1958–1963 guidelines recommended various types of experiments: short-term studies in which the acute toxicity was to be evaluated by single administration of the drugs to four animal species and two sets of long-term tests in which the substances were to be given repeatedly. Two animal species were suggested for the long-term studies and three dosages were to be tested. The duration of the experiments was 2 weeks to 1 month for the subacute and up to 6 months for the chronic toxicity tests, with the option for an extension up to 2 years. Drugs were to be administered by the same routes as anticipated in man. Clinical tests included hemograms, coagulation tests, limited tests on liver and kidney function, and determinations of blood sugar. Gross and microscopic examinations were confined to major organs in short-term studies or were to be done in considerable detail in the longer experiments. No specific recommendations were made for the number of treated animals and controls, the frequency of laboratory tests, and the percentage of animals included in the laboratory studies. Less extensive procedures were suggested for the testing of drugs administered by inhalation and by the dermal, ophthalmic, vaginal, and rectal routes.

Lehman's guidelines became rapidly

The author is visiting research fellow at the Department of Medicine, University of Cambridge, Cambridge, England.