DOCUMENT RESUME

ED 119 137 CS 002 444

AUTHOR	Robeck, Mildred C.
TITLE	Sensorimotor Bases for Language.
PUB DATE	75
NOTE	17p.; Paper presented at a Preconvention Institute of the International Reading Association (New York, N.Y., May, 1975)
EDRS PRICE	MF-$0.83 HC-$1.67 Plus Postage
DESCRIPTORS	Auditory Perception; *Child Language; Cognitive Development; Early Childhood Education; *Language Development; Language Learning Levels; Language Research; Linguistics; *Neurolinguistics; Neurology; Nucleation (Language Learning); *Perceptual Development; Perceptual Motor Learning; *Psycholinguistics; Sensory Integration; Speech Skills

ABSTRACT

Some very practical questions about how children learn the first language compel us to study brain functions and how these functions evolve. They also bring the studies of linguistics and neurology together. The purpose of this paper is to relate some of the research that describes language acquisition with the research about the early development of the human brain, particularly the sensory systems that are involved in speech. Three interrelated propositions that are considered are: (1) that structures for speech are genetically transmitted, including distinct cognitive and affective mechanisms in the brain; (2) that critical periods in development render the child susceptible to particular environmental stimulation according to a predictable sequence which peaks and declines; and (3) that language itself supports and facilitates thought including special learning, and action on objects. These propositions are considered within the chronology of language development, beginning with neonatal response to sound, through sensorimotor integration in infancy, and into the rapid acquisition of propositional language in early childhood. (MKM)

Mildred C. Robeck

University of Oregon

Eugene, Oregon 97405

SENSORIMOTOR BASES FOR LANGUAGE

Presented at a Preconvention Institute of the International Reading Association, meeting in New York City, Americana Hotel, Versailles Terrace, May 12, 1975

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Mildred C. Robeck

University of Oregon

Some very practical questions about how children learn the first language compel us to study brain functions and how these functions evolve. Is language species-specific, as Krech has suggested (8)? Is language modeled after adults, and shaped by selective reinforcement from them (1)? Is language conceptualized as a linguistic structure, whether "surface" or "deep" (2)? Is language the result of a human necessity to communicate and to cooperate for survival? Or is language the phylogenic outcome of a socially gregarious species (5)?

These are questions that bring linguistics and neurology together. The purpose of this paper is to relate some of the research that describes language acquisition with the research about the early development of the human brain, particularly the sensory systems that are involved in speech. Three interrelated propositions will be considered:

(1) that structures for speech are genetically transmitted, including distinct cognitive and affective mechanisms in the brain

(2) that critical periods in development render the child susceptible to particular environmental stimulation (for language) according to a predictable sequence which peaks and declines (at least in some abilities)

(3) that language itself supports and facilitates thought including spacial learning, action on objects, and

conceptualization of affects

These propositions will be considered within the chronology of language development, beginning with neonatal response to sound, through sensorimotor integration in infancy, and into the rapid acquisition of propositional language in early childhood. A few studies, selected for the limitations of this presentation, will be cited in support of these propositions.

Definition of Language

Language is a system of symbols which carry meaning. Many animals are capable of this level of communication (9). They inherit the structures for making sounds and gestures that their youngsters learn to interpret and imitate. Some animal groups, such as the primate groups, use language for social communication between individuals. The psychologists who teach communicative skills to chimpanzees typically employ social reinforcement as well as material rewards when interacting with them.

The potential effect of a superior environment for learning language has been demonstrated by the Gardners whose famous chimp Washoe was taught to communicate with Ameslan (American Sign Language). Project Washoe has shifted recently to the training of neonate chimps, using Ameslan as the language. The infants are taught from day 1 or 2 in a social setting where human handlers all use the same signs for the actions and the objects in the nursery environment. (5) The use of signs was necessary because chimpanzees do not have cortical control over their speech mechanisms. The grunts and squeals which are innate to chimpanzees are triggered in the mid-brain--a phylogenically older and more primitive mechanism than the cortical speech areas of man (14).

The language of Homo sapiens is not only symbolic in content but is universal in structure and propositional in function. Propositional language functions in advance of an action by posing hypothetical events which may be implemented imaginatively or scrapped vicariously without taking physical risks or involving another person. The cognitive function of language, even in young children, is representational thought. Piaget (13) maintains that logical thought in older children and adults is built upon the sensorimotor and concrete structures (schemata) of childhood. For every overt and observable pattern of action there is an internal structure that makes the behavior possible.

Neural Structures of Language

Propositional language requires interconnecting neural structures for speech comprehension and for speech production (Figure 1). The basic unit of these internal structures is the neuron with its system of interconnecting dendrites and its axon for relaying the electro-chemical message (14). Piaget's concept of schema was initially a neurological structure (3, p. 36). Sensory information is stored in genetically designated areas of the cortex by a system that sorts it for perceptual congruity and assures that separate experiences, such as the hearing of words, will be generalized. The activation of particular neural systems, such as that activated by the auditory pattern of a word, stimulates the growth of the relay system and facilitates the activation of that system in the future.

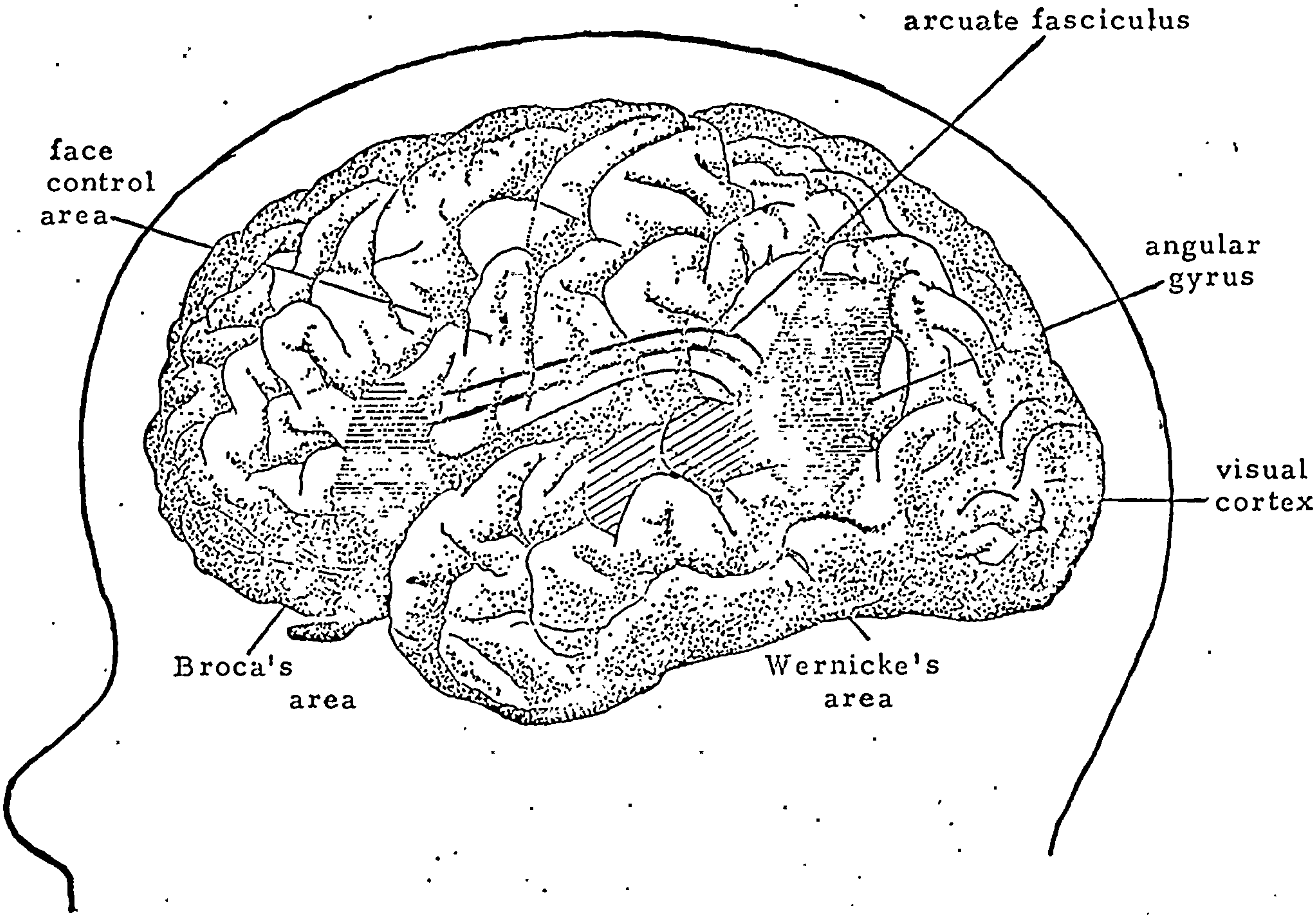

Figure 1. Language Areas of the Human Cortex. Verbal language areas are located in the left hemisphere of most people. Broca's area, which is in the frontal lobe, controls language production. Motor control areas for speech (lips, tongue, soft palate, and vocal cords) lie adjacent. Damage to Wernicke's area interferes with comprehension, but imitative speech is fluent. Damage to the arcuate fasciculus interferes with conduction. Damage to the angular gyrus, where visual and auditory information is integrated, interferes with naming objects. (See Table 1.)

Penfield, a neurosurgeon, has speculated that the memory storage for concepts, or generalizations, is separate from the storage of the particular sensory events from which the concept evolved (12, pp. 229-234). He and his colleagues pioneered in a procedure for mapping the speech and language areas of the cortex prior to brain surgery. They were trying to avoid the removal of cortical tissues which would leave the patient with some form of aphasia (impairment of language functions) after the surgery (16). They confirmed earlier observations that the removal of some areas interfered with the comprehension of language, while the removal of other areas interfered with the patient's ability to produce speech even when able to respond meaningfully to test of comprehension. (Table 1) Brain surgery and pathologies of the central nervous system continue to be major sources of knowledge about the physical bases of language functioning (6). Another fruitful source of knowledge about brain mechanisms is the research on language acquisition in young children.

Neonate Responses to Sound

Condon and Sander found that as early as the first day after birth the human infant moves in sustained patterns that are synchronized with adult speech (4). In a careful analysis of films of neonate movements, matched frame-by-frame to the phones, syllables, and words in continuous adult speech, the investigators found a correspondence of 90% between neonate body movements and the structure of adult speech. This agreement held when a recording of adult speech was substituted for a live speaker in the experiments. By contrast the correspondence

Table 1. Classification of Typical Aphasias.

Type of Aphasia	Site of lesion	Spontaneous speech	Compre- hension	Repetition	Naming
Broca's aphasia	posterior inferior frontal	non-fluent	intact	limited	limited
Wernicke's aphasia	posterior superior temporal	fluent	impaired	impaired	impaired
Conduction aphasia	arcuate fasciculus	fluent	intact	impaired	impaired
Isolation syndrome	association cortex	fluent echolalic	impaired	intact	impaired
Anomic aphasia	angular gyrus	fluent	intact	intact	impaired

Adapted from Gerd Sommerhoff, Logic of the Living Brain, New York: John Wiley & Sons, 1974, p. 375.

of neonate movement and sound was only about 50% when continuous vowels were spoken or when tapping noises were used. The question of how the neonate had learned before birth to discriminate and respond to human speech is not established in this study. However, the authors discussed the significance of their discovery in the language acquisition of children.

> [The infant] participates developmentally through complex, sociobiological entrainment processes in millions of repetitions of linguistic forms long before he later uses them in speaking and communicating. By the time he begins to speak, he may have already laid down within himself the form and structure of the language system of his culture. (p. 101)

It is difficult to evaluate the many (and sometimes conflicting) studies of sound discrimination in neonates. In order to measure the auditory acuity of the newly born, the amniotic fluid must be drained from its ears before sound waves can reach and stimulate the receptors in the inner ear. Also, an appropriate state of alertness must be maintained if optimal responses are anticipated. Current procedures for testing the intelligence of neonates require the examiner to hold the infant in an inclined position with head cupped in the examiner's hand. This position is conducive to alertness and head turning if the infant is inclined to follow a sound or an object. Under these conditions, the normally integrated neonate responds to the examiner's speech and habituates within a few counts by not startling to a repeated noise. Research procedures which fail to elicit the attention and participation of infants are not valid indicators of early potential for speech perception.

Premature infants, seven months after conception, show normal hearing. The development of the hearing mechanism is stimulated by the heartbeat and the visceral sounds from within the mother's body. Apparently other sounds reach the fetus as well. The peak period of mylinization of the auditory nerve occurs in the seventh month. Mylinization is the growth of fatty tissue around the axons, which is essential in the transmission of impulses through them. It seems reasonable that the fetus is conditioned also by tactile responses to sound.

Prespeech and Neurological Organization

If the cries, grunts, and gurgles are recorded and analyzed together with babbling sounds, the infant produces most of the phonemes of his own and other languages. McNeill reviewed research which indicates three distinct periods in prespeech during the first year of life. From birth through the third month, vocalization is characterized by rapid change in the frequency and variety of vowel production, and to some extent in consonant production (10, p. 1132). At four months this rate of change drops abruptly and is replaced by a series of peaks for refinement of particular vowel sounds followed by a series of peaks for production of certain consonant sounds. Near the first birthday the "total collapse" of babbling occurs and the slow process of word speech begins, including the difficult mastery of sounds that had been used freely in earlier periods.

Several writers have suggested that the stages observed in prespeech are related to phases in neurological maturation. I would like to speculate on this relationship by bringing together what is known about the brain mechanisms that control affective responses, primate vocalization, and spontaneous speech in children.

The neonate reacts affectively to language. His most conspicuous utterances are emotional, need oriented, and diffused. The young infant mobilizes its whole body in crying, but within a month its crying expresses different needs and moods. Cooing is an affective expression. During this first month, the prespeech accomplishments of the infant have many similarities to the sound emitions of untrained chimpanzees, whose voice control is limited to the primitive (old) brain areas. It could be that the playful prespeech of young infants is a reflexive response, closely linked to the hypothalamic areas where survival responses are organized and to the limbic areas nearby, where the pleasure-punishment centers are located. Motivations are closely associated with the hypothalamic and limbic systems.

The function of the babbling period in speech is the practice of speech mechanisms and, probably also, the stimulation of neural growth needed to connect midbrain areas with the cortex. Babbling has been called "autistically satisfying" in that the neural activity itself produces inner pleasures that lead to repetition of a particular sensory relay system (11).

It is known that the ten billion neural cell bodies that make up the human brain are nearly all intact at birth and that the cortical cells have moved to their appropriate layers in the cortex by the end of the seventh month after conception. It is also known that many of these cells are in rudimentary form, lacking axonal extensions or dendritic innerconnections. It seems likely that some of the axonal growth during the first few months after birth involves the connections between affective systems in the midbrain and the cognitive systems, which are organized in the thalamus immediately above the hypothalamus. In people neural fibers reach from the thalamus into the speech areas of the cortex. The decline in speech sound variation at the beginning of the fourth month of life, could indicate a change in neural growth priority.

The function of the second prespeech period appears to involve a sensorimotor matching on the part of the infant of phone units with morpheme units (or meanings). Sommerhoff has suggested that mere repetition of sounds makes less demand on speech mechanisms than when comprehension is involved (16, pp. 375-376). In neurological development comprehension requires the growth of long fibers which connect the frontal area of Broca with the auditory association area along the top of the temporal lobe and the speech comprehension area of Wernecke.

During the third period, beginning about the twelfth month, the production of speech is at a low ebb but the child is increasing its comprehension of adult speech. This period has been inappropriately called the passive period in language development, perhaps because of a misconception that language begins with the use of words. In order to build the appropriate neural system for comprehension, the young child must, apparently, attend to speech. It has been noted often that young children have difficulty understanding speech while they are formulating speech, but that adults can do both at the same time. Apparently the child's attention is switched from one function to the other by controls in the motivation mechanisms. As the child begins to form the one-word sentences that characterize the speech of one-year-olds, the priority in neural growth shifts to voluntary control over speech mechanisms, which is a function of the cortex.

Universals in Language Acquisition

Children of all nations learn their native language in much the same way and at approximately the same age periods (15). By age one, or shortly afterward, children speak in one-word sentences, called holophrasic speech. These sentences are predominantly nouns which carry the meaning of a complete sentence. "Car" means, A car has come. "Cookie" means, I want a cookie! A few children in any culture begin by burying the holophrasic word in jargon. By age two most children speak in two sentences, commonly using an object or person and some action or condition as the predicate: Car come, or Michael want. They quickly use possessives: My book, and modifiers: Big bunny. By age three children typically use three words or more, but the structure of the language is intact. They use telographic speech meaning that significant words are selected: Doggie gone now. Can I keep airplane? By age four the child has conceptualized the grammar and syntax of the native language, but a few overgeneralizations are used in those instances where the language employs irregularities. In English some examples are "goed" for went and "mouses" for mice. Having discovered what linguists call the deep structure of the language, the child can create sentences to serve both communicative and physical needs.

May we return, briefly, to the three propositions stated at the beginning of this paper? The universal development of a conceptualized linguistic structure is powerful evidence that the neural mechanisms for speech are species-specific. However, Kagan has shown that the linguistic environment is significant in the speech development of infants, at least in girls (7). By 8-months of age vocalization accompanied excited attention and was predictive of language development at 13 months and later. By 27 months verbalization was related positively in the combined sample to general intelligence, vocabulary level, sustained attention, and nonverbal perceptual problem solving. Kagan cited the literature which indicated earlier and more specific left-hemisphere dominance of female babies for speech and hearing. It is possible that the timing of Kagan's studies favored the girls, who appeared responsive, along class lines, to the face-to-face speech of their mothers in infancy. On the other hand, little difference was found in the behavior of upper- and lower-middle-class mothers toward their sons, who were reinforced for being active rather than for vocalizing. Kagan's studies also support our third proposition, that language itself supports cognitive development.

The evidence for critical periods in learning is sufficiently impressive to compel a review of early education and bilingual education. Wepman (17) has found that the ability to learn phoneme discrimination drops sharply at about 8 years of age. Young children spontaneously add unique vocabulary to their speech after a gap of 2 to 7 months following its contextual use by adults. Penfield (12) has recommended that nursery schools be conducted in the second language as an assurance of language potential in secondary school.

Reading teachers have consistently noted a hierarchy of difficulty in learning the first language by which the reception and understanding of speech precedes functional, or propositional speech. In normally hearing and sighted children, expressive speech precedes reading, a receptive function. Even when a child is taught reading by a writing method, the reading vocabulary quickly and consistently outdistances the writing vocabulary in volume, incidence, and accuracy.

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