A Time Frame of Critical/Sensitive Periods of Language Development

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Abstract

By a focus on three essential elements of language, phonology, semantics, and syntax, a time frame for critical/sensitive periods of language development is presented as a model of central auditory nervous system flexibility. Several studies support the hypothesis that the critical/sensitive period of phonology is from the sixth month of fetal life through the 12th month of infancy. Data indicates that the critical/sensitive periods for syntax runs through the fourth year of life, and for semantics through the 15th or 16th year of life. The data indicate that there is a time dependent series of functions in sequence that is based on responsive adaptations made by the CNS to psychophysical and electrophysiological stimuli.

Key Words

Language development, critical/sensitive periods, phonology, semantics, syntax.

The view that language was an innate function, dissociated from ideas of plasticity, prevailed from ancient times to the beginning of the 19th century. From that time on, cases were reported that challenged the view of language as being an entirely inborn capacity. Starting with itard's case of the "wild boy of Averyon, reported in 1801 (1), numerous cases (2,3,4) catalyzed a modification the conceptualization of language as innate, a product of "nature," and pointed to the significance of the role of sensory input provided by the particular environment, "nurture," and the concomitant dimension of plasticity, in the development of language.

Although awareness of environmental factors in language development has a considerable history, scientific definition of the process has been slow. The current view of critical/sensitive periods for language acquisition is based primarily upon psychophysical observations, many of which are anecdotal, and only a few of which include quantitative data and/or have been reproduced, I will present a summary of the evidence for critical/sensitive periods in language development, and will suggest that the data indicates that there is a time dependent series of functions in sequence which is based on responsive adaptations made by the CNS to acoustic stimuli.

Language can be conceptualized as a communication system consisting of three fundamental elements. These are 1) phonology, the physical structure of the stimuli (specific sound in an auditory-based language) ; 2) semantics, the meaning assigned to specific stimuli (words) ; and 3) syntax, the organization of stimuli for the production of complex meanings (grammar).

The awareness of the critical/sensitive periods with regard to these elements in language development has come to the fore in the last twenty-five years. Most studies have examined effects of auditory stimuli and, thus, the development of language in the aural/oral modality. Research has been centered on the development of aural receptive skills in the normal human fetus, neonate, infant and toddler, and on the acoustic properties of the speech stimulus.

Reception of auditory stimuli has at least two dimensions. The first is detection, whether or not the stimulus is received. The second, identification, requires the differentiation among the auditory signals, implying a categorization of stimuli. This categorization includes assessment of factors such as intensity, frequency and timing, as in a word, and the capacity to discriminate is in part dependent upon the shaping of the central nervous system (5,6,7,8,9,10,11,12). This capacity enables the detection of phoneme, and is the basis of auditory language reception and utilization.

Several studies have shown that the 26-week human fetus has the auditory ability to detect sound (5,6). This has been demonstrated, for example, by changes in ECG and fetal position in response to sound transmitted in utero. Data obtained (7) from neonates indicate that these infants have a preferences for a female voice, that is, the voice most like that to which they were mainly exposed in utero, suggesting some level of discrimination has developed by the time of birth. The report noted that in utero exposure to specific sounds, such as the music of Prokofiev's "Peter and the Wolf," and the fly over noise at the Osaka airport, resulted in a neonatal preference for those sounds -- remarkable evidence for human adaptability and plasticity !

Jusczyk et al, (8) and Meher et al. (9) tested two-day old infants of French-speaking mothers by exposing them to stimuli which contained prosodic elements of either French or Russian. The stimuli were generated by having the same woman, who was fluent in both French and Russian, speak and read about an event of her life in both languages. The utterances were recorded and speech samples broken down and selected so as to reflect the particular prosodic aspects of the native language in which they were spoken. The two-day-old infants of the French speaking mothers, when exposed to these prosodic stimuli, responded positively, with high amplitude sucking, to the French prosodic elements but not to the Russian ones. A similar study (10) carried out in older infants in the United States using American English and Italian produced comparable results. These data demonstrate that, by at least two days of age, the neonate has an ability to discriminate language specific acoustic distinctions. It seems reasonable to infer that some, if not much, of this learnd ability developed during fetal life, which would place the beginning of the critical/ sensitive period for phoneme recognition originates at and before birth.

Other studies indicate that the phonemic critical period may be severely constricted or closed by the end of the first year of life. A series of reports by Werker and her colleagues (11) illustrate the general findings. The capacity of infants to discriminate a number of native and non-native phonemes was assessed at 6-8 months, 8-10, months and at 10-12 months by conditioned head turn. Infants from an English-speaking environment were exposed to the English place contrasts (/b/-/d/). All infants, in all three age groups, were able to make the (/b/-/d/) contrast discrimination. The infants were also presented with contrasts from two languages foreign to them, Hindi and Thompson Salish (a Native American language). Two Hindi contrasts were tested a dental-retroflex stop ($/d_u/$-/d/) and a breathy voiced-voiceless dental stop ($d^h/t^h/$); the Salish phoneme used was on ejective velar-uvular stop (/k'/-/q'/). At 6-8months of age the infants from the English speaking environment were able to discriminate all of the phonemes, the English, the Hindi and the Salish. The 10-12 months old subjects were only able to discriminate the English phonemes, not the Hindi nor the Salish. The 8-10 month old infants had intermediate levels of discrimination.

These data are congruent with other studies in showing that the 12-month old human has developed the capacity to categorize only those phonemes which are in its native language. The year-old child has a neural mechanism which, probably since the sixth month of fetal life, has been engaged in a process of separating out those sound patterns which are auditorially significant from the cacophony of the intra-uterine and then extra-uterine, environment, and through this process laying the foundation of language.

Research indicates that deprivation of auditory stimuli produces interference with this process. A study (12) of hearing loss from otitis media during the first year shows an effect upon the discrimination of phonemes that remains detectable when the children have reached nine years of age. In a prospective study, two groups of children were followed for nine years, the first consisting of children who were otitis free during their first year and second consisting of those with numerous episodes of otitis media. Starting from birth, the children were assessed with periodic examinations that included testing with pure tone auditory evoked potentials, otoscopy, and, after six months of age, behavioral audiometric evaluations (14). The Otitis free children had an average Hl of 20 db and the otitis positive children had an average HI of 38 db during their first year of life. For the next eight years, both groups had normal hearing.

A study carried out in these children at nine years of age examined their receptive phonological skills (13). One finding of this study was that the nine year olds who had been otitis positive and had the average 38 db HL during their first year of life, but normal hearing since, had significantly less capacity for verbal memory than the control group. The 18 db difference in the first year of life was associated with deficient phonetic perception and verbal recall at age nine years. Among a number of tasks, the children were asked to distinguish between ba/da and sa/Sa when these were presented at a 400 ms interstimulus interval. The otitis media positive children made significantly more errors in this discrimination than did the controls. The difference for ba/da was 0 errors for the OM-and 0.71 errors for the OM+ and in the sa/Sa there were 0.57 for the OM-and 3.14 errors for the OM+. The effects of the hearing deficiency during the first twelve months of life persisted, eight years later, as a deficiency in discrimination of timing of a stimulus, a critical component of phonemic discrimination.

It is well known that complex language can develop well once phonology has beeen established during the first two years of life. Conversely, children deprived of appropriate sensory experience in this period will not develop language successfully. For example, research has shown that children who have acquired severe deafness after successfully navigating the phonological period demonstrate superior syntactic and semantic development when compared with children who have been deaf during their entire phonological period (14). The communicative potential of their syntax and semantic development persists, based on early their phonological development. This is one of several approaches to language development that points to the interdependence of syntax and semantics with phonology. Further investigation of the interdependence of these three elements of language is needed.

A series of neurophysiological studies conduct by H. Neville et al. (15) provide some indictions of the

temporal dimensions of the critical periods for semantics -- word meanings -- and syntax -- grammatical rules. The recorded event-related brain potentials (ERP) to two groups of words in normal children and adults. The first group of words, "open class," consists of nouns, verbs and adjectives which make reference to specific objects and events; these 'open class' words, are categorized as semantic. The second group, "closed class' words, are articles, conjunctions and auxiliaries. In the English language they are part of the basis for the grammatical structures and thus may be thought of associated with the syntactical capacity.

Open class words--semantic --evoke in the normal hearing adult a negative ERP occurring at 350 ms after the stimulus, that is, the presentation of the open class word. The response is called the N350. The adult N350 is a large ERP which is found over the posterior brain regions of both hemispheres. The ERP to the closed class words -- syntactic -- in the normal adult occurs at 280 ms (N280) after the stimulus and is found in the anterior temporal region of the left hemisphere.

Developmental studies found that in normal hearing children of four years of age, the youngest age tested, adult like ERP's (N350) were elicited to open class words. These N350 responses were robust and located at the posterior hemispheres.

The N280 ERP, the response to the closed class words, has a different ontogeny. The N280 does not achieve its mature, final configuration until 15 to 16 years of age.

These data, based on ERP/s, suggest that the critical/ sensitive period for semantic organization may occur before the fourth year of life. The critical period of the assessed portion of syntax, as evidenced by response to closed class words, may not occur until age 15 to 16.

Optimal development of the nervous system for the capacities of phonology, semantics and syntax does not appear to be infinitely plastic, but, rather, appears to be linked with specific and sequential time periods in the individual life history. Data suggest that the earliest specialization is phonological, with a limiting of phoneme discrimination by the end of the first year. Phonological specialization appears to precede semantical specialization, for which some evidence suggests a critical/sensitive period in the first four years. The terminus of the critical/sensitive period for syntax may extend into the late teens.

Although this view of language development through time is an approximation, and will certainly be refined by more precise measures in the future, it allows us to identify several important aspects of critical-sensitive periods for language acquisition, The first is that language is the product of a squential multi factorial process, and that different elements of language are governed by different constraints.

Second, although the elements of language may have different critical/sensitive periods, they are apparently developmentally interdependent. Insufficient early phonological input results in flawed semantic and syntactic capacities. Conversely, early linguistically organized sensory input will result in the development of sophisticated, functional language.

Third, it can be recognized that different portions of the central nervous system mediate different elements of language–semantics in the posterior hemisphere and syntax in the anterior temporal region of the dominant hemisphere. Until recently, investigations of language functions of the central nervous system have been based on behavioral discriptions of language. Anatomical studies should produce information to enable an understanding of language development based on underlying neurological mechanisms. It may turn out that a nosology consisting of phonology, semantics and syntax may not be the correct model for the neuro-anatomical and physiological mechanisms which mediate the complex process called language, or it may be found that the conception of language based on these elements will be vindicated.

The information available about the critical/sensitived periods, even in its current incomplete state, carries with it important medical implications which bear on the definitions of pathology. In the light of awareness of critical periods, abnormal and/or inadequate sensory input can be recognized for what they are : disease vectors, as a virus, a bacterium, or an aberrant gene may be a disease vector. Current data indicates that to avert the adverse sequelae, all hearing losses in children, including those that are mild and moderate, should have effective intervention, and that the time threshold for intervention should be lowered.

References

1. Itard JM (1962) : Wild Boy of Aveyron, Humphrey G, Humphrey M, Translators. Prentice-Hall, New Jersey
2. Wardrop J (1813) : History of James Micthell, a boy born blind and deaf, with an account of the operation performed for the recovery of his sight. Blumer and Co., Edinburgh.
3. Lamson MS (1881) : Life and education of Laura Dewey Bridgeman - The deaf, dumb and blind girl. Houghton Mifflin, Boston.
4. Curtis S (1977) : Genie : A psycholinguistic study of a modern-day 'wild child'; Academic Press, New York.
5. Birholz J.C., Benacerraf B.R. (1983) : The development of human fetal hearing, Science, 222 : 516-518.
6. Querleu D., Renard X., Versyp F., Paris-Delrue L., Crepin G. (1988) : Fetal Hearing. Eur J Obstet Gynecol Reprod Bil, 29 : 191-212.
7. DeCasper A.J., Prescott P.A. (1984) : Human newborns' perception of male voices : Preference, discrimination and reinforcing value. Dev Psychol 17 : 481-491.
8. Juscyck P.W., Bertoncini J. (1988) : Viewing the development of speech perception as an innately guided learning process. Lang Speech 31 : 217-238.
9. Mehler J., Juscyk P.W., Lambertz G. Halsted N., Bertoncini J., Amiel-Tison C.A. (1988) : A precursor of language asquisition in young infants. Cognition 29 : 143-178.
10. Levitt A., Murray J./, Jusczyk P.W., Carden G. (1988) : Context effects in two-month-old infants' perception of labiodental/interdental fricative consonants. Exp. Psychol Hum Percept Perform 14 : 361-8.
11. Werker J.F., Gilbert J.H.V., Humphrey K., Tees RC. (1981) : Development aspects of cross-language speech perception. Child Dev 52 : 349-355.
12. Moddy M, Schwartz RG, Gravel JS, Wallace IF, Ellis, MA, Lee, WW. : Speech perception and verbal memory in children with otitis media. In Casselbrant ML, Lim D, Bluestone, CD. eds. Recent advances in otitis media : Proceedings of the 6th international symposium. Toronto B.C. Decker, In Press.
13. Wallace IF, Gravel JS, McCarton C, Stapells DR, Bernstein RS, Ruben RJ (1988) : Otitis media and language development at 1 year of age. J Speech Hear Disord ; 53 : 245-51.
14. Ling D (1989) : Foundations of Spoken Language for hearing impaired children. Washington D.C., Alexander Graham Bell Association for the Deaf.
15. Neville HJ, Mills DL, Lawson, DS (1992) : Fractionating language : Different neural subsystems with differnt sensitive periods. Cereb Cortex 2 : 244-58.