Sensitive Periods in First Language Acquisition

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Research in developmental psychology has not actively addressed the topic of critical periods in development for many years. As evidence, neither the term critical period nor sensitive period appears in the index of any of the four volumes of the fifth edition of the Handbook of Child Psychology (Damon, 1998). The fourth edition of the Handbook of Child Psychology (Mussen, 1983), published 15 years earlier, has only one index reference to critical period. Therein about half of a page is devoted to explaining that the concept derived from Lorenz’s work on imprinting (Lorenz, 1935) and has been replaced by the more popular term, sensitive period, which implies that “a given event produces a stronger effect on development or that a given effect can be produced more readily during a certain period than earlier or later” (Hinde, 1983, p. 41).

Among those who work in the field of language development, the concept of critical or sensitive periods also has not been a focus of attention. To the extent that it was considered at all, discussions of critical periods were blended inextricably with arguments for the nativist side of the nature versus nurture debate. Thus, it was assumed that if language acquisition were driven largely by biological mechanisms, there would be critical periods for its development. Lenneberg (1967) was a seminal figure in this tradition. He noted that language development has parallels in other domains, such as motor development, that are assumed to be driven largely by biological maturation. He pointed out that just as walking and grasping follow
a relatively predictable maturational timetable, the same occurs for many aspects of language development.

A related argument, articulated most vividly by Chomsky (1959), was that many of the characteristics of language understood by mature speakers of all languages in the world are abstract and, in principle, could not be acquired through traditional social learning mechanisms. How is it, Chomsky wrote, that people can recognize nonsense sentences that they have never heard before as grammatical (e.g., colorless green ideas sleep furiously) unless humans are born with an innate language acquisition device that is prewired with the basic grammatical rules of language? Many researchers and theorists followed the nativist lead of Lenneberg and Chomsky. Thus, Brown and Herrnstein stated, “One irresistibly has the impression of a biological process developing in just the same way in the entire human species” (1975, p. 479). Pinker maintained that language acquisition is such a robust process that “there is virtually no way to prevent it from happening short of raising a child in a barrel” (1994, p. 29).

Among recent research that has generated evidence for universality, and thus a probable biological basis for language development, is Goldin-Meadow and her colleagues’ observations of deaf children (Butcher, Mylander, & Goldin-Meadow, 1991; Goldin-Meadow & Mylander, 1990, 1998). In these studies, profoundly deaf children with no exposure to sign language or oral language develop systems of manual sign communication that incorporate many of the formal features of spoken language. For example, Goldin-Meadow and Mylander (1998) observed deaf children of hearing parents in two cultures, American and Chinese, that differ in their child-rearing practices and in the way gesture is used in relation to speech. The spontaneous sign systems developed by children in these cultures shared a number of structural similarities: patterned production and deletion of semantic elements in the surface structure of a sentence, patterned ordering of those elements within the sentence, and linking of propositions within a sentence. The universality of these developments, which occur without linguistic input from parents, argues for a biological program for development of language structures.

A contrasting focus on the role of nurture has been present among many psychologists who study language development. Their work focuses on the role of the social and linguistic environment in shaping the course of language development. These empiricists have noted that the logical counterbalance to nativists’ observation of universality in language development is the clear differences in language that are due to children’s culture and environment. It may be obvious that French children grow up speaking French, while Japanese children grow up speaking Japanese, but it requires no less explanation than the commonalities in their abstract grammars.

Research on environmental factors examines such topics as mothers speak to their young children (learning task) (Snow, 1979), the role of feedback in child language (Bihannan, MacWhinney, 1994), and children’s frequency of exposure to language growth (Huttenlocher, Haynes, 1981).

One example of research on the examination of the effects of frequency is that of Risley who found in a study recorded for 1 hour each month from professional, working class, and of the children’s lives. This was studied over 3 years of age was .84.

There was a difference of all parents with professional careers a related to an estimate that the child heard approximately 6 million words annually. This study is that by age 3, the larger recorded vocabulary than the frequency and quality were aspects of the large amount of the variance in mastery, and IQ scores at age 3 are related, or birth order. These differences were tested again for vocabulary at the same.

**NATURE, NURTURE, AND LANGUAGE DEVELOPMENT**

The purpose of this brief introduction is research and theory on language development of sensitive periods.

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Research on environmental determinants of language development
examines such topics as motherese (the unique, simplified language
that mothers speak to their young children that simplifies children’s language
learning task) (Snow, 1979), the role of conditions associated with economic
poverty in the rate and form of children’s language development (White-
hurst, 1997), the role of feedback in shaping the grammaticality of children’s
language (Bohannon, MacWhinney, & Snow, 1990), and the function of
children’s frequency of exposure to adult language in the rate of their lan-

One example of research on the latter topic is Hart and Risley’s (1995)
examination of the effects of frequency of parental talk to young children.
Over a 2½-year period, vocal interactions in the children’s homes were
recorded for 1 hour each month for the 42 families in the study. Hart and
Risley found a widening gap between the vocabulary growth of children
from professional, working class, and welfare families across the first 3 years
of the children’s lives. This was strongly related to differences in the fre-
quency of verbal interaction between parents and their children: The cor-
relation between frequency of input and children’s expressive language at
3 years of age was .84.

There was a difference of almost 300 words spoken per hour between
parents with professional careers and those on welfare, which can be extrap-
olated to an estimate that the children in professional families heard approxi-
imately 11 million words annually, the children in working class families
heard approximately 6 million words annually, and the children in welfare
families heard approximately 3 million words annually. One observation
from this study is that by age 3, the professional families’ children had a
larger recorded vocabulary than the welfare families’ parents. In general,
frequency and quality were aspects of parental speech that accounted for
a large amount of the variance in the children’s vocabulary growth, vocabu-
lar use, and IQ scores at age 3 and were better predictors than race, gen-
der, or birth order. These differences held up at age 9, when the children
were tested again for vocabulary and language skills.

NATURE, NURTURE, AND CRITICAL PERIODS

The purpose of this brief introduction to the nativist and empiricist tradi-
tions in research and theory on language development is to frame the topic
of sensitive periods.

One point is that equating sensitive periods with a strong maturational
view of language development is unnecessary and unwarranted. Remember
that a sensitive period refers to an effect of environmental stimulation that
can be produced more readily during a certain period than earlier or later.
To the extent that language develops in a lockstep maturational progres-
sion that requires little or no interaction with the environment, an inquiry into periods of special sensitivity to environmental stimulation is pointless.

A second point is that the methods of inquiry that have been characteristic of both the nativist and empiricist traditions are by themselves insufficient for determining the existence of sensitive periods. For instance, Lenneberg's (1967) catalog of the regular timetable for language milestones and related demonstrations that deaf children without exposure to sign language develop sign language with universal features (Goldin-Meadow & Mylander, 1998) does not answer the question of whether these progressions would be the same if somehow they could be prevented from starting until children were 5 years of age or whether the progression depends at all on interaction with environment. In other words, evidence that a developmental progression is driven primarily by biological events is neither necessary nor sufficient for the use of the construct of a critical period.

Likewise, evidence of the malleability of language development as a result of differences in children's social environments, seen in the work of Hart and Risley (1995), is not evidence against a critical or sensitive period. It is possible, for instance, that high frequency parent-child language interactions have their strongest effects during the preschool period, and that similarly rich verbal interactions at later points in a child's development might not make up for relative deprivation of these interactions during early childhood. In other words, Hart and Risley's results, or any other study demonstrating differences in language trajectories as a result of differences in experience within a common developmental epoch, are entirely consistent with the possibility that the epoch is a sensitive period for such development, without, of course, demonstrating the presence of a sensitive period.

Thus, demonstrations of regularity and universality, the meat of most arguments for biological models of language development, as well as demonstrations of malleability and individual differences, the heart of most environmental models of language development, do not argue for or against sensitive periods. This chapter addresses the methods that are suitable for answering questions about sensitive periods.

The third point is that critical periods may be determined exogenously (i.e., by external factors) as well as by an underlying biological process. For example, children in the United States who are failing in reading at the end of first grade are likely to be failing in reading at the end of third grade (Juel, 1988). Children who lag behind in their reading skills receive less practice in reading than other children (Allington, 1984), miss opportunities to develop reading comprehension strategies (Brown, Palincsar, & Purcell, 1986), encounter reading material that is too advanced for their skills (Allington, 1984), and acquire negative attitudes about reading itself (Oka & Paris, 1986). These children are caught in a downward spiral in which they are less prepared to accomplish their more literate peers, more likely encouraged, and likely to fall further behind.

Thus, one could argue that the critical success set is by experiences arising in the preschool period (White). Critical period is not determined by success of adult literacy programs taught to read at any age. In addition, the language of literacy is an asset, Bertelson, and Cary (1988) could quickly learn to perform a task measures phonemic awareness back and instructions. The reason is ation of literacy skills is that school skills-graded curriculum in which an aional step as the gap increases curium and what the curriculum learning to read is cultural and exo. It is in this context that the critical to first language acquisition.

WHAT COUNTS AS EVIDENCE

Evidence of critical periods in development and rearing studies. In such studies, organisms differ only in the time during which they have a particular experience. If that experience was the brain when presented during rearing, then that period can be said to be critical for that experience.

In the context of first language acquisition, children would be rear as children in a typical of the species in all respects except for an early exposure condition might be children in a middle exposure condition input until they are 4 years of age, and adults would begin; and children in an exposed to language as adolescents followed for a fixed period after the
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ess prepared to accomplish their teacher's instructional goals than their
more literate peers, more likely to experience failure and become dis-
couraged, and likely to fall further behind at the next step in their academic
journey.

Thus, one could argue that there is a critical period for learning to read:
If children do not learn to read early in their elementary school careers, it
is unlikely that they will learn to read well later. The stage for early read-
ing success is set by experiences and resulting skills that are acquired dur-
ing the preschool period (Whitehurst & Lonigan, 1998). However, this
critical period is not determined by biological constraints—the worldwide
success of adult literacy programs provides clear evidence that one can be
taught to read at any age. In addition, there is little evidence that the under-
lying components of literacy are age graded. For example, Morais, Con-
tent, Bertelsen, and Cary (1988) found that illiterate Portuguese adults
could quickly learn to perform a pseudoword phoneme deletion task (this
task measures phonemic awareness) when provided with corrective feed-
back and instructions. The reason that there is a critical period for acquisi-
tion of literacy skills is that schools provide an age-graded rather than
skills-graded curriculum in which early delays are magnified at each addi-
tional step as the gap increases between what children bring to the cur-
riculum and what the curriculum demands. Thus, the critical period for
learning to read is cultural and exogenous, not biological and endogenous.
It is in this context that the critical period question is addressed with regard
to first language acquisition.

WHAT COUNTS AS EVIDENCE FOR CRITICAL PERIODS?
Evidence of critical periods in development ideally comes from controlled
raising studies. In such studies, organisms are reared in environments that
differ only in the time during their life course in which they are exposed to
a particular experience. If that experience has a stronger effect on behavior
and the brain when presented during one developmental period than oth-
ers, then that period can be said to be critical or sensitive with respect to
that experience.

In the context of first language acquisition, a controlled rearing study
would involve rearing children in environments that are normal and typi-
cal of the species in all respects except exposure to language. Children in an
early exposure condition might be exposed to language from birth; chil-
dren in a middle exposure condition might be reared without language
input until they are 4 years of age, after which language interaction with
adults would begin; and children in a late exposure condition might be first
exposed to language as adolescents. Children in each condition would be
followed for a fixed period after their first exposure to language, say 6 years,
and their language development would be assessed. Evidence for a critical period would take the form of much greater competence in language at the end of the follow-up period for children exposed to language early compared with those exposed to it late.

Obviously, a controlled rearing study such as this cannot be conducted because ethics and human compassion would not permit it. Further, even if the experiment could be performed, difficulties of interpretation would remain. For example, given the central role of language in human interaction and development, how could one be sure that the children who were deprived of early language stimulation were not also deprived of opportunities for normal social or cognitive development. Effects on language learning at some later exposure to linguistic input might reflect the effects of abnormalities in socialization or thinking on the children’s attention to language, rather than the closing of a biological window for language learning per se. This possibility would cloud the interpretation of the results, but not the demonstration of a sensitive period.

Given that even an ideally designed controlled rearing study would have interpretive difficulties, the actual evidence available on critical periods in the language development of humans is less than definitive. That evidence comes from four primary sources. The first is from so-called “wild” children (i.e., rare cases of children who have been deprived of normal social and linguistic interaction during their first years of life). If such children are exposed to language later in life and do not develop normal language themselves, perhaps it is because they have passed a critical period for language acquisition. However, the possibility that these children had mental retardation to begin with cannot be discounted; neither can the likelihood that the effects of deprivation of language input during the first years are confounded with the effects of deprivation of other forms of experience.

The second source of evidence is from natural variation in the timing of exposure of deaf children to sign language. If deaf children have no exposure to a spoken language, and through differences in cultural or parental practice there are groups of children who are first exposed to sign language at earlier or later points in their life course, then researchers have a naturally occurring approximation of the ethically proscribed controlled rearing study. Of course, sign language may be acquired in different ways and have different features than vocal language. Also, deaf children who experience their first exposure to sign language later in life may have suffered the social or cognitive consequences of lack of early linguistic input that in turn affect their ability to acquire language.

A third method for examination of critical periods is loss of perceptual or learning capacities with age. If a young child can discriminate a speech sound or learn a linguistic skill that an older child or adult cannot learn as easily or as well, this suggests that the critical period may occur early in development. However, whether the critical period is due to age, changes in motivation or opportunity to read described earlier in the text, or learning. These questions speak not to the existence of the phenomena.

A fourth methodology that involves examination of cerebral lateralization indicates that normal brain organization during critical periods. However, it is important to note that these differences in brain organization are demonstrated is neural, not behavioral.

FIRST LANGUAGE DEVELOPMENT

In order to discuss first language development about language in general. First of all, one cannot talk about vision, color perception, binocular and spatial processing or language also is a system of components that interact with each other as a whole. The base component of the visual system is the pattern of sound combinations. Morphology describes how the meanings of words are related to one another, how sounds are produced in the language and how sounds are combined to form words, sentences, and other units of language. Syntax explains the rules for deriving the meaning of a sentence and the transformation of word order in context.

Just as the visual system is a complex system as language and the brain is a complex system as well. The brain is the central organ for language and other cognitive functions. Language development is a complex process that depends on both the brain and the environment. The critical period for language development is the time during which the brain is most sensitive to language input. If language input is absent during this period, language development may be impaired. The critical period for language development is thought to be around the age of two years, although this may vary depending on the language and the language environment.

In conclusion, language development is a complex process that depends on both the brain and the environment. The critical period for language development is the time during which the brain is most sensitive to language input. If language input is absent during this period, language development may be impaired. The critical period for language development is thought to be around the age of two years, although this may vary depending on the language and the language environment.
assessed. Evidence for a critical period competence in language at the early stages of development is not definitive. Further, even if validity of interpretation would suggest that the children who were deprived of opportunity to learn language in human interaction were also not deprived of opportunity to learn language in cultural interaction. Effects on language input might reflect the effects of the children's attention to the critical window for language learning. Interpretation of the results, however, controlled rearing study would not suggest that critical periods are less than definitive. That is, rare cases of children and linguistic interaction during exposure to language later in life suggest that it is because they lack exposure. However, the possibility to begin with cannot be the effects of deprivation of language acquisition. Deprivation of language in the infant cannot be the natural variation in the timing of critical periods. If deaf children have no exposure to sign language, then researchers have a naturally proscribed controlled rearing acquired in different ways and different elements. Also, deaf children who are exposed later in life may have suffered a loss of early linguistic input that in the absence of this input, critical periods is loss of perceptual skills. A child can discriminate a speech sound child or adult cannot learn as easily or as well, this suggests that a critical period for such learning occurs early in development. However, such a demonstration does not reveal whether the critical period is due to a biological window that closes with age, changes in motivation or opportunity (e.g., as in the case of learning to read described earlier in the chapter), or interference from subsequent learning. These questions speak to the reasons for a sensitive period, but not to the existence of the phenomenon itself.

A fourth methodology that permits inferences about critical periods involves examination of cerebral localization of language processing for individuals exposed to languages at different times in their life course. If individuals exposed to a language at a later time than usual utilize different areas of the brain or different neural pathways to process language, this is evidence that normal brain organization for language requires stimulation during critical periods. However, to the extent that individuals perform equivalently on language tasks, or at least perform within a normal range despite differences in brain organization, the critical period that has been demonstrated is neural, not behavioral.

**FIRST LANGUAGE DEVELOPMENT: WHAT IS EXPECTED?**

In order to discuss first language development, there needs to be clarification about language in general. First, language, like vision, is complex. Just as one cannot talk about vision without distinguishing among depth and color perception, binocular and monocular vision, and motion detection, language also is a system of components, each of which contributes to the whole. The base component of the language system is phonology—the patterning of sound combinations that are allowed in a particular language. Phonology generally embodies articulatory phonetics, which is the study of how sounds are produced in the world's languages. Syntax describes the grammatical rules specific to single languages and groups of languages. Morphology describes the rules of word formation. Semantics is the conventions for deriving the meanings of words and sentences. Finally, pragmatics is the rules for appropriate social use and interpretation of language in context.

Just as specific visual functions each have their own critical periods, a system as complex as language may be marked by different critical periods for different components. Furthermore, it is important to distinguish between a first or second language system because learning a first language is different from learning a language while having another language system already in place. Despite these differences, however, both types of learning are relevant to discussions about critical periods. This chapter focuses on first language development, though some references to second language research will be necessary and relevant to the discussion at hand.
Phonetics and Phonology: Normal Gains and Losses

An informative area of research regarding critical periods in first language development focuses on perception and production of speech sounds. Infants' perception of phonetic contrasts changes given specific linguistic input. Early work showed that infants have the capacity to discriminate phonetic contrasts that they have never heard before (Lasky, Syrdal-Lasky, & Klein, 1975; Streeter, 1976; Trehub, 1976). Subsequently, researchers demonstrated that adults are unable to perceive many nonnative phonetic contrasts (Flege, 1989; Logan, Lively, & Pisoni, 1989; Strange & Jenkins, 1978). The implications of these findings for the critical period debate should be apparent. That is, though much of the research on first language critical periods focuses on a cutoff point somewhere around adolescence, research on loss of perception of nonnative contrasts has made it clear that before puberty a lot happens to determine how fluent one is with the sounds of a particular language.

Werker and her colleagues set out to determine precisely when sensitivity to nonnative contrasts begins to decline. In an initial study, Werker (1981) tested Hindi-speaking adults, English-speaking adults, and English-exposed 7-month-olds on two Hindi contrasts (a voicing distinction and a place of articulation distinction). She found that whereas the Hindi-speaking adults and the English-exposed 7-month-olds could readily distinguish between each sound in the two sets of contrasts, English-speaking adults could not. In a subsequent study, Werker and Tees (1983) tested groups of English speakers between the ages of 4 years and adulthood on the same two contrasts. The researchers found that even the 4-year-old English speakers could not distinguish sounds in the two sets of contrasts.

Based on this work, it became clear that a lot happens to lay the groundwork for native-like fluency before puberty and even prior to the fourth year of life. In subsequent work, English-exposed 12-month-olds showed hardly any sign of discriminating non-English contrasts, while those same contrasts were easily distinguished by 12-month-olds exposed to the particular languages in which those contrasts occurred (Werker & Tees, 1984). Werker's studies were the first demonstrations of how early in a child's life exposure to the native language influences subsequent perception. The findings demonstrate a decline in sensitivity to nonnative speech contrasts when no exposure to them takes place. This decline in sensitivity was subsequently shown to take place systematically between the first 6-12 months of an infant's life, regardless of the infant's native language (Best & McRoberts, 1989; Werker & Lalonde, 1988).

Other work challenged just how clear cut this decline in sensitivity actually is. For example, Best and her colleagues (Best, 1991, 1995; Best, McRoberts, & Sithole, 1988) demonstrated that certain contrasts (e.g., be-

tween specific Zulu clicks [the Zulu continue to be distinguishable even if one has heard speech sounding to a native English speaker the lack of proximity of these sounds] to the listeners. Indeed, there is no decline in the Zulu click sounds. Other contrasts tested by Werker and Tees, are also constant; some specific phonetic category is not used and, thus, not discriminated. Sensitivity to nonnative contrasts is not the only kind of perceptual deficit found in other organisms when they are isolated. However, apparent from description by Bruer, it takes a lot to bring about a lot of loss. In fact, adult speakers can apparently nonnative contrasts when given the right information (Flege, 1989; Flege, Takagi, & Mann, 1985; Flege, Takagi, & McClelland, 1998; McClellan)

Some researchers have argued that influences on attentional factors can explain some of the actual loss of a biological sense (Flege, 1985, 1992; Werker, 1981). This period within which attention to language phonology, this could be considered a critical period. Regardless, the influence of the phonological system on one of the most entrenched aspects of language system.

EFFECTS OF LINGUISTIC DEPRIVATION ON FIRST LANGUAGE DEVELOPMENT

Numerous instantiations of linguistic deprivation have been proposed in the literature. The long-term goal of understanding the effects of linguistic deprivation do, in fact, exist. Because of the laboratory setting, myriad situations can be created that have been investigated by researchers to understand the outcomes of such deprivation. Some of these situations include language deprivation.
Gains and Losses

critical periods in first language production of speech sounds. In- changes given specific linguistic are the capacity to discriminate tower before (Lasky, Syrdal-Lasky, 1976). Subsequently, researchers receive many nonnative phonetic Pisoni, 1989; Strange & Jenkins, 1989) for the critical period debate if of the research on first language somewhere around adolescence, the contrasts has made it clear that how fluent one is with the sounds of speech is determined precisely when sen- sible. In an initial study, Werker & Tees (1984) that whereas the Hindi-speaking adults could readily distinguish be- tween voicing distinction and a that whereas the Hindi-speaking adults could distinguishing between Zulu clicks (the Zulu language utilizes many tongue clicks) continue to be distinguishable even to adult nonnative speakers. One can imagine (particularly if one has heard these clicks, which are decidedly non- speech sounding to a native English speaker) that this has to do with the lack of proximity of these sounds to any sounds in the native language of the listeners. Indeed, there is no sound in English that even approaches the Zulu click sounds. Other contrasts, like the Hindi voicing distinction tested by Werker and Tees, are similar enough to sounds that fall within some specific phonetic category in the listener's native language to be confused and, thus, not discriminated. Regardless, demonstrations of loss of sensitivity to nonnative contrasts in general are conceptually quite similar to the kinds of perceptual deficits described by Bruer (see Chapter 1) in other organisms when they are isolated from sufficient environmental stimulation. However, apparent from the work involving monkeys and kittens described by Bruer, it takes a lot to wipe out certain perceptual skills entirely. In fact, adult speakers can apparently regain the ability to distinguish certain nonnative contrasts when given enough appropriate training (Flege, 1989; Flege, Takagi, & Mann, 1995; McCandliss, Fiez, Conway, Protopapas, & McClelland, 1998; McClelland, 2001).

Some researchers have argued that such findings are indicative of the influence of the attentional factors can have on perceptual discrimination rather than of the actual loss of a biologically based sensory capacity (Jusczyk, 1985, 1992; Werker, 1981). This would mean that even if there were a period within which attention were fixed on features of one's native language phonology, this could be overridden given proper training even in adulthood. Regardless, the influence of this training is particularly noteworthy because the phonological system has traditionally been considered one of the most entrenched and sharply defined components of the language system.

EFFECTS OF LINGUISTIC ISOLATION ON FIRST LANGUAGE DEVELOPMENT

Numerous instantiations of linguistic input deprivation have been studied with the long-term goal of understanding whether critical periods for acquisition do, in fact, exist. Because such deprivation cannot be imposed in a laboratory setting, myriad situations in which deprivation has been imposed (most often naturally but, unfortunately, sometimes artificially) have been investigated by researchers interested in measuring developmental outcomes of such deprivation. Several of these deprivation studies and the principle language components affected by the deprivation will be reviewed.
Syntax and Semantics:
Differential Outcomes of Deprivation

Genie  In the late 1960s, social workers discovered a 14-year-old girl in California whose experience matched the criteria for the forbidden controlled rearing experiment. Genie had been tied to a chair for most of her life by her father. She was kept from the rest of the world, including the verbal input she would have received by being a part of that world. Whenever she tried to talk, Genie was severely reprimanded or beaten. Needless to say, she did not have much verbal ability at the time she was discovered. Years of work with Genie by psychologists and speech-language therapists produced little in the way of normal language development (Curtiss, 1977). Genie was unable to learn language—particularly syntactic constructions—to a normal, native-like level, even when given appropriate and abundant input and instruction. The common interpretation was that Genie was discovered past the critical period for developing a first language. Of course, Genie’s experiences were abnormal in more areas than language alone, and one does not know whether she suffered some form of biological or congenital mental retardation. Thus, one cannot claim being past some critical period was the principal cause of Genie’s stunted language capacity.

Deaf Studies

In all cases in which individuals such as Genie have been isolated specifically from linguistic input past adolescence, the circumstances under which such isolation occurred no doubt impacted their development in other, nonlinguistic ways. Given such abnormal upbringing, it is difficult to argue for the passing of some critical period as the sole source of the difficulties for subsequent language development. Deaf studies are an alternative to traditional case studies of deprivation.

Research by Bellugi and others (Bellugi, 1980, 1988; Klima & Bellugi, 1979; Newport & Meier, 1986) shows that signed languages are characterized by the same complexities as spoken languages. In fact, there are notable similarities in specialization of brain functions between native users of signed and spoken languages (Poizner, Klima, & Bellugi, 1987). Moreover, there is evidence that hearing and nonhearing infants exposed to sign language engage in manual babbling (Pettito & Marentette, 1991). These similarities between signed and spoken languages have motivated researchers to look for, and find, what appears to be evidence for critical periods in the acquisition of sign (Mayberry & Fisher, 1989; Newport, 1991) and to argue that this evidence is relevant for spoken languages as well.

Some of the most compelling work in support of the hypothesis that acquisition of grammatical knowledge is constrained by a critical period is based on data collected from deaf speakers of American Sign Language (ASL). Deaf and hearing children whose parents follow the same learning strategies (Newport & Meier, 1985). They are born into hearing families and are exposed to sign language at all. In many cases, their families provide sign language to their children, and the children come to learn sign language. The critical period is long: attempts vary because few complex, multi-syllable words are comprehensible to the deaf child. These children are not exposed to formal educational settings and are not provided with educational instruction. However, they do learn to hear the language spoken by their parents, and those who are exposed to some kind of formal instruction are exposed to the same amount of linguistic input that other children in the same educational setting are exposed to. Thus, the question of whether children can learn sign language at all is a very short period, just as hearing children they are not to be exposed to either the same amount of input or the same amount of educational instruction. Newport compared the progress of two groups of people who were communicating in ASL for different amounts of time: the first group consisted of people who learned ASL from birth. The second group consisted of people who learned ASL after 12 years of age, which is a common age for children with hearing impairments. The third group consisted of people who learned ASL prior to 6 years of age, which is the age at which hearing children typically acquire sign language. The results showed that only individuals in the first group demonstrated significant fluidity in their use of sign language, indicating that the critical period for acquiring sign language is likely to be shorter than the critical period for acquiring spoken language.
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(ASL). Deaf and hearing children who learn sign language from their deaf
parents follow the same learning course typical of spoken-language learn-
ing (Newport & Meier, 1985). The common reality, however, is that deaf
children are born into hearing families in which parents do not know any
sign language at all. In many cases, parents consciously decide not to allow
their children access to sign language because they believe that their deaf
children will come to learn a spoken language by lip-reading and then be
able to make language-approximate pronunciations. The outcomes of such
attempts vary because few completely deaf children ever learn to speak in a
manner comprehensible to the rest of the speaking world. And because
these children are not exposed to sign language, they are effectively de-
prived of linguistic stimulation. In this sense, children who have not been
able to hear the language spoken around them (e.g., spoken English) and
who are unable to learn a true alternative (e.g., ASL) because their parents
have kept them from being exposed to it provide another opportunity for
testing whether people can become fluent if their first opportunity to learn
occurs after childhood.

Deaf children acquire most of their mature grammatical capacity within
a very short period, just as hearing children do. They can do this even though
they often lack access to either the kind of models or responses to poorly
formed attempts at language that arguably help children rapidly learn such
a complex system of behavior. Nonetheless, even though deaf children have
the capacity to invent their own gestural forms for communicating mean-
ing—and acquire words or signs at approximately the same time that chil-
dren exposed to natural spoken or signed language would—Newport (1990)
has shown that when one actually learns a formal signing language can influ-
ence ultimate attainment of fluency.

Newport compared the production and comprehension of ASL in three
groups of people with congenital deafness. People in all three groups had
been communicating in ASL for at least 30 years. The difference among
the three groups was the age at which the individuals actually learned ASL.
One group consisted of people who were born to deaf parents and learned
ASL from birth. The second group consisted of early learners, defined as
those who first came into contact with ASL between the ages of 4 and 6
years. The final group consisted of individuals who were first exposed to
ASL after 12 years of age, which is commonly considered the cutoff point
for a variety of proposed critical periods for language development. All of
the individuals were older than 50 years of age at test time. Newport's results
showed that only individuals in the first two groups, those who had been
exposed to ASL prior to 6 years of age, demonstrated native-like fluency.
The second group (those learning ASL between 4 and 6 years) showed sub-
tle nonnative characteristics in their ASL. Those in the postcritical period
group demonstrated significant deficits that are typically the mark of non-
native speakers. The majority of their problems had to do with ASL equivalents of function morphemes and complex syntactic structures within sentences. Individuals isolated from spoken language prior to adolescence (e.g., Genie) consistently have difficulties with these same things.

**Neurobiological Perspective**

Neville and her colleagues have approached questions about differences between grammatical and semantic processing from a neurobiological position (see Chapter 8). Their work relies in large part on the recording of event-related brain potentials (ERPs), which are the electrical currents generated through the scalp by neuronal firing. ERP recordings allow researchers to measure the timing and patterning of neuronal firing across developmental stages and behavioral tasks (Neville, 1995) and can be used in conjunction with more traditional behavioral measures to determine differences in cerebral processing associated with different forms of behavior. Ultimately, ERP recordings can provide information about the timing, sequence, and location of various forms of processing, including language. Neville has looked specifically at language processing and event-related brain potentials in normal adults, adults with congenital deafness, and typically developing children to determine whether cerebral subsystems specialized for either semantic or grammatical processing are differentially impacted by delays in language exposure.

In order to assess differences in the neural mechanisms used for processing different components of the language system, Neville and her colleagues (Holcomb & Neville, 1990; Neville, Mills, & Lawson, 1992) compared the timing and distribution of ERPs elicited from normal adults when they processed sentences containing anomalous open- or closed-class words. Open-class describes semantic content words, such as nouns, verbs, and adjectives that refer to specific objects and events. The term comes from the fact that in any language, this set openly admits new members. Closed-class describes grammatical function words, such as direct and indirect articles, conjunctions, and auxiliaries. The term comes from the fact that in any language, such function words belong to a closed set. Differences in semantic versus grammatical processing were assessed by comparing whether the differences between ERPs could be accounted for in terms of general processing differences (e.g., the frequency and length of the words) rather than in terms of the different functions the words perform (e.g., grammatical, semantic) when a person processes one or the other of the two classes of words. Results from this work indicate that notably different firing patterns occur when normal adults process grammatical and semantic information (Neville, 1995).

When processing grammatical information from their native language, people show localized firing in the anterior region of the left temporal lobe (Neville, Nicol, Barss, Forster, & Gerstman, 1996); this lateralized firing is not present in native ASL users who learned English after the age of 11 and becomes solidly left lateralized only in late native ASL users who learned English before the age of 11 and becomes solidly left lateralized only in late native ASL users who learned English before the age of 11. However, where the alteration in firing patterns is most pronounced appears to have a pronounced effect on grammatical processing, and the relative degree of localizations appears to have a pronounced effect on grammatical processing. Taken together, these findings provide support in support of arguments for the hypothesis that learning a language after the age of 11 results in a pronounced effect on grammatical processing, and the relative degree of left hemisphere dominance appears to have a pronounced effect on grammatical processing.

In another area of focus, developmental progression to determinants of the course of establishing grammatical knowledge is to be stated on the basis of whether the onset of one or the other hemisphere is determined by factors such as the age of acquisition. As mentioned, no evidence has been found showing that grammatical processing, activity in the left cerebral hemisphere does not hold for semantic processing, and the grammatical asymmetry is not as pronounced in 8- to 13-year-olds as it is in adults. However, children's score on standard grammatical processing semantic information.

This finding speaks directly to the development of density across ages as well. Brain imaging studies indicate that gray matter in the frontal cortex (including the motor and premotor cortex) decreases starting around age 20 and continues to decrease at a slower rate around age 30 (Jernigan, Trauner, Eckenhoff, Zecovic, & Goldman, 1996). Synaptic pruning is associated with...
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(Neville, Nicol, Barss, Forster, & Garrett, 1991; Weber-Fox & Neville,
1996); this lateralized firing is not present when people process semantic
information. Specifically relevant to the critical period question is the fact
that the pattern for grammatical processing does not emerge until around
age 11 and becomes solidly in place only around age 15 or 16. In contrast,
native ASL users who learned English later in life do not manifest this li-
teralized firing pattern when processing English grammar (Neville, 1995).
However, where the alteration in these deaf people's early language expe-
ience appears to have a pronounced effect on the development of systems
relevant to grammatical processing, no such effect manifests for semantic
processing. Taken together, these findings are consistent with behavioral
evidence that adults continue acquiring lexical knowledge late into adulthood,
while grammatical knowledge becomes markedly more difficult to acquire.
Such findings provide some of the most compelling evidence to date in support of arguments for a critical period in grammatical develop-
ment. They show differences in cerebral processing of grammatical informa-
tion when that knowledge has been put in place before and after a
particular point in developmental time, and no such differences in the pro-
cessing of semantic information.

In another area of focus, Neville and her colleagues used typical devel-
mental progression to determine whether there are differences in the
time course for establishing grammatical versus semantic knowledge and
whether the onset of one or the other form of processing varies from per-
son to person. As mentioned, normal adults show highly lateralized firing
during grammatical processing, such that ERPs reflect more electrical
activity in the left cerebral hemisphere than in the right, while this lateral-
ization does not hold for semantic processing (Neville, 1995). Further-
more, the grammatical asymmetry is correlated with levels of grammatical
knowledge in 8- to 13-year-olds. Neville (1995) found that the higher a
child's score on standard grammar tests, the more pronounced the left-
side asymmetry. In a group of 8- to 14-year-olds, ERP recordings that
showed more left-sided asymmetry also were larger and correlated with
lower volumes of cortical gray matter. On the other hand, there was no dif-
derence between patterns of electrical activation in 4-year-olds and adults
processing semantic information.

This finding speaks directly to debates about the relevance of synaptic
density across ages as well. Brain imaging studies have shown that the amount
of gray matter in cerebral cortex (representing the density of synaptic con-
nections) decreases starting around age 8 and continues decreasing until
around age 30 (Jernigan, Trauner, Hesselink, & Tallal, 1991), a finding that
is consistent with anatomical data (Huttenlocher, 1990; Rakic, Bourgeois,
Eckenhoff, Zeccevic, & Goldman-Rakic, 1986). It has been argued that this
synaptic pruning is associated with functional consolidation, such that func-
tion becomes more streamlined and efficient even while brain plasticity decreases. Neville's (1995) work adds support to the view that the lower volume of gray matter associated with more pronounced left-side lateralization of grammatical processing is related to the so-called critical period for development of this kind of processing. It appears that native-like grammatical knowledge gets entrenched through the pruning of those synapses that are not being used for that processing.

Results from the studies reviewed here indicate different developmental time courses and sensitivities for grammatical and semantic processing. Processing of grammatical information appears to rely on different neural mechanisms than those relied on for processing semantic information. The semantic knowledge base continues to expand throughout life, and there apparently is no change in the neuronal firing pattern for processing semantic information from year to year as would be expected if there were a critical period for acquisition of semantic knowledge. Grammatical processing, however, shows gradually differentiated localized responses, reflecting a neural system where decreases in redundancy and increases in specificity manifest over developmental time. These data add support to the view long held by linguists and psycholinguists that language processing can be broken down into different subsystems. Furthermore, the findings reviewed here provide evidence for the biological basis of such distinctions and for component-specific critical period arguments.

INDIVIDUAL DIFFERENCES IN DEVELOPMENT

The concept of critical or sensitive periods focuses on age cutoffs or boundaries for effective stimulation. Much discussion of critical periods implicitly assumes an idealized, archetypal developing child, as if all children developed according to the same timetable. Examination of individual differences in language development divulges a more variable picture, suggesting that even if there are critical periods for language learning for the human species, they play out against a backdrop of individual differences in biological and environmental factors that must necessarily blur the effects of critical periods on individual children.

Evidence of just how flexible the brain is has led neuroscientists to suggest that a young brain can do its work with input that only needs to vaguely resemble a normal environment (Brunner, 1999). It takes pronounced genetic or environmental deprivation for normal firing patterns to go off track.

The phenomenon of expressive language delay is a prime example of such individual variability in the time course of language development. As reviewed by Whitehurst and Fischel (1994), children who will eventually achieve similar linguistic outcomes during the elementary school years may include those who will have hunger years of age and who are combined and those who will have virtually. Likewise, there are children who control over the phonology of their expressive phonology will be in of the children with articulation memory school. From an educational important not to confuse children language development with child critical period for development.

Language development is a scientific literature on critical period and different sensitivities to wanes to speech sounds not hear proper training, adults reacquire the most difficult of all the complex past puberty. Nonetheless, people mars as if they were native speakers knowledge can be expanded as long existing literature on sensitive period many questions as it answers.

1. What kind of learning is occurring high levels of skill outside the or phonological development clear implications for intervention fail to acquire such competitive
2. How gradual (or sudden) is or phonological learning, and this question would have important intervention programs.
3. What are the minimal levels support learning during the sen for and must that stimulation development of the young brain in range of environmental input, this description by Heath (2000) is between a mother and her prototypical of many poor urban in small apartments or public or community: "One mother..." with her children over a 2-
cient even while brain plasticity is relatively high. This view is supported by the lower volumes of pronounced left-side lateralization of the so-called critical period for language acquisition. It appears that native-like grammatical and semantic processing is not due to rely on different neural mechanisms. The redundancy and increase in the firing pattern for processing would be expected if there were no knowledge. Grammatical production of localized responses, redundancy and increases in these data also support the findings of language processing can vary. Furthermore, the findings of such distinctions in arguments.

**DEVELOPMENT**

Focuses on age cutoffs or boundaries of critical periods implicating the developing child, as if all children are equal. Examination of individual differences is a more variable picture, suggesting for language learning for the development of individual differences in must necessarily blur the effects. Brain is has led neuroscientists to work with input that only needs to be reacquired (e.g., non-native), but, given proper training, adults reacquire sensitivity to those contrasts. Grammar is the most difficult of all the components of the language system to develop past puberty. Nonetheless, people are able to learn second language grammars as if they were native speakers. In addition, semantic and pragmatic knowledge can be expanded as long as one is interested in doing so. The existing literature on sensitive periods in first language acquisition raises as many questions as it answers.

1. What kind of learning is occurring when individuals are able to acquire high levels of skill outside the normal sensitive period for grammatical or phonological development? An answer to this question would have clear implications for intervention and remediation in individuals who fail to acquire such competence either early or later in life.

2. How gradual (or sudden) is the drop-off in sensitivity to grammatical or phonological learning, and what are its age brackets? An answer to this question would have implications for the timing of educational and intervention programs.

3. What are the minimal levels of stimulation that are necessary to support learning during the sensitive periods of development, and what form must that stimulation take? Bruer (1999) argued that the development of the young brain is well buffered against an extremely wide range of environmental input. But how wide is that range? Consider this description by Heath (1989) of her research on the interactions between a mother and her preschool children: "One mother agreed to tape record her interactions with her children over a 2-year period and to write notes about her
activities with them. Within approximately 500 hours of tape and over 1,000 lines of notes, she initiated talk to her three preschool children (other than to give them a brief directive or query their actions or intentions) in only 18 instances” (Heath, 1989, pp. 369–370). The rearing conditions in which three preschool children receive only 18 linguistically informative utterances over a 2-year period might fall outside the range of minimal stimulation needed to develop core linguistic competences. What then of the much higher frequencies of stimulation found among the welfare families in the research of Hart and Risley (1995)?

The existence of so many unanswered questions about the neuroscience of sensitive periods for first language acquisition places severe limits on inferences that can be drawn for educational policy. Clearly, deaf children should be exposed to sign language at least as possible in life if they are to acquire full sophistication in that language as adults. Clearly, hearing children should not be raised in a barrel or deprived of linguistic interactions with adults.

If researchers are willing to expand the concept of sensitive period to include exogenous and culturally framed windows of opportunity for learning, then the implications for early intervention and educational practice will expand tremendously. Decades of research have shown that children who start school behind are likely to fall further behind as they progress through their educational careers. Children who fail in school are likely to face economic difficulties in later life, and this relationship is strengthening as blue-collar jobs disappear in an economy that is increasingly knowledge based. Conditions associated with economic poverty are the single strongest predictors of children’s success in school, and the differences produced by these conditions are present at the time children first walk through the school door. The preschool period is a critical window of opportunity for acquiring language and other skills, dispositions, and habits of learning that enable children to succeed in school. Knowledge is needed about how to enhance readiness for schooling in children whose families do not provide sufficient support. Future work in the neurosciences will enable researchers to better understand the neural substrates of early learning and development. The potential of that work for unifying the brain and behavioral sciences is exciting. However, the neurosciences are unlikely to reveal how to design preschool environments that provide optimal support for children in need. Researchers already know the critical importance of that task and have made some progress in solving it.

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A Critical Period Hypothesis for Second Language Acquisition

The critical period hypothesis for second language acquisition posits a sensitive period for second language learning that is most effective during the early years of life. This hypothesis is based on empirical evidence from various domains, including cognitive development, neuroplasticity, and the acquisition of new languages. The critical period is typically understood as a time window during which learning a new language is facilitated, compared to later periods.

The critical period hypothesis suggests that the nervous system is most receptive to new linguistic input during specific developmental stages. This period is thought to be significant for the acquisition of foreign languages, with implications for educational policies and practices. The hypothesis has implications for second language instruction, as it highlights the importance of exposing learners to the target language during the critical period to optimize learning outcomes.

Advocates for early immersion and second language programs, such as those in bilingual education and dual language programs, often point to the critical period hypothesis as a justification for these approaches. They argue that early exposure to a second language can lead to greater proficiency and a more natural acquisition of the language, which is difficult to achieve later in life.

Critics, however, argue that the critical period hypothesis can be challenging to apply in practice due to cultural, social, and economic factors. They suggest that the focus on the critical period may overshadow other important factors in language learning, such as the motivation and background of the learner. Furthermore, the concept of the critical period has been subject to debate regarding its precise duration and applicability across different linguistic and cultural contexts.

In summary, the critical period hypothesis for second language acquisition underscores the importance of early exposure and optimal learning conditions during specific developmental stages. It challenges educators and policymakers to consider how these findings can be integrated into curricula and educational practices to support effective second language learning.