ENCYCLOPEDIA on Early Childhood Development

LANGUAGE DEVELOPMENT AND LITERACY

Biological Bases of Language Development

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Introduction and Subject

Advances in neuroimaging allow for the investigation of the neurobiological bases of language and the effects of environmental and genetic factors on neural organization for language in children. An understanding of the neurobiology of language has important implications for those seeking to optimize language development. Insights from this research may support practical, evidence-based advice for parents as well as the development of language and literacy curricula for first and second language learners.

Problems

A complex interaction between genetic and environmental factors produces substantial variation in rates of language development among children. Many behavioural studies illuminate the effects of environmental factors on language development; however, less is known about the neurobiological underpinnings of these effects. Most neurobiological research concerns individuals from middle and higher socioeconomic status (SES) backgrounds.

Research Context

Research on the neurobiology of language uses neuroimaging techniques with exquisite temporal resolution (e.g., event-related potentials; ERPs) and complementary techniques with exquisite spatial resolution (e.g., functional magnetic resonance imaging; fMRI). ERPs are better suited for use with infants and children, although fMRI is also used with younger populations. Increasingly, these methods are being used to characterize the developmental timecourse of different language subsystems and to more precisely examine the effects of language experience, and the timing of these effects, on the development of different language functions and on the neural mechanisms which mediate these subsystems.

Key Research Questions

Key research questions involve the use of neuroimaging techniques to characterize:

1. the timecourse of the development of neural substrates of different subsystems of language,
2. the effects of environmental and genetic factors on the development of these neural substrates, and
3. the time periods during which the effects of environmental and genetic factors are maximal (i.e., sensitive periods) for each subsystem.

Recent Research Results

The neurobiological bases of three linguistic subsystems have been studied, specifically phonology (sound system of the language), semantics (vocabulary and word meanings), and syntax (grammar). This research shows that brain responses to language at early ages are predictive of later language proficiency.

Within the first year of life infants become increasingly sensitive to speech sound contrasts important to their native language(s) and insensitive to unimportant phonetic contrasts.[1] This sensitivity to native language contrasts is reflected in a brain response which has been shown in adults to be a neural index of phonetic discrimination: in 7.5-month-old infants the brain response to native language contrasts correlated with behavioural perception of these contrasts.[2] Furthermore, an increased neural response at 7.5 months predicts word production and sentence complexity at 24 months and mean length of utterance at 30 months. The inverse relationship was noted for discrimination of non-native contrasts.[2]

ERP methodology has also been used to examine early word learning and associated changes in neural specialization. In 13-month-olds the brain response to known words differs from that to unknown words, with this effect broadly distributed over both the left and right hemispheres.[3] By 20 months of age this effect was limited to the left hemisphere, a pattern more like that seen in adults and one associated with increased specialization for language processing. In addition, such increased brain specialization is also associated with greater language ability in children of the same chronological age.[4]

Developmental increases in neural specialization for language are associated with differences in SES. For example, differences in the structure of left frontal brain areas important for language processing were found in five-year old children as a function of SES.[5] Another study found that SES predicted brain volume in left frontal and posterior brain areas important for language; furthermore, these SES differences may increase with age.[6] Lower SES was also associated with reduced surface area in multiple brain regions, including frontal regions supporting language.[7] These relationships may endure into adulthood: in adults, socioeconomic deprivation predicts the degree of thinning in the cortex in posterior language areas.[8] Retrospective childhood SES also predicts language proficiency and early neural response to syntax over left frontal brain areas in adults.[9]

Neuroimaging studies of young children show increasingly adult-like brain activation patterns to printed letters and cortical thickening in language-relevant areas with differences in parental language input and following reading interventions with children at-risk for reading disorders and with children from lower SES backgrounds.[10,11,12]

Numerous ERP sentence processing studies of adults have shown that semantic and syntactic subsystems are processed by different brain systems across spoken, written and signed languages, which share these different subsystems.[13] Studies of bilinguals of both spoken and signed languages show that these distinct subsystems display different degrees of plasticity with different sensitive periods.[14,15,16] In these studies, a comparison is made between the brain responses to correct sentences versus sentences that violate semantic or syntactic expectations (e.g., “My uncle will blow the movie” or “My uncle will watching the movie”). In adults, specialized and efficient brain function is indexed by neural responses that originate from relatively focal brain areas whereas such responses in children may be more widespread in the brain.[17-23]

The few ERP studies of sentence processing in children suggest that this specialization of different brain systems occurs early in development. A brain response similar to that elicited by semantic violations in adults has been reported reliably in five-year old children, and even in children as young as 19 months.[17,20] This brain response predicted expressive language proficiency at 30 months of age and becomes faster and more specialized with age.[18,19] ERP responses to syntactic violations in children are qualitatively different than the response to semantic violations. Though slower and more widely distributed, the response to syntactic violations found in children is similar to that found in adults.[22-24] The neural response to semantic and syntactic violations in 3- to 8 year-old children has also been found to vary as a function of language proficiency, other cognitive skills, and SES.[25] Longitudinal ERP studies suggest that, between ages four and five years, children from higher SES backgrounds exhibit more rapid maturation of ERP indices of both semantic and syntactic processing than peers from lower SES backgrounds.[26]

Recent ERP research has also examined a cognitive system shown to be important for the development of language skills: specifically selective attention to one auditory stimulus while ignoring a competing auditory stimulus. Selective attention is indexed by a larger brain response (ERP) to the attended auditory event compared with the competing auditory event. This attention effect is reduced in children diagnosed with specific language impairment[27] and in typically developing children from lower SES environments.[28,29,30] Differences in the effects of attention on neural processes in children from lower SES backgrounds have been found to be associated with genetic allelic differences, specifically in the serotonin system (i.e., 5-HTTLPR[31]).

Importantly, this cognitive system is changeable with experience in young children. For example, high-intensity training was found to increase both language proficiency as well as the effects of attention on neural processing in 6-8 year-olds.[32] Essentially, parents can change these cognitive systems: a two-generation intervention study found changes specific to families who received a more parent-focused model of the program. Parents increased conversational turn-taking with their children, and children improved language proficiency as well as brain function for selective attention.[33]

Research Gaps

Further research on the neurobiology of language development is required to better understand underlying environmental and genetic factors; for example, studies of typically developing children from a wider range of SES backgrounds. Additional studies with clinical populations will increase understanding of neurobiological changes that occur with different disorders. For example, see emerging research on neurobiology of stuttering.[34-36] Another important next step is to employ results from this research to design and implement evidence-based interventions which improve the skills necessary for the development of language and to determine the age(s) at which they are most effective.[11,12,33]

Conclusions

Modern neuroimaging techniques are powerful tools for investigating the effects of environmental and genetic factors on the neurobiology of language development. Research using these techniques with children from a wider range of SES backgrounds and other differences in early experience will lead to a more complete characterization of the developmental timecourse of language subsystems and effects of environmental factors on this development.

Implications for Parents, Services and Policy

This basic research can drive the development of evidence-based policies and services which improve language and other cognitive skills important for academic achievement.e.g.,[11,12,33] Such research can also provide specific, evidence-based suggestions for parents. This is the focus of a non-profit video program produced by the University of Oregon Brain Development Lab (changingbrains.org).

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