



Biological Bases of Language Development

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Topic

Language development and literacy

Introduction

Recent 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. 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.

Subject

An understanding of the neurobiology of language development has important implications for those seeking to optimize language development. Insights from this research have the potential to provide practical, evidence-based advice for parents. In addition, evidence from this research can help educators and policymakers identify, develop and adopt evidence-based language and literacy curricula for both first and second language learners.

Problems

The rates of language development vary substantially among children, and this variability is a product of a complex interaction between genetic and environmental factors. This research seeks in part to characterize the relative contributions of genetic and environmental factors to these differences in development. While much behavioral evidence exists concerning the effects of environmental factors on language development, less evidence exists on the effects of environmental factors on the neurobiology of language development. Most previous research on the neurobiology of language in adults as well as on the neurobiology of language development has focused on middle to higher socioeconomic status (SES) individuals. Additionally, little evidence currently exists which specifically addresses the contribution of genetic and *epigenetic* factors to these differences in development.

Research context

Much evidence exists on the neurobiology of language in higher SES adults using 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*). These techniques have also been used to investigate the neurobiological bases of language development, though less evidence exists on the effects of environmental factors on the neurobiology of language development. Based in large part on a substantial body of evidence from behavioral studies of language development, research on the neurobiology of language development is now expanding in scope to include children (and adults) from a wider range of SES backgrounds.

Key Research Questions

One key research question involves the use of neuroimaging techniques to characterize the timecourse of the development of *neural substrates* which subserve different subsystems of language. A related key question involves the use of these techniques to characterize the effects of environmental and genetic factors, and the interaction between the two, on the development of these neural substrates. An important aspect of this question is the investigation of the time periods during which the effects of environmental and genetic factors are maximal (i.e., sensitive periods) and how these periods differ between different subsystems of language.

Recent Research Results

Studies of the development of the neurobiological bases of language have provided evidence on the developmental timecourses of three linguistic subsystems, specifically phonology (sound system of the language), semantics (vocabulary and word meanings), and syntax (grammar). This research also provides evidence that brain responses to language at early ages are predictive of later language proficiency. Most of this evidence comes from studies using ERPs, which is better suited for use with children as young as infants, although neuroimaging methods such as fMRI are increasingly being used with younger populations.

Numerous behavioral studies have found that 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 A recent study using ERPs demonstrated that 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 behavioral perception of these contrasts.² Furthermore, an increased neural response at 7.5 months predicted later language proficiency: 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.

The 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 has been shown to differ from that to unknown words, with this effect broadly distributed

over both the left and right cerebral 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

Two recent fMRI studies have found effects associated with environmental factors on brain areas important for the development of skills important for reading. The degree of specialization for rhyming in left frontal brain areas was found to correlate with SES in 5-year-olds.⁵ In another study of 5-year-olds, a more adult-like brain response to letter processing was observed in typically developing children during the first year of reading instruction, while this response was delayed in children at risk for reading difficulty; however, after three months of kindergarten and, for at-risk children, supplemental reading instruction, both groups showed changes in the brain response toward a more adult-like pattern (Yamada Y, Stevens C, Neville H, unpublished data, 2009).

Numerous ERP sentence processing studies of adults have shown that semantic and syntactic subsystems are processed by different brain systems⁶ and that this is true for spoken, written and signed languages which share these different subsystems.⁷ Studies of bilinguals of both spoken and signed languages show that these distinct subsystems display different degrees of plasticity with different sensitive periods.^{8,9} 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, highly specialized and efficient brain function is indexed by neural responses that originate from relatively specific or focal brain areas whereas such responses in children may be more widespread in the brain.¹⁰⁻¹⁶

The few ERP studies of sentence processing in children suggest that this specialization of different brain systems occurs early in development. Early studies found a brain response similar to that elicited by semantic violations in adults in children as young as five years of age,¹⁰ and showed that this response becomes faster and more specialized with age.^{11,12} This adult-like response to semantic violations has been reported in children as young as 19 months of age¹³ and this brain response predicted expressive language proficiency at 30 months of age. ERP responses to syntactic violations in children are qualitatively different than the response to semantic violations and similar, though slower and more widely distributed, to the response to syntactic violations found in adults.¹⁴⁻¹⁶ 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 and SES, with the syntactic subsystem more sensitive to such differences¹⁷ and childhood SES has been found to correlate with language proficiency and the neural response to syntactic violations in adults.¹⁸

Recent ERP research has also examined a cognitive system shown to be important for the development of language skills: the enhancement of the processing of auditory stimuli with selective attention to those stimuli. The ERP index of such enhanced processing is a larger brain response within one tenth of a second to auditory events when attended.

Moreover, this effect of attention is reduced in children diagnosed with specific language impairment¹⁹ and in typically developing children from lower SES environments.²⁰ 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.²¹ In addition, this brain response differs with variants of certain genes which are also sensitive to differences in language proficiency (Bell T, Voelker P, Braasch M, Neville HJ, unpublished data, 2009).²² However, these genetic differences also interact with and depend upon environmental factors (Dennis A, Bell T, Neville H, unpublished data, 2010). Ongoing research suggests that this cognitive system is also changeable in 3 to 5-year-old children from lower SES backgrounds with focused training programs for both parents and children (Fanning J, Sohlberg MM, Neville H., unpublished data, 2009).

Research Gaps

While research focusing on the effects of environmental factors on the neurobiology of language development is increasing, only few such studies have been published. 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 good language skills and to determine the age(s) at which they are most effective. At least two such studies are currently under review (Fanning J, Sohlberg MM, Neville H., unpublished data, 2009; Stevens C, Fanning J, Klein S, Neville H, unpublished data, 2009).

Conclusions

Modern neuroimaging techniques are powerful tools for investigating the effects of environmental, genetic and epigenetic factors on the neurobiology of language development. Research using these techniques with children from a wider range of SES backgrounds 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, such as evidence-based interventions which improve skills important for language and other areas of cognition which are important for academic achievement (Fanning J, Sohlberg MM, Neville H., unpublished data, 2009; Stevens C, Fanning J, Klein S, Neville H, unpublished data, 2009).²³⁻²⁴ Such research can also provide specific, evidence-based suggestions for parents. Indeed, this is the focus of a non-profit video program recently produced by the University of Oregon Brain Development Laboratory^a.

^a See the University of Oregon Brain Development Laboratory Website. Changing Brains. Available at: <http://changingbrains.org/>. Accessed March 10, 2010.

To learn more on this topic, consult the following sections of the Encyclopedia:

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- [Key messages](#)

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