BRAIN

Auditory Perception and Early Brain Development

Minna Huotilainen, PhD, Risto Näätänen, PhD

University of Helsinki, Finland

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Introduction

Auditory perception begins before birth.[1] During development, the human brain becomes a highly-specialized system for the perceptual, memory and semantic functions required for understanding and producing language and enjoying music. The milestones of this step-by-step development have their underpinnings in neural development and are strongly related to the auditory exposure and communicative actions in childhood.

Subject

Several skills for speech and music perception are present in the infant brain as early as birth.[2] Already the newborn brain can recognize familiar voices and tunes from the foetal period. Also, neonates learn new sounds quickly and pay a lot of attention to combining visual and auditory information. They are interested in matching what they hear with what they see. Soon they learn the correspondences between certain phonemes and their sounds, and the way lips, tongue and larynx move to produce them. Some speech and music perception skills have developed during the foetal period, whereas others are more “hard-wired.” During the first few years, auditory perception becomes so accurate and efficient that it allows the understanding of fast speech even in noisy conditions, the enjoyment of music and the fine-grained retrieval of information from environmental sounds.[3]

Problems

Without brain research methods, it would be very difficult to determine perceptual and memory skills in infants. Most research methods currently permit the use of only very simple behavioural paradigms comparing two short sound patterns, but research is moving towards more ecological paradigms. A major problem in using behavioural methods is that results depend not only on the perceptual and memory skills of the child but also his/her motivational and arousal state.

Research Context

The tradition in cognitive brain research is moving towards more ecologically valid research paradigms that use natural words and speech. *Event-related potentials (ERPs)*,[4] extracted from the *electroencephalogram (EEG)*, provide millisecond-accurate information on brain processes underlying auditory perception and memory functions (i.e., recognizing voices, phonemes, remembering sound patterns, finding similarities between sounds), whereas *functional magnetic resonance imaging (fMRI)*[5] provides a good spatial resolution on the areas involved in perceptual tasks in infants and children. The mismatch negativity (MMN),[6,7,8] especially when recorded in the new, efficient paradigms like the multi-feature paradigm,[9,10,11] is a key tool in the field of ERP research since it currently provides a measure of the perceptual accuracy for all most important acoustic parameters such as frequency, intensity, duration, temporal structure and sound-source location.[10,11] Furthermore, for speech sounds, parameters like vowel or consonant identity, pitch of speaking voice, among others, can also be studied.[11] In addition, this type of paradigm is currently being developed in order to determine the capabilities for perceiving different aspects of natural speech and musical sounds which can also be used in infants. If problems in speech perception are observed in infancy, some experimental training methods are available for strengthening the perceptive skills. In future, very early speech perception training methods may become part of the standard care of these infants.

Key Research Questions

What are the developmental milestones related to auditory perception and memory? What are the neural correspondents of these milestones? What is the role of auditory exposure in auditory development? Can the early auditory perception problems of a child that possibly lead to problems like dyslexia or delayed speech be observed with brain measurements? What are the countermeasures available when such problems are observed? Currently, research is focused on both understanding the underlying mechanisms of auditory perception in the infant brain and applying this information to understand speech perception problems in individual infants and children and to show results of different training methods.

Recent Research Results

Recent results from studies with healthy individuals revealed that the newborn brain is surprisingly skilled in detecting sounds, differences in sound features, even regularities in the auditory environment.[12] Recent results from applied studies show that there are clear deficiencies, in particular in the MMN response, already in newborns and in young infants when they are born prematurely,[13] have an elevated risk for dyslexia,[14] or have suffered from metabolic problems during pregnancy.[15] In some infants, the brain responses related to detecting changes in speech sound duration or change of phoneme are very weak or non-existent. This means that the automatic mechanisms detecting speech sound changes in a healthy infant brain are not functioning as usual, making the detection of speech sounds compromised.

Research Gaps

Currently, several ideas exist for the very early remediation of problems in speech perception and language acquisition. These methods often utilize passive learning (i.e., learning from tapes or from speaking toys etc.). We need scientific evidence as to whether and how these methods work and which of them would be most optimal.

Conclusions and Implications

The auditory system is under fast development in the foetal and neonatal brain. It is important to guide this development towards its natural direction. This is ensured by providing the infant and child with an auditory environment that is safe from strong or continuous noises and includes a lot of child-directed speech and music, especially singing. Background speech or music, for example from the television, has not been found to foster the linguistic development of a child; speech and music need to be directed to the child in a live situation and in a communicative manner. Even babies can engage themselves in communication. Babies are very fast learners. Communication between babies and older children is very effective for speech learning.

The auditory system is especially vulnerable after a premature birth. For these infants, a quiet environment with infant-directed speech and singing, paced according to the infant's individual schedule should be provided, if possible, even during the intensive care period.

Infants learn to produce phonemes by trial and error, by listening and looking at the speaker. For speech learning, it is important that the infant and the speaker are in eye contact. The duration of eye contact is determined by the child or infant and it depends on the infant's age starting from just a few seconds.

It is essential that children who have problems learning to speak, have a quiet background when listening to speech.

Shared attention is vital for speech learning. Adults should actively search for shared moments of attention with infants. When the infant is pointing at an object and the adult pronounces the name of the object a few times, the infant will learn the name very quickly.

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