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Article Type: Review Article

Received: 15/02/2021

Published: 24/02/2021

Open Access Journal of Biogeneric Science and Research
ISSN 2692-1081

DOI: 10.46718/JBGSR.2021.07.000177

# Development of Auditory Skills in Infants

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## Abstract

Speech development is mixture of nature and nurture. Speech and language are an essential part of any child's development. Language development impacts the child's social interactions, behavior and academic skills. The first signs of communication occur when an infant learns that a cry will bring food, comfort, and companionship. Infant's communication skills grow dramatically in their first year of life. They learn how to express themselves, respond to parents or caretakers and understand when they try to communicate with them. Early detection of speech delays requires knowledge of speech and language milestones and recognition of high-risk indicators for disorders. The primary aim of early intervention in children with hearing impairment is to restore or promote the child's communication skills and to optimize the level of language development which impacts the cognitive and socioemotional behavior. Hearing screening programs in newborns enable detection of hearing impairment in the first few days after birth. Early identification and intervention with hearing augmentation within six months of age yields optimal effect. If undetected and without treatment, significant hearing impairment may negatively impact speech development and lead to disorders in psychological and mental behaviors. Infants who fail in hearing screening at hospital are referred for a repeat testing between two and eight weeks after discharge (second stage) and are examined by means of Oto acoustic emissions (OAE) followed by Automated Auditory Brainstem Response (ABR). Positive second stage results should be validated by otologic and audiological consultation. Comprehensive electrophysiological assessment includes diagnostic ABR testing and Auditory steady state response (ASSR) which are performed by audiologist. Finally, infants who are identified with a hearing loss should receive appropriate early-stage intervention very soon after the final diagnosis is made and before six months of age. (287 words).

**Keywords:**Auditory; Assessment; Audiometry; Auditory Brainstem Response (ABR); Otoacoustic Emissions (OAE)

## Introduction

One of the most amazing and important accomplishments of infancy and early childhood is the development of language. Babies start to use their first words around one year of age. And by 4 years, they know more than 1,500 words and begin telling stories. Language skills developed during the preschool years serve as a wonderful foundation for learning in school. Children with solid language skills often become strong readers and writers. When a baby is born deaf, the process of developing language can be delayed. Such delays can be prevented or reduced through early intervention. Family members can encourage a baby's language by listening, singing and speech during natural daily routines.

At birth, a baby's hearing is fully functioning. Children do respond differently at different stages of growth and development. But hearing problems may be suspected in children who are not responding to sounds, or in children who are not developing their language skills appropriately. It is important to remember that not every child is the same. Children reach milestones at different ages. All auditory mechanisms seem ready at 6 to 7 months of gestation Clinical observations suggest that some very premature infants born at 25 weeks react to sound. Support for these observations comes from high-resolution ultrasound imaging. Birnholz and Benacerraf [1] studied response to vibroacoustic stimuli in human fetuses by ultrasound. Blink responses were first detectable between 24 to 25 weeks and were consistent at 25 weeks gestation.

## Pathophysiology

The most basic auditory function is the ability to detect acoustic energy; how well it is done is described as sensitivity. Among the electrophysiologic techniques to study sensitivity in infants, the most often utilized has been auditory brainstem response (ABR) audiometry. ABR results have shown that babies' thresholds for clicks are about

17 dB higher than those of adults [2,3]. The latency of the infant's brainstem response decreases from before birth until the second year of life. This decreasing latency reflects a maturing auditory system, attributed to the process of myelination [4].

It must be kept in mind, however, that the ABR is a neural response and that ABR testing is a measure of synchronous neural discharge. A synchronous neural response is not to be equated with hearing or with the ability of an organism to make meaningful interpretations about its acoustic environment [5], a capacity without which a child cannot acquire auditory language. Visual reinforcement audiometry (VRA) has been tremendously successful with most babies above about 5 months of age. Using VRA, showed that infants 6 to 12- months of age have quite low sensitivity thresholds. They plotted sound field thresholds of 15 to 20 dB intensity at frequency of 500, 1000, and 4000 Hz for infants of 6 to 12 months of age.

In addition to detecting soft sound, infants can localize sound. While all sound processing may have survival value, localization is probably one of the more basic auditory abilities. Hearing is a distance sense; thus, the ability to detect a sound is even more helpful when an individual can tell where the sound is coming from (Consider : hunting / escape).As with most auditory abilities, resolution of auditory space improves with age. Improvement in localization accuracy among infants occurs first in the horizontal plane and then in the vertical plane. Newborns make head turns to the right or left of midline in an orienting response to sound [6].

## Phonetics

It seems a universal belief that incredibly young babies recognize and prefer their own mother's voice. Data support this popular belief. Neonates no older than 3 days have been taught that if they produced a particular sucking pattern, they could listen to their own mother's voice. Even when the criterion to hear one's mother's voice was reversed, the neonates still "worked" to hear their mother's voice rather than the voices of the other mothers [7]. Moreover, newborns can distinguish between their mother speaking in her native tongue versus speaking in an unfamiliar language, even when the signals have been low pass filtered [8]. Perhaps babies are sensitized prenatally to respond to their mother's voice [7].

Languages have categories of speech sounds called phonemes. The ability to perceive speech sounds as belonging to categories denotes the ability to detect a difference between stimuli, even if varying in only one dimension [9]. An example is noting the difference in VOT (Voice Onset Time) that distinguishes /p/ from /b/. Numerous studies since the early 1970s demonstrate that infants group speech sounds into phonetic categories in adult-like fashion [9]. A baby's first words are music to a parent's ears. While every child learns to speak at his or her own pace, general milestones can serve as a guide to normal speech and language development. These milestones help doctors and other health care providers determine when a child might need extra help (Figure 1).

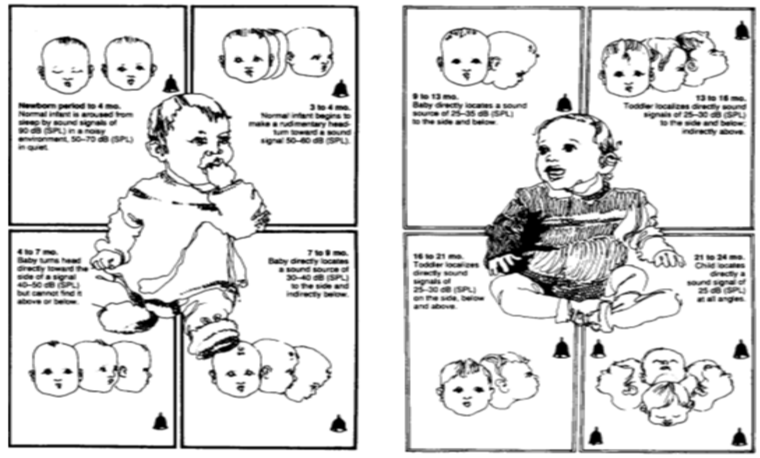


*Figure 1: Illustrations of typical developmental of sound localization in infacts. Left panel shows infact responses from newborn to 9 months. Right panel shows infact responses from 9 to 24 months. (Adapted with permission from northern and downs, 1991).*

## Milestones

**By the End of 3 Months**

1. Smile when a familiar person appears
2. Make cooing sounds
3. Quiet or smile when spoken to
4. Seem to recognize voices
5. Cry differently for different needs.

**By the End of 6 Months**

1. Make gurgling sounds when playing or left alone
2. Babble and make a variety of sounds
3. Use his or her voice to express pleasure and displeasure
4. Move his or her eyes in the direction of sounds
5. Respond to changes in the tone of voices
6. Notice that some toys make sounds

7. Pay attention to music

**By the End of 12 Months**

1. Try to imitate speech sounds

2. Say a few words, such as "dada," "mama" and "uh-oh"

3. Understand simple instructions, such as "Come here"

4. Recognize words for common items, such as "cup"

5. Turn and look in the direction of sounds

**By the End of 18 Months**

1. Recognize names of familiar people, objects, and body parts

2. Follow simple directions accompanied by gestures

3. Say as many as 10 words

**By the End of 24 Months**

1. Use simple phrases, such as "more milk"

2. Ask one- to two-word questions, such as "Goodbye-bye?"

3. Follow simple commands and understand simple questions

4. Speak about 50 or more words

5. Speak well enough to be understood at least half the time by parents and other primary caregivers

## Hearing Screening Tests for Newborns

It is estimated that serious hearing loss occurs in about 2 to 3 of every 1,000 newborns. Without screening or testing, hearing loss may not be noticed until the baby is more than 1 year old. If hearing loss is not found until later years, the brain's hearing centers will not be properly stimulated. This can affect hearing development and can delay speech and language. Social and emotional development along with performance in school may also be affected.

Most hearing loss is present at birth (congenital). But some babies develop hearing loss after they are born. Hearing loss is more likely in:

1. Babies who are born early (premature)

2. Babies with infections

3. Babies with respiratory problems requiring long-term use of breathing machines and certain medicines

Because of these risks, many health organizations now recommend universal infant hearing screening. Today nearly all newborns are screened for hearing loss. This allows earlier treatment to prevent delays in language and development. [10 -11].

## Types of Testing

There are 2 types of hearing screening for newborns. They may be done before babies leave the hospital but should be done before the baby is 1 month old. These may be used alone or together:

**Auditory brainstem response (ABR) (Figure 2)**

Previously, popularly known as Brainstem Evoked Response Audiometry (BSERA). This test uses wires (electrodes) attached with adhesive to the baby's scalp. While the baby sleeps, clicking sounds are made through tiny earphones in the baby's ears. The test measures the brain's activity in response to the sounds. This is a painless test and takes only a few minutes. If the screening test shows a possible hearing loss, more testing is needed. All babies who do not pass the screening test should be checked by a hearing specialist (audiologist) by the age of 3 months. Treatment for hearing loss should start before the baby is 6 months old, as it is an important time for speech and language development. BERA is an effective and non-invasive means of assessing the functional status of the

*Figure 2: Auditory brainstem response (ABR)*



***DOI:*** *10.46718/JBGSR.2021.07.000177*

auditory nerve and brainstem auditory sensory pathway. It is not significantly altered by the state of consciousness, drugs, and variety of environmental factors [12-14].

**Neural Generators of the Bera:** BERA is generated by the auditory nerve and subsequent structures within the auditory brainstem pathways. Information regarding the origin of individual wave components of BERA was provided by Moller and Janetta.

Following waves are generated during this test

**Wave I:** It represents from the compound action potential in the distal portion of cranial nerve VIII.

**Wave II:** generated by the proximal VIII nerve as it enters the brainstem.

**Wave III:** Generated mainly in the cochlear nucleus (second order neuron).

**Wave IV:** It arises from pontine third order neuron. Mainly located in superior olivary nucleus, but additional contributions may come from cochlear nucleus and nucleus of lateral lemniscus.

**Wave V:** Generation of wave V reflects activity of multiple anatomic auditory structures. Sharp positive peak of wave V arises mainly from the lateral lemniscus. Wave V is the component analyzed most often in the clinical application of the BERA.

**Wave VI and VII:** These waves appear to be generated in the inferior colliculus, perhaps in the medial geniculate body (Figure 3).

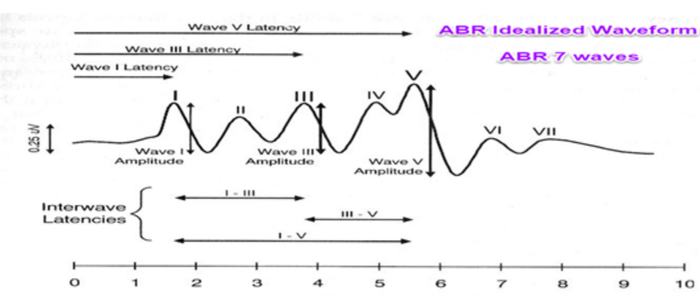


*Figure 3*

**Evoked otoacoustic emissions (EOAE) (Figure 4)**

This test uses a tiny, flexible plug that is inserted into the baby's ear. Sounds are sent through the plug. A microphone in the plug records the responses (otoacoustic emissions) of the normal ear in reaction to the sounds. There are no emissions in a baby with hearing loss. This test is also painless and is often done in a few minutes while the baby is asleep.Otoacoustic emissions (OAEs) are sounds of cochlear

*Figure 4: Evoked otoacoustic emissions (EOAE).*

origin, which can be recorded by a microphone fitted into the ear canal. They are caused by the motion of the cochlea's sensory hair cells as they energetically respond to auditory stimulation. OAE or otoacoustic emission testing is the recording of sounds that the ear produces itself. They appear to be generated by motile cochlear outer hair cells (Figure 5).

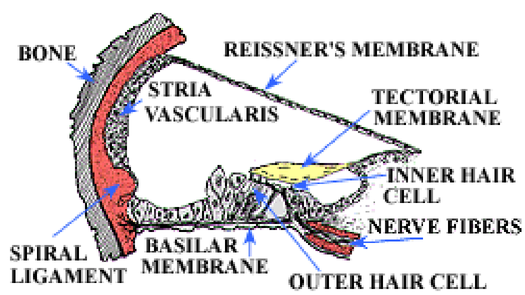


*Figure 5: Anatomy of the Inner Ear.*

There are 2 types of otoacoustic emissions in clinical use: Transient otoacoustic emissions (TOAEs) or transient evoked otoacoustic emissions (TEOAEs) - Sounds emitted in response to an acoustic stimulus of noticeably short duration; usually clicks but can be tone-bursts. Distortion product otoacoustic emissions (DPOAEs) - Sounds emitted in response to 2 simultaneous tones of different frequencies. Any small defect in the peripheral auditory system (middle and inner ear) which can cause even a mild to moderate deafness with make the OAE undetectable. The click evoked



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OAEs re recordable if the hearing is normal that is, within 30dBHL. If the hearing threshold is above 35-40dB, the TOAEs cannot obtained at all.

**Visual Reinforcement Audiometry (VRA) (Figure 6)**

Visual reinforcement audiometry (VRA) is a test that allows an audiologist to assess hearing in infants and toddlers too young for normal tests. VRA relies on behavioral conditioning to train incredibly young kids to respond to sounds. It is designed for children aged between six months to three years. VRA uses both audiometer and visual reinforcers to test a child's hearing threshold levels. Standard pure tone audiometers use headphones and a feedback button, so they are not practical for infants. VRA replaces the headphones with earphones (usually with foam tips) or free field speakers. Visual reinforcers such as video animations or lighted toys are placed 90 degrees to each side of the patient to "train" the child to look toward the direction of the sound.

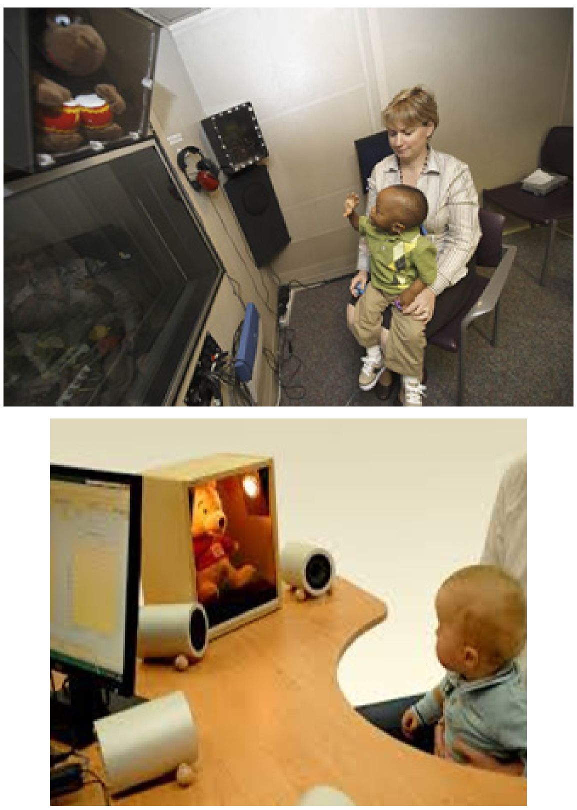

*Figure 6: Visual Reinforcement Audiometry (VRA).*

While the child sits upright on a parent or caregiver's lap in a soundproof room, the audiologist plays a tone or some other sound to one of the child's ears. At first, the audiologist lights up the boxes in conjunction with the sound. This "trains" the child to respond by shifting her eyes or turning her head toward the sound source. Once a child understands what to do, the audiologist can "reward" the child by briefly delaying the visual stimuli. Visual reinforcement audiometry (VRA) is a test that allows an audiologist to assess hearing in infants and toddlers too young for normal tests. VRA relies on behavioral condoning to train very young kids to respond to sounds. It is designed for children aged between six months to three years. VRA uses both audiometer and visual reinforcers to test a child's hearing threshold levels. Standard pure tone audiometers use headphones and a feedback bu>on, so they are not practcal for infants. VRA replaces the headphones with earphones (usually with foam $ps) or free ⍰eld speakers. Visual reinforcers such as video anima$ons or lighted toys are placed 90 degrees to each side of the pa$ent to "train" the child to look toward the direction of the sound.

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This instrument is s handheld infant screening audiometer with a light can be used for VRA. The instrument can deliver sounds at different intensities and frequencies. The instrument is calibrated in way that when it is held at 1 meter from the infant's ear, they hear the sound at intensities marked in the attenuator dial of the instrument. They are particularly good clinical tools in the clinic, but in all cases of suspected hearing loss, it is prudent to confirm the findings in the clinical tests by objective tests like BERA and ASSR (Auditory Steady State Response). During the test, the audiologist reduces the intensity of both the sound and the stimuli until the child's minimum hearing threshold is reached. Tests continue using different frequencies until the audiologist has a complete set of data about the child's hearing in both ears (Figure 7).

*Figure 7*

**Auditory Steady State Response (ASSR) (Figure 8)**

This is an auditory evoked potential test that can be used to objectively predict frequency specific hearing threshold in all patients irrespective of age, mental state, and degree of hearing loss. It can estimate the hearing threshold at 500,1000,2000 and 4000Hz, objectively. It is different from tests like BERA, middle latency response (MLR) and late latency response (LLR) and overcomes some of the inherent limitations of these tests (Table 1).

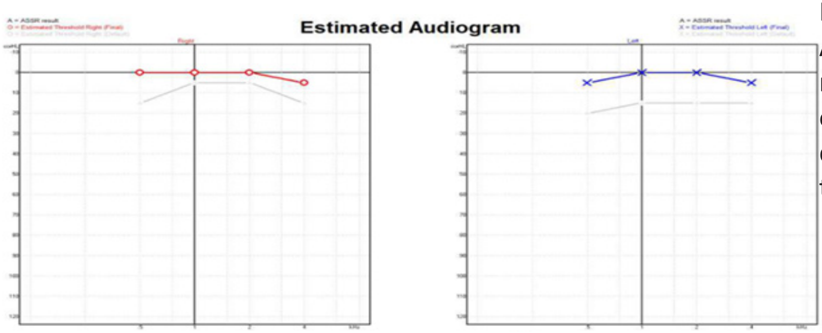


*Figure 8: Estimated Audiogram derived from ASSR.*

## Conclusion

This article has provided the knowledge about the development of auditory skills in infants and necessity of hearing assessment in them. Newborn screening and diagnosis help ensure all babies who are deaf or hard of hearing are identified as soon as possible. Then, they can receive early intervention that can make a big difference in their communication and language development. Proper

*Table 1: Differences between ASSR and BERA.*

| | ASSR | BERA |
|---|---|---|
| 1 | Continuous stimuli at high repetition rate | Single stimulus |
| 2 | Objective, sophisticated, statistics-based mathematical detection algorithm to detect and define hearing thresholds | Detection of the response is done manually |
| 3 | Amplitude and phases in spectral (frequency) domain is done | Amplitude, latency, peak detection done in time domain |
| 4 | Multiple frequencies and both ears together can be tested | Single frequency and one ear at a time to be tested |
| 5 | Can test severe to profound hearing loss and specify the hearing level in this category | Can test up to severe hearing loss; cannot specify exact hearing threshold above 80dBnHL hearing loss |

assessment of all infants with hearing loss especially if it appears to be congenital requires a well-integrated multidisciplinary approach that includes genetic evaluation as well. The earlier a child is diagnosed, better is the result of remedial measures. Best results are obtained if the remedial measures are undertaken before the child reaches six months of age. Problem is that for hearing assessment in infants, no single test is foolproof and adequate to completely evaluate the hearing faculty in an infant. Cross checking is the rule and is a mandatory requirement. Different test both electrophysiological (like OAE/BERA/ASSR) and behavioral (like Free Field Audiometry/VRA) must be combined to confirm and re confirm the status of the auditory function. Public awareness about auditory development and assessment of hearing in infants will lead to enhancement and wellbeing of society.




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