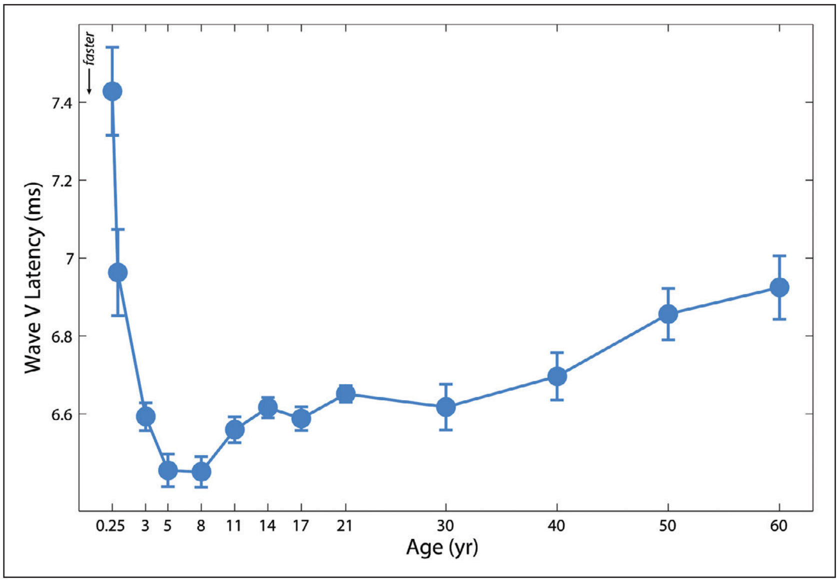
Auditory Brainstem Development: More than Meets the Ear

By Nina Kraus, PhD, & Travis White-Schwoch

Auditory development is a complex and protracted process. While the cochlea is mature at birth, and frequency resolution is mature by 6 months of age, temporal processing likely remains in flux until adolescence. Understanding this time course can aid in diagnosing listening difficulties that are often characterized as maturational delays and in tracking the development of children deprived of auditory experience.

One lesson from the textbooks is that the auditory brainstem is mature by about age 2, when auditory brainstem responses (ABRs) appear adultlike with respect to latency, amplitude, and morphology.

Given what we know about the complex development of auditory behaviors, however, we wondered if there was more to the story.



This figure shows the developmental trajectory of the auditory brainstem response (ABR) from infancy to senescence. For each age group, the average ABR wave V latency is plotted (error bars: ± 1 standard error). Following two years of rapid maturation, wave V latencies match those of adults before continuing to get faster for a few more years. (Adapted from *Cereb Cortex* 2013; doi: 10.1093/cercor/bht311.)

ABRs ACROSS THE LIFESPAN

Erika Skoe and colleagues addressed this question in a study of 586 listeners age 3 months to 72 years (***Cereb Cortex* 2013; doi: 10.1093/cercor/bht311**). The researchers collected ABRs to a suprathreshold click stimulus and compared wave V latencies across the lifespan. What emerged was indeed complex and protracted.

From birth to age 2, latencies got faster by nearly a millisecond. While the 2-year-old latencies certainly matched those of the adults, a remarkable pattern appeared that suggested an overshoot–from age 3 to 5, the latencies got even quicker before starting to peter out around age 8. Consistent with previous evidence, there was a gradual slowing of wave V latency after age 40 that continued into senescence.

These results demonstrated that auditory brainstem development was far more enduring and involved than previously thought.

In a follow-up study, Emily Spitzer and colleagues took a fine-grained lens to the preschool ABR (***J Am Acad Audiol* 2015;26[1]:30-35**). Using identical methodology, the researchers evaluated developmental changes between age 3 and 5 in 71 typically developing preschoolers.

Consistent with the lifespan comparison, they found a systematic pattern whereby wave V latencies got faster and faster as children got older.

ROLE OF AUDITORY EXPERIENCE

What mechanisms underlie this prolonged development? One potential cause is that myelination increases in the auditory pathway, speeding up neural conduction time. The faster latencies also could be due to a proliferation of synapses that are slowly pruned away as listeners enter puberty.

An alternate view considers the role of experience and top-down modulation of auditory processing. The auditory brainstem is subject to a massive series of corticofugal projections that refine its anatomy and physiology. Experience shapes auditory brain circuits through these top-down pathways, and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ABRs reflect the fine-tuning (***Nat Rev Neurosci*** **2010;11[8]: 599-605**).

Most of the research concerning auditory experience focuses on special populations, such as musicians or speakers of two languages, but nothing is as powerful as our daily experiences in and with sound. Think about how important it is to provide children access to sound to bootstrap language development.

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One line of evidence that ABR maturation could, in part, be experience dependent comes from studies of children with cochlear implants. Karen Gordon and colleagues investigated the electrically evoked ABR with respect to age at implantation. Latencies were shown to decrease as a function of auditory experience (***Ear Hear*** **2003;24[6]:485-500**).

Remarkably, interaural latency differences are observed in children who received bilateral cochlear implants at different times (***J Neurosci*** **2012;32[12]:4212-4223**).

That is, the side that was implanted earlier in life has faster latencies, even a year or two after getting a bilateral implant. This discrepancy is not observed in children who receive bilateral implants simultaneously.

Taken together, these studies demonstrate that auditory brainstem development is a nuanced process. Even as robust and reliable a measure as the ABR can undergo a neurodevelopmental push and pull. During childhood, the ABR may only be adultlike transiently before undergoing a second period of developmental flux.

These studies also show that auditory experience can be a major factor affecting these tried-and-true metrics. Thus, when interpreting ABRs, we need to keep in mind the influences of both ongoing maturation and the listener's auditory experiences.

Of course, the click ABR is just the tip of the maturational iceberg. Neurophysiological responses to speech sounds provide far greater insight into auditory processing, its development, and the role of experience, especially because there are so many more aspects of the responses than a few peak latencies, and each has its own distinct course of maturation. Stay tuned!