

Listening Is Where Hearing Meets Brain...in Children and Adults

Research continues to find close links for cognition and hearing

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Hearing is a sense; listening is a skill. Listening can be thought of as applying meaning to sound: allowing the brain to organize, establish vocabulary, develop receptive and expressive language, learn, and internalize concepts. Indeed, listening is where hearing meets brain. *Extraordinary listening* appears to be a uniquely human characteristic. This article demonstrates how “audition matters more as cognition declines, and cognition matters more as audition declines.”

Dogs have extraordinary hearing. The literature varies on the actual spectral response of canine hearing across breeds, but in general, it appears to be from about 50 Hz to 40,000 Hz. In practical terms, dogs hear roughly one octave more than humans—thus allowing dogs to hear annoying dog whistles, which most of us prefer not to hear anyway. However, despite their extraordinary hearing, dogs are not very good at *listening*. That is, even the smartest dogs respond to perhaps a dozen words. Dogs hear, but their cognitive abilities are essentially rate-limited, demonstrating that even extraordinary hearing in the absence of typical human listening ability doesn't get one very far!

Humans can also hear without listening. For example, people with compromised cognitive abilities (perhaps secondary to brain trauma, birth defects, disease processes, etc) who possess normal hearing can provide an auditory brainstem response (ABR), an auditory steady state response (ASSR), and often acoustic reflexes—despite the absence of cognitive function. The ABR and ASSR will generally correlate very nicely with their actual hearing ability (except in extraordinary cases such as auditory neuropathy spectrum disorders, etc), despite reduced, absent, or compromised cognitive function.

However, when typical cognitive abilities are engaged, humans with normal cognitive and normal hearing ability are remarkable at processing the tiniest bits of barely perceptible acoustic information into meaningful percepts, concepts, ideas,

thoughts, and more. Indeed, *listening* can be thought of as applying meaning to sound, allowing the brain to organize, establish vocabulary, develop receptive and expressive language, learn, internalize, and indeed ... *listening is where hearing meets brain*. Extraordinary listening (much like language) is uniquely human.

Hearing Is a Sense, Listening Is a Skill

For hearing care professionals, our fundamental concern has historically been hearing. Of course, that makes perfect sense, and is rational and defensible. Indeed, if one cannot hear the vast multiplicity of sounds from which speech is derived, one cannot listen.

However, the core reason we endeavor to help people hear is to help people listen successfully, through the appropriate use of advanced hearing access technologies, such as hearing aids, FM systems, bone-anchored hearing systems, cochlear implants, brainstem implants, assistive listening devices, aural rehabilitation, alternative listening strategies, etc. All of these strategies center on the ability to make cognitive sense of sound. If the patient cannot listen better, or if they remain unable to apply appropriate meaning to the cornucopia of sounds around them, they're not likely to fully appreciate our efforts on their behalf.

The goal is not simply making sounds louder; the goal is improved (and hopefully successful) listening.

Attention, Listening, and Cognition

Hearing is essentially a sensory-based passive process. Presuming one has normal hearing, it takes no effort to hear; hearing occurs all the time and hearing cannot be switched off. Hearing occurs at every moment of every day.

Listening is an active process; it requires attending and paying attention to things that are of interest to us, while dismissing



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things of less interest. Paying attention has everything to do with listening and cognition. Indeed, psychologist David Strayer, PhD, recently noted that “Attention is the Holy Grail,”¹ while Beck² reported “multi-tasking” is actually the “division of attention” and “where you attend is how you will do.”³

Multi-tasking involves dividing a finite “attention reserve” into smaller pieces. Beck⁴ reported on the National Highway Traffic Safety Administration (2009) analysis showing that 80% of all crashes involve “driver distraction” within 3 seconds of the crash, and the number-one distraction is (as anticipated) cell phone use (ie, multi-tasking while driving). Ashcraft and Klein⁵ report attention “implies withdrawal from some things in order to deal effectively with others.” They note attention is a process that involves a *finite commodity*.

Attention directs the cognitive system to focus effort on an external or internal matter of interest. Lunner, Rudner and Ronnberg⁶ indicated individual cognitive processing resources and ability may significantly impact “listening success.” Craik⁷ reported that, even after audibility is restored via amplification, outcomes are generally dependent on the allocation of attentional processes.

For people with cognitive decline, their ability to attend to particular speech stimuli is reduced or impaired, or may be non-existent, often leading to incorrect or erroneous conclusions about spoken words, meaning, and intention. When factors such as cognitive decline are combined with hearing loss, the outcome is worse than the additive sum of the two individual factors. The multiplication of antagonistic factors is referred to as “negative synergy.”⁸ Beck and Clark⁹ noted the relationship between audition and cognition is interdependent and symbiotic, stating “audition matters more as cognition declines, and cognition matters more as audition declines.”

Although hearing care professionals can make sounds louder and more accessible for people with elevated hearing thresholds, we cannot actually *change* someone’s hearing ability. That is, we can supplement hearing through excellent and judicious use of hearing access technologies (hearing aids, FM systems, bone-anchored hearing systems, cochlear implants, brain-stem implants, assistive listening devices, and more) and listening strategies. However, biologically driven hearing ability remains

essentially the same and returns to the “impaired” status once the sophisticated tools are removed.

Improved listening skills remain useful as long as they are intentionally engaged. Listening is a cognitive skill built on learned behaviors and rewards. Psychologists have demonstrated that when people think about the meaning of new information, they’re much more likely to assimilate, learn, and remember more of it than is possible via rote memory or when only the physical properties of the same new information are processed. The cognitive process of elaborating on the meaning of new information is the very best learning strategy, and processing a new stimulus improves memory only when processing connects the new information to existing relevant knowledge.¹⁰ Therefore, listening skills (such as applying context and deriving meaning and analysis with respect to previously acquired knowledge) will likely enhance successful listening.

All of this clearly argues for proactive aural rehabilitation—learning to listen using a strategic approach—to enhance the acoustic environment and to apply active cognitive processes to the sounds perceived.

Bottom-Up and Top-Down

Therefore, as hearing care professionals, we’re concerned with two complementary systems: specifically, bottom-up (ie, sensory) and top-down (ie, cognitive) processes. Bottom-up processes are sensory input avenues, such as hearing and vision, tactile, smell, and taste. The goal of sensory systems is to perceive many of the physical cues around us and allow our central nervous systems to recognize and organize these cues to make sense of the world around us.

As humans, we are far from perfect in perceiving physical cues around us. For example, we cannot hear high frequencies beyond 20,000 Hz, we cannot see infrared light, and we cannot sense radiation, although these cues are all around us. Of course, with regard to hearing aid and other amplification systems, hearing care professionals directly supplement the bottom-up system.

Top-down processing depends on our cognitive abilities, the things we know about ourselves (ie, our cognitive self) and the world around us, our store of knowledge, our ability to draw upon working

(ie, short-term) and long-term memory (at will) to enhance and supplement our knowledge and to better understand things occurring at every moment in time.

Just as hearing without cognition produces only limited information, bottom-up processing without appropriate top-down processing, and top-down processing of incomplete bottom-up information, is inefficient and highly erroneous.

Pediatric Brains and Cognitive Issues

In essence, we “hear” with the brain—the ears are simply the conduit through which sound travels to access the brain. In that respect, hearing loss and poor acoustic environments prevent sound from reaching the brain. Indeed, favorable acoustic environments—like those with excellent signal-to-noise ratios (SNR) and complete speech audibility, with low or no reverberation—combined with excellent hearing access technologies (see above) enhance acoustic saliency by channeling and delivering complete words efficiently and effectively to the brain. When these processes happen “on schedule” with regard to typical milestone timelines, and when they happen “relatively early” (that is, when children with hearing loss are identified and treated in accordance with Joint Committee on Infant Hearing [JCIH] guidelines¹¹), the significant educational, social, and psychological secondary negative effects of hearing loss (eg, language, reading, and academic difficulties) can be ameliorated.

Children are unable to listen like adults. Simply stated, when normal-hearing adults listen to sounds, the sounds enter an already developed brain with intact language, vocabulary, cognition, and more. In comparison, even children with normal hearing have organic listening limitations in two primary ways:

- 1) The human auditory brain structure is not fully mature until approximately 15 years of age; thus, a child does not bring a complete neurological system to a listening situation.¹²
- 2) Children do not have language and life experience that enables them to “fill-in-the-gaps” of missed or inferred information (called *auditory/cognitive closure*). Children require more complete and detailed auditory information than adults. Indeed, as compared to normal-hearing adults, all children

need a quieter listening environment and a louder primary signal to create new neural maps and to develop their brains. Children who are hearing impaired need an additional SNR of +10 to +15 dB.¹³

Brain development research shows that sensory stimulation of the auditory centers of the brain is critically important and, indeed, influences the actual organization of auditory brain pathways.^{12,14,15} The fact is: the brain can only organize itself based on the bottom-up stimuli it receives. When complete acoustic events are received, the brain organizes itself accordingly. Conversely, when hearing loss filters speech sounds and prevents these same sounds from reaching auditory centers within the brain, the brain organizes itself differently. Additionally, when the brain centers do not realize full and typical auditory sensations, auditory areas may be reassigned to visual processing via neuroplasticity. As Doidge¹⁶ points out:

“When we want to remember (or learn) something we have heard, we must hear it clearly because memory can be only as clear as its original signal...muddy in, muddy out.”¹⁶

Incidental Learning and Distance Hearing

Incidental learning through “overhearing” occurs when children listen to speech not directly addressed to them, yet they learn from it. Amazingly, very young children learn approximately 90% of the information they acquire incidentally.

Of course, incidental learning can occur only if children have access to overhearing conversations that occur at a distance.¹⁷ Unfortunately, without appropriate technology, children with hearing loss (even “minimal” hearing loss) have reduced incidental learning potential because they cannot receive and perceive intelligible speech over distances, like those found in typical classrooms and homes. Reduced distance hearing poses substantial obstacles to classroom (and other) performance, because distance hearing is necessary for casual and incidental acquisition of expressive and receptive language. Therefore, for children with hearing loss, their distance hearing ability must be extended as much as possible through hearing access technologies to capture the “free” auditory information that constantly surrounds them.

Auditory Feedback Loop

The “auditory feedback loop” is the process of self-monitoring and correcting one’s own speech (output). Auditory feedback is of maximal importance for the attainment of auditory goals and to acquire and produce fluent speech.¹⁸ Specifically, children must be able to hear their own speech clearly to produce clear speech sounds. Improving the perceived SNR of the child’s own speech can boost the salience and accuracy of the speech signal.

How Much Practice Does It Take to Learn to Listen?

When skills are mastered as close as possible to the time of “intended biological pre-programming,” developmental synchrony occurs.¹⁹ Children are organically receptive to developing specific skills during certain times of development. Further, the brain requires many practice opportunities to develop appropriate, intentional, and accurate neural connections through repeated exposure.^{20,21} “Experience dependent plasticity” is a critical concept meaning repeated auditory stimulation leads to stronger neural connections.²²

The amount of practice required to continually wire and re-wire the brain for higher-order language skills and the acquisition of knowledge is enormous. Gladwell,²³ Levitin,²⁴ and others report 10,000 hours of practice is needed to become an expert in a particular skill. Hart and Risley²⁵ report that, by the age of 4 years, typical children need to have heard 46 million words to be ready for school. Dehaene²⁶ reports 20,000 hours of listening are necessary in infancy and early childhood as a basis for reading.

Summary

Hearing and *listening* are quite different. Hearing is essentially a passive bottom-up driven process; listening is a top-down process that requires attention, many repetitions of stimuli, and tremendous cognitive coordination and effort. Hearing is a sense and listening is a learned skill. Listening experiences in infancy are the foundation upon which language and literacy and cognitive and psychological development occur.

For cognitively healthy adults with hearing loss, we are less concerned with their top-down processing, as they already have intact language and cognitive skills. Thus, hearing care professionals generally provide rather straightforward hearing

access technologies to make sounds more accessible for these individuals.

However, for all children and for those adults with hearing loss and cognitive decline, it is of paramount importance to address the cognitive needs of the individual—in addition to hearing access technologies. Their knowledge of language and their listening and language skills may be absent or impaired, and learning to attend to and listen to the sounds heard is crucial.

One extraordinary closing thought to ponder is this: in 2011, when the decision has been made (by the parents, caregiver, etc) to provide hearing (auditory access to the brain) to a child who is deaf or hard of hearing, virtually *any* child with *any* degree of hearing loss can receive sound through one or more modern and advanced hearing access technologies. ■

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