
2 Hearing Is the Foundation of Listening— and Listening Is the Foundation of Learning

Douglas L. Beck and Carol Flexer

◆ Introduction

Known and Unknown: A Memoir is the title of a new book by Donald Rumsfeld (2011). Politics aside, the premise of the title is that there are things we know, there are things we don't know but that we are aware of, and—digging deeper—there are important things that, frankly, we don't know and we are not aware of. Rumsfeld refers to these three categories (respectively) as “known knows,” “known unknowns” and “unknown unknowns.” In communication disorders (admittedly a universe somewhat distant from politics) these three categories are also of importance.

For example, we know we are very likely accurate when we discuss tympanograms, auditory brainstem response (ABR), acoustic reflexes, and otoacoustic emissions (OAEs). In Rumsfeld's terms, these clear and objective measures of auditory phenomena, grounded more or less in indisputable facts, might be considered “known knows.” Of course, there are things we don't necessarily know with respect to each child or adult, yet we are aware of their importance. Such “known unknowns” might include ear canal resonance, outer and inner hair cell population integrity, possibly speech-in-noise ability, and perhaps how closely a specific hearing aid fitting approximates the real-ear “target.” Taking the analogy to completion within the communication disorders universe, “unknown unknowns” might include processing speed, auditory processing disorders, listening skills, working memory, and attention—all of which significantly impact the child's listening ability and ultimately the child's learning ability.

The purpose of this chapter is to discuss the neurological and experiential basis of hearing, listening, and learning as impacted by acoustic accessibility in children and adults.

◆ Hearing and Listening

Audiologists generally measure hearing. Specifically, audiologists tend to measure “objective” and sensory-based percepts of pure tones, beeps, clicks, words, phonemes, and more. These test protocols effectively approximate human hearing acuity and help reveal the gross status of the peripheral auditory nervous system with respect to the stimuli used. However, and significantly, these measures do not reflect our formative ability to listen.

Frankly, there is much more to listening than hearing. For humans, the ability to listen is one of the many cognitive processes that separates us from all other animals, including those whose hearing is superior to that of humans. Indeed, “listening is where hearing meets brain” (Beck & Flexer, 2011). Beck and Flexer (2011) noted that dogs have much better hearing (perhaps 50 to 40,000 Hz) than humans (generally stated as 20 to 20,000 Hz). If cognition and learning were actually based on hearing, dogs (and cats, dolphins, whales, and many other animals) would be way above humans on the food chain. They are not. Dogs hear better than we do, but they cannot actually listen. For example, some dogs work tirelessly for years and years to learn to obey the command “sit.” Their performance really is not about hearing; their performance is all about listening. (And don’t get us started on cats.) Specifically, although hearing is the means through which sound reaches the brain, listening is what separates people from all other beings.

Humans with normal hearing and normal cognitive ability learn to listen. That is, humans apply meaning, context, concepts, ideas, thoughts, and more to spoken (and written) words to communicate and share ideas and concepts and to travel backward and forward across time and space. Our words and listening skills allow us to describe things beyond the here and now. We can describe things we have never seen, and we can even describe sounds we have never heard.

The task of normally functioning ears and hearing systems is to transmit acoustic information to the brain. However, hearing is a sense and hearing is passive. Listening is a learned skill and listening is active. At the moment speech sounds are perceived by the brain, listening occurs, and the skills of the listener are of significant importance. When hearing meets brain, “listening” occurs (Beck & Flexer, 2011); that is, we hear with our brains! Unfortunately (or perhaps fortunately), measuring the sensory capacity of a particular person to hear sounds (as represented on an audiogram) is just a small fraction of what matters (i.e., listening). Active

listening is very much the same thing as “paying attention,” and paying attention (and the ability to pay attention) is of critical importance with regard to listening and cognition.

◆ Auditory Processing Disorders

Quite simply, the whole concept of auditory processing disorders in children (and in adults too) remains highly controversial. The exact relationship between hearing, listening, auditory processing, auditory processing disorders (APD), attention, working memory and learning remains elusive. In fact, Kamhi (2011) wrote that APD “is best viewed as a processing deficit that may occur with various developmental disorders” (p. 270). Moore (2011) stated that the problem and the solution in relation to APD may well revolve around auditory cognition—with an emphasis on working memory and attention. Indeed, Moore and colleagues reasoned that when a child performs poorly on a traditional APD test, one should expect the child to demonstrate impaired listening ability. However, APD testing relies on cognitive and sensory abilities, and Moore states that the most common reason children present with poor listening skills appears to be impaired memory and attention-related issues. Although Lucker (2007) noted, “To date, we have not reached a consensus as to how we define, describe, evaluate and manage children with APD problems,” more recently Moore, Cowan, Riley, Edmondson-Jones, and Ferguson (2011) reported a general lack of scientific rigor and testable hypotheses with regard to APD tests and a “bewildering array of tests, the majority of which lack any scientific basis or clearly defined clinical utility.”

◆ Paying Attention

Richtel (2010) reported Strayer’s observation that “attention is the Holy Grail.” In response, Beck (2010) commented, “Where you attend is how you will do.” Attention is finite. Indeed, when one divides one’s attention, that is, multi-tasks, neither task is performed maximally. This is particularly true with regard to cognitively demanding tasks such as driving an automobile and simultaneously texting! Recently, the National Highway Traffic Safety Administration (NHTSA, 2005) reported that 80 percent of all car crashes involve a driver distraction within three seconds of the crash.

Ashcraft and Klein (2011) recently stated that “attention is a process that involves a finite commodity.” Craik (2007) reported that outcomes with respect to hearing aid amplification are generally dependent on the allocation of attentional processes. Again, where you pay attention “is how you will do.”

◆ Working Memory

Working memory is more or less what we used to refer to as “short term memory . . . typically no longer than 30 seconds.” The term “short term memory” has been judged essentially inadequate with regard to defining its role in cognition and has been replaced (for more than a decade) with the term “working memory” (WM). WM allows us just enough time to rehearse the material or perform some other mental operations on the material. Boudreau and Costanza-Smith (2011) note WM impacts a vast quantity of cognitive processes, including learning rate for new vocabulary, language comprehension, literacy skills, reasoning, and problem solving, as well as overall academic success. Further, they state that WM controls attention and information processing.

◆ Bottom-up and Top-down Systems

Many of these issues (and related ones) have been discussed in the audiology and hearing aid literature using the terms “bottom-up” (to represent sensory information transmitted from the peripheral auditory nervous system to the brain) and “top-down” (to represent how the brain interprets the perceived acoustic information). Beck and Clark (2009) stated that when bottom-up and top-down systems function optimally, “precise and extraordinary meaning” is extracted from the “cacophony of sounds” in the acoustic environment—and this occurs virtually without effort. They report humans are unique in their ability to “apply cognitive processes (knowledge, memory, attention, and intelligence) to sensory input, to communicate, to learn, and to share thoughts and ideas.”

Madell (2009) reports that audiologic measures of physiological events (ABR, ASSR, OAEs) are highly correlated with hearing, but cautions that they are not direct measures of hearing and, further, that people (i.e., children) with hearing loss have damaged auditory systems. People with hearing loss cannot achieve maximal auditory competence without specific training and, of note, even

with appropriate amplification they need to learn to listen and to maximally use auditory information. Children taught to maximize their auditory skills develop significantly better speech and language skills than those who do not undergo auditory habilitation and rehabilitation (Osmond, 2011).

◆ **Aural Rehabilitation: Not Just for Kids**

When listeners have been trained to maximally employ the bottom-up (sensory-based) stimuli available to them, extraordinary things have occurred.

Gordon-Salant and Friedman (2011) reported a particularly illustrative example with regard to 10 older blind adults, 60 through 80 years of age, compared with two groups of 10 normally sighted younger (ages 18 through 30 years) and older (ages 60 through 80 years) adults. Using 40 to 60 percent time-compressed speech as a rather challenging listening task, the authors reported the blind adults recognized time-compressed speech better than their age-matched peers, and indeed, the blind adults performed similarly to the much younger, sighted adults. Of note, 8 of the 10 blind adult participants had trained themselves via time-compressed “books on tape” recordings to maximize their listening skills through motivated, dedicated, and conscious practice. Specifically, hearing is a sense and listening is a skill—and skills can be taught to help compensate for sensory deficits (i.e., blindness) and to help improve listening (“where you attend is how you will do”).

Martin (2007) presented interesting observational data based on hundreds of patients fitted with hearing aids. One hundred and seventy-three of her hearing aid patients were given a software-based aural rehabilitation (AR) program (Listening and Communication Enhancement, LACE); 452 hearing aid patients were not given the software. In general, the LACE program requires a total time commitment of 10 hours over a 30-day period. Of the patients who underwent AR training, only 3.5 percent returned their hearing aids. Of those who had no AR training, 13.1 percent returned their hearing aids. Martin reports that statistical analysis revealed the only variable in the two groups was the AR training. One possible interpretation of these data is that patients trained in listening skills were better able to successfully employ hearing aids.

Stacey and colleagues (2010) reported on the effectiveness of a computer-based, self-administered AR training program for adult users of cochlear implants (CIs). Despite each of the 11 adults hav-

ing worn the CI for at least three years, after a total AR training period of only 15 hours a statistically significant increase in consonant perception was recorded.

Akeroyd (2008) reported that when facing acoustically challenging situations, such as hearing amid noise, adult listeners depend on previously acquired knowledge to “fill in the blanks.” Specifically, when hearing loss prevents the entire acoustic image from being perceived at the sensory level, by definition, a degraded auditory signal is transmitted to the brain. For adults with good to excellent cognitive abilities, the missing components of the auditory signal are often resolved via top-down (i.e., cognitive) processes. Pichora-Fuller (2008) notes that cognitive ability, working memory, and vocabulary are indeed closely related to successful hearing aid use. That is, people with the most able cognitive systems tend to do best with processing auditory information.

Rawool (2007) notes that to accurately perceive rapid speech, listeners must attend to the signal while dividing their attention between monitoring the ongoing speech and actively applying cognitive processes to make sense of the acoustic information.

◆ Hearing Is the Foundation of Listening, and Listening Is the Foundation of Learning

With specific regard to children and education, Flexer (2005) reported hearing is of paramount concern. She stated that when a child cannot clearly and easily hear spoken instruction (from the teacher, e.g.), “the entire premise of the educational system is undermined.” Further, she states that *most* of what children learn about language and societal rules occurs through “passive” or “incidental” listening. Beck and Clark (2009) reported that one cannot process that which is not perceived. That is, hearing “drives” the entire process, and fortunately (Beck & Flexer, 2011) “any child with any degree of hearing loss can receive sound through one or more modern and advanced hearing access technologies.”

The amount of practice required for continually wiring and rewiring the brain for higher-order language skills and the acquisition of knowledge is enormous. Gladwell (2008), Levitin (2006), and others report 10,000 hours of practice is needed for one to become an expert in a particular skill. Hart and Risley (1999; 2003) report that, by the age of 4 years, typical children need to have heard 46 million words to be ready for school. Dehaene (2009) reports 20,000 hours of listening are necessary in infancy and early childhood as a basis for reading.

Implications for Children

Indeed, if the bottom-up signal is missing, distorted, or impoverished (due to noisy classrooms, for example), the top-down system must work harder to make sense of the acoustic information (Allen et al., 2003). For children, filling in the blanks (a top-down process) is a remarkably difficult task because children require a very high signal-to-noise ratio to perform as well as adults with respect to acoustics. Further, and of enormous importance, children do not have advanced knowledge as to how conversations are likely to unfold, nor do they have the vocabulary required to “fill in the blanks.” In addition, their ability to predict conversational twists and turns is much less than that of a mature adult.

◆ Summary

Typical mainstream classrooms are auditory-verbal environments where instruction is presented through the teacher’s spoken communication. Children in a mainstream classroom, whether or not they have a hearing loss, must be able to hear, attend to, and listen to the teacher and each other in order for learning to occur. If the brains of children cannot consistently and clearly receive spoken instruction, the major premise of the educational system is undermined. This is what “acoustic accessibility” is all about.

Acoustic accessibility is critical because in environments relying on spoken language instruction, sounds have to reach the brain—the bottom-up feature—in order for learning to occur—the top-down feature. Therefore, we need to consider the environment of the classroom to enable us to provide the brain access to spoken instruction. The following chapters in this text will discuss the details of speech perception, room acoustics, and the use and efficacy of classroom audio distribution systems (CADS) as ways of understanding and managing the classroom learning environment.

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