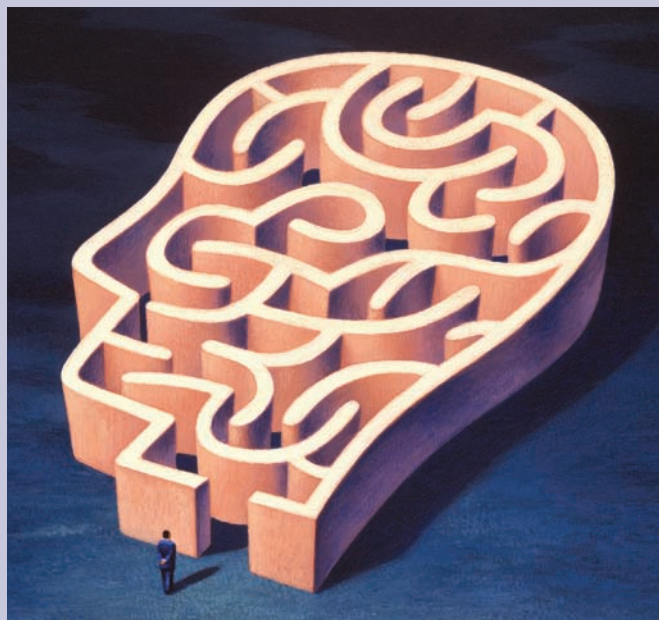


Exploring the maze of the cognition-audition connection

By Douglas L. Beck, AuD



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James Jerger, PhD, once said audiologists sometimes miss the forest for the trees when it comes to cognitive processes like attention, memory storage, and motivation.¹

While there has been a recent uptick in the quantity and quality of professional articles on the interaction of cognition, listening, audition, and amplification, many more questions than answers remain. Because this area of study is particularly important as hearing healthcare professionals incorporate this knowledge into aural rehabilitation, counseling, and hearing aid fitting protocols to better address the needs of patients, new approaches to understanding are needed.

I've asked two experts in this area, Brent Edwards, PhD, Vice President of Research and Director of the Starkey Hearing Research Center, and Kathy Pichora-Fuller, PhD, Professor of Psychology at the University of Toronto, Canada, to take a look at the current status of research and consider where all of these data might be leading us.

Beck: Brent, let's start with your thoughts and observations on cognition and audition. What do we know?

Edwards: Our research has primarily addressed the effect of hearing aid technology on "cognitive load." We've been examining how much of an individual's cognitive resources are being used to accomplish listening in noise, with and without hearing aid technology.

Cognition is finite, and unfortunately when people multitask, neither task is performed maximally as a result of divided attention, and the net result is the individual has fewer cognitive resources available to accomplish the primary or secondary goal. Using dual-task experiments based on this concept, our research demonstrated that hearing aids can reduce listening effort for speech in noise.²

Pragmatically, and with respect to speech-in-noise, we know that listening fatigue is a factor as well, and this very much relates to our ability to attentively process speech in real time.³ In collaboration with Kevin Munro and Piers Dawes in the United Kingdom, and with specific regard to hearing aids, we measured working memory and other tests associated with speech and hearing as they relate to cognitive load and listening effort, with and without different hearing aid technologies.

Our goal was to explore the hypothesis that people with better cognitive abilities might be better able to take advantage of a reduced cognitive load, secondary to hearing aid amplification, and that turned out to be the case. So the next step is to learn which hearing aid technologies, in addition to noise reduction and directional microphones, help facilitate improved listening so as to better support cognitive ability.

Beck: Great point. It seems we'll likely find the answers in technologies that best replicate and deliver a natural acoustic environment. For example, until three or four years ago, commercially available hearing aids weren't able to deliver extended bandwidths to the wearer. This affected the user's ability to hear high frequencies, which is very important with regard to the correct identification and recognition of phonemes, words, and sentences in quiet and noise.⁴



Brent Edwards

Now, more and more we're seeing the usefulness of higher frequencies with regard to spatial cues. The bottom line is for people to understand maximally in noisy backgrounds, they must first be able to tell where the sound is coming from—and the spatial cues that carry that information (Interaural Loudness Differences) reside in the higher frequencies such as 1500 to 8000 Hz.

Edwards: Absolutely.

Another thing many of us have been talking about and working on is the development of a cognitive test that might allow us to measure an individual's cognitive ability, and predict cognitive benefit from hearing aid fittings and aural rehabilitation. Preliminary results indicate that speed of processing tests and working-memory capacity are related to the cognitive

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Brent Edwards, PhD

benefit that subjects can get from hearing aid technology, but there is a significant amount of work necessary to confirm these results and understand these relationships. We're just at the beginning of really understanding the relationship between cognition and audition.

Beck: That brings to mind the study of Gates and his colleagues based on the Framingham Heart Study cohort, which found a significant correlation between speech-in-noise performance and the subsequent onset of dementia.⁵ The more recent study by Lin and colleagues based on the Baltimore Longitudinal Study of Aging also found a significant correlation between pure-tone hearing loss and the subsequent onset of dementia.⁶ What does this mean?

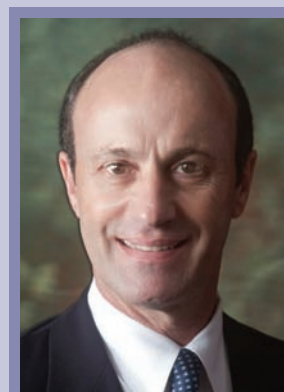
Edwards: My interpretation of those studies is that people with significant hearing loss were more likely to have signs of dementia, but that finding was correlational, not causative. We can't say hearing loss caused their dementia and we can't say that fitting those same patients with hearing aids would have altered their situation with regard to dementia, but these are important questions we're starting to ask and hoping to answer.

Beck: Kathy, does your research support these same opportunities and directions with regard to cognition and hearing aid amplification?

Pichora-Fuller: Yes. These questions are of paramount importance, and as Brent said, we're at the very beginning of understanding and defining the intricate relationships between cognition, listening, and audition. I don't think we'll be solving these questions conclusively in the near future; nonetheless, this is an exciting area that is ripe for exploration and research.

Beck: I agree. How might knowledge of one's cognitive ability affect an aural rehabilitation program?

Pichora-Fuller: The brain is where the action is, and even in healthy normal people there can be vast individual differences in cognitive ability. We cannot predict very much about someone's cognitive ability based on his audiogram, except for the general trends you and Brent already mentioned. Moving forward, we might better define specific cognitive functions that relate to listening.



Douglas Beck

The cognitive functions that most likely seem to be important for listening are working memory, speed of processing, and attentional control. Gillian Cohen wrote about these in the *British Journal of Audiology* in 1987, so these ideas are not really new, but in the last two decades we have become increasingly more aware of how important they could be in hearing healthcare.⁷

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Douglas L. Beck, AuD

If the quality of the incoming sound signal is degraded, then it is almost as if the brain becomes sluggish or inefficient in how it gets the work of listening done. The listeners with hearing loss who seem to have more success are the individuals with larger working memories. That is, they have more capacity to use knowledge and context to disambiguate confusing signals. Similarly, by anticipating what sounds might be coming next,

listeners who are good at using knowledge and context can process information faster and zero in on the correct meaning more efficiently. Listeners who can more readily allocate attentional resources will also do better if they tune into the signals they want to hear and ignore distracting ones.

These types of cognitive skills, especially increasing the use of context and top-down control during listening, can be improved by training, and they seem to be especially important when people are learning how to listen with new hearing aids. As we learn more about how acoustical cues serve these cognitive operations, there may even be ways to design new technologies that promote better skills. For example, in his recent doctorate research on auditory spatial attention, Gurjit Singh discovered that we use binaural cues differently, depending on whether or not the person knows where to listen for a target and whether or not they need to quickly shift between listening at one location and another as they might have to do if there were multiple talkers in a group conversation.

Beck: Do either of you have insight about how these goals might be accomplished?

Edwards: Directional microphones are an example of how research has affected the application of technology to improve cognitive function or listening skills. Data show that directional microphones can continue to reduce listening effort even when speech scores are maximized. This means that even at good signal-to-noise ratios where patients do not need directional microphones to improve speech understanding, they can still benefit from this technology to reduce cognitive load.

Pichora-Fuller: Yes, and in terms of what kinds of cognitive tests might be used in the clinic, I've been doing work with my colleagues Sherri Smith, PhD, and Richard Wilson, PhD, at the James H. Quillen VA Medical Center in Mountain Home, TN, on layering in memory measures, in tandem with word recognition measures using speech materials that audiologists have been using in the clinic for decades. Our thinking is that by using old materials in new ways, it might be easier to translate lab research into clinical practice.

Some of the new hybrid memory-speech tests we're trying to develop incorporate the idea of deep and shallow processing from the seminal 1972 paper by Craik and Lockhart.⁸ Smith has been exploring how to use the NU-6 words as a measure of listening that goes beyond the traditional listen-and-repeat protocol. For example, listeners might engage in deep or shallow processing by deciding if the word starts with a certain consonant, or they might engage in deep or semantic processing by judging if the item is pleasant or could be purchased in a grocery store.

The idea is that when listeners hear words or sentences, how well they remember those words or sentences depends on their depth of processing. Of course, just recognizing the word consumes some of the listener's limited working memory capacity, and adding additional processing tasks allows us



Kathy Pichora Fuller

to get an indication of how much capacity listeners have left over for using the material that was heard. Using the heard information to make a phonological or semantic decision is similar to the idea of a dual-task that Brent mentioned.

Let me give you another example. Researchers at Linköping University in Sweden are using sentences to explore different cognitive operations that are more or

less layered into the listen-and-repeat task using Hagerman-type sentences. In their Auditory Inference Span Test, listeners have to do various tasks with sets of three sentences, and in doing the tasks, listeners have to hear the words and use different cognitive executive functions. This approach draws on the ideas of cognitive psychologists who have been leaders in working memory research such as Akira Miyake, PhD, and his colleagues.⁹

So there are lots of great ideas and opportunities. In the next decade or two, it will be fascinating to see how we develop clinically feasible ways to measure cognitive ability. As I said earlier, there is also huge promise that we can find better ways to train clients to use their top-down cognitive abilities to facilitate learning while they are [getting acclimated] to new hearing aids, and to compensate by using contextual cues and knowledge in those tough listening situations when even the best hearing aid can't deliver a perfectly clear speech signal.

To get back to the issue Brent raised about the connection between hearing loss and cognitive impairment, perhaps we'll find that hearing health helps preserve cognitive health by helping older adults maintain active lifestyles.¹⁰

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