AMERICAN ACADEMY OF AUDIOLOGY

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**On the Importance of Working Memory with Regard to Hearing, Listening, Amplification, Prodigies, and More**

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***Opinion Editorial by Douglas L. Beck, AuD***

Beck and Flexer (2011) coined "Listening Is Where Hearing Meets Brain" to emphasize the fact that attributing meaning to sound (i.e., listening) is the more important and significant goal from the patient's perspective, than simply hearing or perceiving sounds. Indeed, patients want to be able to make sense of sound, not just hear it. Of course, it *almost* goes without saying that rule number one is they must hear it with an excellent signal-to-noise ratio in order to listen to, and process it. Indeed, we have to make all speech sounds audible for maximal listening…but let's assume we've done an excellent job of amplifying all the sounds and we've validated and verified our fitting…now let's talk about what happens *after* the full complement of sound reaches the brain.

Specifically, to "listen maximally" requires much more than simply perceiving sounds. Indeed, listening maximally requires cognitive ability including attention, working memory, listening effort and, of course, the maximal delivery of acoustic information to the brain, including the maintenance of natural acoustic cues such as interaural loudness differences (ILDs) and interaural timing differences (ITDs) to facilitate binaural summation and binaural squelch. That is, for the brain to listen (i.e., process sounds) maximally, it must receive maximal auditory information, and the brain's task is huge—to simultaneously receive, store, and process acoustic information, a phenomena also referred to as working memory (WM). WM is not the same thing as short-term memory. Short-term memory (ability) may be reflected or demonstrated via a person's ability to memorize a few (or many!) items. WM is much broader and involves cognitive processing of the same information.

Baddeley (1992) noted, "working memory refers to a brain system that provides temporary storage and manipulation of the information necessary for…complex cognitive tasks as language comprehension, learning, and reasoning….Working memory require(s) simultaneous storage and processing of information…."

Rudner and Lunner define working memory capacity (WMC) as the cognitive ability that allows one to keep information within easy cerebral reach while simultaneously processing it. Dingfelder (2005) reports WM is so important that it may be the "basis for general intelligence and reasoning" and she reports people who can hold

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many items in their WM simultaneously are better able to consider different angles of complex problems. Rudner and Lunner define working memory capacity (WMC) as the cognitive ability that allows one to keep information within easy "cerebral reach," while simultaneously processing it. Stuart (2014) reports WM is sort of like cognitive juggling, or perhaps a mental "Post-It" note. She reports "…if you struggle with working memory, pieces of information may often evade your grasp like a quickly evaporating dream. You find yourself stripped of the very thing you need most to take action…."

Indeed, for many audiologists, the signs and symptoms of a less-than-ideal (or problematic) WM may appear similar to auditory processing disorders (APDs).

Stuart (2014) notes WM problems may be apparent as one looks for some of the 22 signs from Alloway (published by Pearson Assessment, UK) referred to as the Working Memory Rating Scale (WMRS). Among the strongest and most common WM signs and symptoms are, the child abandons the activity before completing it, the child appears to be daydreaming, the child fails to complete assignments, the child raises his/her hand to answer the question but forgets what he/she was going to say (more common in 5 year olds than 11 year olds), the child mixes up material inappropriately - perhaps combining two or three sentences, forgets how to continue an activity. Alloway reports WM develops (and increases) over time. That is, a five year old may be able to process one or two items at a time, whereas a 10-year-old may process three items and a 14 year old may process four or more items successfully via their WM.

Boudreau and Costanza-Smith (2011) reported WM impacts a child's learning rate for vocabulary, language comprehension, literacy skills, reasoning, problem solving skills, and overall academic success. Further, they indicated WM controls attention and information processing.

Rudner and Lunner (2013) stated "It is well established that successful listening with advanced signal processing ... is associated with individual working memory capacity…." Of note, they reported modern digital noise reduction may facilitate a "release" of "cognitive resources" such that high quality noise reduction makes it easier to listen to speech in noise while also facilitating improved recollection of the speech signal.

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Meister, Schreitmuller, and colleagues (2013) reported the impact of WM on speech perception is important and the need for clinically applicable WM tests within the framework of aural rehabilitation and diagnosis is demonstrable.

All of which begs the very important issue of "Can WM be trained?"

Kronenberger et al (2011) reported their use of the Cogmed Working Memory Training Program (an adaptive algorithm with increasingly difficult challenges) including Digit Span, Digits Forward and Digits Backward subtests. The authors reported "statistically significant short-term improvement in verbal working memory capacity" and in non-verbal working memory capacity and they reported improvements in "real-world" WM behaviors and "transfer of training" effects were demonstrated.

Among the most amazing findings associated with WM is the fact that child prodigies (in math, music and art) consistently demonstrate elevated WM ability. Ruthsatz and Urbach (2012) report child prodigies typically demonstrate elevated levels of intelligence, yet their "full scale" IQs were not extreme. However, their WM scores were consistently in the 99th percentile (i.e., better than 99 percent of the people taking the same test) and the authors found a relationship between childhood prodigies and autism. Indeed, the authors report "the prodigies had an over-representation of autism in their families. Autism occurs in 1 in 120 individuals. Of the eight prodigies (reported), four of the families either have an autism diagnosis themselves, or have a first-or-second degree relative with an autism diagnosis…." The authors concluded "the prodigies consistently displayed an elevated level of general intelligence and exceptional WM and attention to detail…"

Finally…Hearing (in isolation) is certainly not the ability that places humans at the top of the food chain. That is, although one must hear all the sounds in the environment in order to make maximal use of them, as Beck and Flexer (2011) noted, "listening" is the key. They defined "listening" as applying meaning to sound. Although humans typically hear from 20 Hz to 20,000 Hz, dogs and cats hear up to 40 and 50,000 Hz (respectively). If it were all about hearing, Sparky and Snowball would be the top of the food chain….they're not, we are. Listening is where hearing meets brain, and a substantial part of the listening process is WM.

For More Information, References, and Recommendations

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