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Evaluating Central Auditory Processing: The (Sound) Wave of the Future?

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Consider what you, as an audiologist, might do in the following scenario: A healthy 25-year-old individual with no history of excessive noise exposure or genetic hearing loss reports having difficulty understanding speech, especially in complex listening environments such as in restaurants or at large-group social events. When the standard test battery is performed, the patient's in-quiet pure tone audiogram and tympanometry appear normal. Would you assume that the patient has normal hearing and is perhaps malingering? What if the patient were over the age of 60? Would your approach change?

Recent data collected at the National Center for Rehabilitative Auditory Research (NCRAR) in Portland, Oregon, USA suggest that even when the audiogram is normal it may be worthwhile to investigate a potential central auditory processing (CAP) deficit. Such deficits, which are poorly understood in adult populations, may represent an issue with the physiology of the brain that can affect a range of functions, from temporal processing to the ability to combine multiple sources of input. While CAP deficits may not be problematic for patients asked to detect tones or repeat single speech utterances presented over headphones or in a quiet test room, CAP deficits are hypothesized to cause serious difficulties in situations in which the brain is required to evaluate very complex acoustic information, such as multiple speech signals or speech in noise. As the future of clinical audiology advances toward a more complete understanding of how the brain is involved in hearing, audiologists may wish to increase their knowledge of how to test and diagnose CAP deficits.

In current clinical practice, testing for CAP deficits is commonly reserved for children experiencing difficulties in school or who are slow in acquiring language skills. However,

peripheral hearing loss and aging can affect CAP function in adults.[1,2] Adults with traumatic brain injury (TBI) may also be susceptible to decreased CAP function. As a part of the United States Department of Veterans Affairs (VA), the NCRAR has been collecting evidence that suggests CAP testing should be part of standard clinical procedures for a number of patients normally not considered to be in need of services. The impetus for this work, which has implications for the general population and for all those with head injuries, has come from the NCRAR's recent investigations of auditory difficulties being experienced by recently deployed veterans of the wars in Iraq and Afghanistan. The first study in this area, which was funded in 2007 by the Department of Veteran Affairs (VA) and designed by Drs. Marjorie Leek and Stephen Fausti, was motivated by reports that a number of audiologists working for the VA were receiving patients experiencing difficulty hearing in complex listening environments, despite having normal audiograms as determined by in-quiet pure tone or speech-reception threshold (SRT) testing. Many of these

patients were younger than 35 years of age, raising questions about how central auditory processing may play a role in the veterans' impaired hearing. In response to these reports, a theory which was subsequently articulated by Gallun et al. was developed that described a wide variety of ways in which exposure to high-intensity bomb blasts could potentially damage the central auditory system even if the periphery system remained relatively undamaged.[3]

In order to obtain evidence to support or refute the relationships between central auditory function and blast exposure postulated by this theory, a series of tests were run at the NCRAR and the former Walter Reed Army Medical Center (now the Walter Reed National Military Medical Center). The tests compared recently blast-exposed service members with age- and hearing-matched control participants. The data, which were described by Gallun et al., provided evidence that a set of common CAP tests could be used to identify processing deficits left unobserved by a standard audiometric examination.[4] That study, as well as studies currently underway at the NCRAR, have revealed the utilities of using CAP tests in an adult population with: (1) blast exposure, (2) complaints of difficulties hearing in noise, and (3) normal or near-normal peripheral function. The data represent only the most striking of a variety of pieces of evidence supporting the theory that aging, hearing loss, or traumatic brain injury can influence the CAP abilities of a listener.

Now think back on our 25-year-old patient experiencing trouble with speech in noise. A trained clinician audiologist with sensitive CAP tests on hand would be able to recognize that the patient was experiencing impairment, and an examination of the patient's medical history (let's say revealing a past concussion) would inform the audiologist of why the patient might be experiencing CAP deficits. A variety of behavioural tests could be used to assess the central auditory function of a patient. These tests evaluate temporal pattern perception, auditory temporal resolution, binaural processing, and dichotic listening. You may be familiar with the Gaps-In-Noise test (which requires listeners to identify brief silent intervals in ongoing noise[5]), the Dichotic Digits Test (in which two numbers are spoken to each ear and the listener repeats the numbers back to the tester[5]), the Masking Level Difference test (which evaluates binaural processing of tones in noise,[6]) the Staggered Spondaic Words test (which asks the listeners to repeat back two spondees staggered in time of onset and played to the left and right ears[7]), or the Frequency Patterns test (which involves identifying the order in which a sequence of three low and high tones have been presented.[8]) Other tests developed at the NCRAR have been proven effective in the laboratory at identifying differences in auditory processing among listeners with similar audiograms,[9,10] and several are currently under development as potential clinical tests of CAP function.

The battery of tests described in Gallun et al., have included tests of speech-in-noise perception, spatial release from masking ability (SRM), monaural and binaural thresholds, and temporal processing abilities for younger and older subjects and subjects with a history of TBI or blast exposure.[4,9,10] In order to better relate these findings to a general clinical population, some of these experiments have examined listeners varying in age (18–78) and varying in hearing loss, with moderate hearing loss being the most severe amount tested. In many cases, age and hearing loss were correlated in the sample being tested, and so statistical tests were used to separate the individual impacts of each.

In addition to the findings of Gallun et al., described above, some important findings revealed through that work were[4]: (1) Individuals with more hearing loss (HL) exhibited greater difficulty

perceiving speech in speech stimuli, even when stimuli were divided by azimuthal degrees of separation to encourage spatial release from masking, and even when the audibility of the stimuli was equated for each subject. The listeners with more hearing loss also had poorer target-to-masker thresholds in speech-in-speech tasks compared to listeners without HL, and often the listeners with more HL achieved less spatial release from masking than their normal-hearing, age-matched counterparts.[9] (2) An analysis of temporal processing capabilities in listeners representing a wide range of ages was conducted, revealing that older listeners had more difficulty than younger listeners in monaural and binaural listening tasks and that the effects of aging were greater in the presence of even mild hearing loss.[10] This suggests that aging alters temporal processing abilities in a way that affects both the monaural and the binaural systems and interacts with the basic sensitivity of the system.

Such findings stress the importance of CAP testing in order to evaluate not just how a patient's outer and inner ear function, but how the upper-level neurological processes of hearing function as well. The role of the audiologist may rapidly be changing, and the toolbox of the clinician is expanding. Otoscopy, tympanometry, and pure-tone testing will continue to be important, yet the audiologist may soon feel the need to diagnose pathology all the way from the outer ear to the brain. As we know, hearing does not stop at the auditory nerve.

Knowledge of a patient's CAP abilities might also direct the audiologist toward a more appropriate hearing aid fitting, as an individual with a normal audiogram and CAP deficits might not do as well with a traditional amplification paradigm. More importantly, however, the patient who has traditionally been told that his hearing is "normal" may finally receive justification that his hearing issues do indeed exist, and are related to CAP functions extending beyond the cochlea.

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