Cognition and Audition: Perspectives and Review 2023

The evidence indicates that untreated hearing loss exacerbates cognitive decline.

By Douglas L. Beck AuD

Introduction

The goal of this article is to review the knowledge base and the relationship between cognition, audition, and amplification as it appears in January of 2023. This article serves to present an overview of multiple foundational concepts and understandings. This article will present what appears to this author (DLB) to be a chronology of important article abstracts with an emphasis on publications from 2022. It appears that, in all probability, many of these newly-cited publications will impact our understanding of these matters as science evolves, as older and unproven ideas are discarded, and as new ideas and thoughts emerge.

Cognition and Audition

Science is dynamic, and science changes over time. As such, there is no finished science.[1] An observational hint to new and emerging scientific areas of interest can often be found via the quantification of Pub Med publications. With regard to the terms 'cognition' and 'audition,' there were 31 citations of the two combined terms between 2000 and 2002, 80 between 2010 and 2012, and 453 between 2020 and Oct 25, 2022. Indeed, with 15 times as many publications between 2020 to 2022, as compared to twenty years earlier, it appears researchers, geriatricians, gerontologists, optometrists, dentists, audiologists, public health officials, scientists across disciplines, otolaryngologists, opticians, hearing aid dispensers, ophthalmologists, nurse practitioners, internal medicine, general and family practitioners and the public (and more) are researching, teaching, contributing and learning more about the relationship between cognition and audition.

Dr Beck began his career in Los Angeles at the House Ear Institute in cochlear implant research and intraoperative cranial nerve monitoring. By 1988, he was Director of Audiology at Saint Louis University. In 1996 he co-founded a multi-office dispensing practice in St Louis. In 1999, he became President and Editor- In-Chief of AudiologyOnline.com, SpeechPathology.com and HealthyHearing.com. Dr. Beck joined Oticon in 2005. From 2008 through 2015 he also served as Web Content Editor for the American Academy of Audiology (AAA). In 2016 he also became Senior Editor for Clinical Research at the Hearing Review and also, Adjunct Clinical Professor of Communication Disorders & Sciences at SUNYAB. In 2019, he was appointed Vice President of Academic Sciences at Oticon Inc. Dr. Beck is among the most prolific authors in audiology with more than 211 publications. Although he officially retired from Oticon in March, 2022, he became Vice President of Clinical Sciences for Cognivue, Inc., Victor, NY in April, 2022. Dr Beck continues to consult for a number of professional and private concerns. Hundreds of publications and videos are available for free at www.douglaslbeck.com.

Dementia Facts and Figures

Nichols and Voss[2] estimate that the number of people with dementia globally will likely increase from an estimated 57 million cases in 2019 to approximately 153 million in 2050. The Alzheimer's Association (AA)[3] reports more than 6 million Americans have Alzheimer's, and by 2050, this number will also double or triple. The Milken Institute[4] states that for Alzheimer's Disease and Related Dementias (ADRD) there are some 9.5 million cases in the USA and approximately 2/3rds of all cases are not reported or diagnosed. Dementia (including Alzheimer's Disease, AD) kills more people than breast cancer and prostate cancer combined, and currently, one in three senior deaths is attributed to dementia. A 17% increase in Alzheimer's and dementia deaths were noted in 2020 attributable to COVID-19. Dementias (including AD) will cost the nation $321 billion in 2022, and by 2050, the anticipated cost will be 1 trillion dollars. In the USA, unpaid care for people with AD or other dementias is currently provided by some 11 million unpaid caregivers.

Mild Cognitive Impairment (MCI) can be an early stage of Alzheimer's or other dementias, yet only 1 in 5 Americans are familiar with MCI. One-third of people with MCI (due to AD) develop dementia within 5 years of diagnosis. Although 90% of physicians acknowledge it is important to diagnose MCI due to AD, over half report they are not comfortable diagnosing it. As AD and other dementias increase, so too does the need for additional professionals to refer, diagnose, treat, and care for those with dementia. The AA[3] reports that the USA needs to triple the number of geriatricians to address our needs by 2050. As of 2022, only 12% of nurse practitioners have expertise in gerontological care, and fewer than 1% of registered nurses, physician assistants, and pharmacists specialize in geriatrics. Likewise, only 4% of social workers have certification in geriatric social work. The AA[3] states the demand for direct care workers is projected to grow by more than 40% from 2016 to 2026, while availability for direct care workers is expected to decline.

One of the many reasons ADRD is not readily diagnosed is the lack of a well-recognized, universal and consistent biomarker (Beck, 2022).[5] Indeed, the foundational cause of AD is still hotly debated, and is admittedly, as-of-yet unresolved. Certainly, the amyloid cascade hypothesis, and the importance of the amyloid precursor protein (APP, is the molecule enzymes

break apart thus forming amyloid-beta, thus causing overproduction of amyloid) are significant. Another important etiology candidate includes retromers within endosomes which may malfunction causing amyloid to accumulate in neurons (referred to as the endosomal-lysosomal hypothesis). Additionally, APOE4 is a genetic marker which is often correlated with the development of ADRDs, and as genetic representation increases, so too, does the apparent risk of ADRDs (Saplakpglu, 2022).[6]

Cognitive Ability and Intellectual Ability

Admittedly, it is difficult to identify clear and consistent definitions for abstract terms. For example, the definitions, differences, and essence of the words 'cognition' and 'intelligence' vary by author, context, and more. I'll go out on a limb and state that as typically applied across casual and clinical scenarios, 'cognitive ability' and 'intellectual ability' are often used interchangeably and without regard for the fine differences which academics and scholars may reasonably dispute. Legg & Hutter[7] reviewed 70 definitions of intelligence and summarized them essentially as; 1) A property/characteristic a person has as it interacts with its environment, 2) The person's ability to succeed or profit with respect to goals/objectives, 3) How the individual adapts to different objectives or environments. Sternberg,[8] as well as Sternberg & Detterman[9] report that intelligence is a capacity for problem-solving and profiting from experience. Hasa[10] and Cambridge Cognition[11] report that cognition is the mental process of acquiring and understanding knowledge through thought, experience, and the senses, while intelligence is the ability to learn or understand things easily and to deal with new or difficult situations. In brief, it might be argued that cognitive ability and intellectual ability are (practically speaking) significantly intertwined and overlapping concepts.

Information processing may be described as how one perceives, processes, recalls, prioritizes, and uses information. Information Processing will be described in detail by Drs Herbert & Pisoni later in this Special Edition of Hearing Review.

Auditory Processing Disorders

As is the case with cognition and intelligence, the definition of Auditory Processing Disorder (APD) is rightfully debatable and

is based on the perspective of the professional or association describing the same. The American Speech Language Hearing Association (ASHA)[12] notes terms such as "auditory processing disorder, "(central) auditory processing disorder," language processing disorder," and "auditory information processing disorder" are generally synonymous. Others may argue they are not. When I use the term APD, I am referring to processing deficits of auditory information possibly due to auditory discrimination, temporal processing, auditory pattern recognition, binaural processing localization, lateralization, or auditory performance with competing or degraded acoustic signals, etc., and importantly, not due to higher order language or cognition. Beck, Clark, and Moore[13] reported that the diagnosis of APD should indicate a problem processing auditory information within the central auditory nervous system (CANS). However, if the primary problem lies beyond the auditory cortex, such as a neurocognitive disorder, the diagnosis of APD is often trumped by the more prominent differential diagnosis, although both may be present.

Hearing Loss and Cognition

The evidence indicates that untreated hearing loss exacerbates cognitive decline. However, as Beck, Bant, and Clarke[14] reported, the exact causal mechanism(s) remain unknown. They hypothesized four possible candidates, which include common cause, cascade via social effects, cascade via auditory deprivation, and cognitive load. All four remain viable in 2023, and other candidates have been added to the list of possibilities.

Despite significant research, publications, and numerous professional presentations on these and related topics, there remains a multitude of primary unanswered questions, including:

1. How much (if any) cognitive benefit might one expect from amplification (i.e., hearing aid fittings)?

2. Who are the most/least likely candidates for amplification benefits regarding demographic factors such as age, gender, sex, economic staus, duration of hearing loss, type and degree of hearing loss, race, ethnicity, etc.?

3. When patients/clients demonstrate improved cognitive benefit post amplification how do we determine if the benefit is indeed a cognitive benefit, or rather, the result of an improved sensory signal availing more information to the brain, facilitating more efficient information and/or auditory processing, thereby decreasing cognitive load? Perhaps, if the patient demonstrates improved performance, it doesn't matter whether the change is due to a sensory enhancement or a cognitive improvement?

4. Auditory or Non-Auditory? This question may be the 800-pound gorilla in the room. Specifically, given older adults with audiometric thresholds characterized as normal or given typical mild-moderate (or worse) sensorineural hearing loss (SNHL) in those who present with hearing difficulty and/or speech in noise difficulty, how do we know their manifested auditory problem is exclusively auditory? Might APD, cognitive, intellectual, language, emotional,

psychological, or other problems be present? Is this an even greater concern for the 26 million Americans who have hearing difficulty, speech in noise problems and normal thresholds, (Beck and Danhauer)?[15] Typically, when we identify SNHL, we conclude that SNHL is the reason for hearing difficulty and/or speech in noise difficulty. However, in so doing, perhaps we arrive at a conclusion prior to ruling out other rational and reasonable etiologies? This question seems pivotal in 2023 regarding early referral, diagnosis, and management of modifiable non-auditory risk factors for dementia. There are 26 million Americans who have Supra-Threshold Listening Disorders (STLDs) without hearing loss,[16] and some 40% of dementia risk may be attributable to 12 modifiable risk factors, of which hearing loss was the most significant.[14] It is noteworthy that 12% to 18% of Americans over age 60 have Mild Cognitive Impairment (MCI),[3] and for those over the age 65 years, (MCI) is present in 22% of the population,[17] and for many, their chief complaint (C/C) will be the inability to understand words or to make sense of what they just heard and they perform even worse in noise (i.e., the cocktail party effect). Of course, every HCP recognizes these as the exact same C/C as those reported by people with hearing loss and STLDs, in the exact same demographic group. AA[3] reports fewer than 20% of Americans (across all racial and ethnic groups) are familiar with MCI, and more than half of all Americans report MCI seems a lot like "normal aging."

Chronology of Abstracts

Myklebust[18] stated, "clinical psychology has an important contribution to make in audiology." Seventy years ago, he noted; 1) There are overlapping basic relationships between both areas of study. 2) Knowledge within clinical psychology regarding children and adults with hearing loss should be applied more effectively in the practice of audiology, and 3) There are problems associated with psychological evaluations which are in urgent need of mutual investigation by clinical psychology and audiology. Myklebust[18] reported that the whole-person, all-inclusive approach (i.e., consideration of more than the hearing loss) is preferable and is the acceptable and justified approach.

Lindenberger and Baltes[19] reported 156 older adults (age range 70-103 years) regarding age, intelligence, and auditory and visual (A&V) sensory acuity. Five cognitive abilities were measured (speed, reasoning, memory, knowledge, and fluency). The authors report A&V combined acuity accounted for half the variance in intelligence. Their results indicate A&V acuity/functioning is a strong late-life predictor of individual differences in intellectual functioning. They suggest A&V acuity represents the physiological integrity of the aging brain (i.e., common cause hypothesis)..

Christensen, Mackinnon, Korten, et al[20] reported that increased symptoms and depression were associated with greater variability in cognitive scores, yet higher education was associated with reduced variability. They reported greater cognitive variability at older ages for memory, spatial functioning, and speed, however crystallized intelligence (such as knowledge, fact retention, and skills) was less susceptible to changes than fluid intelligence (the ability to reason and think), and they reported variables beyond age affect cognitive performance. Although this is relatively common knowledge in 2023, Christensen and colleagues reported their findings almost a quarter of a century ago.

Captions Captions

The National Council on Aging (NCOA)[21] survey reported seniors with hearing loss who did not wear hearing aids (i.e., untreated hearing loss) reported significantly greater feelings of sadness or depression. The NCOA reported that people who didn't treat their hearing loss were considerably less likely to participate in social activities. NCOA reported hearing aid users experienced significant improvements ranging from relationships at home and their sense of independence to their social life and their sex life.

Schneider and Pichora-Fuller[22] reported perception and cognition represent (essentially) an integrated system. They offer 4 hypotheses of perceptual and cognitive decline in aging. 1) Perceptual decline causes cognitive decline. 2) Both perceptual and cognitive declines may represent widespread CNS degeneration or specific functional changes with systemwide results. 3) Cognitive decline may contribute to age-related changes in sensory measures. 4) Cognitive performance may result from unclear and/or distorted perceptual information delivered to the cognitive systems, compromising cognitive performance.

Barry, Ferguson, and Moore[23] reported the ability to hear is "only the first step towards making sense of the range of information contained in an auditory signal," which they referred to as listening skills or auditory processing, AP. They noted that listening skill deficits are associated with delayed language and literacy development.

Beck and Clark[24] addressed top-down (cognitive) and bottom-up (sensory) systems. They stated that when the BU system (i.e., hearing) is compromised, the TD system (i.e., cognition) works harder to decode, untangle, comprehend, or make sense of the input. When the BU sensory system transmits an attenuated, distorted, or compromised signal to the TD system, the TD system reallocates cognitive resources to better identify and recognize the BU signal. As cognitive load increases, the reallocation of cognitive resources slows and reduces processing ability.

Dawes, Wolski & Himmelsbach, et al[25] report the typical age-related hearing and vision (i.e., sensory) problems are common among people with dementia. They note that these same sensory problems are associated with poorer function, reduced quality of life, and increased caregiver burden. Significantly, people with dementia generally are unaware of, or simply under-report, hearing difficulties. Dawes, Wolski, and colleagues note that hearing impairment is undetected in dementia patients up to 80% of the time.

Slade, Plack & Nuttall[26] reported age-related hearing loss (ARHL) is a common finding among older adults, and ARHL leads to communication difficulties, isolation, and cognitive decline. They report listening in acoustically challenging environments and/or listening through a damaged auditory system strains cortical resources, which potentially alters how the brain responds during cognitively demanding challenges.

McDonough, Dookhy, and McHale[27] reported the quantity of people with dementia is expected to triple by 2050. As knowledge of modifiable risk factors increases, the possibility of disease modification during the early (or pre-clinical) stages (mild cognitive impairment, MCI) increases. Targeting patients with mild cognitive impairment (MCI) and reducing their risk factor profile could delay or prevent dementia, resulting in significant personal and societal advantages.

Petley, Hunter, et al[28] reported children who present with caregiver-reported listening difficulties often have normal audiograms. They report 146 children ages 6 to 13 years-old children with normal audiograms. Of note, all scores from the clinical test suite for auditory processing and the National Institutes of Health Cognition Toolbox were significantly lower for the subjects in their study (with normal audiograms and listening difficulties) than for typically developing children. The authors concluded that evaluations of children with complaints of listening difficulties should include caregiver observations and consideration of broad cognitive abilities.

Strutt, Barnier, Savage, et al[29] report adults who self-report hearing loss were 1.5 times more likely to develop dementia than those who didn't. Based on more than 1000 subjects ages 70 to 90 years and with 6 years of follow-up, those who self-reported moderate-to-severe hearing loss showed poorer cognitive performances overall and a 1.5 times greater risk for mild cognitive impairment or dementia.

Gaeta, Azzarello, Baldwin, et al[30] reported the performance on the Mini Mental State Examination (MMSE) on 30 older adults with hearing loss unaided, aided with hearing aids (HA), and aided with a personal listening device (PLD). They reported MMSE scores were improved significantly with HAs and also with PLDs.

English[31] reports that "these days" we find ourselves having non-audiology-only discussions with patients because these discussions are relevant to patient health and overall safety as holistic, patient-centered care. She notes audiologists often discuss medications that interact with hearing, tinnitus, and dizziness, and audiologists are "typically" required to refer when they suspect suicidal ideations or self-harm, and reports are often required when elder or child abuse is suspected. English reports other areas in which we're involved include screenings for vision, cognition, memory, and more, not to diagnose, but to assume responsibility and, equally important, to direct those suspicions and reports to the appropriate professionals in an efficient and timely manner.

Marinelli, Lohse, Fussell, and colleagues[32] reported the Mayo Clinic Study of Aging (MCSA), a prospective population-based study exploring the incidence of MCI in Minnesota. Participants included 1200 people, with a mean age of 79 years; approximately half were male. Subjects enrolled between 2004 through 2019. Participants underwent formal audiometric evaluations of pure tone averages (PTAs) and word recognition scores (WRSs). The authors note that despite changes in PTAs and WRSs, which did correlate with poorer performance on cognitive measures, neither measure was associated with the development of dementia. Further, the measure which did correlate with dementia development was informant led reports of increased hearing difficulty.

Zhizhong, Jingnian, Yuou, et al[33] report major disagreements as to the effects of hearing aid treatment on cognitive decline. They performed a meta-analysis on 15 studies meeting their criteria; most were published in the last five years. They report that for subjects without dementia, hearing aid use facilitated cognitive test improvements in global cognition and working memory. However, in patients with AD, no significant improvements were seen in global cognition or anterograde memory, visual memory execution speed, or attention, and hearing aids were not significantly more effective than placebo at 6 months. Zhizhong, Jingnian, Yuou and colleagues,[33] report that for people without dementia or with normal cognitive function, hearings aids improved performance regarding global function, working memory, and executive function. In people with mixed cognitive results, hearing aids improved cognitive performance in tests of global

function. In subjects with AD or dementia, no improvements were found. The authors report the cognitive screening process can be problematic as people with hearing loss tend to score lower following oral instructions on screening tools like the MOCA. They report significant improvements on pre-vs post-tests are often likely due to hearing-dependent sub-tests of the screeners, as has previously been reported with the MMSE.

Yeo, Song, Toh, and colleagues,[34] report that hearing loss is associated with cognitive decline. The authors evaluated the interactions among hearing loss, cognitive decline, hearing aid amplification, and cochlear implants. They reduced their pool of 3243 screened studies down to 31 acceptable studies with some 138 thousand participants. They concluded that using hearing aids and/or cochlear implants (i.e., restorative devices) resulted in a 19% decrease in hazards of long-term cognitive decline and a significant 3% improvement in general cognitive test scores in the short term when compared to those with untreated hearing loss.

Discussion

One might readily argue that emerging sciences are the most frustrating of all! Just when you think you've wrapped your arms around a problem, you've arrived at the answer, and you own the knowledge…POOF! It all changes. Then again,there are relatively few things we know with absolute certainty. For example, in 2023, it appears clear that untreated hearing loss has the potential to exacerbate cognitive decline, but some responsible authors say perhaps not. Further, the answers to the questions asked at the beginning of this article (and many more) remain demonstrably open, and they foster additional queries, such as…

How much (if any) cognitive benefit might one expect from hearing aid fittings? Who are the best candidates regarding type and degree of hearing loss? What about OTCs versus prescription hearing aids - same or different cognitive benefits? How do we know? Which OTCs or prescription hearing aids might offer the best cognitive test score improvements and why? Which amplification factors matter regarding cognitive test improvements (gain, spectral bandwidth, frequency transposition, compression, attack and release times, noise reduction, signal-to-noise ratio, directional or omni or beam-former microphones, real ear measures, hours of use)? Who are the most/least likely candidates to benefit from amplification? Younger middle age, middle age, older middle age, young old, middle old, older old? When patients/clients demonstrate improved cognitive benefit post-amplification, do we truly know if it is a cognitive benefit or perhaps an improved sensory signal facilitating improved information and/or auditory processing? Does it matter? And how do we know if the manifestation of listening problems (for example, hearing difficulty or speech in noise difficulties) are auditory or non-auditory?

These clinical and research questions, (and many more) will hopefully be addressed in the next few years as we continue to explore the emerging and ongoing relationships between hearing, listening, information processing, auditory processing, psychology, speech-in-noise, cognition, cognitive screening tests, MCI, dementia, amplification, and rehabilitative strategies.

I suspect Dr Myklebust would be delighted to know that his prescient observations from 70 years ago regarding clinical psychology and audiology have attracted so much attention.

REFERENCES can be found in the online version of this article at: hearingreview.com