

# Cognition Friendly Amplification



**Douglas L. Beck**  
**Au.D.**  
Director of Professional  
Relations  
Oticon Inc Somerset,  
N.J.

## Introduction:

*Cognition and audition interact and influence each other at many levels and in many ways. Indeed, separating audition from cognition is like separating hearing from listening. Perhaps in its simplest form hearing can be thought of as the awareness of sound primarily in the ear and lower brainstem, whereas listening can be thought of as assigning meaning to sound in the temporal lobes and across the entire brain.*

Cognition refers to brain-based processes such as “knowing” and the acquisition of knowledge. Cognition includes; language, memory, thinking, problem solving, intellectual capacity, applying acquired knowledge to new stimuli and situations and includes dreams, ideas, concepts, imagination and more. Thus, as one considers the differences between hearing and language, the topic expands logarithmically. Pichora-Fuller (2006) noted cognition has become “an imperative” with regard to rehabilitative audiology.

This article will address two points; There exists a mutually dependent relationship and interaction between cognition and audition, and “Cognition Friendly Amplification” facilitates an improved overall (re)habilitative strategy.

## Cognition and Audition:

Multiple factors appear to have inspired the interaction between cognition and audition. For example; the need to understand how hearing impaired listeners perform in ecologically realistic situations (e.g. Bregman, 1990; Pichora-Fuller, 2007), how aging alters performance (e.g. Schneider & Pichora-Fuller, 2000), how to design new communication technologies using advanced signal-processing (e.g. Edwards, 2007) and how to apply educational and rehabilitation programs to improve performance based on evidence of brain plasticity (e.g. Tremblay, 2007).


Lyxell, Andersson, Borg and Ohlsson (2003) noted working memory (WM) remains intact despite extended periods of hearing loss or deafness. They determined the size of the WM is related to skill and individual ability with regard to speech reading and to speech understanding for cochlear implant patients. Further, they reported

WM is correlated with the perceived effort required within noisy acoustic environments.

Lunner (2003) reported 72 subjects assessed for cognitive function based on working memory and verbal information processing speed. After controlling for age and hearing loss, significant correlations were found for cognitive performance and speech recognition in noise with and without hearing aids. Higher cognitive ability was correlated with greater performance regarding speech recognition in noise. In a related experiment with 17 subjects, those with high working memory capacity were better able to identify and report processing effects of experimental hearing aids. Lunner noted careful attention should be focused on the cognitive ability of patients with hearing loss, as their cognitive ability may have significant impact on their hearing aid experience.

Humes (2005) evaluated 213 elderly subjects with hearing loss with regard to auditory processing and cognitive function. Four measures of auditory processing and three measures of cognitive function were employed. For three of the four measures of auditory processing (duration discrimination, temporal-order discrimination, dichotic CV identification) measures of cognitive function (IQ and age) were the two strongest predictors of individual performance differences. Thus, performance on the battery of auditory processing measures was related to cognitive ability - more so than auditory ability.

Craik (2007) noted even after audibility had been restored via amplification, difficulties with comprehension can remain and remaining difficulties are most highly correlated with individual cognitive differences. Craik stated information flows from bottom-up (sensory) and



top-down (cognitive) systems and the entire process of adequate perception and comprehension is interactive, mutually compensatory, malleable and outcomes depend on where attentional processes (i.e. cognitive focus) are allocated.

Jerger (2009) noted among the most important concepts psychologists have contributed to audiology, is - that behavioral tasks require allocation of cognitive resources, and these resources are limited. Jerger reports cognitive resources include memory, speed of processing and attention. Stewart and Wingfield (2009) noted that as adults age, cognitive slowing occurs and cognitive efficiency generally decreases with particular impact on working memory and attentional resources.

Lunner, Rudner and Ronnberg (2009, in press) note the importance of the individuals' working memory (WM) capacity and how it reflects their unique processing ability combined with their individual storage component capacity. Lunner, Rudner and Ronnberg note as WM demands increase, there are fewer resources available for processing and storage and the cognitive abilities and capacities of each individual is unique. Indeed amplification considerations should be tailored to be congruent and in compliance with the cognitive needs and abilities of the patient. Lunner, Rudner and Ronnberg note some hearing aids incorporate technologies to facilitate improved language understanding and "listening success" such as is often provided via directional microphones to increase the signal-to-noise ratio (SNR) in difficult and deleterious listening situations (see Walden et al 2004). Likewise, noise reduction systems effectively reduce annoyance while increasing listener comfort and with little or no impact on speech intelligibility (Dillon, Ching and Golding, 2008). Multi Channel Non-Linear (MCNL) compression allows people with limited dynamic range to appreciate greater audibility without loudness discomfort.

Rönnberg, Rudner, Foo & Lunner (2008) model ease of language understanding as being highly correlated with working memory capacity in difficult listening situations. Thus, in difficult listening situations, the ability to understand speech may well be a function of "explicit cognitive capacity." The authors present a pragmatic model which indicates working memory (WM) equals the processing component (of WM) and the storage component (of WM). Thus, if and when processing or storage requires additional

work, energy or effort (such as understanding speech in noisy backgrounds), the total WM is reduced and speech understanding errors are likely to increase.

### **Cognition Friendly Amplification (CFA):**

Although the term "CFA" is relatively new, the impact of cognition upon audition has been explored in the psychology literature for more than 50 years (Jerger, 2009 and Craik, 2007). Beck and Clark (2009) noted the goal of aural rehabilitation is to provide excellent sound quality at the best possible signal-to-noise ratio (SNR) thus reducing the cognitive burden while employing ease-of-listening strategies. Multiple strategies were suggested to ease cognitive burden, such as; binaural hearing to better maintain spatial cues, directionality to (occasionally) improve the SNR, FM to maximize SNR and reduce reverberation and effects of distance while reducing or eliminating background noise, extended bandwidths to allow more high frequency information for speech, music and spatial cues and others.

### **CFA and Artificial Intelligence:**

Artificial intelligence (AI) and parallel processing were introduced into hearing aid amplification systems less than a decade ago and these too, are examples of CFA.

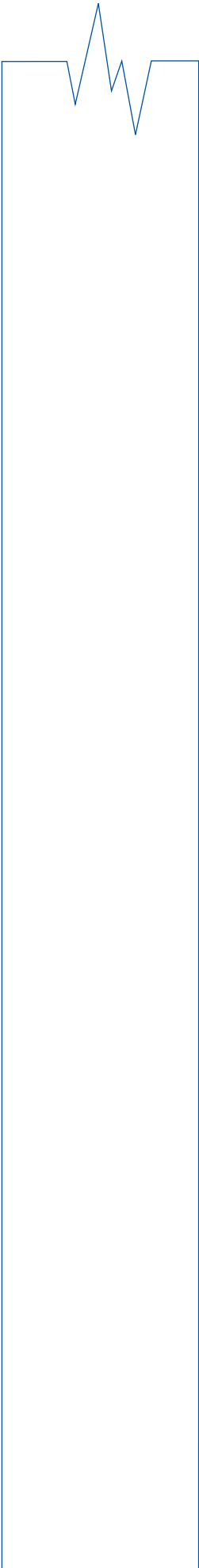
AI allows hearing aids to intelligently process sound such that **if and only if** the signal-to-noise ratio (SNR) is improved through an automatic action (such as adaptive directionality or digital noise reduction) the automatic action is engaged. Likewise, if the SNR cannot be improved through the automatic action, the automatic action is not engaged (Beck and Schum, 2006). AI endeavors to produce an improved bottom-up signal, if and only if, the SNR can be improved through the engaged automatic system(s), thus reducing cognitive demand while facilitating improved listening.

### **Three CFA Examples:**

More recent examples of advanced technology which can lower cognitive demand include extended bandwidths, improved feedback management and improvements with regard to spatial hearing.

#### **1 - Extended Bandwidths:**

Beck and Olsen (2008) addressed extended bandwidths in hearing aids. Technologies like the Oticon RISE platform have significantly increased processing power, thus allowing sophisticated algorithms and increased bandwidths.



Hearing aid bandwidths have thus effectively changed from approximately 4 to 6k Hz to 10,000 Hz. Extended bandwidths generally provide higher quality speech and music sounds and greater access to high frequency information to better localize and understand speech-in-noise. When children have access to high frequency speech sounds, they are better able to develop speech, language and auditory processing skills while building a more complete language-based lexicon of speech sounds.

## 2 - Improved Feedback Management:

In previous generations of hearing aids, meeting high frequency prescriptive targets often meant acoustic feedback might occur. To reduce or eliminate feedback, audiologists often attenuated these same high frequencies. However, advanced technology feedback management (for example, the Oticon DFC2) allows 180 degree phase reversal of acoustic feedback spikes to quickly and effectively reduce and eliminate acoustic feedback in advanced amplification products – as the circuit demonstrates instability, just before going into oscillation. Thus, DFC2 allows high frequency information to remain intact. Advances in feedback management allow greater flexibility with regard to open canal fittings with regard to improved feedback management and increased possibilities for extended bandwidths., too.

## 3 - Spatial Hearing:

The normal human auditory system uses inter-aural time differences (ITD) and inter-aural level differences (ILD) to determine from where sound originates. To best perceive speech in noise, one must first locate the speech source physically. Knowing the location of the speech source (in quiet and noise) allows one to better attend to the speech source. Previous generations of hearing aids were unable to provide significant spatial cues. Nonetheless, extended bandwidths and coordinated compression have allowed more realistic ITD and ILD acoustic cues. Coordinated compression allows binaurally fitted hearing aids to preserve more of the naturally occurring ITD and ILD differences, thus helping people identify the physical sound source while permitting improved speech recognition in noisy backgrounds (Neher, Behrens and Beck, 2008).

## Cognition and Audition are Dynamic:

Mild Cognitive Impairment (MCI) and Alzheimer's Disease (AD) may impact one in four people (or more) over age 65 years. Thus, as aging occurs, cognitive decline and hearing loss become more likely. When cognitive and sensory systems fail simultaneously the result is often "Negative Synergy" (Schum & Beck, 2008).

Beck and Clark (2009) noted "audition matters more as cognition declines and cognition matters more as audition declines." Lunner, Rudner and Ronnberg (2009) noted working memory (WM) equals the processing component (of WM) plus the storage component (of WM). Thus, when processing or storage requires additional cognitive work, WM is reduced and errors will tend to increase. Further, they suggest that hearing aid signal processing which incorporates individual cognitive capacity would likely maximize speech perception.

## Final Thoughts:

The sensory input we provide patients through amplification might be thought of as "acoustic nutrition" for the brain. Indeed, audition is clearly pivotal with regard to what the brain needs to make sense of the world. However, even an excellent bottom-up signal is of little value without accessible and efficient working memory. Therefore, CFA concepts and implementation must consider not only the amplification system but the individual's cognitive ability. Our goal is not only to make it easier to hear - but more importantly - easier to listen. Listening is where hearing meets brain.

As audiologists recognize the importance of cognition to audition (and vice versa) in amplification protocols, and as manufacturers provide additional CFA features to provide improved and appropriate acoustic information, hearing aid wearers will benefit with regard to their ability to hear, and more importantly, their ability to listen.

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