Cognitive Decline and the Role of Hearing Aids

Dania Rishiq, Ph.D.

Brief History of Cognitive and Auditory Research

Research scholars began investigating the interaction between hearing and cognition more than three decades ago (Duquesnoy, 1983; Bronkhorst & Plomp, 1988). In fact, groundbreaking research that studied cognition and hearing was conducted in the 1950s by Broadbent, Cherry and others in Cambridge (Broadbent, 1958). Following World War II, scientists embarked on studying the connection between cognitive and auditory processing; however, it was not until the 1990s that the study of cognition and hearing started to gain momentum and the number of publications linking hearing and cognition started to remarkably grow (Arlinger et al., 2009).

Because listening and understanding speech is a complex task that involves a wide variety of sensory and cognitive processes, researchers have always sought to understand how the brain builds meaningful descriptors of the auditory world. Further, the critical implications and impact of cognition-audition interactions on the diagnosis and treatment of hearing loss have lead researchers to combine their efforts in studying auditory and cognitive functions. As reported by Arlinger and colleagues, 2009, there are numerous factors that have contributed toward the convergence of auditory and cognitive research—some of them are listed in Table 1.

Factors contributing toward the convergence of auditory and cognitive research

<table>
<thead>
<tr>
<th>CONTRIBUTING FACTOR</th>
<th>REFERENCE</th>
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</thead>
<tbody>
<tr>
<td>The need to understand the listener’s performance in real-world environments</td>
<td>Bregman, 1990; McAdams &amp; Bigand, 1993; Neuhoff, 2004</td>
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<td>The need to understand how aging and impairments change performance</td>
<td>Schneider &amp; Pichora-Fuller, 2000; Wahlén, MacDonald, de Frias, Nilsson &amp; Dixon, 2006</td>
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<td>How to design new communication technologies using advanced signal processing</td>
<td>Edwards, 2007</td>
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<td>How to design educational and rehabilitation programs that improve performance</td>
<td>Kraus, McGee, Carrell, King, Tremblay &amp; Nicol, 1995; Tremblay, 2007</td>
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<td>The emergence of new research tools, such as eye-movement tracking devices and advanced physiological methods</td>
<td>Durlach &amp; Mavor, 1995; Allopenna et al., 1998; Belin et al., 1999; 2000</td>
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<tr>
<td>The proposal of new models for cognition-audition interaction</td>
<td>Holt &amp; Lotto, 2008; Stenfelt &amp; Ronnberg, 2009</td>
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</table>

Table 1

Connection Between Hearing Loss and Cognitive Decline

A large and growing body of literature exists on the connection between hearing loss and cognitive decline. Hearing loss has been associated with greater declines in cognitive function in older adults than in their counterparts without hearing loss (Lin et al., 2013; Lin et al., 2004; Lindenberger & Baltes, 1994; Ulhmann et al., 1989; Tay et al., 2006; Baltes & Lindenberger, 1997). For example, audiometric hearing thresholds have been linked to cognitive performance on test-specific tasks involving memory and executive and global functions in older adults (Lin et al. 2011a, b).
More specifically, hearing loss has been linked to dementia. Dementia was found to be more prevalent in older adults with hearing loss than those without [Uhlman et al., 1986; 1989]. Pure-tone thresholds [Lin et al. 2011a, b; 2013] and scores on tests of auditory central processing [Gates et al., 2003; 2010; 2011] were found to be correlated with incident dementia. The study by Lin and colleagues (2011a) found that older adults with hearing loss are two to five times at risk of developing dementia compared to their counterparts with normal hearing. They also found that with every 10dB increase in hearing loss, there was a 20 percent increased risk of developing dementia [Lin et al., 2011b]. Further, Gurgel (2014) reported that the mean time to develop dementia was found to be 10.3 years in individuals with hearing loss as opposed to 11.9 years for those without.

This link between hearing impairment, cognitive performance and incident dementia has lead epidemiologic researchers to suggest that hearing loss may be a risk factor for cognitive decline [Lin et al. 2011a, b; 2013]. The results of these studies demonstrate that indeed there is a link, but it is secondary to the predictive effects of hearing loss. There is no clear proof that hearing loss is the cause of the reduced cognitive function, but indirect evidence from many studies supports this hypothesis.

Table 2 lists some of the studies demonstrating the link between hearing loss and cognitive decline.

<table>
<thead>
<tr>
<th>STUDY</th>
<th>N</th>
<th>COGNITIVE MEASURE</th>
<th>COGNITIVE ABILITY TESTED</th>
<th>RESULTS</th>
<th>OUTCOME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lin, 2011</td>
<td>605</td>
<td>Digital Symbol Substitution Test (DSST)</td>
<td>Executive function and psychomotor processing</td>
<td>Greater hearing loss was associated with lower scores on the DSST; hearing loss was positively associated with cognitive functioning.</td>
<td>Hearing loss is independently associated with lower scores on the DSST.</td>
</tr>
<tr>
<td>Lin et al., 2013</td>
<td>1984</td>
<td>3MS and DSST</td>
<td>Global and executive functions</td>
<td>Rates of cognitive decline and the risk for incident cognitive impairment were linearly associated with the severity of an individual’s baseline hearing loss.</td>
<td>Hearing loss is independently associated with accelerated cognitive decline and incident cognitive impairment in older adults.</td>
</tr>
<tr>
<td>Lindenberger &amp; Baltes, 1994</td>
<td>156</td>
<td>Digit Letter Test, Figural Analogies, Practical Knowledge, Activity Recall and Letter S</td>
<td>Speed, reasoning, knowledge, memory and fluency</td>
<td>Auditory acuity explained 34.6 percent of the reliable total variance in intellectual functioning.</td>
<td>Sensory functioning is a strong late-life predictor of individual differences in intellectual functioning.</td>
</tr>
<tr>
<td>Uhlmann et al., 1989</td>
<td>100 subjects with Alzheimer-type dementia; 100 matched controls</td>
<td>Mini-Mental State Examination (MMSE)</td>
<td>MMSE score used as an indicator of the severity of dementia</td>
<td>The prevalence of a hearing loss of 30dB or greater was significantly higher in cases than in controls. Greater hearing loss was associated with a higher adjusted relative odds of having dementia.</td>
<td>Hearing loss was also significantly and independently correlated with the severity of cognitive dysfunction.</td>
</tr>
<tr>
<td>Baltes &amp; Lindenberger, 1997</td>
<td>516</td>
<td>Digit Symbol Substitution, Figural Analogies, Paired Associates, Practical Knowledge and Letter S</td>
<td>Reasoning, memory, perceptual speed, knowledge and fluency</td>
<td>All five intellectual abilities were strongly correlated to sensory (including hearing) functioning than to socio-biographical factor.</td>
<td>Results suggest that aging-induced biological factors are a prominent source of individual differences in intelligence in old and very old age.</td>
</tr>
</tbody>
</table>

Table 2
Explanatory Hypotheses

Two main explanatory hypotheses have been proposed to explain the mechanisms underlying the association between hearing loss and cognitive decline. The first hypothesis suggests that hearing loss and cognitive decline share a common neuropathologic origin, such as age-related neurodegenerative changes caused by microvascular diseases and inflammation (Lindenberger, & Baltes, 1994; Baltes & Lindenberger, 1994). In other words, this model proposes that hearing loss and cognitive impairment in older adults may share the same underlying pathology.

The second hypothesis, known as the “cascade” hypothesis, argues for a causal relationship between hearing loss and cognitive decline, and suggests that hearing loss exists in conjunction with or interacts with other risk factors to accelerate cognitive loss (Lin et al., 2013).

According to this hypothesis, hearing loss may impact cognition in three main ways:

1. Long-term auditory deprivation may result in reduced cognitive function (Birren, 1964; Wahl & Heyl, 2003).

2. One possibility is that the link between hearing loss and cognitive decline is mediated by lifestyle factors. Hearing loss may result in reduced participation in social leisure activities and in withdrawal from social interactions. In fact, hearing loss is independently associated with social isolation and depression (Gates & Mills, 2005). There is also a connection between social isolation and depression and cognitive decline (Plassman et al., 2007, Steffens et al., 2006). The cascade hypothesis suggests that social isolation can lead to depression and other psychological consequences that may affect cognitive function.

3. Hearing loss may result in increased compensatory cognitive effort exerted to fill in the gaps caused by missing speech information, which may result in a shortage of cognitive resources dedicated for encoding speech into memory in an already reduced working memory in older adults (Schneider et al., 2010; Tun et al., 2012; Pichora-Fuller & Singh, 2006).

A third hypothesis suggests that the reduced cognitive function seen in older adults can be confounded by hearing loss. Individuals with hearing loss are at a disadvantage if cognitive tests are to be administered using auditory stimuli (Gussekloo et al., 2005). This hypothesis seems unlikely because the link between hearing loss and cognitive decline remains unaltered whether cognitive tests are administered through the auditory or visual modality (Tay et al., 2006). In order to account for hearing loss when

Cascade Model

Common Cause Model

Figure 2. Cascade and common cause hypotheses. Duplicate figure from Dawes, P (2014). Can Hearing Aids Prevent Cognitive Decline and Dementia? Audacity, 4: 20–22.
administering cognitive tests, an effort should be made to ensure that the auditory signal is presented at an adequate level. In addition, visual stimuli can be used as an alternative to auditory stimuli when testing cognitive performance in patients with hearing loss.

**Hearing Aids and Cognition (Review of Studies)**

A small number of studies have examined the effects of hearing aid use on cognitive performance in older listeners. The findings of these studies were inconclusive. The inconclusive results may be attributed to differences in methodology. For example, some of the cognitive tests used in these studies employed auditory stimuli; therefore, improvements in cognitive function may be due to improved audibility with hearing aids. Also, there was a lack of information on whether amplification was well fitted and whether the hearing loss had been appropriately compensated for.

Up to date, there is a lack of strong evidence on the long-term protective effects of hearing aid use against cognitive decline (Kalluri & Humes, 2012). Further research is needed as to whether hearing aid use could prevent, reduce, arrest or reverse cognitive decline in older adults.

Table 3 lists some of the studies that looked into the effects of hearing aid use on cognitive function in older adults.

<table>
<thead>
<tr>
<th>STUDY</th>
<th>COGNITIVE MEASURE</th>
<th>HEARING AID USE</th>
<th>SHOWED IMPROVEMENT IN COGNITIVE FUNCTION?</th>
<th>MODE OF ADMINISTRATION</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mulrow et al., 1990</td>
<td>Short Portable Mental Status Questionnaire (SPMSQ)</td>
<td>4 months</td>
<td>Yes</td>
<td>Verbally</td>
<td>The SPMSQ is commonly used as a simple screening tool that is not designed to detect changes in cognitive function.</td>
</tr>
<tr>
<td>Acar et al., 2011</td>
<td>MMSE</td>
<td>3 months</td>
<td>Yes</td>
<td>Verbally</td>
<td>Cognitive test was administered verbally</td>
</tr>
<tr>
<td>Lin, 2011</td>
<td>DSST</td>
<td>At least once a day over the preceding year</td>
<td>Yes, HA use was positively associated with cognitive function</td>
<td>DSST is a nonverbal test.</td>
<td>Results must be interpreted with caution because of the small number (n = 13) of participants using hearing aids.</td>
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<tr>
<td>Choi et al. 2011</td>
<td>Visual Verbal Learning Test (VWT)</td>
<td>6 months</td>
<td>Yes, significant changes in the total score</td>
<td>Visual</td>
<td>Due to the small sample size, the findings of this study should be interpreted with some caution (n = 18)</td>
</tr>
<tr>
<td>Tesch-Römer, 1997</td>
<td>Executive function and memory</td>
<td>6 months</td>
<td>No</td>
<td>Verbal and nonverbal</td>
<td>Since the subjects were not randomly assigned, six months of HA use is too short to cause any significant change.</td>
</tr>
<tr>
<td>Van Hooren et al., 2005</td>
<td>Processing speed, reasoning, memory, knowledge and verbal fluency [broad range of cognitive tests]</td>
<td>12 months</td>
<td>No improvement was observed</td>
<td>Verbal and nonverbal</td>
<td>Older adults did not pursue intervention for eight to 12 years after the first notice of a hearing impairment</td>
</tr>
<tr>
<td>Wong et al. 2014</td>
<td>MMSE</td>
<td>6.9 (4.3) years</td>
<td>No. Out of the eight domains measured on the MMSE, auditory factors (i.e. duration of hearing aid use, aided noise composite SRTs, and aided sound-field thresholds) predicted the scores on five MMSE domains that required understanding of the verbal instructions</td>
<td>Auditory and visual</td>
<td>Monaural hearing aid fittings</td>
</tr>
</tbody>
</table>
Implications on Clinical Practice

It is crucial for clinicians to learn whether earlier or better hearing healthcare could arrest, reverse or slow down the progression of cognitive decline in older adults (Pichora-Fuller, 2010). Further, older adults with hearing loss tend to wait a long time before they wear hearing aids. Therefore, it is important for hearing healthcare professionals to know whether or not to make evidence-based recommendations to try hearing aids early on.

In order to address these clinical questions and many more, a carefully planned longitudinal study is still required to examine the casual relationship between the long-term use of appropriately fitted hearing aids and the progression of cognitive function.

References


Pichora-Fuller, M. K. (2010). Using the brain when the ears are challenged helps healthy older listeners compensate and preserve communication function (pp. 53–63). In L. Hickson (Ed.). *Hearing care for adults*. Phonak: Stäfa, Switzerland.


Pichora-Fuller, M. K. (2010). Using the brain when the ears are challenged helps healthy older listeners compensate and preserve communication function (pp. 53–63). In L. Hickson (Ed.). *Hearing care for adults*. Phonak: Stäfa, Switzerland.


