The Role of Hearing in Aging and Hearing Rehabilitation Technology with an Outlook on Future Applications

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Abstract: The purpose of this position paper is to raise awareness about the negative impacts of age-related hearing loss and the importance of providing good hearing healthcare. We also provide an overview of state-of-the-art hearing aids - the standard rehabilitative technology for hearing loss – along with some thoughts about the future of hearing healthcare. Provision of hearing intervention is critical because untreated age-related hearing loss is associated with numerous negative impacts on the health and well-being, such as increased odds of falling, social isolation and cognitive decline. We suggest that, hearing technologies that combine intelligent computer systems with user centred approaches to hearing healthcare provision will ensure that hearing aids result in improved quality of life for those with hearing loss.

1 INTRODUCTION

Age-related hearing loss (ARHL) is one of the top 5 contributors to years lived with disability. ARHL has broad negative psychosocial impacts and, perhaps more alarmingly, untreated ARHL is known to be associated to cognitive decline and dementia (GBD 2015 Disease and Injury Incidence and Prevalence Collaborators, 2016) Gerontologists and others with an aging clientele therefore need to be aware of options for audiological rehabilitation of their aging patients.

The purpose of this position is to describe the impacts of untreated hearing loss on the individuals and their family, to discuss the role of audiological care, and to make the case that gerontologists need to adjust their practice if a client has untreated hearing loss. Additionally, this work provides an overview of state-of-the-art hearing aids (HAs) - the standard rehabilitative technology for hearing loss – along with some thoughts about the future of hearing healthcare, so that the reader knows the options available to those with ARHL.

2 IMPACTS OF ARHL

Hearing loss is a chronic condition, the prevalence of which is strongly associated with age. Epidemiological studies indicate that approximately 25-50% of people have a bilateral hearing loss of 30 dB or more by age 70 years, which increases to between 40% and 75% by age 80 years, (Roth et al., 2011, Feder et al., 2015; Goman and Lin, 2016). The rate of onset of hearing loss increases at faster pace yet in those aged 80 years and older (Wattamwar et al., 2017).

Untreated hearing loss has many negative impacts – it limits the ability to conduct activities of daily living (Gopinath et al., 2012) and increases the odds of falling (Jiam et al., 2016), as well as increasing utilization of healthcare services and hospitalization rates (Green and Pope, 2001; Genther et al, 2013). At a psychosocial level, hearing loss is associated with social isolation, loneliness, and depression (Sung et al., 2016; Mick et al., 2014; Hay-McCatcheon et al., 2018). Further, data are rapidly accumulating that show a robust link between hearing loss and cognitive decline (Dawes et al., 2015; Amieva et al., 2015, Lin et al., 2013).

The mechanisms of the above associations are not always clear, although hearing loss as a mediator between use of healthcare services and other conditions has certainly been demonstrated. For example, in a study by Crealey and O'Neill (2018), hearing loss was found to consistently predict aspects of cognition, autonomy, mobility and memory, which in turn, predicted frequency of GP visits. On a positive note, whether directly or indirectly, use of

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hearing aids seems to moderate some of these negative effects (Amieva et al., 2015; Crealey and O'Neill, 2018; Hay-McCutcheon et al., 2018; Ray et al., 2018; Weinstein et al., 2016).

Unfortunately, the use and uptake of hearing aids among individuals with ARHL is low. Data suggest that people wait on average 7-10 years after noticing hearing problems before seeking help (Davis et al., 2007), and that just 15-30% of people who would benefit from hearing aids obtain and use them (Chien and Lin, 2012; NIDCD, 2016). Explanations for low help seeking and uptake of hearing healthcare include a lack of awareness of hearing loss because of its very gradual onset, stigma associated with hearing loss and hearing aids, the cost of hearing aids and a lack of access and/or knowledge of how to access services (Wallhagen and Reed, 2018; Wallhagen, 2010; Saunders et al., 2018).

Primary care is an important entry way to almost all health care services. Unfortunately, screening for ARHL in primary care is uncommon with overall rates found to be about 23% (Abrams and Kihm, 2015). Of even greater concern are reports from older patients that their primary care practitioners (PCPs) do not view ARHL as a health-related issue, or as a priority during office visits (Chou et al., 2011). More alarmingly yet, is the finding that even when issues related to ARHL are raised by individuals seeking care, practitioners often negate the concern, and/or view hearing aids as stigmatizing or ineffective (Wallhagen, 2010). It is thus important bring awareness of the impacts of untreated hearing loss to practitioners who provide services to the elderly, and to educate them as to how hearing loss can be managed.

3 TECHNOLOGY FOR HEARING REHABILITATION

This section describes state-of-the-art hearing aid technology and provides some ideas about the future of hearing healthcare which will allow for novel functionalities and possibilities in rehabilitation, service delivery, and research.

3.1 Current Technologies

A traditional hearing aid consists of a microphone to pick up external sounds, an amplifier to increase the incoming signal gain and some form of transducer to transfer sound from the amplifier to the ear canal. However, today's devices incorporate many additional features that provide signal enhancement via digital signal processing. These features include the following:

- Multiple channels
- Directional microphone systems
- Noise reduction
- Feedback management
- Wireless connectivity
- Data logging
- Learning features
- Binaural processing
- Multiple programs

Current developments are also focussing on increasing the processing power of the built-in computing units, while reducing the power consumption overall. It is important that the audio processing happens as fast as possible to reduce the time delay between the picked-up signal at the microphones and the transmitted signal at the speaker.

3.1.1 Multiple Channels

A channel is essentially a filter that breaks out a broad band signal into discrete bands of frequencies. Signals within a frequency band or channel are analysed and processed independently from signals in other bands. Parameters that are typically analysed and processed within a band are gain (for overall amplification, feedback and output control), noise reduction processing and directional microphone polar patterns. Broadly, the advantage of multiple channels is customization of the hearing aid output to a specific configuration of hearing loss.

3.1.2 Directional Microphone Systems

Almost all of today's hearing aids are equipped with multiple microphones, that enable incoming signals to be differentially amplified depending on their source relative to the microphone ports. Directional microphones aim to provide greater amplification for signals arriving from the front than for signals arriving from the left, right or behind, thus improving the signal-to-noise ratio of signal from the front that are delivered to the ear of the hearing aid user. Most hearing aids today automatically adjust the directionality of the microphones in response to the environmental input. This is generally beneficial for the user, but it has its limitations if the hearing aid software misclassifies an incoming signal or if the user wants to listen to a sound source that is not located in front of them.

3.1.3 Noise Reduction

The most common complaint of hearing aid users is difficulty hearing in a noisy environment. Noise reduction algorithms were thus implemented into hearing aids to decrease the annoyance caused by noise, and to improve speech understanding. Noise reduction algorithms have generally been shown to be effective at the former, but not the latter (Brons et al., 2015). Digital noise reduction algorithms vary greatly across hearing aids and new signal processing approaches are continually being developed.
Wind noise, caused by the vibration of the microphone membranes due to wind turbulence around the microphone inlets is another problem for hearing aid user, so noise reduction algorithms targeting wind noise have been developed with some success.

3.1.4 Feedback Management

Acoustic feedback occurs when the sound that has been amplified by the hearing aid re-enters the microphone and is amplified again, causing a high pitch whistle or ringing. Feedback can be a problem in hearing aids because the receiver and microphone are physically close together and thus acoustic leakage can easily occur. Leakage can also occur when the speaker is not properly inserted into the ear. Signal processing algorithms to combat feedback have been successfully developed. Typically, these systems work by limiting the output from a hearing aid channel when feedback is detected in that channel or in newer hearing aids, by introducing an oscillating signal that cancels out the feedback signal

3.1.5 Wireless Connectivity

Telecoil systems allow the hearing aid to pick up signals from compatible electromagnetically looped systems. These systems are typically found in auditoriums, churches or larger meeting rooms where external microphones are utilised by a speaker. The telecoil system transmits the recorded voice signal via an induction loop directly to the hearing aid. The principle is shown in figure 1.

The signal then is processed by the digital sound processor and fed to the speakers of the HA. This way the microphones of the HA are bypassed, which increases the signal-to-noise ratio and should enhance speech understanding. This system allows a large group of hearing aid users to receive the same signal. A different wireless solution is a FM based system, where an external audio signal is picked up by an amplifier and transmitter device – called streamer –

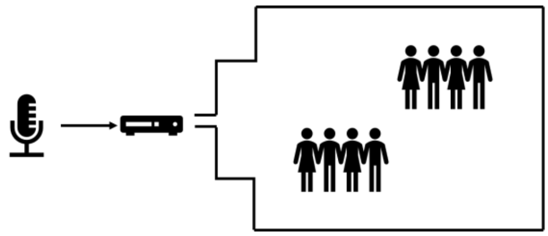

Figure 1: A telecoil system consists of an external microphone, an amplifier and an induction coil that is placed in the room around the HA users.

and then transmitted via radio frequency to an antenna in the HA. Thereby the signal is bypassing the integrated microphone and is processed directly by the sound processor. The principle for streamer functionality can be seen in figure 2.

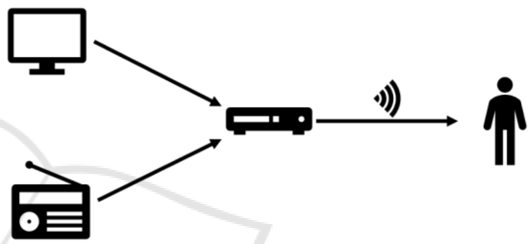

Figure 2: The FM system consists of an external signal source like TV or radio and an amplifier and transmission device that directly couples to the patients HAs.

The difference to the telecoil system is that here the signal is transmitted to one single pair of hearing aids. This connectivity method can also be used to utilize a portable external microphone that can be handed to a conversation partner.

Bluetooth connectivity gains more popularity these days as it allows for direct connection with smartphones and other certified Bluetooth audio devices. Sound can be streamed directly to the processor of the hearing aid. This functionality also allows the patient to handle steering inputs for the HAs, like adjusting the volume or program. This technology enables two-way data communication, which is important for some of the future technologies, that will be described further on. Newer Bluetooth standards are allowing for less energy consumption, while the connection is active.

3.1.6 Datalogging

The internal digital memory space on the hearing aids is used for data logging. When visiting the audiologist, the data log can give insights into the usage pattern of the devices. The internal memory can include data on the total usage of the device, daily average, average of sound pressure levels, classified environments or program usage. The environment classification usually differentiates between: quiet, speech, speech in noise and noise.

3.1.7 Learning Features

Some hearing aids now offer a learning functionality, a logic software saves the user interactions on the hearing aid in correlation with other logged data. Over time this can lead to less need to interact with the HA, as the devices could automatically adjust volume or program when detecting a known environment. This feature is very new and holds a lot of potential for the future, especially to increase device usability.

3.1.8 Binaural Processing

With binaural processing capabilities, a pair of hearing aids is communicating wirelessly with each other. This feature is used to make program or volume changes on both hearing aids by just using the button on one of them. In recent years, the protocol also allows for sound source location detection, meaning the side from which the sound is represented can be detected and amplified accordingly, also allowing for a better directional effect.

3.1.9 Multiple Programs

Hearing aids provide the possibility for the audiologist to create different programs, that suit different auditory environments and personal preferences. Optimised settings e.g. a high level of directionality and high level of noise reduction can be saved as settings in a 'conversation program'. The different programs can be accessed by the patient easily and quickly on the hearing aids or through the connected smartphone application, to suit the patients' needs in different environments.

3.2 Future Technologies

With the implementation of smart connectivity new opportunities present themselves as hearing aids are now opening to be used as Internet-of-Things activated devices. Remote monitoring as well as changes to the personalization of the devices have been introduced very recently. Self-monitoring features have also gained increasing recognition. Over-the-air firmware updates for hearing aids start to be available from this point forward (Hoppe and Hesse, 2017). Thanks to the low energy and high bandwidth wireless connection, more complex signal processing could be handled by a smartphone, as that offers more processing power. Rechargeable batteries have recently been introduced but they have yet to be implemented widely in more HA models.

Applications that include data transfer could incorporate artificial intelligence – supported optimisations. Continuous monitoring of HA usage via data collection in a cloud service enable usage pattern recognition and, through machine learning, better automated setting prediction of the device for certain situations (Zhang et al., 2016). These could enhance the user experience through an 'always right' option based on the learned preferences of the user in certain situations.

Research in auditory fields is also transformed through the availability of remote data collection. The EU-project 'EVOTION' is utilizing the collection of different variables from the hearing aids as well as smartphones, health sensors and clinical repositories. These data should then be used to find possible success factors for hearing loss treatment and support the formulation of hearing healthcare policies based on real world evidence (Dritsakis et al., 2018). This concept of evidence collection through connected devices could also be applied to other fields of policy making.

Additional, to the objective data collection, new possibilities for subjective feedback would improve the labelling of data. Giving the user the possibility to report on the quality and functionality of hearing aids in a current situation would provide personal labels, which in turn could be used at later points to intervene in challenging situations. These personal labels and notes can also be used for improved counselling.

4 CONCLUSIONS

In conclusion, ARHL has numerous negative impacts on life, thus limiting the ability to conduct activities of daily living. Furthermore, increased odds of falling, social isolation as well as a strong connection with cognitive decline are significant indicators that an ARHL should be treated. A hearing loss, that is recognised and treated, is battling these and other negative impacts. Hearing health as a part of general health is an important factor for aging well and should be recognized by the science of gerontology and research into this area is worthwhile as well as important.

Hearing aids are the standard rehabilitative technology for hearing loss and modern HAs offer a large number of features that should help increase speech intelligibility and usability. Wireless connectivity and software enhancements have a great impact on the usability and versatility of the devices and can lead to better rehabilitation in the future. In combination with artificial intelligence, data collection and powerful computer systems as well as user centred approaches, the rehabilitation with these devices can have a positive impact on the quality of life of those living with ARHL.

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