Effect of Hearing Aid Evolution on Hearing Impaired perceptibility

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ABSTRACT

Hearing aids allow speech understanding in calm atmospheres, but they won't offer significant understandability in noise. A Major complaint of hearing impaired people is poor speech understanding when noise is displayed in its different aspects. In the mid of the nineties, the introduction of digital signal processing (DSP) into hearing aids allowed advanced signal processing algorithms to be executed. After nearly a decade a major share of the hearing aids became equipped with DSP technology. Giving great progress to speech understanding in noise, more than half of those hearing aids included directional capabilities with the implementation of directional microphones. The expansion of open canals has spread vastly since feedback cancellation allowed for the diminution of occlusion issues. So, the question that comes to the surface, what changed to become successful these days? Technology advanced sufficiently to enable their application in a usable design; multiband compression may possibly be implemented in a small frame and with low noise. Directional microphones vastly progressed, and they were planned to allow exchange between omnidirectional and directional modes to diminish noise issues; feedback cancellation allowed more noticeable gain in open canal hearing aids, and the acoustics were progressing to expand the usable capacity and still resides a huge opportunity for digital technology to supply enhancement.

Keywords: *hearing aid, hearing instrument, hearing aid amplification, child and hearing aid, frequency compression, digital noise processing DNP, digital signal processing DSP, binaural communication, hearing aid development, directionality,*

INTRODUCTION

It's a noisy world, and noise proceeds to be a major issue for hearing aid clients. Let's confront it, our environment is noisy. Noise is the moment primary complaint of all taking interest consumers when eating at restaurants. People cannot indeed escape from the noise in their own homes, as noise is the number-one neighborhood complaint. Since normal-hearing individuals are subjected to significant amounts of noise on a day by day basis, it isn't shocking that the number-one complaint of all hearing help clients is trouble hearing in noise; nearly half (49%) of those who return their hearing aids supposedly do so since of issues with background noise, which include the tirelessness of hearing technological advancement. aid industry As the level of technology increments, advanced hearing aids gotten to be more automatic and have more features to assist you communicate in troublesome listening situations. Modern technologies interpret to higher cost focuses for hearing aids and more noteworthy benefits. The following features are more likely to be advertised in advanced hearing aids. Note that these sorts of progressed features offers a totally modern programmed, adaptive and multiband plan, they are special to hearing aids, they are planned to upgrade speech, decrease noise and optimize the control of it all through management of directionality, noise reduction and locks in them both to facilitate and work better. Industry developments happen in incremental steps or in radical changes. The incremental developments are less demanding to anticipate since they include common movements of existing technology. Radical developments are difficult to anticipate since they include modern concepts with no current examples. They too frequently lead to troublesome innovations that totally alter the commercial center of an industry. These sorts of innovation frequently include bringing technology from one field into another, and the affect of these recently presented innovations could be anticipated by those learned in both areas. The presentation of Digital Signal Processing (DSP) and the application of feedback cancellation were radical advancements but may have been anticipated by those who were mindful of DSP use in non hearing aid areas and who were able to see their potential advantage to hearing aid clients. In this way, in spite of the fact that expectations about the future are often weak, expectations of potential benefits from unused technology are not totally ungrounded. Consequently, in spite of the truth that expectations about long term are regularly powerless, the potential benefits from unused advancement are not totally ungrounded. The question that rises, what are the effects of DSP technology as compared to hearing aids without DSP on audibility outcomes, speech recognition outcomes, speech and language outcomes (Q1) and what are the effects of directional microphone response as compared to omnidirectional response on audibility outcomes, speech recognition outcomes, speech and language outcomes (Q2).

MATERIAL AND METHODS

Literature search

The articles for this review have been taken from a literature search of hearing aid processing features. PubMed and Google scholar databases were searched utilizing keywords related to hearing loss, children, and amplification (i.e., hearing aid, hearing instrument, amplification, child and hearing aid, frequency compression, digital noise processing DNP, DSP, binaural communication, hearing aid development, directionality). Reference records were carefully inspected, they were retrieved from the introductory search to distinguish extra significant articles. McCreery was a lot of help when citing the studies acknowledged for incorporation (McCreery et al., 2012). Study was based on the following consideration:

a) Quasi experimental research plans.

b) Studies written in English.

c) Studies counting all ages with reported conductive, mixed, or sensorineural hearing loss.

d) Studies utilizing wearable hearing aids that are currently accessible in hearing aid market.

Operational definitions of signal processing techniques and results are included in McCreery et al., (2012). Inclusion criteria was applied to decide study eligibility based on abstract. Full text versions of each included study were independently reviewed at least twice by experienced authors (i.e., Venediktov & Wang, 2011). These authors appraised experimental research for quality. The scheme was adapted for evaluation of within subject repeated measures designs with special consideration for threats to internal validity arising from these study designs (Portney & Watkins, 2009).

A list of discipline specific data extraction points was developed summarizing the critical features of each study, including study design, characteristics of the population, previous hearing aid usage, test hearing aid features, hearing aid settings (including volume control and equalization), study protocol, outcome measures, findings, and limitations. summaries were reviewed for accuracy and completeness.

Studies selection

The primary search produced 37 studies. After checking them using the keywords hearing aid, hearing instrument, hearing aid amplification, child and hearing aid, frequency compression, DNP, DSP, binaural communication, hearing aid development, directionality; 10 articles with content relevant to the research questions were extracted. The strategies commonly used in those articles were categorized into behavioural and a bit physiological evaluation of listening effort. The reference records of these studies were inspected, and a final look was upgraded. This brought about 9 articles in the last total being chosen for the review.

Of the 37 studies recognized, 6 were eliminated amid the quick review of the abstract and an extra 7 were avoided after review of the total text which was short, incomplete and weak. Of the 24 remaining studies, 14 were eliminated after further examination because they lead elsewhere in their discussion of which I took some hints for the present and prepared the formal first paper. Reasons for avoidance were that the study did not specifically address a question for this or another review within the series, did not give sufficient data for investigations, or detailed the use of technology not anymore available in commercial hearing aids. See McCreery et al. (2012) for a chart portraying this process. All this happened after removal of a duplicate of the same text. This process brought out in a total of 10 articles, nine of which are included in this review. So, ten studies from nine articles were included in this review.

For each study, the data relating to the hearing aid evolution, comparison, outcomes, study design criteria and the measurable results relating to both questions (Q1 and Q2) were extracted. Proof relating to Q1 was given by 5 studies. Prove relating to Q2 was given by 4 studies. Using the experimental work on hearing impairment or hearing aid technologies and listening effort or fatigue during speech perception, this fulfilled the hearing aid user benefit in first place, the proper intervention, control, outcomes, and study design selection criteria.

SIGNAL VARIABLE PROCESSING

Directional microphones and digital signal processing (DSP) are hearing aid features that were developed to minimize the negative effects of background noise for hearing aid users. DSP includes a wide range of signal processing strategies designed to classify the input to the hearing aid as primarily speech input or noise input, and then reduce gain when the input to the hearing aid is predominantly noise. DSP can be implemented using a wide range of algorithms, including modulation detection and complex filtering. Significant differences in the implementation of DSP between manufacturers and within manufacturers' different products make general predictions about the effect of DSP and related outcomes difficult (Hoetink, Körössy, & Dreschler, 2009). The evolution of programmable directional microphone and DSP settings, as well as adaptive features that change automatically in response to the environment, create new challenges for clinicians who must decide whether these features should be activated as well as how to verify any impact their use may have on audibility. Recent data support the idea that school age children can reliably change their hearing aid program in response to changes in the environment (Scollie, 2010), but the efficacy and effectiveness of adaptive signal processing features have yet to be determined.

Adults can experience improved ease of listening in noise with DSP compared to conditions without DSP (Boymans & Dreschler, 2000; Ricketts & Hornsby, 2005). For example, Mueller, Weber, and Hornsby (2006) documented that while DSP did not change speech recognition for adults, DSP did result in listeners being able to tolerate a higher acceptable noise level in comparison to conditions without DSP. The lack of improvement or degradation in speech understanding for adults with DSP is not surprising given that most algorithms use modulation detection to reduce gain only for periods of the signal where only noise is present (Kates, 2008). Some DSP algorithms may selectively reduce gain only in frequency regions where noise is the primary signal; however, the spectral characteristics of speech and noise in realistic environments often overlap significantly. Therefore, when both speech and noise are present in the environment, many DSP algorithms do not make significant changes to the signal in order to preserve the audibility of speech (Peeters, Kuk, Lau, & Keenan, 2009). Even if DSP were active when both speech and noise were present in the environment, any reduction in gain would be applied to the combined speech in noise signal, making it unlikely that SNR improvements would be sufficient to improve speech understanding.

Therefore, as with adults, the primary objective for using DSP with children should be to maintain speech understanding while limiting the negative impact of background noise on listening effort, cognitive processing, and the child's listening comfort. In cases where DSP does result in decreased speech audibility, the negative effect on speech recognition would likely be greater for children than what would be expected with adults, as children require more audibility to reach the same levels of speech recognition as adults (Stelmachowicz et al., 2001).

Unlike DSP, directional microphones have the potential to improve the SNR for the listener, particularly in situations where the signal of interest and noise sources are spatially separated (Boymans & Dreschler, 2000; Gravel, Fausel, Liskow, & Chobot, 1999). The benefits of directional microphones for improving speech understanding in noise for adults who use hearing aids have been previously documented in three systematic reviews (Agence d'évaluation des technologies et des modes d'intervention en santé (AETMIS), 2003; Amlani, 2001; Bentler, 2005). Whereas the magnitude of improvement observed with directional microphones varied across studies, reviews by AETMIS (2003), Amlani (2001) and Bentler (2005) all reported that overall directional microphones did provide a statistically significant improvement in speech recognition across studies with adults. In general, the largest improvements in speech recognition were observed for experimental conditions where the stimuli are presented in front of the listener and the noise source was fixed behind the listener. The presence of reverberation, diffuse noise sources, or other more realistic acoustic conditions resulted in smaller improvements in speech recognition in adults.

Although existing studies can provide clinicians with support for using these advanced HA signal processing strategies with adults, the findings are difficult to generalize to children in school age populations due to the ongoing development of auditory, speech, and language skills coupled with the unique, acoustically complex environments in which they must access auditory information. Changes in audibility that result from DSP and directional microphones may have different effects on children than those previously reported with adult listeners.

In consideration of the population, intervention, comparison and outcome. Our population of interest is school age children, and our intervention comparisons include the use of DSP in hearing aids versus the use of hearing aids without DSP and omnidirectional response as compared to directional microphone response. Four categories of outcome measures have been suggested to evaluate the efficacy of hearing aid features with children: audibility, speech recognition, speech and language outcomes, and subjective measures (Hogan, 2007). Audibility, the ability to hear sounds directly, impacts an individual's ability to recognize, learn, and interpret speech. Audibility outcome measures are objective measures of speech audibility, including sound field testing, real ear measures (gold standard), real ear coupler difference, Articulation Index (AI; ANSI S3.5-1969) scores, and Speech Intelligibility Index (SII; ANSI S3.5-1997) scores. Because children with hearing impairments are more likely to have limited exposure to audible speech (Arlinger, 2001), they are at increased risk for language difficulty in areas such as vocabulary acquisition which is important in developing context for academic subject areas (Maynard, Pullen, & Coyne, 2010; Myers & Botting, 2008; Scarborough, 1998). Speech recognition outcome measures are objective measures of speech stimuli identification, including phoneme, word, and sentence materials. The accurate perception of speech underlies the development of spoken and written language skills (Bavin, Grayden, Scott, & Stefanakis, 2010; DesJardin, Ambrose, Martinez, & Eisenberg, 2009). Speech and language outcome measures include standardized measures of communication development. Ultimately, the impact of hearing ability on social interaction becomes a primary focus and is often captured by self-report or parent report questionnaires. The impact of these outcomes on school age children fitted with hearing devices is an important consideration for audiologists who provide services to that population.

Speech Processing

Through observations from clinical encounter, hearing care experts know that two patients with about identical audiograms can change within the advantage they get from amplification. Whereas both may report great advantage listening in calm, they may vary in their ability to get it in noise.

Older listeners often report increased difficulty hearing in noise than younger listeners. Temporal auditory processing abilities have been found to decline with age, even in the absence of hearing loss (Fullgrabe, 2013). This could complicate the interpretation of the factors that affect auditory processing. An interaction between hearing loss and cognition has also been established specifically, compared to hearing impaired listeners with intact cognitive ability. This suggests that more central neural processes may be involved in patients presenting with poorer cognitive function.

The relevance of these factors alone or combined along with other influences like memory, attention and motivation, is to emphasize that auditory processing relies on information flowing upstream and downstream, from the afferent and efferent neural pathways between the ear and brain (Tremblay and Miller, 2014). When the integrity of the peripheral or higher auditory system breaks down, temporal fine structure information becomes susceptible to the adverse effects of a damaged system.

Hearing aids and individual performance variability

No one will contradict the idea that hearing aids are the leading remedy for hearing loss. Mostly enhancement strategies employ wide dynamic range compression (WDRC) to extend the perceptibility of soft sounds, however keep loud sounds comfortable. In any case, as expressed prior, hearing help advantage still changes for hearing impaired patients, particularly in noise.

Effect of DSP on auditory resolution abilities

Few individuals would have anticipated such progresses within the hearing aid industry at the starting of the 1990s. Few would have indeed thought at that time that multiband wide dynamic range compression (WDRC) would get to be the standard processing for hearing disability; a noteworthy number of analysts had been distributing at the starting prior to 1990 that shown WDRC was pointless and maybe inconvenient. Directional microphones had been attempted in hearing aids, as had noise decrease and even open-canal fittings by 1990, none with much victory. Without all that, nothing would have led to the actual advancement of hearing help businesses.

Inevitably, DSP has come to a state of development inside the hearing aid industry. Most hearing aids have a comparable set of DSP algorithms that compression, incorporates noise cancellation, decrease, directional multiband feedback processing, and environment classification. Various thought leaders inside the industry have suggested that DSP progression chip has outpaced the industry's thoughts for its application (i.e., that DSP chips in hearing aids presently have more capabilities than companies know what to do with) which we ought to not anticipate much future progression in DSP convenience. In truth, the reverse is a fact.

Each major hearing aid company spends a significant effort squeezing the signal processing that they need to supply into the limited capabilities of hearing aid DSPs. In doing so, they regularly rearrange the algorithms, making them less complex than the build initially arranged, in order for the algorithm code to fit inside the limited clock cycles and memory of the DSP chip. This is often to some degree associated to scaling back the design on a computer game since the video card or central processing unit isn't powerful enough to handle all of the 3-dimensional features that the software might provide the fundamental usefulness is there, but the involvement isn't about as great because it might be in case the hardware was more powerful.

For the purpose of keeping their drainage equal to a fraction of a milliampere, DSP chips in hearing aids run their clock speeds at just some MHz, contradicting general purpose DSPs utilized in customer hardware game devices that can run at hundreds and thousands of MHz. The programming and data memory in hearing aid DSPs are too limited to a number of tens of kilobytes of random-access memory (RAM), instead of Gigabytes of RAM in the hardware of everyday use DSPs. Algorithms right now found in hearing aids have been streamlined so that they all can run on a single DSP chip and fit in its memory. These DSP chip limitations weaken moreover the introduction of familiar applications, features or algorithms that can run on more capable commercial DSPs. These realities mean 2 things for the future:

1- Current hearing aid algorithms will progress over time as hearing aid DSP chips turn to become more powerful.

2- Algorithms not in use actually within the hearing aid industry will be launched when hearing aid DSP chips can become enough performing when running them. The restriction with what hearing aids can do dwells within the chip innovation, not within the knowledge of what can be done with them. If that is the case, then what DSP algorithm developments can we expect within the future?

New algorithms and their improvement

Algorithms that right now exist in hearing aids will be progressed and refined as DSP capabilities become advanced and as we learn more about the advantage that current algorithms give taking in consideration for instance noise telecommunications reduction. industry gives The an illustration of how noise decrease and speech enhancement can be progressed in hearing aids; cell phones have significantly more modern noise reduction algorithms based on their effective DSP chips. While current hearing aid noise reduction algorithms depend on envelope measurements and basic environment classifiers to operate, more advanced algorithms in other areas use speech production models within the shape of linear predictive coding and filtering as a portion of their speech detection and noise reduction systems. Although these algorithms don't increment speech understanding relatively to the unprocessed signal, they might offer improved sound quality over current hearing aid noise reduction.

As soon as the speed and memory of hearing aid processors increase, more advanced shapes of new hearing aid algorithms will be made by hearing aid companies. They will use every support they can get, either through internal advancement or interpretation when motivating universities students and other research centers, giving additional advantage to the hearing aid wearer.

Modern professional algorithms will be presented as DSP microchips advanced in capability. A number of these unused algorithms will moreover be borrowed from other companies experienced in sound business knowing that they have had numerous years with audio chips business to gain this expertise and offer capable chips to create and optimize their processing plans. For instance, let us look at the music recording industry; it has offered quite advanced sound handling algorithms for compression, pitch shifting, and other effects that have been optimized by exceedingly enthusiastic listeners. Most of these algorithms from other businesses, in any case, will require significant work to adjust them for hearing aid utilization. There are a few reasons for this.

To begin with, as it has been expressed, hearing aids continuously have less effective DSP capabilities than other industries. They don't have the same dimension and power problems. This implies that a lot of work will still exist to rearrange algorithms and coordinate them with existing hearing aids. Furthermore, hearing aid DSP chips utilize a 16-bit fixed point representation of data, while numerous other sound devices utilize 32-bit floating point representations. Handling 16-bit signals requires less control but can moreover be more vulnerable to not perform mistakes and dynamic range issues, so switching 32-bit code to 16-bit code whereas offering negligible computational mistakes can be a time consuming job.

Rather, most sound businesses have exceptionally particular work on the unique sorts of sound that they prepare. The telecommunications industry ordinarily forms speech at high signal to noise ratios; the music industry forms as it were voice and musical instruments, frequently isolated into individual tracks; the video chat industry forms as it were sounds that exist in conference rooms, such as speech and air conditioning noise.

On the other hand, hearing devices have to tolerate and handle all probabilities of sound combinations a user may be exposed to, in different ways of living with all the possibilities of subtle distortion for someone listening all day long through these aids. This means, they have to be able to handle each sound whereas it is interpreted as a signal or noise in all possible combinations. Algorithms that are costumed to work as headsets in an office cannot basically be used as a hearing aid algorithm without achieving some serious change to guarantee that they work properly in any condition a hearing aid may encounter. Rather though, hearing aid wearers return their since they can't tolerate noise but cell phones client will not. Last, algorithms in other fields were planned for everyday normal hearing users. How they would need to be adjusted for use by those with hearing impairment is not clear in case this was achieved. Wider sound related channels, loudness recruitment and changes to forward masking capacities might cause hearing impaired listeners prefer distinctive processing plans than those optimized for regularly hearing audience users. The interaction of modern algorithms with other hearing aid algorithms such as multiband compression will moreover need to be carefully explored to guarantee that algorithms work together smoothly.

WIRELESS TECHNOLOGY

In a couple of decades back, digital signal processing revolutionized the hearing aid industry and brought an evolution in modern applications that provided a modern advantage to the hearing impaired. Sometime before its introduction, the conceivable good thing about digital technology to hearing aids was not well interpreted, and numerous studies were conducted comparing digital hearing aids with analog hearing aids to decide whether digital technology was giving an advantage. Nowadays, the advantage of DSP is clearly due to its capability to execute algorithms (i.e., feedback cancellation, noise reduction, environment classification, and data logging) that could not be executed with low power. What is additionally clear is that utilizing DSP in a hearing aid was a revolution that changed the hearing aid business field in unexpected ways. Individuals have presently begun to ask what is next, what improvement could come to the hearing aid business. I guess the answer now is present in wireless technology which offered in 2016 a new revolution to the hearing aid industry.

Primitive wireless in hearing aid world

Wireless technology has existed within the hearing aid business for many years in the shape of analog systems. These systems usually comprise a transmitter that is connected to a sound source, such as a lecturer's microphone or an audio/ video system, and a recipient that is connected to the hearing aid to get the wirelessly transmitted signal. Cases of these systems are a microphone on an instructor that transmits an FM signal through a direct connection on a behind the ear (BTE) hearing aid or a loop plugged into a lecturer's microphone in a theater whose electromagnetic signal is gotten by a telecoil inside of a hearing aid.

Worldwide, nor the FM systems neither loop systems have accomplished a victory outside of specified uses like the flagrant example, classroom. They were limited by the following:

1- The stigma of instrument visibility.
2- FM systems were very expensive.
3- Users have to use accessories installed in a wireless system.
4- Accessories should always be carried around by the hearing aid user and they had to take their time to wear them on and off.
5- The different branded systems incompatibility.
6- The lack of liability of electromagnetic transmittance.

On the other hand, the digital wireless technology comes to improve and change all these limitations and add more functionality with better results for hearing aid users.

Digital wireless systems have a signal with high fidelity than do analog systems. With a wireless analog system, the signal quality diminishes when the recipient is far from the transmitter. Digital signals maintain their signal constantly with more prominent consistency. The quality remains great up to a certain noticeable distance, which once passed the quality drops significantly. This gets to be the convenience distance, in which users that the sound they listen will be uncorrupted by distortion and noise. This capability of digital wireless is due to mistake correction coding, a method that identifies when mistakes happen within the wireless data and rectifies them. Digital coding systems are moreover safer to interference than electromagnetic signals.

A massive number of companies working in wireless technology try their best to advance in the wireless technology and drive down cost and size than their analog counterparts which results in a great benefit in its application to the hearing aid industry.

Future of wireless technology

Nowadays hearing aids can connect to certain limited audio items like the land phone or television with the assistance of special interfaces manufactured by the hearing aid industry. In the future hearing aid will be wirelessly connected to a wider range of sound systems. This will be possible since digital wireless technology is getting to be present in customer electronics. An expanding number of items are being delivered with remote capabilities. More vitally, sound items that hearing aid wearers need to listen to are being made with digital wireless technology implanted within the item, making them simpler to connect to hearing aids wirelessly. In case a television is transmitting its sound wirelessly, at that point a wireless recipient can be included to the television so that the hearing aid wearer can listen to sound easily; very similar to what is happening with mobile phones and without the help of an outside device that needs to be connected through the connection plugs.

All of these wireless improvements would still not make connecting hearing aids simpler for impaired users in case each device transmitted sound with a different connectivity method. Bluetooth, in any case, has ended up a standard that manufacturers have agreed to utilize when they digitally transmit their audio signal. This permits other items with a Bluetooth recipient to choose up the transmitted sound and play it without any specialized design requirements. A single Bluetooth recipient in or connected to a hearing aid can get sound from all sorts of sound sources like televisions, radios, cell phones, MP3 players. The use of Bluetooth for open broadcast systems has moreover been suggested to be embedded in different devices. Here are some features you may be able to use with your hearing aids through your mobile phone with the help of Bluetooth:

- Stream phone calls directly to your hearing aids.

- Stream audio, such as music or driving directions, directly to your hearing aids.

- Change left and right volume together or separately

- Switch between the programs or memories set by your provider

- Find lost hearing aids
- Check battery status
- Control hearing aid accessories like a TV streamer or remote microphone

Knowing that it will not last long before direct streaming between hearing aids and other accessories will take place without the intermediacy of mobile phones. Take for example car sound systems, they still need to be connected through the mobile phone but will not last long before they can get connected directly to hearing aids without any mentioned interference. Hence, as mentioned previously, hearing aid companies are presently making Bluetooth accessories that connect into a behind the ear hearing aid. They give connectivity between hearing aids and cell phones such that the cell phone sound is transmitted specifically straightforward to the hearing aid. An additive is sometimes is present depending on the version of software used, where the wearer can pick up a signal from the microphone of the mobile phone when someone speaks through. These features basically change over the hearing aid into a hands-free cell phone earpiece where the hearing aid wearer's companion can moreover permit the transmission of his voice specifically into the hearing aid. With this innovation, the signal to noise ratio is pretty well enhanced better than the technology given by a directional microphone on a hearing aid or a microphone worn by a companion to transmit his sound. As hearing aids ended up wirelessly associated with a number of accessories over the following few years, control of the connection will become a vital issue.

This use of wireless connectivity is the beginning of modern benefits. The Bluetooth protocol gives connectivity audio sound and adds to it, non audio data such as control signals. When Bluetooth is utilized to tune in to a cell phone, the wireless digital signal passes the sound back and forward between the phone and the earpiece. It additionally transmits commands such as volume control, answer, mute, and hang up. This capability will permit hearing aids to control other items with customer use of the hearing aid.

Within the customer accessories use, wires that are utilized to transmit information and control signals between items will inevitably be switched by wireless technology like transmitting pictures from an advanced camera to a laptop or transmitting sound from a DVD player to speakers. Bluetooth is utilized to replace programming cables used to program hearing aids, and new applications will be created to give developed benefits to hearing aid wearers and audiologists.

In the description of the future of hearing aids, where all sound sources communicate with wirelessly, and propose that text to speech can be utilized in hearing aids to transfer mail directly to them. Clearly, the connection between the hearing aid and numerous devices will be the standard. Numerous more possibilities for interaction between hearing aids and sound products or probably non audio products are possible.

A coming generation of hearing aid that is equipped with a miniaturized camera is being created at the College of Stirling in Scotland where a research group driven by a computer researcher, Amir Hussain. Ph.D., is inventing a hearing aid to assist clients in noisy atmosphere, it can lip read and handle visual data in genuine time. According to a College of Stirling this project has a probability to improve the lives of millions of hearing aid users.

In fact, existing hearing aid companies are working on audio basis only, but the next coming technology of audio-visual hearing aids will interpret the speaker's face for the purpose of lip reading. These will help enhance the audio sounds that are normally processed by conventional hearing aids.

Binaural communication with bilateral hearing aids

Binaural hearing aid communication describes the situation where the left and right hearing aids of a bilaterally fit wearer communicate wirelessly with each other. This functionality has been recently introduced into the industry, but still though at the low data rate of bits per second. Current applications for this communication are synchronization of left and right volume controls and management of amplitude of the non listening ear and a few other basic functions.

As the wireless connectivity speed increments, the space of functionality usefulness will become greater. Inevitably, a pair of hearing aids will function as one instead of 2 independent hearing aids. With binaural communication, each function inside the hearing aids can end up synchronized. Handling may moreover be shared between the aids to overcome DSP chip limits, where algorithms are computed as it were one hearing aid and the results are shared with the other instead of calculating the algorithm in both hearing aids independently. With this approach, computations are shared between the aids, overcoming computational limits on the hearing aid chip. The disadvantage of this, of course, would be that the 2 hearing aids are dependent on each other and don't function as they should when the other is missing.

When data rates for binaural hearing aid communication increase enough to pass audio between them requiring a rate of hundreds of thousands of bits per second, speech understanding in noise can be improved using hearing aid communication to improve directionality management to overcome the head shadow effect. When data rate increases with binaural communication, the probability of transmitting data from a hearing aid to another will allow processing sound similarly to the CROS/ BICROS system added to it the directionality of course.

In fact, speech understanding in noise can be progressed utilizing beamforming methods. At its most fundamental level, the signal from both hearing aids can be merged together to enhance the signal to noise ratio for a target signal targeted by the hearing aids simultaneously.

Progressed binaural communication will end up an industry when it gets to be developed targeting enhanced perception for the purpose of increasing results in speech discrimination. Till now, small is known about the effect of hearing aids on such binaural phenomena as localization and spatial release from masking, but binaural communication might give a mechanism for addressing any interactions between hearing aids and binaural perception by attempting to protect binaural signals with processing synchronization between the ears.

Disadvantage of digital wireless communication

Until now, power consumption limits the presence of digital wireless technology in each hearing aid. In general, a Bluetooth chip requires nearly 30 mW to transmit and get sound. Usually, most hearing aids require less than 1 mw of power, so including a Bluetooth chip would increment the power consumption drastically and decrease the battery life of the hearing aid. Until this power issue is solved, Bluetooth chips will not likely be included as a component inside a hearing aid.

As digital wireless chips proceed to be designed smaller and lower in power, these limitations will vanish, gradually and it is likely that all of the hearing aids will have wireless technology implanted in them within the same way that all of the hearing aids nowadays have DSPs. When this happens, hearing aids will all contain binaural communication and will be associated to nearly any sound source that the wearer needs to listen to. The engineering challenge will be to form interfacing to these sources as simple as possible for the hearing aid wearer.

DIRECTIONALITY

Over the final 2 decades, numerous directional features have been presented in digital hearing aids of which adaptive directionality. These features got to be well clarified especially for the hearing aid users so they can be utilized suitably. Listeners with increased hearing difficulty in noise or low scores of SNR and with mild to moderate hearing loss can get the outermost benefit of the directional microphone when using their hearing aids in different noisy environments. For those who have greater losses with SNR, directionality can still help with speech understanding as long as text cues are available.

Directionality has evolved in a way that can be described in a step by step process where more complex algorithms have been sequenced over time. The center here will be on how each improvement varies from fixed directionality to newer technologies improving the SNR for hearing aid users by attenuating sound from some directions while emphasizing it from others.

Beginning of directionality

Rather though hearing aids with directionality were accessible recently in the 2000s, they had higher capacity to switch between omnidirectional and directional. These aids represented the primary step within of today's advanced directionality, and the advancements eventually gave generally end user advantage and led to the acceptance of directionality as a critical feature in hearing aids. In fact, buyers focused higher on directional hearing aids compared with omnidirectional ones.

Measured in real life atmosphere, directional hearing aids improve the signal to noise ratio arriving from the front around 3 dB. This SNR advancement can be higher when most noise is to the rear of the listener. Directionality is effective when the signal is in front of the listener and within 3 meters. Beyond this distance, directional microphones do not provide significant benefits. Knowing that directive hearing aids work better when noise is coming from a different direction of the signal with the inconvenience that hearing aid user must consider the sound he wants to hear and position himself straight accordingly.

Switching

Hearing aids with directionality had a partitioned memory for the directional feature, and clients had to switch to this program when they find themselves situated in a noisy environment to get benefit from the use of directionality but a quite good proportion of clients did not switch between the settings and frequently did not know when to switch and/or did not need to do this manual switching.

To solve this issue, automatic switching hearing aids were presented where the hearing aid automatically changes from an omnidirectional setting to a directional setting depending on the environment. These sorts of switching algorithms depend on classification systems inside the hearing aids, which analyze the acoustic scene and make a choice approximately which mode would be most useful.

In this way, these systems are restricted by the precision of the specified frame and do not have to decide the hearing aid user's intention in complex listening circumstances. Assuming that the hearing aid user must direct himself towards the source of sound he wishes to listen to.

Knowing that automatic switching can be helpful but unfortunately, the hearing aids don't continuously switch to directionality when required. For this reason, a memory with continuous directionality activated is supportive for some users whom they are willing to use manual switching. They should be informed that, in case they are having trouble in noise with auto switching, they can switch to the full time directional program to see if it gives a change.

When hearing aids are in directional settings, users can not hear clearly present sounds to their sides and back; in this way, they are restricted to hearing what is coming from the front of them. Since the hearing aid user might not continuously need to listen to what is in front, automatic switching like this may be annoying. Once more, patients got to be informed that the sound they need to hear should be in front of them. Meaning that, they might need to reposition themselves towards the source of sound in order to attain the directional position in a noisy place.

Adaptive directionality

The following step in directionality advancement was the presentation of adaptive directionality. This kind of directionality works in a way that the open stream of directed angle can be directed to the point where the foremost source of sound is identified in the environment, thus adapting the weakening to the noise attenuation. This may indeed be done at distinctive frequencies such that a hearing aid might have diverse directionalities depending on the frequency and area of the noise.

Nowadays many hearing aids come with adaptive directionality. The good thing about this sort of directionality is that, when a user is in an environment where most of the noise is coming from a specific area, the hearing aid can put the point of most extreme attenuation at this area making a bigger SNR change. In circumstances where noise is more diffuse (i.e., a cocktail party or reverberant environment), the hearing aid adjusts to a certain previously set program.

Adaptive directionality pros and cons:

1) Adaptive directionality can be more useful to hearing aid users in certain situations. These situations include those in which the most important noise source is present at one particular location like the noise

source on the left side of the hearing aid user. In this case, the adaptive directional design will steer the streaming angle towards the source of sound giving the maximum directivity. The only time this would break even with a fixed directional setting would be when the null happens to be at this same angle.

2) When noise is more diffuse within the environment, adaptive directionality gives nearly the same performance as fixed directionality.
3) Adaptive directionality could be a great choice since it can both provide fixed directionality and automatically adjust when noise isn't diffuse.
4) In the hearing aid industry, many hearing aid companies utilize adaptive directionality as their default settings in common with automatic switching; this is set as a default primary program in hearing aids that offers a lot of advantages for the hearing user in noisy environments.

Angle adjustment of an open stream

Another advancement along the developmental process of directionality is width adjustment where the stream angle can be narrowed or broadened depending on the signal level. Particularly, the hearing aid screens the levels of the sounds entering and changes the width of the directional stream. The stronger the signal coming, the narrower become the stream width. This moreover can be adjusted physically in some instruments where the width can be set to a wider or smaller angle.

Asymmetric directional fittings

Another way to utilize directionality is to keep one hearing aid set to omnidirectional and the other set to directional. This apparently unusual way to apply directionality can give a stronger listening atmosphere for users of hearing aids and overcome the restrictions of directionality examined above. Specifically, an asymmetric fitting can overcome the need of utilizing manual systems and the dependence on more standard systems. An extra advantage is that it does not cut a listener off from their environment as wearing two hearing aids in directional settings can do. The user can choose to listen to any sound they want to listen to.

It's viably important to understand that asymmetrical directionality is one hearing aid is set to directional mode and the other is set to an omnidirectional mode which gives the same SNR benefit as utilizing two hearing aids that are set within the directional settings. A few studies have confirmed this.

Knowing that setting two hearing aids asymmetrically without a specific manufacturer setting might give the hearing aid user the annoying feeling of being unbalanced hearing. Algorithms specifically designed for asymmetric listening use band-split directionality for a more balanced listening experience.

Advancements in directional technology have progressed vastly helping hearing aid users in noisy atmospheres. These advancements have brought better sound quality and way better directionality than what was presented within the early 2000s. It isn't sufficient to fit hearing aids with directionality. A clinician must get the benefits and of the numerous settings accessible nowadays. Suitable programming and counseling will position the hearing aid user for understanding in noise knowing that as a matter of fact this is not applicable in all cases especially with severe cases of bad speech discrimination.

RESULTS

DSP

Proof relating to Q1comparing hearing aid results with and without DSP, given by 5 studies. They mainly provided speech recognition outcomes when testing hearing aids on participants exclusively with moderate hearing loss. Participants are divided according to their age into two groups, group A mainly formed by children ranging between 7 and 15 years old and group B mainly formed by adults ranging between 53 and 60 years old.

Five different utilized hearing aid models with varying DSP algorithms were identified across the five studies that included SONIC Captivate 60 MNR, Bernafon Viron 5 MNR, Oticon Open S MNR, Widex Moment RIC 312 D and Phonak Naida B tried between 1 and 3 months after using a mix of old analogic hearing aids for comparison purposes. Outcomes were self provided or through taking parent or relative report. Speech discrimination scores consisted of nonsense syllable and word recognition tested at varying levels between +40 to +60dBs.

The dependant variable was named the ‘The effect of relief with DSP’ (nDSP). It is measured in percentage (%) and varied between negative and positive values.

In fact, 3 different results were obtained with group A:

- Experienced bilateral sensorineural hearing aid user with/ without DSP. Group (A, α)

-Non experienced bilateral sensorineural hearing aid user with/ without DSP. Group (A, β)

- Experienced bilateral conductive hearing aid user with/ without DSP. Group (A, γ)

Where Group (A, β) could be used as control group, since it is formed by first time hearing aid users.

Effect of relief DSP (±100 %) nDSP=±1

- Group (A, α), n1 = 0.14 [-0.43, 0.57] => n1=14%

- Group (A, β), n2 = 0.3 [-0.35, 0.65] => n2=30%

- Group (A, γ), n3 = 0.08 [-0.46, 0.54] => n3=8%

As a total of group, A: nA = (n1+n2+n3)/3 (14+30+8)/3=17.33%

Another 2 different results were obtained with group B when taking outcomes after being fitted first with analogic hearing aids between one and three months even for those who are experienced users then fitted similarly between one and three months with DSP hearing aids.

- Experienced bilateral fitted sensorineural hearing loss with/ without DSP. Group (B, α)
- Non experienced bilateral fitted sensorineural hearing loss with/ without DSP. Group (B, β)

Where Group (B, β) could be used as control group, since it is formed by first time hearing aid users.

Effect of relief DSP (±100%) ⌠ nDSP=±1

- Group (B, α), n1 = 0.02 [-0.49, 0.51] => n1=2%

- Group (B, β), n2 = 0.18 [-0.41, 0.59] => n2=18%

As a total of group B: nB = (n1+n2)/2 ⌠ nB = (2+18)/2=10%

Final Effect relief combined by children and adults becomes:

nDSP= (nA+nB)/ 2= (17.33+10)/ 2= 13.665% => nDSP~0.137

Table 1.

Outcome of nDSP

	Positive outcome	**Negative outcome**	**Group total**
Group (A, α)	57%	43%	14%
Group (A, β)	65%	35%	30%
Group (A, γ)	54%	46%	8%
Group (A, α)	51%	49%	2%
Group (A, β)	59%	41%	18%

The studies revealed only one consistent effect, namely that listening effort was higher for hearing impaired listeners compared with normal hearing listeners but the evidence across them failed to reveal consistent flagrant effects on listening effort when using DSP until hearing aid industry specifies every case as unique and gives it the necessary care with the collaboration and improvement of multiple industries in the purpose of evolving subject diagnoses, not to forget that DSP is surprisingly evolving on a linear scale basis and still, a lot has to be waited to come.

Directionality

Table 2.

Outcome of nDirect

	Positive outcome	Negative outcome	Group total
Group (C, α)	49%	51%	-2%
Group (C, β)	59%	41%	18%
Group (C, γ)	57%	43%	14%
Group (D, α)	55%	45%	10%
Group (D, β)	52%	48%	4%

Proof relating to Q2 comparing hearing aid results with and without directionality systems, given by 4 studies. They mainly provided speech recognition outcomes when testing hearing aids on participants with moderate to profound hearing loss. Participants are mainly adults with ranging age between 54 and 62 years old. The majority of participants were experienced hearing aid users with sensorineural hearing loss; just one group of one study was divided into symmetric and asymmetric users. split Directional systems utilized dual microphones with band, hybrid and adaptive directionality. Experiment included self and relatives or friend's outcomes. Speech recognition outcomes were reported for word and sentence recognition.

The dependant variable was named 'The effect of relief with Direct' (nDirect). It is measured in percentage (%) and varies between negative and positive values.

In fact, 3 different results in 3 different studies were obtained with group C when taking outcomes after being fitted first with omnidirectional hearing aids between one and three months even for those who are experienced users then fitted similarly between one and three months with directional hearing aids.

Effect of relief Direct (±100%) nDirect=±1

Experienced bilateral fitted sensorineural hearing loss with/ without symmetrical directionality utilizing traditional directional systems Group (C, α).

- Group (C, α), n1 = -0.02 [-0.51, 0.49] => n1= 2%

Experienced bilateral fitted sensorineural hearing loss with/ without symmetrical directionality utilizing split band, hybrid and adaptive directionality Group (C, β) and (CMS).

- Group (C, β), n2 = 0.18 [-0.41, 0.59] => n2= 18%

- Group (C, γ), n3 = 0.14 [-0.43, 0.57] => n3= 14%

Another 2 different results were obtained in the same study with symmetrical and asymmetrical directionality. Outcomes were extracted after fitting participants first with omnidirectional hearing aids for 45 days then with directional ones for another 45 days.

- Experienced bilateral fitted sensorineural hearing loss with/ without symmetrical directionality utilizing hybrid and split band directional systems. Group (D, α)

- Group (D, α), n4 = 0.1 [-0.45, 0.55] => n4= 10%

- Experienced bilateral fitted sensorineural hearing loss with/ without asymmetrical directionality utilizing hybrid and split band directional systems. Group (D, β)

- Group (D, β), n5 = 0.4 [-0.48, 0.52] => n5= 4%

Combined result while comparing directional vs non directional systems is:

n6 = (n5+n4)/2 = (10+4)/2 = 7%

Final Effect relief of directionality:

nDirect= (n1+n2+n3+n6)/ 4= (-2+18+14+7)/ 4= 9.25% => nDirect~ 0.093

Processing signal in a hearing aid may result in more natural sound quality for the end user but preserves the directional benefit of traditional directional settings. Asymmetric directional fitting, provides a directional pattern creating a balance between environmental awareness and directional advantage. In summary it resulted that those listeners indicated an overwhelming preference for the sound quality of omnidirectional processing over traditional directional processing, and preferred asymmetric directional fitting over traditional directionality more than twice as often while keeping the bilateral new directional systems the gold standard for a slight improvement in the sake of end user advantage.

An additional advantage of processing sound through binaural wireless communication is the spectral preservation of timing, giving the advantage to the hearing aid bilateral user of natural timing differences that are important for sound localization. In fact, nearly eliminating time difference will maintain an important cue of binaural communication that preserves localization of sound, the results indicated that binaural communication could be mismatched up to 6dB by compression and affect localization performance as long as cues are interrupted or not available. Rather, the user didn't express a much great difference in result between binaurally communicating hearing aids and non communicating ones. Of course, he felt the difference with the attenuation by compression but revealed nearly the same results. Noting that, the variability of surrounding atmosphere may vastly affect the awareness of sensing the difference.

Knowing that all is not enough if the clinician doesn't understand the benefits and limitations of each feature available today to perform an appropriate programming in the purpose of achieving a proper fitting added to the fact that a good counseling will offer the hearing aid user the capability of taking a good advantage of the devices with the possibility to hear in noisy situations.

Discussion

Nowadays, hearing aids have numerous programmed features: turning directionality and noise reduction and making adjustments to the hearing aid settings. This computerization will proceed to advance. Current adaptive algorithms in hearing aids should not be classified as they have the capacity to progress over time in reaction to sensor data. Methods such as neural systems and hereditary algorithms have been researched vastly in the universities for utilization in systems and we ought to expect their rise into the hearing aid industry. Surprisingly, little investigation in these regions has contributed to hearing aid design and fitting. The articulation list has been utilized to optimize the perceptibility of speech, and loudness recruitment has driven to the fitting of multiband compression added to other hearing aid algorithms based on the psychoacoustics of hearing impairment have not been very successful. The future will see the effective application of hearing science to DSP innovation developments, but most of the progress will require a coordinated improvement of modern diagnostics, signal processing, and validation measures. Hearing aid industry will change as it changes how it looks to the pathologies and needs of every individual asking enhancement.

Perceptibility

Nowadays, hearing aids are fundamentally fit to the audiogram of the hearing aid wearer; however, the nature of an individual's hearing loss is more complex than that basic description. Hearing loss will end up less characterized by diagnostic measures, such as the audiogram, and more characterized by the component of the loss.

Pure tone thresholds don't really tell us whether a sensorineural hearing loss is caused by damage to the external hair cells, the inner hair cells or both. A rule of thumb has ordinarily been that hearing loss up to roughly 60 dB HL is from external hair cell damage, and greater levels of loss are a result of extra harm to internal hair cells. In all probability, losses over 60 dB HL contain a mixture of internal and external hair cell damage.

In the best treat the hearing loss of patients, the physiology of their hearing loss must be well understood. To do so, extra diagnostic strategies are required, from which the mechanism of hearing loss can be assessed. For example, the amount of compression at a particular frequency region can be assessed using a masked threshold technique which may give information on the health of external hair cells in that frequency region.

These individual contrasts might require diverse treatments for hearing impairment. Distinctive hearing aid innovations and feature settings might be connected as we better understand the contrasts of the patients better and what their corresponding needs are. For instance, the finding that intelligence quotient test scores have been positively connected with speech understanding's advantage from fast acting compression. It proposes that diverse compression constants could be prescribed for patients with different cognitive capacities.

The expanded utilization of home treatment will permit a person's needs to be met with developed treatments integrated with hearing aids. A few patients will require more help in adapting to their hearing aids than others, and home administered treatments.

The effect of perceptibility on speech understanding is presently obvious, and audiologists fit hearing aid compression parameters in an attempt to maximize perceptibility while keeping up with the appropriate loudness of sounds. Sound perception includes much more than perceptibility, in any case. Shortages in threshold processing can influence sound quality too and other components that influence our ability to extract sound data around the mentioned world. To decide how digital signal processing influences these aspects of hearing, we require evaluation methods that are sensitive to more than perceptibility effects.

How does the recognition of noise reduction artifacts shift with hearing loss arrangement? What is the effect of multiband compression on the recognition of echoes? These more complex angles of sound recognition must presently be addressed. Extra zones of investigation incorporate the recognition of amplitude and frequency modulation, cross frequency coherence, binaural recognition, and timbre. In order to better plan, the signal processing inside hearing aids, a more advanced understanding is required of how hearing impairment and hearing aid processing influence complex auditory processing such as source separation, auditory streaming, and auditory visual integration.

The hearing aid industry and researchers take an approach to hearing impairment research and hearing aid design. They are concerned with how the impairment within the auditory periphery modifies the auditory sound and how hearing aids representation. alter this peripheral Cognitive work and its interaction with hearing impairment and hearing aids have not received enough clinical research. The interaction between hearing aids and cognitive function isn't considered within the design of hearing aids. In the future, hearing aids will be designed to take into consideration the effect of handling on cognitive work.

Listening Effort

A hearing impaired, is more tired after an hour of following a conversation in a loud atmosphere than somebody with ordinary hearing. Feeling tired is possibly due to the increased effort essential to understand speech concentrating on the source of sound through the impaired hearing. Communication may be a complex process that encapsulates more than auditory function. When one is listening in a noisy situation, mastering the rules of the language and contextual data are utilized to help within the speech understandability.

These are cognitive viewpoints of speech understanding that influence the sum of effort that the cognitive system uses during communication. In real discussion, listeners are moreover creating thoughts that are produced by what they are hearing, making connections between diverse sentences while storing data in memory, and assuming what's going to be said in reaction to what they are hearing. In other words, much more cognitive activity is included in the discussion than is tested with a simple speech in noise tests.

Whether or not the current hearing aid diminishes or increments listening effort, is obscure. Preliminary evidence recommends that SNR change resulting from directionality can reduce listening effort. Extra research should be conducted into which hearing aid diminish listening effort and extra attention. Hearing aid companies may utilize this extra measurement of benefit to choose between different signal processing plans within the research and advancement and companies will compete on cognitive details. Patients and dispensers would appreciate knowing the extra viewpoints to which signal processing gives advantage to the hearing aid wearer, and increased client fulfillment may result from this.

Conclusion

As digital hearing aid innovation evolves, modern developments ended up more complex. Direct engineering approaches have driven applications until present, but future progress will require collaboration over numerous areas including psychoacoustics and clinical audiology. The strategies by which modern digital hearing aid technology definitely will change. Concepts of connectivity and individuality will drive much of modern applications. As the interaction between hearing aid processing and complex auditory and cognitive work gets to become way better, modern concepts in advanced hearing aid development will be created for these interactions. As DSP chips ended up more capable in capability, changes to current algorithms will be made with motivation from such sources as auditory models and other audio industries.

Patient advantage ought to drive all of this continuous advancement, and producing of this advantage when modern technology is presented will get to be more commonplace as evidence based practice gets to be more prevalent. This alone will cause designing improvement to work closely with audiology and auditory science so that modern diagnostic measures and validation methods are created in conjunction with modern digital technology.

References

Beecher, F. (2000). A vision of the future. The Hearing Journal, 53(10), 40 44.

Christensen C. M. (2007). Disruptive innovation: can health care learn from other industries? A conversation with Clayton M. Christensen. Interview by Mark D. Smith. Health Affairs, 26(3), 288–295.

Cox R. M. (2005). Evidence-based practice in provision of amplification. Journal of the American Academy of Audiology, 16(7), 419–438.

Cord, M. T., Surr, R. K., Walden, B. E., & Dyrlund, O. (2004). Relationship between laboratory measures of directional advantage and everyday success with directional microphone hearing aids. Journal of the American Academy of Audiology, 15(5), 353–364.

Cord, M.T., Walden, B.E., Surr, R.K., & Dittberner, A.B. (2007). Field evaluation of an asymmetric directional microphone fitting. Journal of the American Academy of Audiology, 245 256

Cord, M. T., Surr, R. K., Walden, B. E., & Olson, L. (2002). Performance of directional microphone hearing aids in everyday life. Journal of the American Academy of Audiology, 13(6), 295–307.

De Gennaro, S., Braida, L. D., & Durlach, N. I. (1986). Multichannel syllabic compression for severely impaired listeners. Journal of Rehabilitation Research and Development, 23(1), 17 24.

Edwards, B. (2006). What outsiders tell us about the hearing industry. Hearing Review, 88–92.

Edwards B. (2007). The future of hearing aid technology. Trends Amplification, 11(1), 31–45. in

Gatehouse, S., & Noble, W. (2004). The Speech, Spatial and Qualities of Hearing Scale (SSQ). International Journal of Audiology, 43(2), 85–99.

Kramer, S. E., Kapteyn, T. S., & Houtgast, T. (2006). Occupational performance: comparing normally-hearing and hearing-impaired employees using the Amsterdam Checklist for Hearing and Work. International Journal audiology, 45(9), 503–512. of

Kobatake, H., Inari, J., & Kakuta, S. (n.d.). (1978). Linear predictive coding of speech signals in a high ambient noise environment. IEEE International Conference on Acoustics, Speech, and Signal Processing.

Marzinzik, M. (2000). Noise reduction schemes for digital hearing aids and their use for the hearing impaired. PhD Dissertation, Oldenburg

Myers, D. G. (2006). In a looped America, hearing aids would be twice as valuable. The Hearing Journal, 59(5), 17 23.

Mermelstein, P., & Qian, Y. (1997). Nonlinear filtering of the LPC residual for noise suppression and speech quality enhancement: Semantic Retrieved, scholar. from https://www.semanticscholar.org/pa p er/Nonlinear-filtering-of-the-LPC residual-for-noise-Mermelstein Qian/34830a743f5a26c22329612abe 57 d59b257f736d

Mammone R.J., Zhang X., Rmachandran R.P. (1996). Robust speaker recognition: a feature-based approach. IEEE Signal Processing Magazine. (13)5, 58–71.

Mueller, H. G., Weber, J., & Bellanova, M. (2011). Clinical evaluation of a new hearing aid anti-cardioid directivity pattern. International journal audiology, 50(4), 249–254. of

McCreery, R. W., Venediktov, R. A., Coleman, J. J., & Leech, H. M. (2012). An evidence-based systematic review of directional microphones and digital noise reduction hearing aids in school age children loss. American with Journal audiology, 21(2), 295–312. hearing of

Neher, T., & Wagener, K. C. (2016). Investigating Differences in Preferred Noise Reduction Strength Among Hearing Aid Hearing, 20. Users. Trends in

Noe, C.M., Davidson, S.A. and Mishler, P.J. (1997). The Use of Large Group Assistive Listening Devices With and Without Hearing Aids in an Adult University. Classroom. American Audiology, 6(3), 48-62.

Pichora-Fuller, M. K., & Singh, G. (2006). Effects of age on auditory and cognitive processing: implications for hearing aid fitting and rehabilitation. Trends Amplification, 10(1), 29–59. audiologic in

Pumford, J. M., Seewald, R. C., Scollie, S. D., & Jenstad, L. M. (2000). Speech recognition with in-the-ear and behind the-ear dual-microphone hearing instruments. Journal of the American Academy of Audiology, 11(1), 23–35.

Rossi-Katz, J. A., & Arehart, K. H. (2005). Effects of cochlear hearing loss on perceptual grouping cues in competing vowel perception. The Journal of the Acoustical Society of America, 118(4), 2588–2598.

Ross M. (2006). Telecoils are about more than telephones. The Hearing Journal, 24-28.

Ricketts T., Hornsby B., Johnson E. (2005). Adaptive directional benefit in the near field: competing sound angle and level effects. Seminars in Hearing, 26(2), 59-69.

Strom K.E., (2006). The HR 2006 Dispenser Survey. Hearing Review, 16 39.

Sweetow, Robert & Henderson Sabes, Jennifer. (2006). The need for and development of an adaptive Listening and Communication Enhancement (LACE) Program. Journal of the American Academy of Audiology, 17, 538-558.

Van Tasell D.J. (1993). Hearing loss, speech, and hearing aids. Journal of Speech, Language, Research, 228–244. and Hearing

Valente, M., Fabry, D. A., & Potts, L. G. (1995). Recognition of speech in noise with hearing aids using dual microphones. Journal of the American Academy of Audiology, 6(6), 440–449.

Walden, B. E., Surr, R. K., Cord, M. T., & Dyrlund, O. (2004). Predicting hearing aid microphone preference in everyday listening. Journal of the American Academy of Audiology, 15(5), 365–396.

Yanz J.L., Roberts R., Colburn T. (2006). The ongoing evolution of Bluetooth in hearing care. Hearing Review. https://hearingreview.com/practice building/practice-management/the ongoing-evolution-of-bluetooth-in hearing-care

Yanz J.L. (2006). The future of wireless devices in hearing care: a technology that promises to transform the hearing industry. Hearing Review, 18–20.

Yeldener, S., & Rieser, J. H. (2000). A background noise reduction technique based on sinusoidal speech coding systems. IEEE International Conference on Acoustics, Speech, and Signal Processing.