



Mapping the Future of Hearables: Lessons from Online and the “Oldest Old” Consumers

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Abstract. Living with hearing loss presents challenges for an aging population. Hearing loss without intervention is associated with a plethora of negative consequences for older adults including loneliness, cognitive decline and falls. In this study, members of the MIT AgeLab 85+ Lifestyle Leaders Panel were surveyed and interviewed to learn about their experiences with hearing loss and audio-assistive device adoption, and their hopes for the hearables of the future. Additionally, 583 written customer reviews were accumulated from Amazon.com and HearingTracker.com for analysis. Several themes emerged along with an imperative to industry to explore further the enduring challenges and future opportunities of human-hearable design.

Keywords: Hearing loss · Hearables · Online reviews · Older adults · Technology adoption

1 Introduction

As humans our sense of hearing is often considered vital to our ability to participate in and experience the world around us. Hearing engages our brains in continuous, complex information processing and is a powerful means of communication we often take for granted. In the United States, current epidemiological audiometry estimates suggest approximately one in three people between the ages of 65 and 74 has hearing loss, and nearly half of people 75 and older have difficulty hearing [1]. Unprecedented global longevity means that more people than ever before are living to an age where they will experience age-related hearing loss (or presbycusis) [2]. By 2050, the proportion of the world’s population over age 60 will nearly double from 12% to 22% [3]. The World Health Organization (WHO) estimates that by 2025 over 500 million people over 60 years of age worldwide will suffer significant impairment from presbycusis [4]. In the United States, the number of people aged 85+ is projected to more than triple from 6 million to 20 million by 2060 [5]. Because hearing loss increases with age, particularly after age 65, these “oldest old” adults are more likely to have had some hearing loss and are in the position to offer a unique understanding of the motivations, challenges and opportunities of hearable adoption in the latest phase of life.

Hearing loss without intervention is associated with a plethora of biopsychosocial consequences for older adults. For example, in the United States, census survey estimates approximate that over 42.6 million older adults suffer from chronic loneliness

[6]. Current research suggests there is a relationship between a sensory loss, such as hearing loss, and loneliness, particularly among older adults [7, 8]. Additionally, many studies have demonstrated strong associations between magnitude of hearing loss and accelerated cognitive decline, greater risk of dementia onset, and higher risk of falling [9–12]. Hearing loss negatively impacts the vestibular system and balance control, increases cognitive load, reducing people’s ability to multi-task, and fundamentally changes how individuals evaluate, interact with and overcome obstacles within the environment [13]. As a result, research has continued to test the association between auditory interventions, such as hearing aid adoption, or modification of hearing impairment indicators (e.g., degree of hearing loss, hearing-related quality of life, etc.) and decreased loneliness, delayed cognitive decline, and reduced fall risk [14–18].

Hearing aids, direct-to-consumer devices and other audio-assistive devices referred to as *hearables* are technological solutions shown to promote positive outcomes among individuals with hearing loss. The development of hearables began with the early stethoscope, used by medical professionals to obtain biological information and eventually as a diagnostic instrument [19]. Medical grade hearing aids as well as audio headphones came with the boom of the radio and telecommunication industries in the early 1900s [19]. But it was not until the release of the Sony Walkman portable cassette player in 1979 that audio electronics offered beloved and customized experiences [20]. Today, though there is no universal definition of a hearable, they are best understood as a sub-category of wearables to be worn in or around the ear that use computing technology [21]. Current hearables include devices from smart hearing aids to wireless earbuds. They have evolved not only to improve individual hearing ability and communication, but to also collect biometric data, connect across devices, and offer more customization than ever before. Despite these advances, however, a gap persists between consumers who would benefit from hearable technologies and those who adopt these devices.

As hearable technologies proliferate and become accessible across diverse marketplaces, consumers face challenges around the choice of device that is best for them – what works best at the price points they can afford. Because many hearable technologies can be relatively expensive, consumers may seek expertise on which products are worth investing in. Traditionally organizations such as AARP or Consumer Reports served as clearinghouses for objective product advice. Yet other people one knows are often people’s most trusted sources of advice. With the proliferation of platforms and websites that offer users the opportunity to review products and services, these public review systems provide people with an easy means to get advice from “other people like them.”

Reviews offer rich insights into the narratives and nuances of the product purchase decision, real-world functionality, and normalization of user experience. Because such reviews can be accessed from anywhere, for older adults in particular they offer convenient opportunities to compare experiences, products and prices. For hearable technologies, which may not be widely used, online reviews provide potential users with reviews from a larger number and wider range of consumers with experience with a given product or device under varying conditions.

Traditionally the hearable industry has been medicalized: hearing aids were prescribed by doctors and fitted and adjusted by specialists. With the rise of a wider range of consumer audio-assistive devices, however, hearables have become much more accessible to all consumers. Given these shifts in the industry, little is known about what older consumers and online reviewers expect and desire from their hearable device(s). The objective of this study is to better understand hearable consumers' experiences with, expectations of, and aspirations for their devices. In an effort to understand the current state of human-hearable interactions, we draw on user reviews and survey data to explore consumers' current device use, overall experiences, and ideas for future device design.

2 Data Collection

Two unique sources of data were collected for the purposes of this study: online consumer reviews of the top 10 and bottom 10 hearable products by average user rating generated from HearingTracker.com and Amazon.com (see Tables 1 and 2); and in-depth interviews, discussion groups, and a survey with the Massachusetts Institute of Technology (MIT) AgeLab's 85+ Lifestyle Leaders panel. The online reviews provide snapshots of people's experiences with different devices and offer a picture of the nature of information available to consumers who are considering these different technologies. In contrast, the data from the Lifestyle Leaders offer in-depth portraits of people's experiences with different devices and insight into the decision-making process older adults rely on when choosing the hearable technology that is right for them.

Table 1. Top 10 and bottom 10 products from HearingTracker.com

Top 10 products	Bottom 10 products
1. Unitron N Moxi Fit Pro	1. Starkey Halo 2 RIC 13 i2400
2. Phonak Audeo V 312T V90	2. Oticon Agil Pro miniRITE
3. Widex BEYOND Fusion 2 440	3. Oticon Alta Pro CIC
4. Phonak Audeo B R B90	4. Oticon Chili SP9
5. Oticon Opn 1 BTE13 PP	5. Phonak Virto B Titanium IIC B90
6. Kirkland Signature (Costco) 8.0 Premium Hearing Aids	6. Starkey Muse micro RIC 312t i2400
7. Oticon Alta2 Pro miniRITE	7. Oticon Alta2 Pro BTE13 100
8. Kirkland Signature (Costco) 7.0 Premium Hearing Aids	8. Siemens Nitro x01 301
9. Unitron Moxi Kiss 20	9. Phonak Virto B Titanium CIC B90
10. Signia Pure Primax 13 BT 7px	10. Beltone Legend RIE 64 9

Table 2. Top 10 and bottom 10 products from Amazon.com

Top 10 products	Bottom 10 products
1. Toedler Ear Hearing Amplifier	1. HEARNA HAS338 Amplifier
2. Otonifix Apex Mini Hearing Amplifier	2. Flexzion Digital Hearing Amplifier Device
3. Otonifix Elite Mini Hearing Amplifier	3. NewEAR Digital Personal Sound Hearing Amplifier Aid
4. Empower Hearing Amplifier	4. Woodland Whisper II
5. Otonifix Encore Premium Hearing Amplifier	5. Soundlab Hearing Amplifier
6. Neosonic Digital Hearing Amplifier	6. Ultra Ear Hearing Enhancer Communication Aid (Walker Game Ear)
7. HA-302 from Hearing Assist	7. HEARNA HAS302 Amplifier
8. Ulaif Hearing Amplifier	8. Woodland Whisper
9. LumiHear Hearing Amplifier	9. AuriClear BTE Digital Bluetooth Amplifier
10. Wellness Tree Digital Personal Sound Amplifier	10. LifeEar Hearing Amplifier

2.1 Online Reviews

Online reviews were collected from HearingTracker.com and Amazon.com. The reviews on HearingTracker.com included a Hearing Tracker Rank based on a 10-question survey taken by users, as well as information about completeness and recency of the written review [22]. Some reviews also included audiograms and information about service providers. While Amazon.com does not sell medical grade hearing aids, the search term “hearing aid” was utilized to identify hearable devices designed to act most like a hearing aid. These products were then sorted by average customer review and compiled by the highest and lowest ranked products. The top reviews for each product, as determined by other site users’ indication of “overall helpfulness,” were included for analysis. Only products with more than three total reviews were included in analysis.

A total of 583 reviews were collected; 579 reviews were included in analysis. Four reviews were excluded from analysis as they were repeated reviews from the same user. Of the 579, 441 (76.2%) reviews were from HearingTracker.com and 138 (23.7%) reviews were from Amazon.com. The majority of products reviewed were audio amplifiers and receiver in the ear (RIC) hearing aids (HAs).

Across both platforms, there was wide variance in the date the review was completed, length of device use prior to review, reviewer relationship to device wearer, occupations of reviewers, and severity as well as onset of the device user’s hearing loss. For example, the oldest review dates back approximately 5 years prior to this analysis, while the newest reviews were left less than 24 h prior to the time of this analysis. Several users had been wearing a device for over 40 years, while others had received a device a day prior to writing a review.

Three variables – person for whom hearable was bought, gender, and geographic location – were chosen to describe online review demographics because this information was publicly available and highlights potential considerations for different groups of consumers. Reviewers most often reported purchasing a device for themselves or their mothers. Gender of reviewers was determined by the username as displayed on the review posting. Gender was dichotomized into male and female. Usernames that were uncategorizable or listed as anonymous were grouped together in their own category. Across both platforms, the majority (65.1%) of reviewers were anonymous or uncategorizable. Relative to the percentage of anonymous or uncategorizable usernames, 34.9% of usernames were clearly male or female-sounding. Reviews that could be coded for gender had overwhelmingly male-sounding names (see Fig. 1).

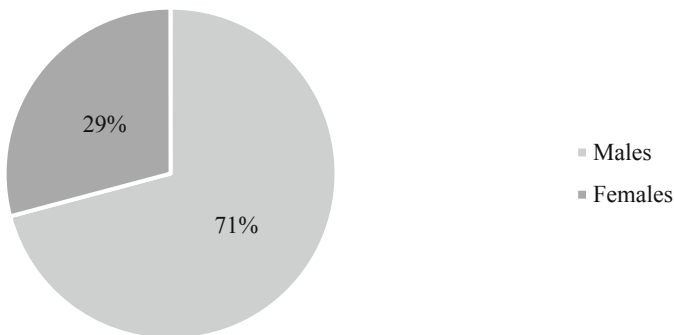


Fig. 1. Dichotomized gender demographic of reviewers, excluding anonymous users (n = 199).

When isolated by platform, 57% of Amazon.com reviewers were male compared to 43% female, while 80% of HearingTracker.com reviewers were male compared to just 20% female. For reviews where U.S. location was available, the majority of reviewers were concentrated in California and Florida. Texas, South Carolina, Pennsylvania, Oregon, and Michigan were closely behind. Among reviews for which an international location could be identified, reviewers were heavily geographically located in Canada.

Among Amazon.com reviews only, products listed in the bottom 10 product list were rated an average of 3.15 stars while products in the top 10 product list had an average of 4.59 stars. Similarly, more users were engaging with Amazon.com's top 10 product reviews versus the bottom 10 product reviews as measured by rated helpfulness. An average of 60 users per review found reviews among the top 10 products helpful compared to just 21 users per review for the bottom 10 reviews. Longer reviews were correlated with greater "helpfulness." Amazon.com product reviewers also more often indicated they had started with just one device for use in one ear as opposed to purchasing devices for two ears. Amazon.com reviewers were likely to state that they had tried other types of hearable products before. A smaller sub-population of Amazon.com reviewers noted they were using a device as a backup or alternative to a regular hearing aid due to cost barriers or practicalities of using hearing aids during

events like travel or sporting. Amazon.com reviewers were more likely to provide an update to their review later on.

2.2 MIT AgeLab Lifestyle Leaders Panel

The Lifestyle Leaders are a panel of adults aged 85 and older who meet bimonthly at the MIT AgeLab in Cambridge, Massachusetts, to discuss a range of topics related to living longer. The MIT AgeLab hosted a Lifestyle Leaders workshop exploring hearing loss and hearables; data were collected via multiple methods. All participants were invited to complete a detailed questionnaire prior to the workshop either online or on paper. The questionnaire included questions on: (1) current hearing conditions and any changes in their hearing; (2) effects of hearing changes they have experienced; (3) experiences around adjusting to changes in hearing; and (4) attitudes and experiences regarding hearing technologies and devices. All participants were assigned to different small discussion groups according to their self-reported and previously-observed degree of hearing loss. The small discussion groups represented four degrees of hearing loss: no evident loss, and little, moderate, and severe hearing loss. A subset of panel members participated in additional individual interviews in order to capture breadth of device use (e.g., use of hearing aids versus use of an amplifier) and a spectrum of adaptive behaviors (e.g., environmental modifications) to hearing loss.

Compared with the overall 85+ population in the United States, the Lifestyle Leaders are overwhelmingly Caucasian and have higher levels of income, education and better overall health. Among questionnaire respondents ($n = 25$), 79.2% reported living independently in their own homes, condos, townhomes or apartments. A majority of the Lifestyle Leader respondents are widowed or married/living with a partner; thus most live alone or with a spouse/partner. Just under half receive help with daily tasks (e.g., shopping, making appointments) from adult children, spouses or friends. Just over half of the survey respondents identified as male (52.2%) and 47.8% identified as female. The average age was 89.96. Most respondents also participated in the Lifestyle Leaders workshop, meaning that the demographics of workshop participants closely mirrored that of survey respondents.

The vast majority (92%) of the Lifestyle Leaders reported that they have experienced or are currently experiencing hearing loss. Among all Lifestyle Leaders surveyed, 84% most frequently reported having either a little or a lot of trouble hearing (as opposed to no trouble hearing or no usable hearing) in both ears. Similar to online reviewers' descriptions, the Lifestyle Leaders also reported wide variance in age at hearing loss onset. Among those experiencing hearing loss, 43.5% stated they first noticed changes in their hearing only within the past 5 years. Unsurprisingly, the majority of the Lifestyle Leaders also report being relatively new hearable users – only having used their device(s) for 5 years or less. Overall, three-quarters of Lifestyle Leaders (75%) said they currently use a hearing aid or other audio-assistive device. Among Lifestyle Leaders wearing hearing aids, they most often reported wearing them in both ears every day for more than 8 h a day. Additionally, the Lifestyle Leaders used audio-enhancing headphones and Bluetooth streaming microphones both in place of and as augmentation to hearing aids.

3 Findings

3.1 Device Performance

Across both data sources, the theme of improving overall device performance was mentioned the most clearly and frequently. Online reviewers and Lifestyle Leaders expressed a desire for greater clarity, better reduction of background noise, and improved music quality. As one reviewer described their experience with background noise, “If there’s loud background noise I can’t hear at all. Overall it’s like listening to a radio that’s on the fritz.” Many of the Lifestyle Leaders indicated that they will take off or stop using their hearables in response to background noise. “In a crowded restaurant, I typically remove the devices because they amplify the background noise, and this is an intolerable irritant,” said one Lifestyle Leader. Focused efforts on improving the functional performance of hearables across everyday environments could contribute to increased device adoption in the future.

3.2 Physical Product Design

Hearables also leave much to be desired when it comes to physical product design. For online reviewers and Lifestyle Leaders, stigma related to device use came up less often compared to the desire for a larger physical device with improved access to a power button and volume knob and bigger batteries. One Lifestyle Leader with late onset hearing loss stated, “The craziest thing—here’s what the problem is, everybody is vain, and they want to have hearing aids that nobody sees, but what the hell of a difference does it make if you’re 70, 80 years old, if you have a hearing aid? Doesn’t make a damn bit of difference, so you shouldn’t care about it.” Current device size was also associated with a host of concerns from poor fit in the ear to persistent loss of the device during daily tasks, forcing many users to use a personal sound amplifying product (PSAP) as a less expensive, more accessible alternative to hearing aids. Amazon.com alone sells over 300 different types of PSAPs – many of which are used by reviewers as alternatives to hearing aids in scenarios such as travel and sporting events. A male Lifestyle Leader and routine wearer of Bose Hearphones described his transition away from hearing aids: “I was asked to bring them [his Widex hearing aids] in today and I couldn’t find them. Six thousand dollars and I don’t know where it is. I have become somewhat of a prophet of these [his Bose Hearphones]. I proselytize actively.”

3.3 Device Features

In addition to highlighting device functionality and design needs, when the Lifestyle Leaders were asked about what they hoped future hearable devices would do better than current iterations, many mentioned specific features that overlapped with those from online consumer reviewers. Seamless integration across devices (e.g. TV, phone), rechargeable batteries, waterproof properties, and ability to adjust volume or program settings for individual ears came up most frequently in both data sources. Both data sources also emphasized the relationship between their hearable and other technology

devices; however, this connectivity was slightly more salient among online reviewers rather than Lifestyle Leaders, possibly due to age differences between the two data sources.

Bluetooth. Online reviewers in particular expressed either a deep satisfaction or outright disappointment with the quality of their device's Bluetooth. The reviewed PSAPs did not have Bluetooth capabilities, but among hearing aids reviewed, 50% had built in Bluetooth capabilities not requiring a secondary accessory or other device. Often described as "crackling," "popping" and "too much static," the quality of music, podcasts, phone calls or other audio material streamed through devices leaves much to be desired. One online reviewer stated about their Widex hearing aids, "I'm very disappointed in the sound quality of Bluetooth for conversation: it has some static and is somewhat distorted – as a psychologist who needs to talk to my patients on the phone, I must resort to my trusty Bang and Olufson headphones instead." On the other hand, others found customizable Bluetooth features highly desirable. According to a reviewer of Kirkland Signature (Costco) hearing aids, "I was blown away by my iTunes streaming music directly to my hearing aids directly from my iPhone 7+. The sound clarity and bass is hard to believe when you first hear it. You can even use iOS' sound equalizer to output sound tuned to your particular preference."

However, users also ran into trouble initially pairing or experiencing random unpairing of their hearables – particularly with cellular phones and vehicles. Two online reviewers illustrate these concerns best: "They [my hearing aids] continually disconnect from the Bluetooth and can't reconnect without me having to open and close the battery;" and "My Mercedes car Bluetooth allows me to dial out and speak directly, but I cannot receive incoming calls without having to find the phone. Driving whilst holding a phone is a penalty offence here [in the UK] so that is not possible and is driving me to distraction." As these reviewers noted, many found their own work-arounds when their Bluetooth connectivity did not function, and despite Bluetooth dysfunction, user reviews generally highlighted their reliance on it and its significance for them. As one HearingTracker.com reviewer wrote, "The Bluetooth connection to phone is a feature that I would find hard to live without."

Mobile Applications. The state of current innovation in hearable-device interaction generally requires use of a third-party mobile application or "app." Online consumer reviewers overwhelmingly use an app with their hearable device if one is available. As one tech-savvy Lifestyle Leader mentioned, "Those who don't have an iPhone or a smartphone [connected to their device] aren't as happy." In fact, in reviews alone, the word "app" was mentioned at least 91 times. Mobile apps serve a variety of purposes for online reviewers and Lifestyle Leaders, including troubleshooting, controlling functionality, and preprogramming hearing environments. Many users noted the app associated with their hearable was either incompatible with or unavailable on their Android or iOS operating system, depending on the hearable model. However, when available, these applications still lack important practical capabilities. One online reviewer and new user of Kirkland Signature (Costco) hearing aids pointed out that the "app lacks a find-my-lost-hearing-aid feature, which ironically would have come in very handy on week two." Another reviewer mentioned, "I find the app lacking pretty much every feature I go looking for, starting with a basic equalizer. With everything

being automatically adjusted constantly there are times when certain frequency ranges are amplified excessively. I would dearly love to just take control and tell it what to do at times. No can-do.”

3.4 Trust in Customer Service and Audiology

In addition to hearable design and features, the future of human-hearable interaction will be built on the cornerstones of human relationships. For these samples, customer service can make or break the overall hearable fitting and acquisition experience and impacts short-term device adoption. Perceived competence of fitting specialists and/or company customer service representatives and timeliness of device delivery came up frequently among online reviewers. For example, for hearables acquired through Amazon.com, free shipping and rapid turnaround from order to delivery were salient among positive reviews. Comparably, for hearing aids acquired from Costco, quality of the in-store hearing specialist was varied. As one review commenter detailed, “Not to be mean, but I would suggest checking reviews about various Costcos in your area in regards to the Hearing Specialists. Or even just visiting another one. My original guy was wonderful and a great man but either didn’t have the training or understood all the programming advantages.”

Even when a device was not a good fit for a variety of reasons, positive customer service experiences could compensate for perceived device and company shortcomings. One reviewer explained, “This item was not comfortable for me, but I was quite impressed with the consideration afforded to me by the Otofonix staff. They made no attempt to convince me that I should not return them, and my payment was promptly refunded. I would recommend this product even though it was not comfortable for me personally.” Nonmedical grade devices, such as those found on Amazon.com, accompanied by warranties, free and easy returns, and trial periods had reviews with more positive language and perceptions of company transparency. These reviewers were also more likely to suggest they would continue using the device. “Additionally, as icing on the cake, the company stands behind the product as a purchaser would hope; quickly, honestly, and with absolutely zero run-around. Customer support could not be better,” explained one Amazon.com amplifier reviewer.

However, when an error or technical concern with their device arose, many online reviewers were apt to blame the hearable company. As one reviewer of a bottom 10 product stated, “I wish I could start all over again with another company.” This was in contrast to the Lifestyle Leaders. When considering blame around the shortcomings of their devices or their failure to restore hearing capabilities completely, the Lifestyle Leaders often placed the locus of blame internally – on their own hearing difficulties – instead of on the company that made their device. Trust seemed to play a role in this exchange. As one Lifestyle Leader said, “I wholly trust Williams Sound [the manufacturer of her audio-assistive device]. I blame my hearing, not the Siemens company [manufacturer of her hearing aids] for my problems...” Of Lifestyle Leaders who responded, 64.7% of Lifestyle Leaders indicate they fully or somewhat trust the company who makes their hearable device (see Fig. 2).

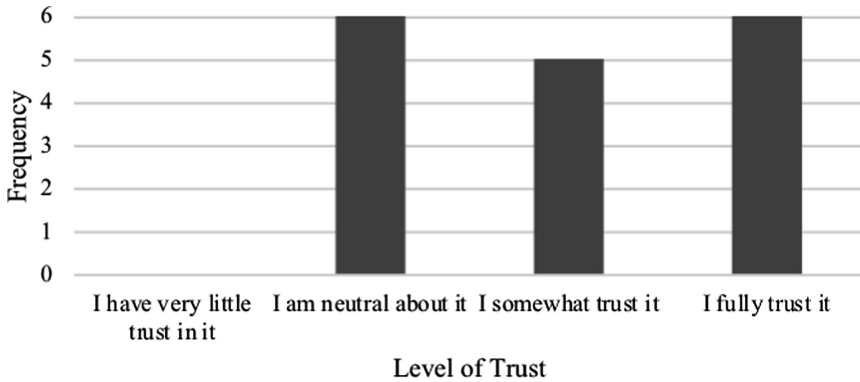


Fig. 2. Trust in companies that manufacture hearing aids and other audio-assistive devices among the Lifestyle Leaders (n = 17)

Additionally, the Lifestyle Leaders trusted the process of hearing aid acquisition. The most commonly trusted sources to help them decide on a brand of device include audiologists, doctors and organizations like AARP, Consumer Reports and the Better Business Bureau (see Fig. 3).

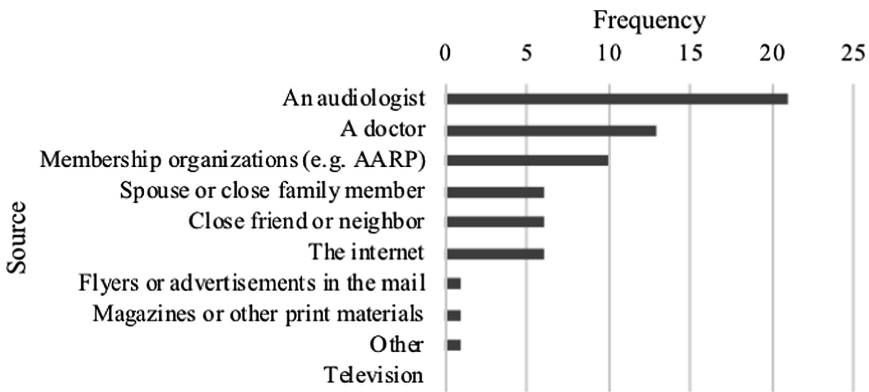


Fig. 3. Trusted sources of advice for hearing aids and other audio-assistive devices among the Lifestyle Leaders (n = 23)

The Lifestyle Leaders and online reviewers frequently mentioned the role and professional expertise of the audiologist in facilitating acquisition of a “good” hearing instrument. For online reviewers there was greater distrust in audiologists who only sell specific devices. One long-time member of HearingTracker.com advised others, “Try many brands - don’t get railroaded into brands by audiologists whose business is limited to certain brands.” The Lifestyle Leaders, however, had high trust in their hearing providers when it comes to their hearing health: they are most often receiving

information from or talking with an audiologist, primary care physician or other doctor about hearables compared to other sources of potential advice. Furthermore, provider coordination could significantly ease or hinder access and continued use of hearables. One Lifestyle Leader stated, “I was actually going to another doctor who suggested this doctor to me because he knew he wasn’t doing as good a job as he should be doing, and it made a world of difference, because once I got to this new doctor, I could actually hear much better.” However, as many online reviewers expressed, repeated and long-wait times in between appointments created bottlenecks around device troubleshooting and fitting. This is perhaps best illustrated by one Lifestyle Leader and new user of hearing aids who said, “I got the hearing aid through my primary care doctor. But then he sent me to another specialist. That one sent me to another set of people, specialists.” This Lifestyle Leader visited specialist doctors and an audiologist, yet her new hearing aids still fit her poorly and, as a result, she does not wear them.

3.5 Troubleshooting

Regardless of age, hearable adoption is often accompanied by learning a new technology and troubleshooting when things go wrong. The Lifestyle Leaders described some of the difficulties in learning how to use a new device. One self-described “tech-savvy” Lifestyle Leader said, “You open up the box, and there are 14 different wires and connectors there. And the book is about this thick. And I just haven’t had the gumption or the unctio[n] to go through the whole thing.” Many Lifestyle Leaders used a variety of resources when they needed help with their devices, but when asked about the most effective methods to teach them new skills about their device(s), they repeatedly mentioned the value of a mentoring-based or classroom-style teaching model. A Lifestyle Leader and new user of hearing aids exclaimed, “[I have] a strict income and I have to question money-wise things. But I have time, and I would love to have somebody to assist me until I feel comfortable I’m okay.”

A feature of online reviews is that consumers can access them not only when making purchase decisions but also when troubleshooting. Hearable users took to reviews to detail an exact problem they were having with their device, to share sources of information for problem solving, and to caution others of defects or poor aspects of devices. A new hearing aid user from HearingTracker.com warned, “Within 5 days [my hearing aids] were sent back to repair but came back with the same problem.” Several reviewers frequently included the quality of the device instruction manual as a contributor to their overall satisfaction with a hearable product. A verified purchaser of an Amazon.com amplifier mentioned, “The instructions: The text, although it contained a few errors, was pretty easy to see and comprehend. The pictures are so tiny they are basically worthless.”

4 Conclusion

Historically, the hearable industry has been medicalized – specialists address the challenge of fitting an advanced piece of intricate technology within the ear and adjusting it to meet the user’s needs as best as they are able. Meanwhile, however, the

competitive development of new audio-assistive devices and market demand requires all hearables to be better, leaner and more connected. The growth of artificial intelligence and the Internet of Things means that consumers will increasingly demand more and demand better of their devices.

Older adults and online consumers alike are inundated with choices and must negotiate quality, brand recognition, price, and style when they decide to purchase a hearable. A mixed methods approach with the MIT AgeLab's Lifestyle Leaders and online consumer reviews was used to explore engagement with and decision making about hearable technologies.

The experiences and observations of these consumers reviewers offer unique insights. The first is that generational differences in expectations around aging, hearing devices and the companies that make them may change over time. As Baby Boomers, for example, age into hearing loss, their expectations are likely to shift around phenomena like device functionality and connectivity compared with previous generations of users in the oldest old market segment. How will these expectations of hearing devices evolve for later "digital native" generations as they grow older? Even now there are rapid changes around norms of wearing something in the ear – as long as it is not the "big, beige and boring" of hearing aids of old: witness the rise in popularity of products like Apple AirPods or Bose SoundSport in-ear headphones [23]. Similarly, increased access to information and social media have forced companies to embrace a new reality of transparency – a transparency that can shape long-term brand loyalty, recognition and trust over time. Generational cohorts from Millennials to Baby Boomers perceive access to and interact with their favorite companies in different ways. How will they hold manufacturers responsible for their hearing experiences with a certain device, and how might this change as these groups grow older?

Another implication is the capacity of the hearing care industry to anticipate and adapt to the development of technologies such as amplifiers, microphones, conversation-enhancing headphones and other direct to consumer products that consumers like the Lifestyle Leaders have found to be as functional (if not more functional) and less expensive than hearing aids. Devices are increasingly linked and integrated around the user experience. How might products from the hearing care industry, for example, fit into a bigger picture of a connected smart home? Future investment into new hearing technologies will have to strike a balance between delivering on sophistication and integration – while still being easy for wearers to use – and offering accessible value.

Without intervention, hearing loss has major negative effects on loneliness, cognitive functioning, and fall risk [7–13]. Further research is needed to assess the relationship between online review use, hearable purchase decision-making, and subsequent adoption rates. Additional research should also investigate cross-cultural similarities and differences in experiences with hearing loss and hearable adoption across age cohorts, gender and geography. Emerging hearable technologies for an aging population will require industry to stay up-to-date and engaged with an older end-user. As one reviewer wrote, "If Starkey wants to succeed in this market space they cannot ignore the poor quality of this current offering. The Baby Boomers that are just reaching retirement age are technologically sophisticated." Both Lifestyle Leaders and online consumer reviewers are an active and engaged marketplace - ready not only for

the promise of the future hearable, but to also hold hearable technologies and the companies that make them to a high standard. The hearing care industry will always face the challenge of forging imperfect solutions at an imperfect cost. But as the demand for hearing support increases, the industry has an opportunity to leverage emerging science and technologies to deliver increased ease in access and value from using hearing aids and audio-assistive devices that can yield life-changing outcomes.

This is a cross-sectional study that leverages multiple data sources collected at a single point in time. Findings were integrated across data sources; however, certain themes emerged more saliently among online reviewers versus the Lifestyle Leaders and vice versa. Results from these data sources may not be generalizable. User reviews are written by self-selected individuals who may have particularly good or bad experiences with a product. Reviewers may be more likely to be male. Findings from the Lifestyle Leaders are not generalizable to all individuals aged 85 and up or to all older adults. However, a mixed methods approach adds value to the reliability and validity of results and hedges against the limitations and biases of a single methodological approach.

In addition to directly surveying the Lifestyle Leaders, online reviews represent a popular source older adults may use to help make a purchase decision about a hearable. Hearable reviews, in particular, differ from reviews written about other technology products because they are heavily impacted by degree of hearing loss and device fitting. Two individuals with the same device and hearing provider may have very different experiences and levels of satisfaction. Findings from online consumer reviews and the MIT AgeLab's 85+ Lifestyle Leaders Panel create an imperative for further research, development and adoption of best products and practices for the hearables market.

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References

1. National Institute on Deafness and Other Communication Disorders (NIDCD), NIH Pub. No. 97-4235, March 2016. <https://www.nidcd.nih.gov/health/age-related-hearing-loss>. Accessed 29 Jan 2019
2. Coughlin, J.: *The Longevity Economy: Unlocking the World's Fastest-Growing, Most Misunderstood Market*. PublicAffairs, New York (2017)
3. Steverson, M.: *Ageing and health*. World Health Organization (WHO), February 2018. <https://www.who.int/news-room/fact-sheets/detail/ageing-and-health>. Accessed 29 Jan 2019
4. Blevins, N., Deschler, D., Kunins, L.: *Presbycusis- UpToDate*. Wolters Kluwer. <https://www.uptodate.com/contents/presbycusis>. Accessed 29 Jan 2019
5. Mather, M., Jacobsen, J., Pollard, K.: *Aging in the United States*. Population Bulletin, Population Reference Bureau, December 2015. <https://www.prb.org/wp-content/uploads/2016/01/aging-us-population-bulletin-1.pdf>. Accessed 29 Jan 2019
6. AARP Research, *Loneliness Among Older Adults: A National Survey of Adults 45+ (2010)*. https://www.aarp.org/content/dam/aarp/research/surveys_statistics/general/2012/loneliness-fact-sheet.doi.10.26419%252Fres.00064.002.pdf. Accessed 29 Jan 2019

7. Sung, Y., Li, L., Blake, C., Betz, J., Lin, F.: Association of hearing loss and loneliness in older adults. *J. Aging Health* **28**(6), 979–994 (2016). <https://doi.org/10.1177/0898264315614570>
8. Mick, P., Parfyonov, M., Wittich, W., Phillips, N., Pichora-Fuller, M.: Associations between sensory loss and social networks, participation, support, and loneliness. *Can. Fam. Physician* **64**, e33–e41 (2018)
9. Lin, F., et al.: Hearing loss and cognitive decline in older adults. *JAMA Intern. Med.* **173**(4), 293–299 (2013). <https://doi.org/10.1001/jamainternmed.2013.1868>
10. Deal, J., et al.: Hearing impairment and incident dementia and cognitive decline in older adults: the health ABC study. *J. Gerontol.: Med. Sci.* **72**(5), 703–709 (2017). <https://doi.org/10.1093/gerona/glw069>
11. Su, P., et al.: Age-related hearing loss and dementia: a 10-year national population-based study. *Eur. Arch. Oto-Rhino-Laryngol.* **274**, 2327–2334 (2017). <https://doi.org/10.1007/s00405-017-4471-5>
12. Lin, F., Ferrucci, L.: Hearing loss and falls among older adults in the United States. *Arch. Intern. Med.* **172**(4), 369–371 (2012). <https://doi.org/10.1001/archinternmed.2011.728>
13. Gopinath, B., McMahon, C., Burlutsky, G., Mitchell, P.: Hearing and vision impairment and the 5-year incidence of falls in older adults. *Age Ageing* **45**, 409–414 (2016). <https://doi.org/10.1093/ageing/afw022>
14. Contrera, K., Sung, Y., Betz, J., Li, L., Lin, F.: Change in loneliness after intervention with cochlear implants or hearing aids. *The Laryngoscope* **127**, 1885–1889 (2017)
15. Amieva, H., Ouvrard, C., Giulioli, C., Meillon, C., Rullier, L., Dartigues, J.: Self-reported hearing loss, hearing aids, and cognitive decline in elderly adults: a 25-year study. *J. Am. Geriatr. Soc.* **63**, 2099–2104 (2015)
16. Maharani, A., Dawes, P., Nazroo, J., Tampubolon, G., Pendleton, N.: Longitudinal relationship between hearing aid use and cognitive function in older Americans. *Am. Geriatr. Soc.* **66**, 1130–1135 (2018). <https://doi.org/10.1111/jgs.15363>
17. Rumalla, K., Karim, A.M., Hullar, T.E.: The effect of hearing aids on postural stability. *The Laryngoscope* **125**, 720–723 (2015)
18. Lacerda, C., Silva, L., de Tavares Canto, R., Cheik, N.: Effects of hearing aids in the balance, quality of life and fear to fall in elderly people with sensorineural hearing loss. *Int. Arch. Otorhinolaryngol.* **16**(2), 156–162 (2012)
19. Plazak, J., Kersten-Oertel, M.: A survey on the affordances of “hearables”. *Inventions* **3**(3), 48 (2018). <https://doi.org/10.3390/inventions3030048>
20. Haire, M.: The Walkman. *Time*, 1 July 2019. <http://content.time.com/time/nation/article/0,8599,1907884,00.html>. Accessed 29 Jan 2019
21. HEARnet Online.: Hearables. HEARING CRC, The University of Melbourne. <https://hearnet.org.au/hearing-technology/hearables>. Accessed 29 Jan 2019
22. HearingTracker.com. <https://www.hearingtracker.com/hearing-aids>. Accessed 14 Sept 2018
23. Coughlin, J., Yoquinto, L.: Technology for older people doesn’t have to be ugly. *The Wall Street Journal*, 14 October 2018. <https://www.wsj.com/articles/technology-for-older-people-doesnt-have-to-be-ugly-1539546423>. Accessed 29 Jan 2019