

LISTENING IN: AN EXPLORATION OF FORMS FOR HEARING AID DESIGN

By Janice Tjan

Submitted to the Department of Architecture on
in Partial Fulfillment of the Requirements for the Degree of

Bachelor of Science in Art & Design

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ABSTRACT

Motivated to inspire more proactive hearing aid adoption and retention, this thesis explores how to generate new forms for OTC hearing aids. In the process of doing so, the opportunity gap between the success of consumer audio hearables and the lack of proactivity for hearing aid adoption is investigated. Information collected from interviews, surveys and codesign sessions was synthesized into three design considerations: expressivity, versatility, and extensibility. Feedback and critique about existing hearable forms inspired the formulation of a user-centric design method for hearing aid form design and two example implementations of this method are presented.

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1. INTRODUCTION

The hearing aid industry has struggled to capture a captive audience. Only one in five adults who would benefit from a hearing aid ultimately get one. The majority resign themselves to coping with their hearing loss for reasons ranging from costs, access to specialists, and social stigma. Recent changes in the regulation of over-the-counter (OTC) hearing aids and the growth of telehealth are slowly chipping away at the cost and access obstacles for treating hearing loss. Still, hearing aid purchases are often delayed and reactionary. How may we look to redesign hearing aids to make them into devices that people look forward to using, rather than dread having to consider?

Motivated to inspire more proactive hearing aid adoption and retention, this thesis explores how to generate new forms for OTC hearing aids design centered around the lifestyles of its users. Strategies utilized for finding inspiration for new forms included understanding the opportunity gap within the hearable category and exploring the opinions surrounding existing hearable forms. Input was gathered from makers, wearers, and viewers of hearing aids via surveys, interviews, and co-design sessions. The output was key learnings which were synthesized into a set of design considerations and a new design method for generating hearing aid forms.

2. BACKGROUND

A thorough understanding of OTC hearing aids brings the motivation of this thesis work into focus. Notably, there are challenges with communicating ideas in this innovation space where engineering and design converge. OTC hearing aids exist in the grey areas of device classifications and for this reason designers inevitably face the challenge of retrofitting existing language to describe this new category to stakeholders. Thus, it is important to clarify how this thesis will use certain vocabulary and recognize the advantages and shortcomings of categorizing OTC hearing aids in particular ways. Equipped with a framework for how to discuss this device and its design challenges, designers may be able to collect data about these devices in a more intentional and effective manner.

2.1. Key Terms

This thesis will be discussing a variety of devices in terms of categorizations that may be loosely used elsewhere but refer to a particular set of characteristics in this text. Two key categorizations that will be referred to throughout are 'hearable' and 'health' device.

While 'hearable' may be used interchangeably with 'headphone' in some circumstances, this thesis will refer to it in a broader sense as an umbrella term for any ear-

mounted wearable computer interface. Subcategories of this classification are consumer audio, medical, and wellness hearables. Consumer audio hearables tend to take the form of headphones and a common example of medical hearables are hearing aids. While there exists devices that are distinctly wellness, like ear-mounted EEG readers, one could argue certain medical and consumer audio devices may adopt features that bring them to converge in this category.

A 'health' or 'wellness' device will refer to a non-invasive, direct-to-consumer device that is used routinely to maintain one's health but does not perform life-sustaining functions. For example, a smart watch with an ECG would be a health device, but a pacemaker would not. Most health devices monitor vitals, but this categorization can include devices that provide treatment or diagnostics as well. This thesis makes a distinction between 'health' and 'medical' devices because of the implications each term has on who is producing the product, how it is stigmatized by the public, and how it is marketed to prospective users. Notably, as health devices become capable of addressing more diverse health care needs, there will be a growing overlap between health devices and conventional medical devices. This is especially relevant for the OTC hearing aid, which is currently considered an exclusively medical device, but is likely to adopt characteristics of a health device as companies who typically produce consumer audio enter the space.

2.2. Dissonance in Hearables Adoption

The hearing aid is a device designed to do a job that many people need but apparently do not want. Fewer than one-fifth of the 36 million Americans with hearing loss ever seek help for their condition.¹ Unfortunately, this minority of proactive patients often trek a drawn-out journey in the search for satisfactory solutions to no avail. Most hearing aid users are late adopters who schedule a fitting with an audiologist after a decade-long delay from their initial diagnosis.² At this point of adoption, hearing loss has progressed to a moderate-to-severe level that can no longer be ignored. Moreover, one study aptly titled "Why My Hearing Aids are in the Drawer," suggests about 16 percent of hearing aid owners never wear their hearing aids.³ Seemingly, the path to a hearing aid and transition into becoming a habitual user is fraught with hesitation and avoidance. This is unacceptable because of the harm delayed and reactionary purchases have on users. In addition to the detrimental health effects of coping with untreated hearing loss, there is an emotional cost.

¹ Donahue, Amy, Judy R. Dubno, and Lucille Beck. 2010. "Accessible and Affordable Hearing Health Care for Adults with Mild to Moderate Hearing Loss." *Ear and Hearing* 31 (1): 2.

² Davis, A., P. Smith, M. Ferguson, D. Stephens, and I. Gianopoulos. 2007. "Acceptability, Benefit and Costs of Early Screening for Hearing Disability: A Study of Potential Screening Tests and Models." *Health Technology Assessment* 11 (42): 95–105.

³ Bahadornia, Babak. 2000. "MarkeTrak V: 'Why My Hearing Aids Are in the Drawer': The Consumers' Perspective."

During her interview, a long-term hearing aid user recalled the exact moment she realized her hearing loss could end her teaching career: "one student came up to me after class and said, 'you just can't hear me' and I think that was the moment when I knew. It was really a painful moment." Earlier adoption of hearing aids can empower users to come to terms with their hearing loss at a healthy pace and give them more opportunities to integrate these devices into their existing lifestyle.

This trend of avoidance and delay shows no sign of letting up. Unit sales for hearing aids in the United States increased steadily each year 2-9% from 2007 to 2019.⁴ Though hearing aid sales are showing incremental growth (except for a drop in units sold in 2020), it may be attributed to the incoming silver tsunami, the growth of an aging population that is outpaces the rate of births. This slow growth is overshadowed by the exploding category of consumer audio, more specifically earbuds. During 2020, the year when other hearable categories suffered in sales, worldwide earbud sales nearly doubled from 120 million units sold in 2019 to 233 million units sold in 2020.⁵ Enthusiasm for earbuds have led experts to project that hearables will overtake smartwatches as the top category of the wearables market in coming years. Taken side-by-side, the contrast between the hype around earbuds and the hesitation around hearing aids is clear. Hearing aids and earbuds, despite sharing a category by virtue of their physical form, has seen different levels of success. Can we exploit this categorical association and reinvigorate interest in the hearing aid?

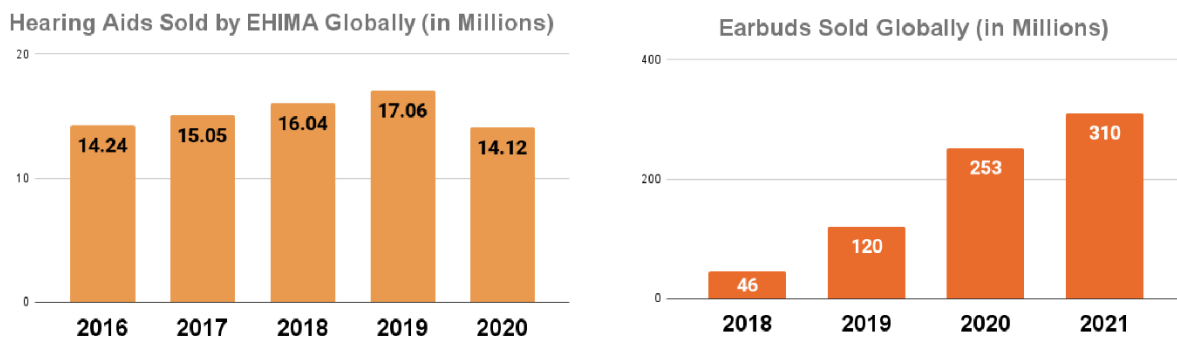


Figure 1: Chart of hearing aids units sold per year globally by the European Hearing Instrument Manufacturers Association which produces 90% of hearing products worldwide, scaled to millions of units. (right) Earbuds units sold globally, scaled in millions.

⁴ "Annual change in U.S. hearing aid sales from 2007 to 2020" Graph, *Hearing Review* (January 18, 2021): Statista.

⁵ "Unit sales of true wireless hearables worldwide from 2018 to 2021 (in millions)." Chart. (May 4, 2021) Statista.

2.3. The ‘Health’ and ‘Medical’ Device in Harmony

In recent years, the line between the trendy commercial health device and trusted personal medical device has become increasingly blurred. For instance, it is not out of the ordinary today to come across smartwatches that feature EKGs and blood oxygen sensors. So far, very few of these smartwatches will go as far as to claim that users should rely on them to manage or diagnose a medical condition. To make such a claim in the United States, a company would need to commit to a lengthy process and receive clearance from the Food and Drug Administration (FDA). One product that has successfully crossed over this hurdle and has paved the way for the rest of its category the Withings ScanWatch. The ScanWatch emerged from regulatory limbo in November 2021 after its sleep apnea detection abilities were cleared by the FDA.⁶ Sooner than we may expect, products like ScanWatch will become the norm, rather than the exception. The increasing presence of the Internet of Things (IoT), growing population of tech-native users, and rising concern for chronic disease are driving the growth of the wearable technology market. Especially after the COVID-19 pandemic, consumers are interested in features that would transform our current perception of the mass-market health device into a more personalized and invasive medical one.

Lines are beginning to blur in the hearing aid space as well. “A hearing aid can totally be a feature in an earbud,” Andrew Sabin, a research engineer at Bose, explained, “the limit is not technical... what are you allowed to say to customers? That is constantly being tested.” Such a device could exist as an OTC hearing aid, a category formally proposed by the FDA in October 2021.⁷ Hearing aids that fit into this category can be acquired directly online or in a store to address low to moderate hearing loss without consulting an audiologist. Though this new category has raised concerns about the quality of healthcare its users may receive, it also holds promise for a future where healthcare is more accessible. The OTC hearing aid, when coupled with other emerging technologies (like 3D printing systems for custom ear tips⁸ or self-fitting software based in mobile apps⁹), has contributed to a move towards the decentralization of hearing loss treatment delivery. This decentralization, while increasing the risk of mismanagement without the oversight of specialist care, also makes treatment more approachable and maintainable over a long period of time.

As technological momentum drives the convergence of certain health and medical devices, we become more capable of answering the question of what services and features a futuristic OTC hearing aid may provide. Yet will consumers be able to recognize this added value? Will it be enough that hearing loss treatment becomes cheaper or can be

⁶ Nicole Wetsman. “FDA Clears Withings’ EKG and Blood Oxygen Features,” *Verge*. October 12, 2021.

⁷ “Over-the-Counter (OTC) Hearing Aids.” 2021. *NIDCD*. October 22, 2021.

⁸ “How to Make Custom Fit Ear Tips With 3D Printing.” 2021. *Formlabs*. August 16, 2021.

⁹ Andrew T. Sabin, Dianne J. van Tasell, Bill Rabinowitz, and Sumitrajit Dhar. 2020. “Validation of a Self-Fitting Method for Over-the-Counter Hearing Aids.” *Trends in Hearing* 24.

camouflaged as more fashionable items? It is effective to co-opt the imagery around more popular hearables or does it make more sense to reinvent the reputation of familiar over the ear hearing aids?

3. EXPERIMENTAL DESIGN

Information collection methods were varied on the premise of exploring the insights of makers, users, and viewers of hearing aids with a range of breadth and depth. The following methods are presented in the approximate order they were conducted.

3.1. Stakeholder Interviews

Eight interviews were conducted to explore the perspectives of makers and wearers of hearing aids in both one-on-one and group contexts. Half of the interviewees were involved in the production or research surrounding hearables. The other half were either prospective or experienced users of hearing aids. More context regarding the interviewees is shown in Figure 2. A sample discussion guide can be found in Appendix A.



Figure 2: An overview of the interviewees. (Orange) From within the hearables industry realm were Andrew Sabin and David Pearl who both worked on Bose’s SoundControl Hearing Aids. Interviews about surrounding infrastructure and adoption were had with Chaiwoo Lee and Terra Moran. (Blue) Paul Pettigrew was a prospective hearing aid user who was actively doing product comparisons. The AgeLab Lifestyle Leaders (85+ years old) were interviewed as a group regarding their long-term experiences as hearing aid users.

While these interviews were explorative in nature, discussion was directed at discussing current challenges in hearing aid adoption, speculating about the future of hearable devices, and sharing what personally excited them about emerging technologies.

3.2. Public Survey

In April 2022, a survey was shared on the social news site, Reddit, and sent over email to the MIT undergraduate community and architecture department. The goal of the survey was to identify trends in viewer perceptions regarding different hearable forms. The survey contained two tasks: (1) characterization of four different hearables devices and (2) ranking of perceived “appropriateness” of the four devices in three scenarios. The full contents of the survey are contained in Appendix A.

Respondents were shown four wearables, which are shown in figure 3, and were asked to briefly predict the function and describe the appearance of each of them. Each hearable form was based on an existing consumer audio or hearing-aid device that conformed to different regions of the ear. They were depicted as drawings from varying perspectives for viewing clarity and uniformity.



Figure 3: Four devices were presented to survey takers to discuss. (Row 1) Perspective drawing of the device with their respective letter label (Row 2) The devices from different angles on the ear (Row 3) A visual mapping of where the device interfaces with the ear surface (Row 4) The respective reference product that the device was based on.

After viewing and discussing each hearable independently, respondents were told that all the hearables contained software that enabled them to be used as a hearing aid. Next, they were asked to rank all four hearables from least to most appropriate according to a certain scenario. The three scenarios were (1) a Thanksgiving dinner party with friends and family, (2) a morning walk in the park alone, and (3) buying a hearing aid for yourself. Scenarios 1 and 2 were included to test for a difference in preferences based on different levels of social interaction; Scenario 1 being the more social and scenario 2 being more solitary. Scenario 3 was included to provide context for the 'true' preference of the survey taker.

3.3. Co-Design Workshop

Two workshops were held with two individuals with hearing loss. The premise behind these workshops were to directly involve people with hearing loss the ideation process. During separate 60-minute sessions, the participants walked through their day-to-day social interactions, discussed in depth the values that influenced their preference in hearing aid form, and then had time to draw or sculpt the form of a hearing aid that would fit their lifestyle. The full discussion guide and worksheets are contained in Appendix A.

4. RESULTS AND DISCUSSION

4.1. Stakeholder Insights

Interviews with experts, producers, and wearers of hearing aids contributed to a more nuanced explanation for the challenges facing hearing aid adoption and the perceived potential of OTC hearing aids. Certainly, individual insights inspired reinterpretations of how barriers to hearing aid adoption are commonly presented and introduced new pain points of hearing aid design. However, while stepping back and looking at the whole body of information provided, one could identify reoccurring themes across interviews with producers and wearers. Three key takeaways were identified after analyzing interviews according to where the insights of individuals from different backgrounds converged.

Insight 1: Users are waiting for the next best thing

While the blame for the delay in hearing aid adoption usually falls on barriers like cost and social stigma, interviews revealed a silent waiting game. An AgeLab Lifestyle leader, who will be referred to by the pseudonym Maggie, summarized her disappointment, "I am technologically illiterate, but there is so much hope in technology. I expect it to go faster."

She promptly followed up with a hopeful statement, "I expect it to catch up and I am assuming it will on every level."

Paul, a recent adopter of a hearable device with hearing enhancement features, insisted on avoiding hearing aids in favor for waiting to adopt future technology that would fit his tastes. When asked whether his attitude toward hearing aid usage would change if his hearing loss progressed, he replied, "I would still try to avoid it as much as possible. I would go so far as hacking a traditional pair of medical hearing aids and glasses so that the two could come together as a form factor. I am convinced it can be done."

This techno-optimism exists on the production side of hearing aid technology as well. As Andrew Sabin, a research lead at Bose Hear, expressed his motivations for working in the field, he mentioned a sense of excitement and anticipation. "Now, the world has changed in the last few years because of the regulations... It is a good time to be someone with hearing loss. They'll be lots of options. They'll be cheaper and more accessible."

All in all, prospective hearing aid users' expectations for technological progress may affect the timing or likelihood of adoption. This reveals a different value proposition for hearing aids. In addition to providing the latest technology in a hearing aid, these devices could present the possibility for extensibility. This approach to device design could incentivize users to adopt sooner because an extensible hearing aid would be more likely to fit the future lifestyle they envision in addition to the one they currently have.

Insight 2: Hearing aids as earbuds are not an end-all solution

There was agreement among experts that it was possible to put hearing aid software onto a form factor like an earbud and successfully provide hearing loss treatment. However, whether this was the form factor that people could come to favor was unclear. There are some inherent advantages of adopting the form of consumer audio products. For instance, being able to wear something that was not associated with the stigmas of old age, or what Paul identified as "something your grandparents wear."

One concern from a producer's perspective was that the form factor of an earbud would unintentionally make someone look rude or inattentive.

"I feel that you will see someone with Air Pods when they're in line at the coffee shop. I always ask my team, 'if you ever see someone at a restaurant with a tablecloth, wearing an earbud at that table, take a picture.' No one has done it... invisibility still matters to users."

– Andrew Sabin

There was some agreement that the solution to this problem was to wait for a more appropriate time, the point where people would "have something in [their] ears all the time." Contemporary social norms appear to align with this expectation: "walking around with headphones in your ear now is normal. That was not the case 10 years ago."

While most could imagine stigma fading with time, there were conflicting ideas on what alternative forms a hearing aid would successfully appropriate. Andrew Sabin distilled the current approach to hearing aid form design into two pathways, “make it smaller or make it more visible.” However, even on the end of making a device more visible exists the option of tech camouflage, disguising the device in a less conspicuous accessory like glasses. “I am not sure we have found it, yet.” David Pearl, a human factors researcher, explained, “What I mean [to say], is a seamless integration of technology and people that [is] not too freaky or creepy that accomplishes this goal that also fits into socio-cultural norms.” In summation, there is plenty research that has yet to be done in the field of hearing aid design with respect to its form. Section 5 of this thesis will propose possible approaches to creating new forms for OTC hearing aids.

Insight 3: Hearing aids are more than communication devices

Undoubtedly, hearing aid users recognized that their hearing aid improved. Yet, users asserted that more could be done and described how they were reshaping their routines and habits to cope with the pitfalls of their hearing aids. Despite being a device designed to be worn at all waking hours, it has failed to accommodate an active and social life. Maggie reflected on her initial visits to the audiologist to get fitted, “I sense that these hearing aids are designed for communication... The audiologist during the one-hour visit asked if I wanted to listen to music or hear a crowded room. Those are the sorts of linear questions that don’t address the comprehension of sound. It’s a comprehensive problem... not either-or.”

Further, the premise that a hearing aid should be an all-purpose, all-day device is an assumption challenged by some people’s preference for silence in some activities. Maggie described her experience working in her art studio in silence: “I love the solitary experience. It is my modus. It is the direction I would go in any case... Sometimes I take my hearing aids off and it is better.” Other activities, revisited in the analysis of codesign sessions, reveal that users may take off their hearing aids for activities such as studying or playing an instrument.

Hearing aid form goes beyond making a hearing aid more pleasing to the eye or being an effective container for hardware and software. It is also a change in the design mindset. When asked about his view regarding the difference between designing from the hearing aid perspective or consumer audio perspective, David Pearl explained,

“...hearing aids for a long time have been purpose-built. They are built to do one thing and over the last bit of time, they have had more functionality added to them... On the other hand, you have earbuds that are purpose-built for different things right off the bat (listening to music, taking phone calls, noise-canceling) but also typically have a more diverse set of software that runs on the backend to deal with a wide variety of things.”

Expanding the expectations of what a hearing aid looks like has implications beyond style preferences, it also effects what functions it is expected to have. The gap in consideration for how the form and function of hearing aids affects each other deserves more exploration.

4.2. Public Preferences and Perceptions of Appropriateness

Most respondents of the public survey were between the ages of 20 and 35 and did not have hearing loss themselves. Of 85 respondents to the survey, 42 respondents knew someone with hearing loss and 21 respondents knew someone who owned a hearing aid. When asked what hearable devices they owned, 64% of respondents reported owning a pair of wireless earbuds. Taking this into consideration, the following interpretations of survey data may reflect the sentiments of a younger demographic with little first-hand experience with hearing aids, but plenty of experience with consumer audio products.

A hearable for every situation?

When presented with the first scenario, “a Thanksgiving dinner party with friends and family,” respondents ranked Device B (over-the-ear) first most often and Device D (earbud) last the most often. Meanwhile, when presented with the second scenario, “a morning walk in the park alone,” respondents ranked Device D first most often and the rest of the options showed no statistically significant difference from each other (figure 4).

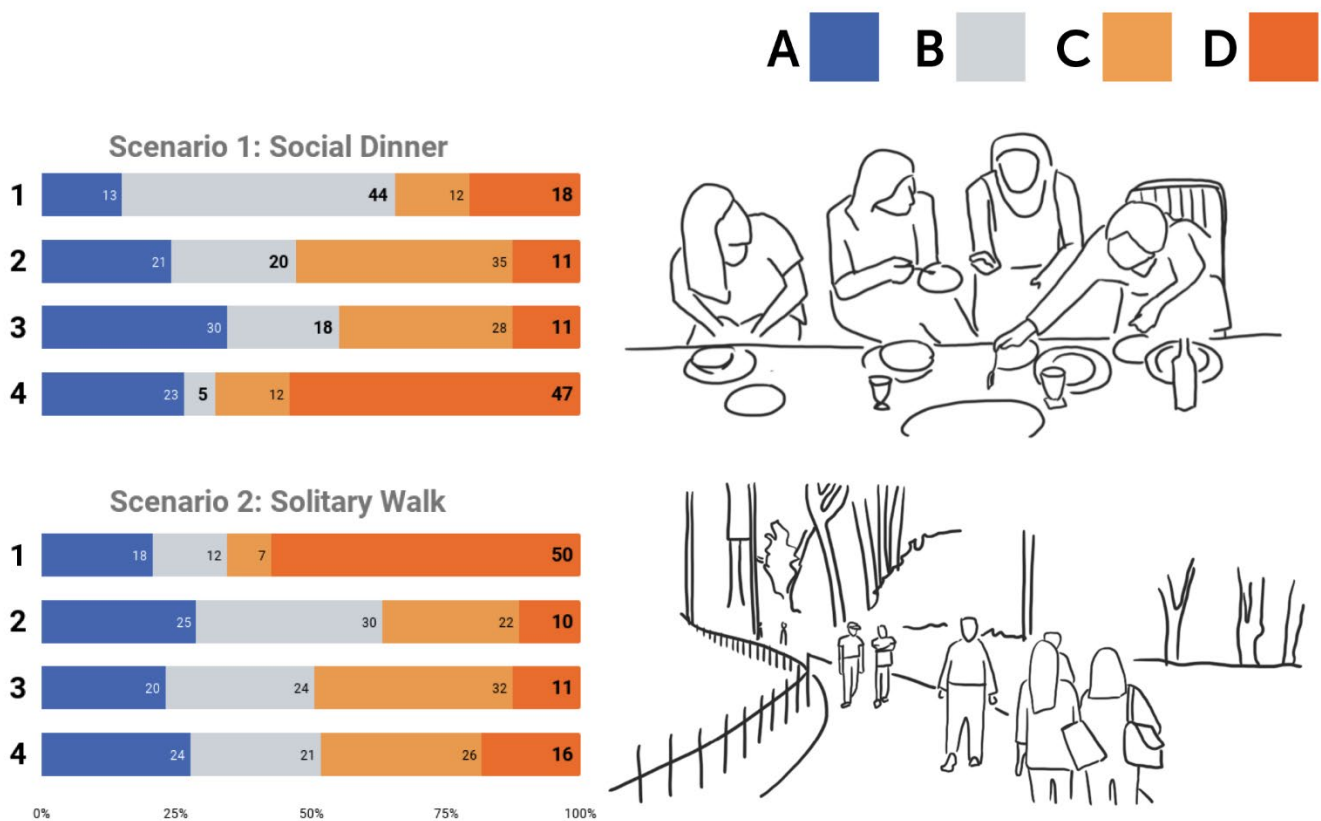


Figure 4: Preference distribution for two scenarios.

The ranking of devices when presented with the scenario, “you are buying a hearing aid for yourself,” did not skew as strongly as when respondents were given specific social scenarios (figure 5). Notably, those who chose Device B (over-the-ear) were more likely than other respondents to think that Device B was the most appropriate for both scenarios. This was also the case for Device D (earbud). In other words, individuals would choose devices they felt would be appropriate both the social and solitary situation, but the idea of which device was more appropriate varied person to person.

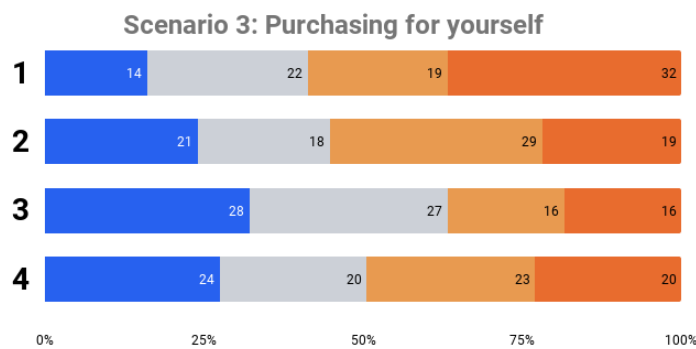


Figure 5: Preference distribution for Scenario 3.

When open responses explaining respondents’ rankings for scenario 3 were sorted based on first preferences and were analyzed qualitatively, interesting patterns began to emerge. Factors that contributed to a person’s personal preference generally can be sorted into three categories: familiar product associations, perceived functionality, and desirable characteristics. Table 1 shows how respondents described the device of their choice and the factors that contributed to their decision.

	Product Associations	Perceived Functions	Desirable Characteristics
<p>(A)</p>	<ul style="list-style-type: none"> Hearing aid Bluetooth headphone 	<ul style="list-style-type: none"> Sound amplification Directional sound Unobtrusive to ambient sound 	<ul style="list-style-type: none"> Visible/Obvious Stable/Secure Futuristic Bulky/Large
<p>(B)</p>	<ul style="list-style-type: none"> Hearing aid Gadget 	<ul style="list-style-type: none"> Sound amplification 	<ul style="list-style-type: none"> Discreet/Subtle Comfortable Elegant/Sleek Standard/Familiar

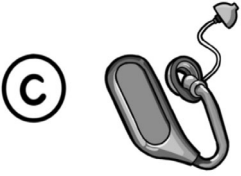

	<ul style="list-style-type: none"> • Hearing aid • Jewelry • Gadget 	<ul style="list-style-type: none"> • Sound amplification • Bone conduction • Unobtrusive to ambient sound 	<ul style="list-style-type: none"> • Discreet/Subtle • Stylish/Sleek • Awkward • Comfortable
	<ul style="list-style-type: none"> • Earbud • Gadget 	<ul style="list-style-type: none"> • Plays music • Phone call 	<ul style="list-style-type: none"> • Discreet/Subtle • Hidden/Private • Minimalistic/Compact • Snug/Fitted/Secure

Table 1: A summary of associations, perceived function, and desirable characteristics provided by people who chose the respective device for scenario 3.

Insight 4: There is room for variety

Analysis of the descriptions of devices provided in survey responses revealed patterns relating to the familiarity of devices. The higher the familiarity of a device, (like the over-the-ear hearing aid and earbud), the stronger association it had with certain socio-cultural norms. Less familiar devices (Device A or C) were associated with a more varied set of perceived functions and desirable characteristics. Though, familiarity did not seem to contribute to whether a person preferred one device over another. In fact, the lack of consensus about what form was preferred, or even what traits are desirable, implies that having a wider variety of options for hearing aids would be the best way of fulfilling the hearing aid's market potential. The exact degree of variability may be determined by conducting further research into what forms are associated with commonly desired traits like comfort, discreetness, and sleekness.

4.3. Co-Design Creations

Two co-design sessions were conducted with individuals who have varying degrees of hearing loss. The first was done in-person with a professor of the Mechanical Engineering department, Dr. Hughey, who has surgically corrected hearing loss. The second session was conducted via Zoom and Miro with Erick, an undergraduate student who uses his hearing aids daily. Images documenting these sessions are found in figure 6.

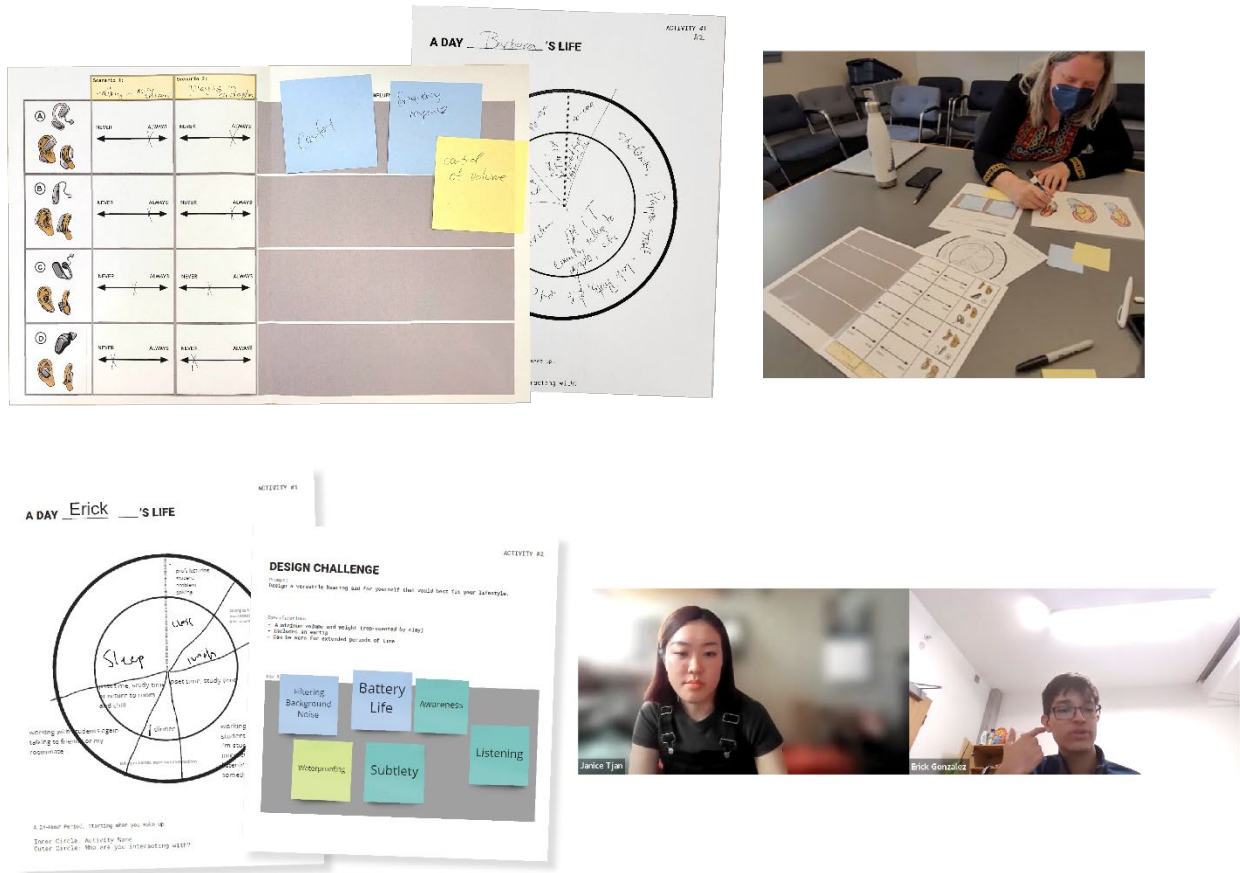


Figure 6: Snapshots of the in-person and virtual co-design sessions alongside the worksheets used to guide discussion and ideation.

After walking through the events of a typical day and listing the interactions that occurred at each event, the co-designers identified specific values and features they would find desirable in a hearing aid.

Insight 5: Over-the-ear, a great form factor with implementation issues

The co-designers were prompted to reflect on the values and features they identified and draw their ideal hearing aid. Both co-designers drew an over-the-ear device (figure 7).

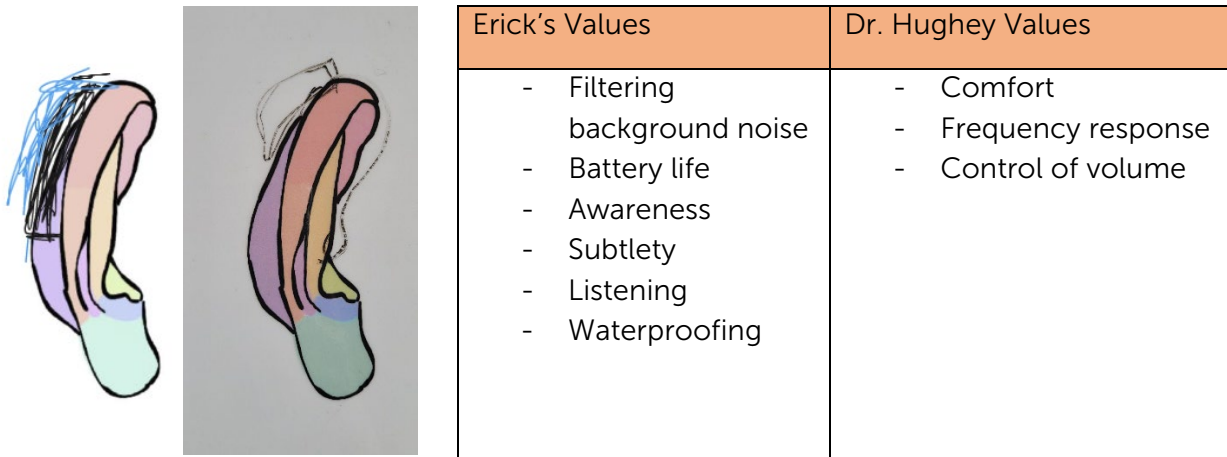


Figure 7: Drawings made when prompted to draw the ideal device for their lifestyle [(left) Erick, (right) Dr. Hughey] alongside a chart listing the values/features both co-designers identified as part of the ideal hearing aid.

This was a form that they both appreciated for its discreetness. From their personal experiences they also felt it was comfortable and recognizable. Instead, while discussing desirable features, both respondents tended to focus on function.

Extended conversations over the drawings delved deeper into how each function would serve their lifestyle. For instance, Erick pointed out that his current hearing aids were not waterproof which meant that he had to take certain measures to make sure they did not get sweat on them when he worked out. Dr. Hughey also expressed concern about waterproofing and being able to do water sports. Another one of Erick's concerns was battery-life because his waking activities often outlasted his hearing aids. In summation, the motivation some of listed values/features was the desire for a robust, low-maintenance, device that could withstand their active lifestyles.

Another set of features was having more control over sound. Both co-designers explained how hearing is more difficult in certain scenarios like a conversation that takes place in a crowded room. Erick mentioned that there were buttons on the back of his hearing aid, but also was unsure what they were for: "when I press them, nothing happens." Dr. Hughey also shared that she would want to control volume for purposes like playing a musical instrument in orchestra. Potentially, rethinking the interfaces and ease of control over hearing aid settings could make them a more versatile device.

5. A NEW DESIGN METHOD AND EXAMPLE IMPLEMENTATIONS

Experimental methods addressed reasons why hearing aid adoption rates are lower than they should be and what stakeholders wanted their hearing aids to be like. Yet, the question of how to tackle the challenge of making an OTC hearing aid that people could look forward to using was left unaddressed. The following is a proposed method a designer may use to draw more focus on accommodating for users' dynamic lifestyles and to inspire the use of form as a functional part of a device, rather than a vessel for software.

5.1. A User-Centered OTC Hearing Aid Design Method

The goal of this proposed design method is not to create a custom hearing aid for a specific individual, nor is it to find the silver bullet of OTC hearing aid form design. Rather, it should be a tool for generating a variety of forms to further develop and evaluate.

Intentionally, this method starts with the user. First, a persona is created based on research about the intended wearer. Once the persona is established, two routine activities of this persona are identified. Preferably, these activities involve varying levels of social interaction, a variety of movements, or occur in different environments. The next input is a design consideration, which is elaborated more in the next section. Depicted in figure 8 are two representations of this method, first in a diagram and second as a sentence.

Also included are possible approaches to manifesting these abstract concepts into physical forms. The first approach is to create a marginal object, an object described by Sherry Turkle as "on the lines between categories" and able to "incite us to reaffirm the line, sometimes they call them into question, stimulating different distinctions."¹⁰ The second approach is to create a transforming object, or an object that has distinct states associated with activities. The final method is to create an evolving object that is not introduced to the wearer in its final form, but rather is designed to be altered or built upon as the wearer's desires change.

¹⁰ Sherry Turkle "Child Philosophers." Essay. In *The Second Self: Computers and the Human Spirit*, 1st ed. Twentieth Anniversary Edition. New York: Simon & Schuster, 2005, 34.

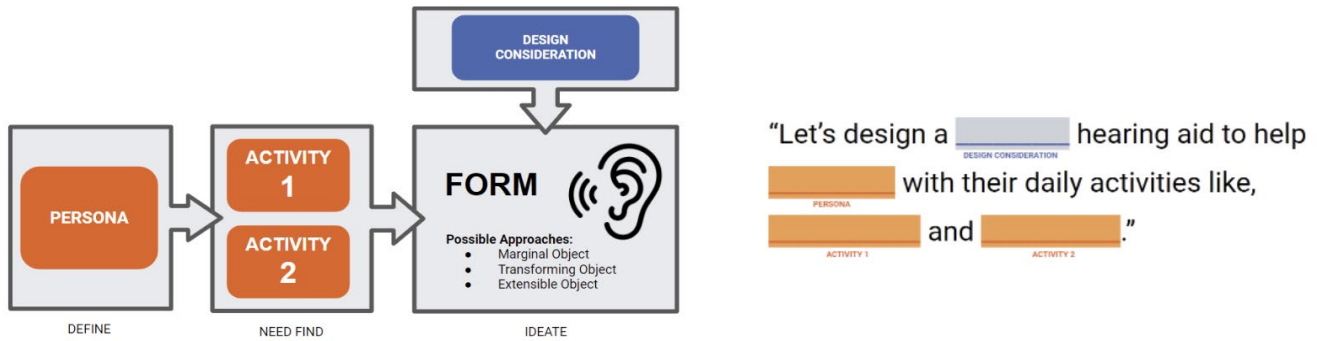


Figure 8: (left) a diagram representation of the design method. Persona information is depicted in orange. (right) The design method and its corresponding inputs articulated as a sentence.

5.2. Design Considerations for Hearing Aid Form

The five previously discussed insights were further distilled into three design considerations which are shown in figure 9. These design considerations function as qualitative requirements for form design and guiding concepts when considering engineering trade-offs. Expressivity, versatility, and extensibility were considerations that were identified based on this thesis' collected data. Further research and interpretations of the data may lead a designer to identify another set of design considerations.

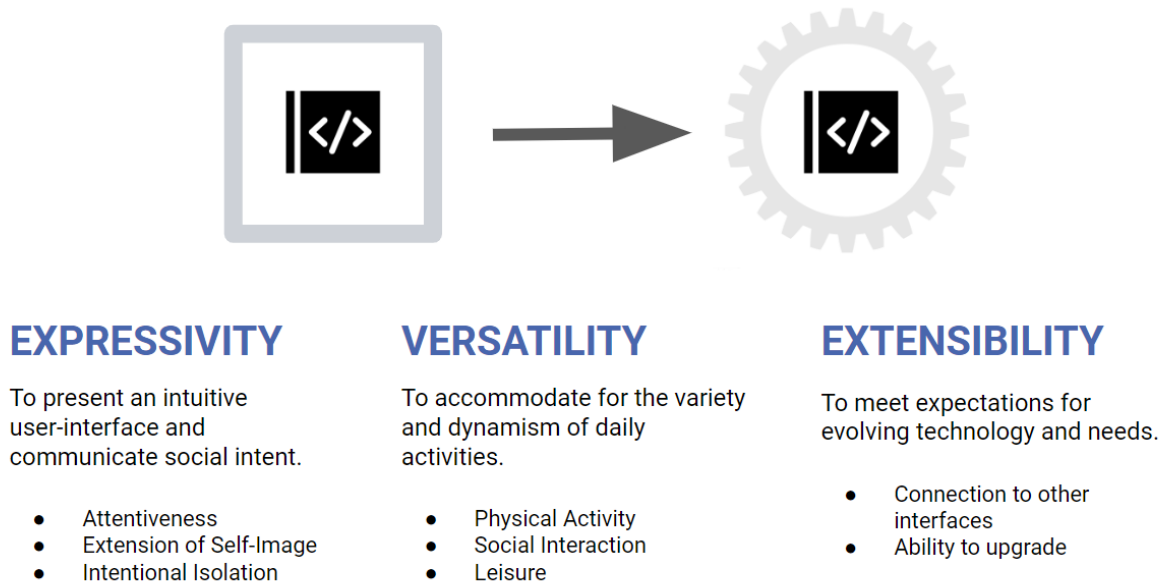


Figure 9: Three design considerations and their description. Example qualities associated with the consideration are included in a bulleted list.

5.3. Example Implementations

Example implementations of this design method were completed to demonstrate its effectiveness and explore the unexpected lessons that came with interacting with the resulting prototypes. Personas were crafted based on the interviews described in section 3.1 and the design considerations used were those depicted in section 5.2.

Implementation 1: Versatile Transitions

The method used to create this first implementation is shown in figure 10. The resulting form was a marginal object that was both an over-the-ear and earbud-like hearable. To transition between the two modes, a wearer would need to remove an ear-tip attachment from one end of the device and attach another ear-tip attachment to the other end. This process is shown in figure 11.

Man in his 40s who is active and has mild hearing loss. He does not want to look older than his age, but also wants to continue to be able to communicate effectively.

“Let’s design a **versatile** hearing aid to help **Keith** with his daily activities like, **teaching** and **walking his dog.**”



Figure 10: A summary of example implementation 1. To the left is the design method statement and a brief elaboration of the user persona. On the right is a prototype of a device that was created via the design methods.

Keith would be able to choose between either state of the device at his own discretion. Perhaps, he may be less accepting of his hearing loss when he first adopts this device and would rather present it as an earbud, but over time he would transition to over-the-ear. He might also prefer the look of a sleek earbud but would like to make sure he does not present as rude when in more social situations like teaching or at a dinner. Regardless of the reason, the built-in versatility allows Keith to define the requirements for how he uses his hearing aid and have these requirements evolve as his relationship with hearing loss develops.

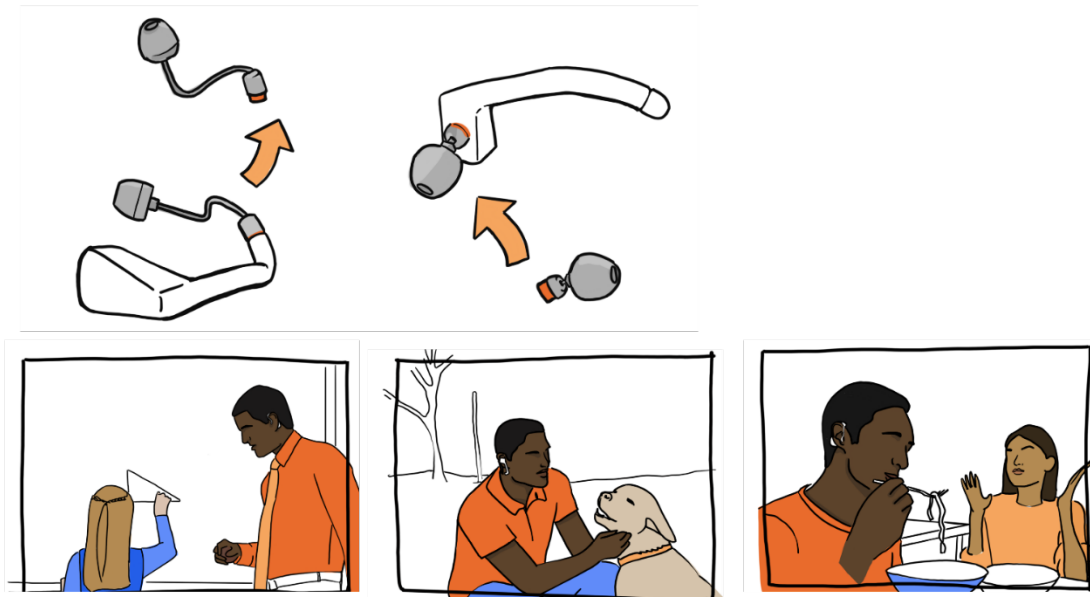


Figure 11: (top) Proposed removable features that enable the device to be used in different orientations on the ear. (bottom) A storyboard depicting Keith teaching and at dinner with the hearing aid worn over-the-ear, but also at the park with the device in an earbud orientation.

5.3. Example Implementation 2: Expressive Listening

The method used to create the second implementation is shown in figure 12. The resulting form was a transformable object with a rotating ring attachment. By rotating the ring, a user can adjust the volume of their hearing aid in real time. When the ring is fully overlapping the earbud body, the wearer is blocking out all sound. When the ring is deployed away from the earbud body, it is relaying sound at a higher volume (figure 13).

Woman in her 50s who has moderate hearing loss and participates in activities that range from collaborative to solitary.

“Let’s design a **expressive** hearing aid to help **Sam** with her daily activities like, **playing in orchestra** and **painting.**”



Figure 12: A summary of example implementation 1. To the left is the design method statement and a brief elaboration of the user persona. On the right is a prototype of a device that was created via the design methods.

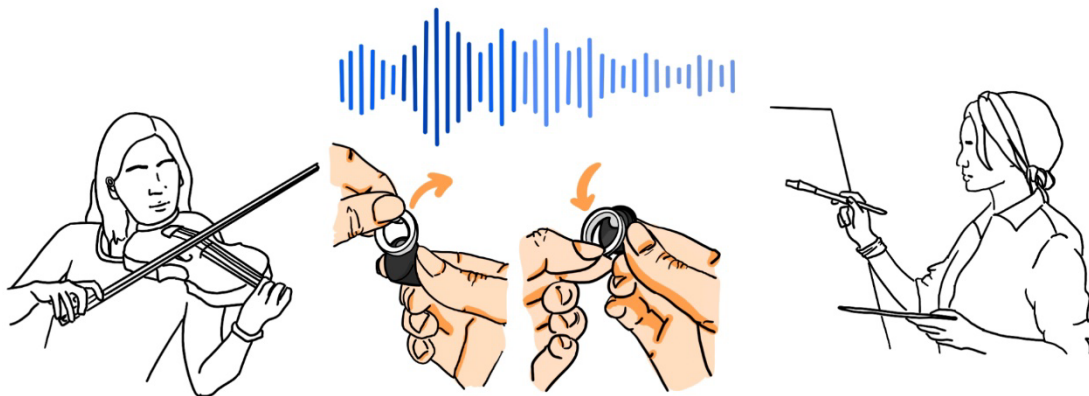


Figure 13: A depiction of the volume control using the ring interface. (left) Sam is playing violin and would like to max out the sound she is hearing, so she turns the ring away from the body of the earbud. (right) Sam enjoys working in silence and solitude. She tunes out the world by turning the ring over the body of the earbud.

While other OTC hearing aids may be controlled using an app, Sam is able to change the volume settings on her pair in a snap. This function is of interest to her because she has an appreciation for silence and sound in certain activities. Like lifting her hand to her ear, she is also able to use the gesture of turning up the volume to show that she is actively listening to someone (figure 14). People are also aware when she is not able to hear them or whether she would like to be left alone by just looking at the state her hearing aids are in.

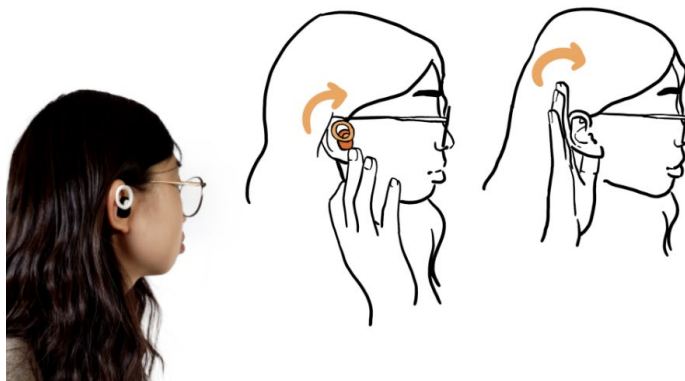


Figure 14: In this implementation, expression involves being able to communicate the intent to listen or ignore surrounding sound. The act of raising the volume of her surroundings looks like the gesture of raising a hand up to her ear.

6. CONCLUSIONS

Hearing aids solely designed for communication have failed to capture the hearts of their prospective users. Rather, these prospective hearing aid users have been deterred by the perceived lack of added value that hearing aids may bring in exchange for the necessary maintenance and cost they require. Exploring hearing aid form and the potential added function they may contribute can be the added value these wearers seek. While further explorations into hearable form and their associated qualities need to be done, one may employ the proposed design method to generate forms based on available information about prospective wearers' lifestyles and pre-determined design considerations. The two

example implementations presented in this thesis demonstrate how this method may generate designs are not only visually evocative but have functions that assist in and bring delight to the many 'jobs to be done' in their daily lives.

APPENDIX A: Materials for Experimental Methods

A1. Interview Discussion Guide Example:

For Makers:

- Can you describe who you are and what motivates you to do the work that you do?
- What sets a health device apart from a medical device?
- A narrative that persists when I talk to users of hearing aids is that they would wait several years before getting a hearing aid. In your experience, what are the major factors that contribute to this?
- What contributed to the design of the form of a hearable?
- What is driving innovation in the hearing aid space?

For Wearers:

- Can you describe who you are and how would you describe your experience with hearing loss?
- What sets a health device apart from a medical device?
- Can you describe who you are and how would you describe your experience with hearing loss?
- Can you describe who you are and how would you describe your experience with hearing loss?

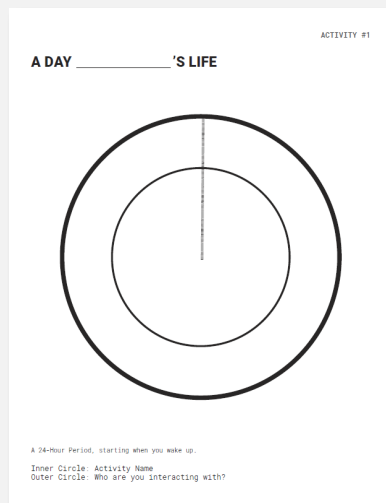
A2. Survey Contents

1. Tell me a bit about yourself by continuing to the next section
 - a. What is your *date of birth*??
 - b. **Do you have a friend or family member with hearing loss?** If so, what is your connection to them, and do they wear a hearing aid?
 - c. Do you own headphones or earbuds? What **brand** and **model**?
 - d. What is your estimation of what the **average age** of hearing aid users would be?
2. For this section of the survey, we will be discussing "**hearables**" which are defined as: electronic in-ear devices designed for multiple purposes.
 - a. Take a look at Device A on the left. In 10 words or less, what would you expect its **function** to be and how would **describe its appearance**?
 - b. Take a look at Device B on the left. In 10 words or less, what would you expect its **function** to be and how would **describe its appearance**?
 - c. Take a look at Device C on the left. In 10 words or less, how would you expect its **function** to be and how would **describe its appearance**?
 - d. Take a look at Device D on the left. In 10 words or less, how would you

- expect its **function** to be and how would **describe its appearance**?
3. In this final section you will assume that all these hearables contain software that enables them to be used as a hearing aid.
 - a. Scenario 1: A Thanksgiving dinner party with friends and family
 - b. Scenario 2: A morning walk in the park alone
 - c. Scenario 3: You are buying a hearing aid for yourself
 - d. What factors influenced your ranking for Scenario 3
 4. Any comments or concerns?

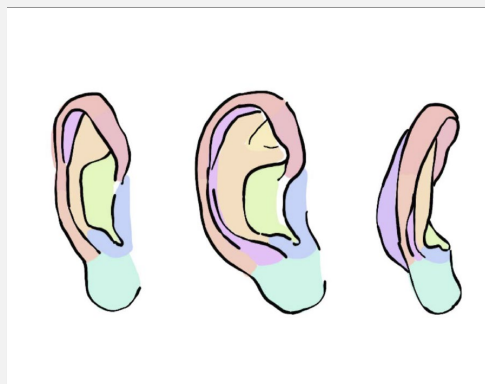
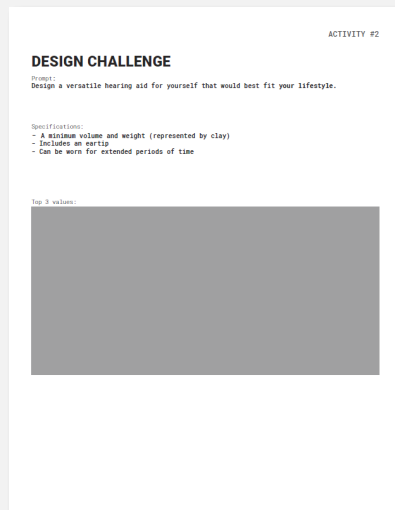
A3. Co-Design Workshop Discussion Guide and Materials

Activity #1:



	Scenario 1:	Scenario 2:	VALUES THAT INFLUENCED MY DECISION
A	NEVER ← ALWAYS	← NEVER ALWAYS	
B	NEVER ← ALWAYS	← NEVER ALWAYS	
C	NEVER ← ALWAYS	← NEVER ALWAYS	
D	NEVER ← ALWAYS	← NEVER ALWAYS	

Activity #2:



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