An Analysis of Advancements in Technology and Its Social Impact on the Audiology Landscape

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Abstract

With machine learning technology becoming more prevalent in hearing aids and the accelerated adoption of telehealth services as a result of the COVID-19 pandemic, there has been an array of relationship-transforming implications introduced to society. As a result, the current service delivery model for audiology care has been disrupted, triggering a potential power shift in relationships between actors involved in the audiology landscape. Through Actor-network Theory and a series of user studies, I will attempt to discover the ways in which advancements in technology have transformed relationships between audiologists and patients as we transition into a new era of what has been termed "Connected Audiology." Readers can expect to learn about the Doctor-Patient relationship model as applied to audiology, how telehealth services and machine-learning enabled hearing aids have disrupted this model's status quo, and how surveys reveal the sentiments of audiologists and patients with respect to these changes.

An Analysis of Advancements in Technology and Its Social Impact on the Audiology Landscape

Introduction

Hearing loss and balance disorders are among the most commonly diagnosed health conditions worldwide, and their prevalence is increasing as the World Health Organization (WHO) estimates 2.5 billion people worldwide are projected to have some degree of hearing loss by the year 2050-- with 700 million requiring hearing rehabilitation (*Deafness and hearing loss. (n.d.)*). Treating these individuals are the healthcare professionals that specialize in the assessment, diagnosis, and treatment of hearing disorders known as audiologists. According to a multi-scale spatial and political economic analysis of audiologist availability in the United States, the field of audiology faces a growing shortage as marked by a 41% attrition rate between 1985 and 2012 compounded with a 40% decrease in the number of students matriculating into clinical audiology programs (*Windmill and Freeman, 2013*). One can speculate that this decline is likely attributed to rising tuition costs as well as negative career outlooks of audiology in the long term. Increasing sales of hearing aids online as well as competition with large companies make it incredibly difficult for audiologists to establish their own practices and attract new patients.

The decreasing supply of audiologists combined with an expected increase in the number of aging individuals needing access to treatment has highlighted a need for both an advancement in hearing aid technology and a rapid change in the delivery of health services. In 2018, a Danish hearing aid manufacturer known as Widex, launched the first ever hearing aid to feature advanced machine learning technology powered by artificial intelligence. With greater control over their listening preferences in different auditory environments, patients have the potential to

become less reliant on their healthcare professionals. Benefits of this independence from audiologists include being able to create new auditory programs in different listening environments through the use of A/B testing. This eliminates the need for patients to waste time scheduling appointments and gives them direct control over acoustic settings by interacting directly with smartphone applications that connect to these hearing aids. In terms of delivering hearing care services to patients, the World Health Organization's declaration of a global pandemic surrounding COVID-19 has sparked renewed interest in teleaudiology (*Differentiate your audiology practice with patient-centered care. (2021, February 03)*).

From the beginning, audiologists have been immersed in a field that inherently intertwines technology with healthcare. However, the recent technological advancements and a major transition to teleaudiology are the first to signal a shift in power from audiologists to patients, as patients who were once uninformed now have a greater sense of empowerment. The two most disrupting factors in the audiologist landscape has been telehealth services and machine learning technology because of the improved convenience and independence they offer hearing aid patients. In order to answer how telehealth services and machine learning technology will reshape the social practice of audiology, we will explore their impact in terms of transformed relationships between audiologists and patients.

Historical Context

In order to understand the paradigm shift that the audiology landscape is evolving towards (*Kuhn, T. S. (1962*)), it is important to first consider the nature of the audiologist-patient relationship in the past and up to the status quo. First, it is worth noting that the audiologist-patient model is a variation of the physician-patient model. The physician-patient relationship is defined as a clinical encounter and its effective outcome has a direct impact on the quality of

care and the achievement of a successful treatment (*Razzaghi, M.R., & Afshar, L. (2016)*). Given that a core tenet of the physician-patient relationship involves practicing effective communication, there is an inherent challenge implementing the audiologist-patient model given that hearing loss negatively affects communication. In the past, audiologists theorized that patient-centered care where the patient is involved at each level of hearing aid fitting procedures would elevate the patient experience. This could also be identified as a case of technological momentum, where this sociotechnical system resisted modification until recently, when COVID-19 accelerated telehealth rapidly to protect the elderly, unwittingly setting off a series of relationship-changing events From a sociotechnical perspective, this was an example of stakeholders trying to enact social change without the support of technology. Additionally, technology itself finally caught up in the form of patient-empowering hearing aids.

Historically, audiologist-patient relationships have followed what is called the "Informative Model." In this model, the objective of the audiologist-patient interaction is for the audiologist to provide the patient with all relevant information, for the patient to select the medical interventions that he or she wants, and for the audiologist to execute the selected interventions (*Emanuel, E. J., & Emanuel, L. L. (1992)*). In this scenario, the patient's values are well defined and known. However, what the patient lacks is facts, so it is the audiologist's obligation to provide all the available facts and maintain expertise while the patient uses their values to exercise control over what audiology care they want to receive. This plays into the theme of hearing care patients having little control over their listening intentions given that they did not have the education nor the technology to adjust their hearing settings in different environments. Hearing care professionals, or audiologists, largely drive the hearing aid fitting prescription with little or no participation from the end user. Additionally, this fitting rationale

typically occurs in a clinic under a low-noise, low-reverberation environment that translates poorly into real-world acoustic environments. Dissatisfaction with the prescribed hearing settings would require a patient to return to the clinic for potentially multiple visits across inconvenient periods of time. In a PhD dissertation from Stanford, Aldaz writes that they "envisioned a system where users had the opportunity to participate in their own hearing by immediately self-reporting preferences, rather than waiting weeks or months for their next appointment with a professional" (*Aldaz, G., Puria, S., & Leifer, L. J. (2016)*). This idea of making sure technology development efforts are aimed at the social embedding of such technical solutions has driven the hearing aid manufacturing industry to consider user-centered design. By applying this sociotechnical principle in all stages of the technological development of AI-powered hearing aids, it is ensured that future technologies meet the needs of people with hearing impairments and are well perceived by them (*Nierling, L., & Maia, M. (2020)*).

The transformation of patients into educated and engaged health-care consumers, combined with a proliferation of digital technologies, has transitioned the audiologist-patient relationship from an informative model to an interpretive model. In Ezekiel Emanuel's "Four Models of the Physician-Patient Relationship," the "Interpretive Model" is similar to the informative model in that the audiologist still supplies relevant information and suggestions, but is required to engage the patient in a joint process of understanding, as the patient has come to know more clearly who he or she is and how the various audiology options bear on his or her identity (*Emanuel, E. J., & Emanuel, L. L. (1992)*). This is where the introduction of machine-learning and AI-enabled technologies have allowed patients to better understand their own listening intentions and thus equipping them with resources to communicate their own needs to their audiologists.

ANT applied to Connected Health/Audiology Model

In order to analyze how the social landscape of audiology is being reconfigured, it is worthwhile to apply Actor Network Theory (ANT). Actor Network Theory is a form of constructionism suggesting that scientific knowledge is an effect of established relations between objects. By focusing on the connections being made and remade between human and non-human entities that are part of the issue at stake and are commonly applied to IT and healthcare ecosystems (R. Dankert, in International Encyclopedia of Housing and Home, 2012). The components of this theory that will be focused on in this socio technical breakdown include the *actor* and the *network.* Within this theory, an actor is defined as an entity, human or non-human, that in some way influences or perturbs the activity of socio-technical systems (*Crawford, T. (2020, September 28)*). For an entity to be considered an actor, it is required to be able to perform actions as a behaviour describable under some intention (W. Detel, in International Encyclopedia of the Social & Behavioral Sciences, 2001). These actors have interests that lead to a creation of a network to produce effects that meet these interests. The second element of this theory is called a network, which is defined as a set of actors such that there are relations and translations between the actors in which one actor gives a role to others (https://www.sciencedirect.com/topics/computer-science/actor-network-theory). This framework is unique in that it recognizes both objects and technologies as network nodes equal with humans. By applying the same weight to each actor in the network and removing humanity, we are allowed an unbiased evaluation of the interactions that shape that network.

Using this STS theory as a lens to view the role of technology in shaping social processes, we can use it to examine how machine learning and telehealth technology implementations in these hearing care settings are being used more to facilitate and improve the

delivery of audiology care. Several authors have illustrated how actor network theory can be utilized as a tool for exploring changing power relationships in relation to Information Technology (IT) introductions (*Chris McLean & John Hassard, 2004*).

Extending this idea into audiology, we will apply an ANT analysis to an up-and-coming healthcare delivery framework: the *Connected Health* model. Before actor network theory can be applied, it is worth unraveling the background concepts associated with Connected Health. As a new paradigm, Connected Health manages individual and community health in a connected and holistic manner by leveraging a variety of technologies, making it a promising vehicle for the delivery of telehealth and integrated artificial intelligence opportunities in the field of audiology (*Chouvarda, I (2019)*). This reorganization of services around the person or citizen is expected to bring an important impact in the audiology domain and reflects the power shift from audiologist to patient as mentioned previously. In this model, devices, services, or interventions are designed around the patient's needs and health-related data are shared in a way that the patient can receive care in a proactive, personalized, and efficient manner. All stakeholders in this process are connected by means of data, technology, communication platforms, and people (*Ferguson, M. D. G. (2019, November 1)*).

From research, we are able to identify the primary human actors: audiologists, patients, manufacturers, healthcare IT developers, and the families of patients. These groups were chosen because these actors most directly impact the success of patients' listening intentions through technology development, service delivery, fitting procedures, and emotional support. These human actors are involved in complex relationships between themselves and the non-human actors which will be limited to: artificial intelligence and machine learning, telecommunication platforms, and smartphone applications. All of these stakeholders are interconnected in this

delivery system of Connected Health in that each play a significant role in reshaping the audiology landscape. For example, the introduction of machine learning-enabled hearing aids by manufacturers has elevated the expectations of patients and has applied pressure on audiologists in clinical practice to work at the top of their license in order to compete with new competitors in the market. In turn, this has required the software developers in the healthcare IT industry to create a patient-centered smartphone application that leverages new artificial intelligence.

A novel implementation of this includes the Widex Moment app which uses a feature called SoundSense learn that uses A/B testing to create personalized hearing programs in different noisy environments and "learns" how to fine-tune sound parameters (*Widex. (2020)*). Rather than relying entirely on an initial audiological assessment that involves choosing a fitting formula best suited for an idealized "average" person, audiologists must now adjust this fitting process by interacting with machine learning results to guide the fine-tuning of hearing aids and improve the efficiency of follow-up visits. This alters the audiologist-patient relationship by transitioning from a verbal, questionnaire-based fitting approach to discussions with their patients regarding the results of their machine learning programs and potentially incorporating their preferences into their devices(*Martin, J. (2018)*).

Continuing to analyze the social effects of this "Connected Audiology" network, it is worth noting that a majority of the power in this network is hosted among three nodes: audiologists, patients, and telecommunication. Therefore, the rest of this analysis will be primarily focused towards investigating the relationships that emerge as a result of these actors. Audiologists must now interact with telecommunication platforms in order to deliver remote-fitting procedures to their patients which will allow them to service a larger number of patients. A side effect in preparing for this change is that now clinician education and training actors are

introduced into this Connected Audiology network, which likely involves communicating with the manufacturers of machine learning-enabled hearing aids, receiving hands-on training from experts, and using their colleagues as a support system.

Given the specific guidelines required for an initial fitting of the hearing aids, it is best to consider the changes of this network in the context of follow-up appointments. In considering the role of artificial intelligence in allowing users to experiment with different customizable hearing settings, it can be illustrated the role that an artifact, such as a smartphone application, has in transforming care by influencing relationships between human and non-human actors. Armed with more informed approaches to arriving at preferred listening settings and increased accessibility to remote care, patients are influenced to schedule follow-up appointments more frequently to have their needs met. From a sociotechnical perspective, it is important to note that these social effects are not necessarily to have any specific origin but emerge from this complex network of human and non-human forces.

A shortcoming of ANT's practical applicability is that it has been criticized for being too descriptive and fails to come up with any detailed suggestions of how actors should be seen and their actions analyzed and interpreted (*Cresswell, K.M., Worth, A. & Sheikh, 2010.*). Given its broad nature and description as "too complex and brittle to be of much use for S&TS research papers", as described in "Chapter 11: Understanding STS Perspectives", it is appropriate to use actor-network theory in combination with another STS concept. In this particular case, we will be complementing actor-network theory with user studies that collect sentiments directly from the stakeholders in this network; the patients and the audiologists.

User studies

The previous sources pulled from different scholars have done a sufficient job at arguing how and why the audiology landscape has shifted. While an exploration into these traditional questions have taken us far in explaining the transformed relationships between different actors in this new "Connected Audiology" model, it is important to consider posing a new question from a practical perspective: As members of the audiology field transition to this new sociotechnical model known as Connected Audiology, how can we determine whether their needs are being met? The methodology for approaching an answer to this question will involve the use of User Experience Research Methods, which is a qualitative or quantitative method for understanding the target population's experience and to determine their needs. By tailoring studies to this current research topic, we ensure that the data presented is representative of real world context, guaranteeing that the research will be realistic. By collecting information in the form of surveys from relevant social groups, our analysis becomes stronger in that we reduce our exposure by only relying on past research.

Patient Perspective

The primary user study for assessing patient sentiment towards this paradigm shift to telehealth services will be one produced by WSAudiology, "*Help Seeking Adults Receptive To Telehealth As Complement To In-Person Care" (Remote care wsa whitepaper telehealth survey_0720. (n.d.)*). Figures in this paragraph will be pulled from this study unless stated otherwise. The study mentions how telehealth services emerged as an important component for helping fight the spread of the COVID-19 virus. This introduces an important STS concept which involves recognizing that technologies mean different things to different people-- and they act accordingly. Interpretive flexibility is the idea that people look at technologies in very different ways, and interpretation of a technology shapes the way they act toward them (*Pinch &*

W. E. Bijker, 1984a). The implementation of telehealth services by healthcare professionals was likely in order to protect the at-risk population from contracting COVID-19. However, users of this service saw it as a way to make visits more efficient as part of their daily life. A recent nationwide survey of 2,000 adults found that 82% of survey respondents who have used telehealth services indicated that they actually enjoyed using them. The top reasons for this included the improved conveniency meeting online versus in an office, the elimination of potential exposures to covid, and the streamlined nature of setting up follow-up appointments. While this is promising data, it is important to understand that these statistics may not necessarily be generalizable to the population of people with hearing loss. Adults with hearing loss will typically be older and in turn, more reluctant to use telehealth services. WSAudiology conducted a survey to account for this-- a total of 800 individuals with a median age of 73 years old completed the survey, with 80% of respondents being full time hearing aid wearers. When asked about the skills they value most from their hearing care professionals, they mentioned that the initial fitting and fine-tuning procedures were most important. Coming in second was being assured that their hearing care professional is an expert. This aligns with our previous statements regarding the significance of hearing care professionals being incredibly familiar with their products-- users who are not satisfied often leads to resentment in the audiologist-patient relationship. However, an intriguing statistic from the study is that 53% of respondents still have no experience with telehealth services, but 27% of respondents had used telehealth services for the first time within the first few months following the pandemic. From an STS perspective, this indicates that the Audiologist-Patient relationship has still not transitioned completely from an Informative Model (see above) to an Interpretative model, as many users still rely entirely on their audiologist for the optimization and fine-tuning of their hearing aids both in-person and

virtually. This is a good example of the STS concept which "warns researchers to beware of the mainstream literature"-- a vast majority of the sources surrounding this topic have been biased towards there being a clear and complete power shift from audiologists to patients. What they failed to recognize is that technology and society intertwine in different ways across different population segments. In this case, the movement towards telehealth services for the hard-of-hearing population will be a much slower transition, as this segment of people include much more elderly individuals that are less receptive to new technology introduced. Given that 68% of respondents indicated they were "very likely" to return to in-person visits, with 33% indicating they were going to continue using remote care appointments, it is fair to say that in-person appointments where the audiologist is generally more empowered will continue to reign as the incumbent power dynamic-- at least until the aging population becomes more familiar with a technology that is becoming increasingly more commonplace. This study was useful in that it allowed us to take a closer look at whether the audiology landscape has truly made the transition we thought it would make-- which early data says may not necessarily be true yet. Time and future studies will play a critical role in assessing whether the implementation of a "Connected Audiology" model will be a practical approach in ensuring the hard-of-hearing population has their needs met.

Audiologist Perspective

An additional study allows us to dissect the other side of this relationship that is also impacted by the introduction of Connected Audiology, and it is titled "*Audiology in the time of COVID-19: practices and opinions of audiologists in the UK" (Gabrielle H. Saunders & Amber Roughley (2021)*). This survey involved taking a sample of 120 audiologists in the UK to gauge their opinions regarding a move from almost exclusively providing face-to-face patient care to

providing almost all care from teleaudiology. Backing up points made in the previous study, audiologists are reluctant to use it with specific patient populations, particularly children and older adults. An interesting result of the survey was that the collective sentiment was that remote care would have positive outcomes for travel, convenience, flexibility, and scheduling for patients and audiologists alike, that it will have little or no impact on satisfaction or on the quality and confidence of care, but that it would have negative impacts on personal interactions. Specifically, 56.9% said remote care would not alter quality of service or satisfaction. Additionally, 58.8% of respondents said that it would be detrimental to the quality of interpersonal interactions. Given that the research question at hand pertains to whether the needs of the patient are met-- we heavily weigh the satisfaction and interpersonal data from audiologists over the data collected regarding convenience. It appears that the introduction of telehealth technology has added more strain on the social relationships between patients and audiologists involved in the Connected Audiology model despite easing the individual stress surrounding audiology appointments.

Conclusion

The introduction of machine learning in hearing aids and telehealth services have paved the way for an empowered listening experience for hard-of-hearing individuals. The growing number of information and communication technologies has triggered a shift in the audiologist-patient from an informative model to an interpretive model where the patient now is armed with greater resources and information about their own hearing impairments. The implementation of Connected Audiology as a service delivery model has social repercussions as audiologists are pressured to gain mastery of the latest technology in order to assist the now-empowered patients.

However, the use of user studies put the previous scholarly resources in a more realistic perspective, as surveys indicated that the hard-of-hearing population isn't necessarily ready to engage with the new social norms of telehealth services. Additionally, it was revealed that audiologists are hesitant to adopt Connected Audiology as a viable framework yet given that it may impair interactions between them and their patients. Despite these limitations, the sociotechnical indicators still signal a transition in power from audiologists to patients-- it just may take longer than expected as the hard-of-hearing population slowly learns to navigate these new technological resources at their disposal. Realistically, this area of healthcare will likely still rely heavily on audiologists in person given the time it will take for patients to master these new technological developments. However, audiologist-patient interactions will begin to change as patients more clearly communicate their needs after navigating machine-learning enabled technology to better understand their own listening intentions.

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