



How people who are deaf, Deaf, and hard of hearing use technology in creative sound activities

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ABSTRACT

Creative sound activities, such as music playing and audio engineering, are said to have been democratized with the development of technology. Yet, the use of technology in creative sound activities by people who are deaf, Deaf, and hard of hearing (DHH) has been underexplored by the research community. To address this gap, we conducted an online survey with 50 DHH participants to understand their use of technology and barriers they face in their creative sound activities. We find DHH people use four types of technology — hearing devices, sound manipulation, sound visualization, and speech-to-text — for three purposes — to improve sound perception via auditory and visual means, to avoid hearing fatigue, and to better communicate with hearing people. We also find their barriers to technology: unknown availability, limited options, and limitations that technology can solve. We discuss opportunities for more inclusive design specific to DHH people’s creative sound activities, as well as facilitating access to information about technology.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in accessibility**.

KEYWORDS

accessibility, deaf, Deaf, hard of hearing, audio engineering, music

ACM Reference Format:

Keita Ohshiro and Mark Cartwright. 2022. How people who are deaf, Deaf, and hard of hearing use technology in creative sound activities. In *The 24th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '22)*, October 23–26, 2022, Athens, Greece. ACM, New York, NY, USA, 4 pages. <https://doi.org/10.1145/3517428.3550396>

1 INTRODUCTION

It is said that creative sound activities, such as music playing and audio engineering, have been democratized with the development of technology [13, 25]. Nowadays, these activities are not only limited to professionals working with high-end studio equipment but also opened to amateurs and novices using personal computers and audio production software called Digital Audio Workstations (DAWs)

[29]. Those who engage in creative sound activities enjoy performing, producing, and distributing their works in audio-related fields including music, film, TV, radio, and podcasting [23].

However, they have not been democratized for all in the context of accessibility and disability. With a growing interest in the accessibility of audio and sound technologies [17], we have begun to see research on creative sound activities by people with disabilities, for example, by people who are blind or have low vision [42, 44]. Yet, the research community has underexplored how people who are deaf, Deaf, and hard of hearing (DHH) [8, 26] use technology in creative sound activities. In 2021, the World Health Organization reported that more than 1.5 billion people (1 in 5 people) worldwide are affected by some degree of DHH, and they estimated that this number will increase to nearly 2.5 billion people (1 in 4 people) by 2050 [40]. Given this increasing DHH population and that creative sound activities are often primarily auditory, we feel it is important to develop an understanding of the current state of accessibility by DHH people in creative sound activities.

In this paper, we aim to understand how DHH people use technology in their creative sound activities and what barriers they may face. We present our findings from an online survey with 50 responses by DHH people who engage in creative sound activities. We conclude by discussing future research directions to make technology more available and inclusive of DHH people.

2 RELATED WORK

DHH people often have difficulty perceiving sound characteristics such as pitch, loudness, timbre, and spatial information [15, 16, 48]. Some use medical hearing devices such as hearing aids (HA) or cochlear implants (CI) to improve auditory perception, yet they can cause additional challenges such as worsening pitch perception or increasing noises [9, 14, 27, 30–32, 43]. Issues such as tinnitus, hearing fatigue, and hearing fluctuation can also affect their quality of hearing [24, 47]. To overcome these limitations of their auditory system, DHH people often rely more on other senses such as vision and touch to experience sound [46].

Prior work has offered understanding of DHH people’s experiences in creative sound activities. DHH musicians utilize visual and physical cues as well as music theory to develop musical self-efficiency [18]. Social and cultural factors affect how DHH people approach their creative sound activities as being DHH [11]. Stories by DHH individuals show their unique experience in creative sound activities as being DHH [2, 10, 15, 19, 22, 48]. For example, Richard Einhorn shared how he was able to continue his professional audio engineer career after becoming deaf later in his life [15]. There also are organizations that support DHH people’s creative sound activities [1, 34–37, 39]. For example, the Frequlise Project by Music

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ASSETS '22, October 23–26, 2022, Athens, Greece

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ACM ISBN 978-1-4503-9258-7/22/10.

<https://doi.org/10.1145/3517428.3550396>

and the Deaf [34] demonstrated the effectiveness of technology to provide positive music learning experience to 63 young DHH people through 26 sessions of workshops [33]. In addition, research on Accessible Digital Music Instruments (ADMI) has been exploring the design and evaluation of how technology can be used for DHH people to play music and collaborate with other DHH and hearing people [6, 17], such as Music Aid [45] and Felt Sound [7].

While this related work gives an idea of how DHH people are using technology in creative sound activities, it remains partial and sparse because it consists mainly of individual stories, the use of technology is not the primary focus, and its scope is limited to music-specific activities. Focusing on technology with a broader scope, our work extends past work to understand the current state of accessibility in creative sound activities by DHH people.

3 METHODS

We conducted an online survey targeting DHH people who engage in creative sound activities. To understand their experience with technology, we asked about their use of technology to make their activities accessible and the challenges they face in using and choosing the technology. Using snowball sampling, we recruited survey participants via individuals and online communities related to DHH, accessibility, music, and audio engineering. All participants were fluent in English and over 18 years old. The survey took approximately 20 minutes. Participation was voluntary and not compensated. The study received the New Jersey Institute of Technology IRB approval.

50 participants completed the survey (Table 1). The degree of hearing loss [12] of the participants varies from mild to profound, and the time of becoming DHH varies from birth to adulthood. Their creative sound activities largely consist of music playing and audio engineering (Table 2). Music playing includes singing and playing musical instruments. Audio engineering includes recording, editing, mixing, mastering for music, radio, film, podcast, as well as transcribing and captioning. We analyzed the survey data using a thematic analysis approach [4, 5, 28, 38].

4 FINDINGS

4.1 Use of Technology

We found participants use four types of technology — hearing devices, sound manipulation, sound visualization, and speech-to-text — and for three purposes — to better perceive sound through auditory and visual means, to avoid hearing fatigue, and to communicate with others and understand speech.

The most commonly reported technologies are hearing devices. Many use one or a combination of medical and non-medical hearing devices such as HA, Bone-Anchored HA [3], CI, headphones, earbuds, and speakers. They use hearing devices primarily to improve auditory perception. To hear more clearly, some use them together with Bluetooth, noise cancelling features, and neck loops (a loop of wire worn around the neck that transmits audio signals to hearing devices). However, the use of hearing devices can also induce hearing fatigue and physical and mental overload. Thus, some people choose not to wear HA and CI all the time because they become overwhelmed by the unwanted effects such as distortion and muffling, especially when listening to music rather than speech.

For example, P12 sometimes switches from HA to bone conduction headphones to rest his ear.

Participants also commonly use sound manipulation technology to improve auditory perception. Some use equalization to boost or cut certain frequencies. P27, an advanced amateur musician, octave-shifts the pitch with an octave pedal when writing songs with his electric guitar and bass. To hear sound from their non-DHH side ear, many of the single-sided DHH participants use technology such as signal routing and mono-to-stereo conversion. Single-sided DHH audio engineers also use stereo flipping (swapping the left and right channels) to check stereo-field panning and phase cancellation.

Participants use visualizations both to better perceive sound and to avoid hearing fatigue. For example, participants who engage in audio engineering commonly reported using waveform (i.e., time-amplitude) and a few also use spectrum (i.e., frequency-amplitude) and spectrogram (i.e., time-frequency) displays. Such visualizations allow them not only to supplement their auditory perception, but also to edit sound with their eyes so that they can rest their ears. P29, a professional audio engineer for podcasts, said *“I can sometimes do edits with no headphones and a script, because I can edit sound by sight.”* For music playing, some use a tuner and metronome to visually ensure that pitch and tempo were correct. Also, P34 uses a piano roll to visually see the notes and P12 uses sound waves as a metronome to see the click sound when it was difficult to hear.

With one exception, all participants who practice audio engineering reported the use of DAWs. We assume participants who reported the use of DAWs are also familiar with some use of the technology mentioned above such as equalization and waveform / spectrum / spectrogram displays, as they are basic features in DAWs. In contrast, the use of DAWs was typically not reported by participants who only play musical instruments or sing but do not practice audio engineering.

Some participants use speech-to-text technology for communication with hearing people during their activities, such as Google’s Live Transcribe [21] and Otter.ai [41]. At online meetings, they also use an auto caption feature in video conference software such as Zoom [49] and Google Hangouts [20].

No participants use the technology specialized for tactile feedback. However, P42, an electric bass player who is Deaf, reported the usefulness of tactile feedback with his instrument and amplifier. He said *“a five strings bass helps me feel the pulsating bass line to the backbeat... Musical amplifiers are the best instrument to feel the beat for me.”*

4.2 Barriers

While some participants reported their use of technology, others described barriers to technology such as unknown availability, limited options, and limited solutions that it can provide. In fact, when we asked about the technologies that make their activities more accessible, more than one-third of participants (n=19) did not specify any technologies.

Some participants reported not knowing if technology that would make their activity accessible is available in the first place. P8, an intermediate amateur musician, expressed his frustration saying *“Don’t even know what’s available. Ignorance.”* They feel difficulty in finding the right technology for their hearing and activities. P4,

Table 1: Participant Demographics. (Numbers in parentheses are the number of participants)

Gender	Male (26), female (19), non-binary/non-conforming (3), transgender male (2)
Age	18-24 years old (6), 25-34 (18), 35-44 (8), 45-54 (6), 55-64 (6), 65-74 (4), 75-84 (1), 85+ (1)
DHH identity	Hard of hearing (25 including three single-sided), deaf (18 including six single-sided), Deaf (4), others (3)

Table 2: Participants' Activity and Level of Experience. (beg = beginner; int = intermediate; adv = advanced)

Activity	Amateur beg	Amateur int	Amateur adv	Professional	N/A	Total
Music playing	4	12	8	14	2	40
Audio engineering	1	4	7	12	1	25

a professional musician and audio engineer, said *"I am not aware of any technology/tools developed specifically for my problem."* Whereas, P16 expressed reluctance to try using technology: *"Since I can't hear well, I haven't even tried using most technology from a musical perspective."*

Even when the challenge seems solvable or improvable with technology, the limited variety of products do not solve the challenges unique to each individual. P22, an advanced amateur musician and audio engineer, expressed a sense of resignation by saying *"the idea... is so niche that it's not something product designers tend to think about or cater for."* Some wish to have more inclusive products. A few use DIY solutions specific to their hearing and activity. However, that is not a feasible solution for others who are unfamiliar with technology: *"Software is still a mystery to me."* (P6).

Participants reported limited solutions that current technology may provide for certain tasks. P9, who became deaf after establishing his career as a professional audio engineer, said *"I can't master as well as I used to and no tool will fix that."* P30, who started audio engineering for podcasts after becoming deaf, said *"There are definitely times when I just cannot do a specific task — creating certain kinds of sound effects or soundscapes, or I don't always catch if speech isn't as clear as it should be or if it fully 'matches' the audio from other actors, etc. It's simply not a thing I can always do."*

With these barriers, technology still cannot ease participants' lack of confidence. P2 said *"Most of my challenges come from lack of confidence that what I am hearing is accurate."* It also created a concern for their professional career. P48, who works as a Digital Signal Processing (DSP) engineer, said *"I feel I am held back when learning advanced DSP and filter design since I can't properly hear... (I) don't feel like I can advance super far in that field."* To deal with the lack of confidence, many mentioned seeking hearing people's feedback as a workaround. P27 said *"I must get a second opinion. Must."* However, the availability of hearing people is a challenge. They need to be familiar with creative sound activities to provide valid feedback. Scheduling them is also not easy. Otherwise, participants had to rely on guessing. P48 said *"I'm always second guessing my ears"*. P16 said *"(I'm) trusting it sounds ok... I have no idea how I actually sound."*

5 DISCUSSION

Our study found participants' current use of technology and the barriers they face in creative sound activities. Aside from HA/CI, most of the technology was not specifically designed for their specific

DHH situations and activities. For future research, we recommend researchers to work closely with DHH users to identify specific challenges in their activity and design inclusive technologies. We also see an opportunity for research that facilitates community where both hearing and DHH people who engage in creative sound activities can exchange knowledge and information about technology. That would help raise awareness of available technologies and how to use them effectively.

6 CONCLUSION

In this work, we provide early insight into DHH people's use of technology and its barriers in creative sound activities. To support these activities, we found DHH people use four types of technology — hearing devices, sound manipulation, sound visualization, and speech-to-text — and for three purposes — to better perceive sound through auditory and visual means, to avoid hearing fatigue, and to communicate with others and understand speech. We found DHH people also have barriers to technology in terms of its availability, limited options, and limitations that technology can solve. In future work, we plan on conducting interviews that focus on more specific tasks of creative sound activities that DHH people find challenging.

ACKNOWLEDGMENTS

We thank all participants, organizations, and communities that contributed to this study.

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