Field Study of a Tactile Sound Awareness Device for Deaf Users

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ABSTRACT

Sound can provide important information about the environment, human activity, and situational cues but can be inaccessible to deaf or hard of hearing (DHH) people. In this paper, we explore a wearable tactile technology to provide sound feedback to DHH people. After implementing a wrist-worn tactile prototype, we performed a four-week field study with 12 DHH people. Participants reported that our device increased awareness of sounds by conveying actionable cues (*e.g.,* appliance alerts) and 'experiential' sound information (*e.g.,* bird chirp patterns).

CONCEPTS

• Human-centered computing ~ Accessibility technologies

KEYWORDS

Haptics, tactile, vibration, accessibility, deaf and hard of hearing.

1 Introduction

Sound provides rich information about the world, including actionable cues (*e.g.,* microwave beep), safety cues (*e.g.,* a fire alarm), or cues that make one feel present (*e.g.,* a bird chirp). In many situations, however, sound is inaccessible to people who are deaf or hard of hearing (DHH) [2,5]. While hearing aids and cochlear implants can improve sound awareness, they are not suitable for all hearing ranges and are not always effective due to issues with comfort, noise, and training [10,13]. In this paper, we explore a complementary approach: wrist-worn wearable vibrotactile feedback to convey ambient sound levels.

Prior work in sound awareness for DHH people has largely focused on visual displays [2,7,8,12]. For tactile, researchers have investigated supporting speech therapy by conveying voice tone or frequency—for example, using electro-tactile stimulators worn on the forearm [17] or abdomen [15]. A few field studies in the 1980s and 90s also examined the utility of these early devices for environmental sounds; however, the focus was primarily quantitative (*e.g.,* percentage of sounds the user identified) [1,4,16] rather than on the holistic user experience. One exception is from Phillips *et al.* [14], who asked participants to rate several usability aspects (*e.g.,* ease of wear) of clinically fitted wrist-worn tactile devices. However, that work was conducted more than 20 years ago; tactile technology, perceptions of wearable devices [9], and cultural norms of DHH people [11] have changed much since then.

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To investigate how ambient haptic sound feedback on modern wearable technology might integrate into the lives of DHH people, we performed a four-week exploratory field study of a custom wrist-worn vibrotactile device, called *Vibes*, with 12 DHH people. Vibes senses the loudness of sounds around the wearer and vibrates with proportional intensity (Figure 1). Through an initial semi-structured interview, a field deployment, and a post-study interview, our study examines how a custom wrist-worn device is used and perceived over four weeks.

Our findings suggest that Vibes increased sound awareness for all participants, helped them take any required actions (*e.g.,* turn off an appliance) or feel more present (*e.g.,* notice bird chirps during nature walks). At least half of the participants also became more conscious of how some of their own activities produce sound, such as speaking or putting down a cup. However, four participants did not use Vibes in their homes, and three took it off in noisy environments. In summary, our work contributes insights from a field study of a tactile sound feedback device with 12 DHH people.

2 Vibes Design

Figure 1: Vibes prototype

Vibes is a wrist-worn device that senses ambient sound and emits a vibration proportional to the sound level (*i.e.,* loudness). We built our own custom device because, when our research began, most commercial devices (*e.g.,* a smartwatch) only offered a single vibration intensity level (some had two), and to convey loudness, we needed to provide varying intensity in a continuous spectrum. Compared to other sound properties that are potentially of interest (*e.g.,* direction, pitch) [2,5], we chose loudness because it can be reliably sensed with current technology and is relatively easy to comprehend—particularly for those who are born fully deaf and may not have a perceptual basis for sound. Vibes takes four hours to charge, and lasts for about 24 hours of continuous use. For more details, see our open source repository: https://git.io/JJabu.

3 Field Study with 12 DHH people

To investigate how Vibes integrates into the lives of DHH people, we performed a field study with 12 DHH participants. The study procedure included a 30-min initial semi-structured interview on general experiences related to the sounds and a device tutorial, a four week in-situ device use, and a 45-min post-study interview on experience with the device. After the study, two coders performed a thematic analysis on the interview transcripts. The final codebook contained 10 codes; Krippendorff's alpha between the two coders was on average 0.69 (*SD*=0.25), and the raw agreement was 87.4%. We detail our findings below.

Overall usage. When asked about usage, participants reported using Vibes in various contexts (*e.g.,* home, work, outdoors, restaurants). Six participants reported wearing the device every day throughout the study period, except during sleep and bath; another two reported wearing it at all times unless they occasionally forgot. The remaining four participants continued to wear Vibes outside their homes (*e.g.,* at work, during commute) but eventually stopped using it at home, because, as explained by P12: *"it provides very little information, and I know what is going on around my home.*

Environmental awareness. Vibes increased sound awareness in several instances, but also presented challenges, particularly in noisy environments. On a positive side, all participants were able to use contextual and visual cues with Vibes feedback to learn about sounds in some cases. For example,

[at office] "It alerted me to loud sound, and I saw a siren outside…" (P3)

[At home] "I am fully deaf [...]. When I was doing laundry, I realized that my dryer is very noisy. My dog also barks very often […] We seem to have a noisy home. I wonder if we make more noise than hearing people..." (P9)

In some cases, Vibes also helped participants take required actions—for example, when cooking (*e.g., "to check when my microwave beeps and get my food"*, P11), to clear the path for a vehicle coming from behind, or to attend to someone calling out.

Unlike past work [14] which used a single constant vibration for sound feedback, participants appreciated that Vibes' vibration intensity varied with loudness, which helped them locate sounds or identify patterns of some sounds. In quiet environments, such as at home, eight participants reported being able to identify some sounds based on a repeating vibration pattern, such as a microwave beep or dryer ending a cycle. Four participants could also locate the sound in some cases by gradually moving closer to the source:

"When this vibrates, I get up and move in the direction in which the vibration gets louder and louder. This helps locate the sound source.." (P5)

However, seven participants mentioned that Vibes was initially troublesome in noisy environments because it vibrated constantly. However, through the course of four-weeks, four of the seven participants adapted to the constant feedback and were able to selectively pay attention to the device based on the situation. *E.g.,*

"I was in my office working on my computer and the device vibrated. As I was focused on my task, I chose to ignore the beep. But, if I was expecting someone, say my boss, then I would react to [the device]…" (P1)

The remaining five participants switched off Vibes in noisy environments.

Self-awareness. Besides environmental awareness, Vibes was also used for knowing about the sounds produced from the wearer's actions. For example,

"[When riding a bike] what frequently happens is that my hand accidently touches the bike bell. And it rings. I didn't know about that. When I recently rode the bike, the device vibrated frequently. I moved my head here and there [to see what was causing the vibration] and I found out [the bell] has been ringing. That must have been annoying for other riders..." (P11)

"[while driving] I sometimes leave my car indicator light on as I can't hear. This usually happens after I take a very short turn and the light doesn't go off. Now with the device, I know when to turn it off." (P6).

Because Vibes informs the wearer of the sounds they produce, six participants became more careful about their own actions:

"I was told by my hearing friends that I put down my cup too hard on the table sometimes… I think with this [the device] I have learned to put down my cup down [slowly and softly]." (P3)

"I used to slam my [apartment] door too hard. Now, the device vibrates hard [every time] I bang the door, so I learned…" (P6)

One participant who wanted her son to use the device said:

"I would like my son to learn about how much sound he makes when he [is] play[ing] This device gives a subtle indication of [the sound] […] While he is in his earlier years, this is the time to change his habits." (P8)

However, two Deaf participants reacted apprehensively to the idea of the behavior change caused by the device: *"I do not need a technology to tell me to behave in a certain way. If I make a lot of noise, that's hearing peoples' problem..."* (P2)

Feeling present. Vibes also allowed users to perceive sounds for experiential purposes, thus making them feel more present. For example, P3 describes her experience during nature walks:

"I do bird photography. So, when I was walking in the woods, the device started vibrating [in patterns] similar to the bird calls. That gives me some indication of how a bird call might sound. Makes me closer to nature…"

And P11 said: *"I realized that wind also makes sound. Maybe when it rustles the leaves? That was good to know".* These observations around using sound feedback for 'experiential purposes' did not come up in past research.

Physical design. Participants had varied reactions to the physical design of the device, suggesting the need for end-user customization. Three participants found the device obtrusive:

"[When] I am in a party with this [device] on my wrist, I worry what others might think: Does it look ok? Do people stare at me?" (P1)

At the same time, others (*N*=3) found the device fashionable:

"People asked me: 'Wow! What are you wearing? This looks cool.' And I explained to them what this is and felt proud." (P3)

4 Discussion and Conclusion

This study showed that DHH participants used the wrist-worn tactile device for performing critical actions (*e.g.,* to turn off the microwave), for 'experiencing' their environment (*e.g.,* to understand bird chirp patterns), and to learn to be conscious about their own activities that produce sound (*e.g.,* putting down objects on a table). Some of our findings (*i.e.,* need for customization, some findings of 'environmental awareness') extend prior findings from surveys and lab studies [2,5,6]. Yet, other findings are only possible via a real-world longitudinal use—*i.e.,* long-term effect on environmental awareness, use of the device for self-awareness and 'experiencing' sounds, and varying perspectives of DHH people on behavior change. Even for the findings that are not new, our work provides a higher ecological validity from real-life field use.

Incorporating the device's functionality into a commercial smartwatch may address some of the physical design issues that arose. In retrospect, we should also have done experience sampling during the four-week deployment to gather more in-depth day-to-day experiences—a limitation to be addressed in future work. Finally, though we linearly mapped the ambient loudness to a vibration motor's intensity, future work should investigate other designs, such as using temporal vibration patterns (*e.g.,* tactons [3]).

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