Sound & Speech Sensing and Feedback for Deaf and Hard of Hearing (DHH) Users
Our world is filled with a rich diversity of **sounds**.
A microwave beep...
A waterfall...
15% of US adults “some trouble hearing”

“disabling hearing loss”

2% of adults aged 45 to 54

50% of those 75 and older

[National Institute on Deafness and Other Communication Disorders, 2016]
Many DHH people use alternative ways to deal with sound information.

- Sign Language
- Flashing Doorbell
- Vibratory Alarm Clock
Deaf and Hard-of-hearing Individuals' Preferences for Wearable and Mobile Sound Awareness Technologies

Very interested
Extremely interested
25%
50%
75%
100%
Interest in sound awareness by percentage of 201 participants

73.1% were “extremely” or “very” interested in sound awareness
HEARING AID

COCHLEAR IMPLANT

LIVE TRANSCRIBE

Good morning. This is a demonstration of Google Live Transcribe. This is a really cool technology. It allows you to transcribe conversations that you are hearing in real time.
[Restaurants] “My hearing aids fail miserably in areas with background noise. I can’t understand anything in a restaurant. So, I just sit and do my own thing. I feel left out all the time…”

[Home] “I have [a] flashing doorbell. [...] But, one day I was sleeping, and somebody came at night [and] rang the doorbell, and I couldn’t see the light. So, I had to get a vibratory bed shaker [for the doorbell]. How many devices [...] should [I] keep?”
[Outdoors] “I always have cars trailing behind me in the [mall] parking lot, and I can’t get away in time because I can’t hear the faint sound. I feel embarrassed.”

[Home] “I left my vacuum cleaner running for such a long, long time. The person next door got annoyed and came and told me that there is a terribly loud sound in my home. Gosh, it was running for three days!”
Outdoors: “I always have cars trailing behind me in the [mall] parking lot, and I can’t get away in time because I can’t hear the faint sound. I feel embarrassed.”

Restaurants: “My hearing aids fail miserably in areas with background noise. I can’t understand anything in a restaurant. So, I just sit and do my own thing, and just nod away…”

Home: “I left my vacuum cleaner running for such a long, long time. The person next door got annoyed and came and told me that there is a terribly loud sound in my home. Gosh, it was running for three days!”

When walking: “It’s really hard to walk and talk and lip read and process all of that information on the go. 90% of the time you’re unsure if you have understood the conversation well.”

Recreational activities: “In martial arts: you have an instructor showing you how to move the arms, hands, body, etc. while talking. They have to hold the phone. It’s hard to make the conversation smooth enough to go deep…”

When cooking: “I always leave my kitchen fan open.”

In a group conversation: “Live Transcribe isn’t perfect because it demands that I look at the phone instead of the person in front of me and [also] have one hand holding the phone. It’s hard to make the conversation smooth enough to go deep…”

Participant Responses from Our Studies:

[Restaurants] “My hearing aids fail miserably in areas with background noise. I can’t understand anything in a restaurant. So, I just sit and do my own thing, and just nod away…”

[When walking] “It’s really hard to walk and talk and lip read and process all of that information on the go. 90% of the time you’re unsure if you have understood the conversation well.”

[Outdoors] “I always have cars trailing behind me in the [mall] parking lot, and I can’t get away in time because I can’t hear the faint sound. I feel embarrassed.”

[When cooking] “I always leave my kitchen fan open.”

[Home] “I miss my kid crying upstairs.”

[Recreational activities] “In martial arts: you have an instructor showing you how to move the arms, hands, body, etc. while talking. They have to hold the phone. It’s hard to make the conversation smooth enough to go deep…”

[When walking] “It’s really hard to walk and talk and lip read and process all of that information on the go. 90% of the time you’re unsure if you have understood the conversation well.”

[Outdoors] “I always have cars trailing behind me in the [mall] parking lot, and I can’t get away in time because I can’t hear the faint sound. I feel embarrassed.”

[Recreational activities] “In martial arts: you have an instructor showing you how to move the arms, hands, body, etc. while talking. They have to hold the phone. It’s hard to make the conversation smooth enough to go deep…”

[When walking] “It’s really hard to walk and talk and lip read and process all of that information on the go. 90% of the time you’re unsure if you have understood the conversation well.”
“My hearing aids fail miserably in areas with background noise. I can’t understand anything in a restaurant. So, I just sit and do my own thing, and just nod away…”

“I left my vacuum cleaner running for such a long, long time. The person next door got annoyed and came and told me that there is a terribly loud sound in my home. Gosh, it was running for three days!”

“I always have cars trailing behind me in the [mall] parking lot, and I can’t get away in time because I can’t hear the faint sound.”

“It’s really hard to walk and talk and lip read and process all of that information on the go. 90% of the time you’re unsure if you have understood the conversation well.”

“Live Transcribe isn’t perfect because it demands that I look at the phone instead of the person in front of me and have one hand holding the phone. It’s hard to make the conversation smooth enough to go deep…”

“New approaches to enhance sound awareness for DHH people…"
transform how DHH think about, experience, and engage with the sound.
Two studies (ASSETS’20)

Field studies (CHI’20)

Three initial explorations (DIS’18, ASSETS’18, ASSETS’20)
Two formative studies

Field studies
HomeSound

- Two formative studies
- Field studies

SoundWatch

- Two studies
- End-user customization
- Field study

HoloSound

- Three initial explorations
- Field study

Yellow: proposed work
HomeSound: Smarthome Sound Awareness
THE HOME Sound TEAM

Dhruv Jain
djain@uw.edu

Kelly Mack
kmack3@uw.edu

Steven Goodman
smgoodmn@uw.edu

Rose Guttman
rguttman@uw.edu

Angela Lin
angelacareylin@gmail.com

Aileen Zeng
aileenz@uw.edu

Marcus A.
markamal@uw.edu

Matt Wright
matth3w@uw.edu

Akli Amrous
akliamrous2001@gmail.com

Jon Froehlich
jonf@uw.edu

Leah Findlater
leahkf@uw.edu

SPONSORS

Dhruv Jain: Sound Sensing & Feedback | Project 1/3: HomeSound
THE HOME SOUND TEAM

Dhruv Jain
djain@uw.edu
Kelly Mack
kmack3@uw.edu
Steven Goodman
smgoodmn@uw.edu
Rose Guttman
rguttman@uw.edu
Angela Lin
angelacareylin@gmail.com
Aileen Zeng
aileenz@uw.edu

Marcus A.
markamal@uw.edu
Matt Wright
matth3w@uw.edu
Akli Amrous
akliamrous2001@gmail.com
Jon Froehlich
jonf@uw.edu
Leah Findlater
leahkf@uw.edu

SPONSORS

Dhruv Jain: Sound Sensing & Feedback | Project 1/3: HomeSound
THE HOMESOUND TEAM

Dhruv Jain
djain@uw.edu

Kelly Mack
kmack3@uw.edu

Steven Goodman
smgoodmn@uw.edu

Rose Guttman
rguttman@uw.edu

Angela Lin
angelacareylin@gm

Aileen Zeng
aileenz@uw.edu

Marcus A.
markamal@uw.edu

Matt Wright
matth3w@uw.edu

Akli Amrous
akliamrous2001@g

Jon Froehlich
jonf@uw.edu

Leah Findlater
leahkf@uw.edu

SPONSORS

DHRUV JAIN: SOUND SENSING & FEEDBACK | PROJECT 1/3: HOMESOUND
THE Homesound Team

Dhruv Jain
djain@uw.edu

Kelly Mack
kmac3@uw.edu

Steven Goodman
smgoodmn@uw.edu

Rose Guttman
rguttman@uw.edu

Angela Lin
angelacareylin@gmail.com

Aileen Zeng
aileenz@uw.edu

Marcus A.
markamal@uw.edu

Matt Wright
matth3w@uw.edu

Akli Amrous
akliamrous2001@gmail.com

Jon Froehlich
jonf@uw.edu

Leah Findlater
leahkf@uw.edu

Sponsors

[NSF and Google Faculty logos]
Smarthome technology has been a longstanding topic of interest in HCI research. However, examination of its potential to support accessibility is only recent...
Two formative studies

Field studies
Two formative studies

Field studies
Two formative studies

Field studies
While prior work has examined sound awareness needs of DHH users, only a few studies that explored needs in multiple contexts have included questions about the home.
TWO FORMATIVE STUDIES

Study 1
A **semi-structured interview** on sound awareness needs in the home with 12 DHH participants

Study 2
A **scenario-based evaluation** of three initial sound awareness prototypes with 10 DHH participants
TWO FORMATIVE STUDIES

Study 1: A semi-structured interview on sound awareness needs in the home with 12 DHH participants.

Study 2: A scenario-based evaluation of three initial sound awareness prototypes with 10 DHH participants.
“I don’t want to know if someone is using toilet or whatever they are doing in the bathroom... It's their privacy, you know?"
“Don’t show every sound when there’s a large guest party, [because] I don’t want to be distracted at that time”

- P4
Two formative studies

Field studies

Prototype 1: Simple but accurate sound feedback (e.g., loudness, pitch)

Prototype 2: More complex sound features (e.g., sound identity)
A Microsoft Surface Pro Tablet is placed in a laser cut wooden frame on a kitchen counter.
Each home contained 3-5 displays.
“Every time I walked around the house, I saw disks [pulses] on displays [emanating from] multiple rooms. I realized that my whole wooden home makes a lot of noise when I walking”

- P1
"I was [...] working on my laptop, the system showed my dog was barking [in another room]. I went and corrected my dog right away. This system helps me train my dog over time [...]."

- P2
Two formative studies

Field studies
Two formative studies

Field studies

HomeSound

SoundWatch

HoloSound

Two studies

Three initial explorations

DHRUV JAIN: SOUND SENSING & FEEDBACK | PROJECT 2/3: SoundWatch
SoundWatch: Sound Awareness on a Smartwatch
SoundWatch: Sound Awareness on a Smartwatch

SoundWatch is informed by **lived experiences** of many DHH people.
P4 in the **HomeSound** study:

“I want to be able to use this system when I am commuting to work, taking my kids to school, when I am hiking, going on a beach, in a movie theater, etc.”
Our survey with 201 DHH participants showed that smartwatch was the most preferred device for non-speech sound feedback.
Using both visual and vibration modalities, smartwatch can provide always-available and discreet sound feedback in multiple contexts.
Prior evaluations of smartwatch-based sound awareness have been in a **Wizard-of-Oz format**.
TWO STUDIES

Study 1
A *quantitative* comparison of small deep-learning models to classify sounds on portable devices.

Study 2
A *qualitative* evaluation of a smartwatch-based sound classification app in which 8DHH participants used the app in different locations on the campus.
**FINDINGS**

*Study 1*  
Our best classification model had *similar accuracy* as the state-of-the-art for non-portable devices (81.2%) but required *much less memory* (~1/3rd).

*Study 2*  
All participants generally liked SoundWatch but were concerned with *errors in noisy environments.*
“The app is perfect for quiet settings such as home or outdoor activities like hiking. In noisy situations, some sounds were misinterpreted, such as cars were recognized as water running...”

- P4
“Sure there were some errors outdoors, but it tells me that a sound is happening. [...] So, I can look around for the source...”

- P7
SoundWatch
Always-available sound feedback

Released on Google store!
THE SOUNDWATCH TEAM

Dhruv Jain
djain@uw.edu

Khoa Nguyen
akhoa99@uw.edu

Hung Ngo
hvn297@uw.edu

Rachel Grossman-Kahn
rachelgk@uw.edu

Steven Goodman
smgoodmn@uw.edu

Pratyush Patel
patelp1@uw.edu

Jon Froehlich
jfroehli@uw.edu

Leah Findlater
leahkf@uw.edu

SPONSORS

Dhruv Jain: Sound Sensing & Feedback | Project 2/3: SoundWatch
Non-speech sound feedback

- **HomeSound**
  - Two formative studies
  - Field studies

- **SoundWatch**
  - Two studies

- **HoloSound**
  - Three initial explorations
Non-speech sound feedback

HomeSound

Two formative studies

Field studies

SoundWatch

Two studies

Speech feedback

HoloSound

Three initial explorations
HoloSound: Head-Mounted Displays for Speech Feedback
THE HOLOSOUND TEAM

Dhruv Jain
PhD Student, CSE, UW
djain@uw.edu

Rachel Franz
PhD Student, HCDE, UW
franzrac@uw.edu

Leah Findlater
Assist. Prof., HCDE, UW
leahkf@uw.edu

Jackson Cannon
UG Student, CSE, UW
jackscan@uw.edu

Raja Kushalnagar
Prof., Gallaudet University
raja.kushalnagar@gallaudet.edu

Jon Froehlich
Assoc. Prof., CSE, UW
jonf@uw.edu

SPONSORS

NSF
UW Reality Lab
Google Faculty Research Awards
Microsoft
Many DHH people use **real-time captioning** to access speech.
Typically, these captions are shown on a laptop or a large screen...
or on a smartphone...

Good morning. This is a demonstration of Google Live transcribe. This is a really cool technology. It allows you to transcribe conversations that you are hearing in real time.
This forces the user to **shift attention to the captioning screen**, drawing their gaze away from the conversational partners or the environment.
Display captions directly in the **user's field of view** using a head-mounted display.
While past work has suggested showing captions on an HMD, prior to the beginning of my dissertation research, no work has evaluated a working prototype.
Three initial explorations

Two formative studies

Field studies
Three Initial Explorations of HMD-captioning

A 45-day autoethnographic evaluation

A semi-controlled evaluation with 10 DHH participants

A preliminary prototype that displays captioning with speaker location and non-speech sounds
Three Initial Explorations of HMD-captioning

Current HoloSound prototype
A preliminary prototype that displays captioning with speaker location and non-speech sounds
HoloSound
Combining Speech and Sound Identification for Deaf or Hard of Hearing Users on a Head-Mounted Display

ASSETS 2020 supplementary video
Three Initial Explorations of HMD-captioning

A 45-day autoethnographic evaluation

While past studies inform the design of future HMD conversation support, **longer-term, more ecologically-valid field studies** are necessary.

A semi-controlled evaluation with 10 DHH participants

A preliminary prototype that displays captioning with speaker location and non-speech sounds
Too Bulky!
Ongoing Work: **Field study** of HMD-captioning with DHH users.
Summary

- **HomeSound**: Two formative studies
- **SoundWatch**: Two studies
- **HoloSound**: Three initial explorations
I largely explore providing sound information to take an action. How can we design for “experiential” sound awareness?

I largely explore visual feedback. How best to provide haptic feedback?

I provide transcription verbatim. How to summarize topics of a conversation?
Broader Impacts
SoundWatch is released. Used by more than 400 people daily.

For HoloSound, we’re collaborating with Google.

My work can benefit a large DHH population.

Can also benefit hearing people, e.g., when wearing headphones, or for home surveillance.

Wide applications for other domains as well such as wildlife survey, ocean surface mapping, game audio debugging, mechanical appliance repairs, and military.

Broader Impacts
Any Questions?

Email: djain@uw.edu  
Twitter: dj_hci