Evaluating Smartwatch-based Sound Feedback for Deaf and Hard-of-Hearing Users Across Contexts

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Introduction

Sound Awareness

(e.g., Matthews et al., BIT 2006)

Hearing people use sound to maintain situational awareness and respond to their surroundings.

For people who are Deaf and Hard of Hearing, however, sound awareness can be limited. Developing new tools that can communicate sound information in a non-auditory manner would be beneficial to many in this community.

Sound Awareness Needs

(e.g., Matthews et al., ASSETS 2005; Bragg et al, ASSETS 2016; Findlater et al., CHI 2019)

Understanding the wide-ranging preferences of the Deaf and Hard of Hearing community is necessary to design effective sound awareness technology.

Surveys of this population have highlighted:

- Desire for output through both visual and haptic modalities
- Devices that filter some sounds out rather than informing of all
- Cultural and contextual factors influencing sound awareness preferences

Introduction

Sound Awareness

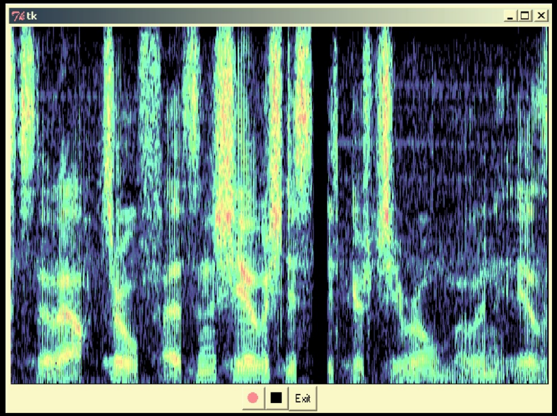
Hearing people use **sound to maintain situational awareness and respond to their surroundings**; from microwave beeps alerting that food is ready, to horns that warn of vehicles passing by.

For people who are Deaf and Hard of Hearing, however, sound awareness can be limited. Developing **new tools that can communicate these sounds in a non-auditory manner** would be beneficial to many in this community.

A note before continuing...

Introduction

Sound Awareness Tools

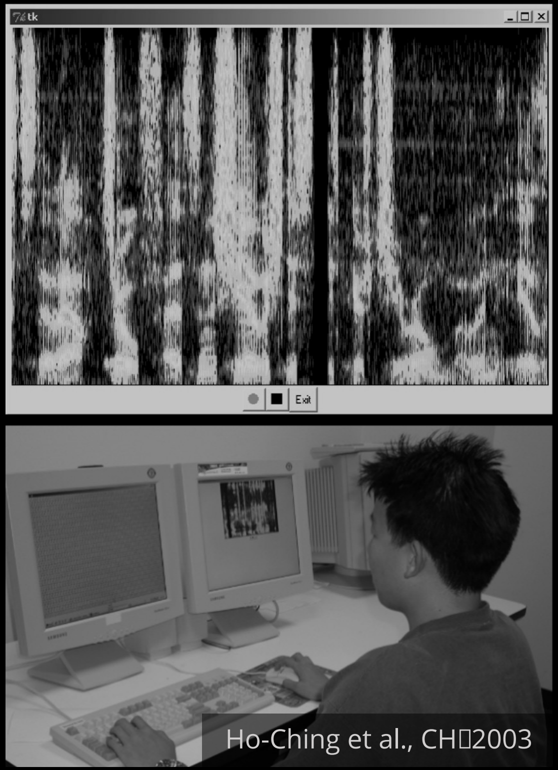


Ho-Ching et al., CHI 2003

Stationary

Introduction

Sound Awareness Tools



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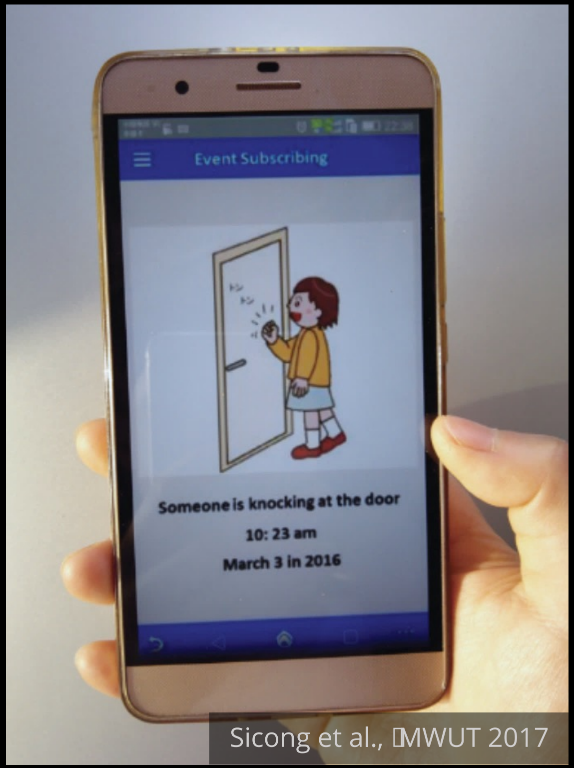
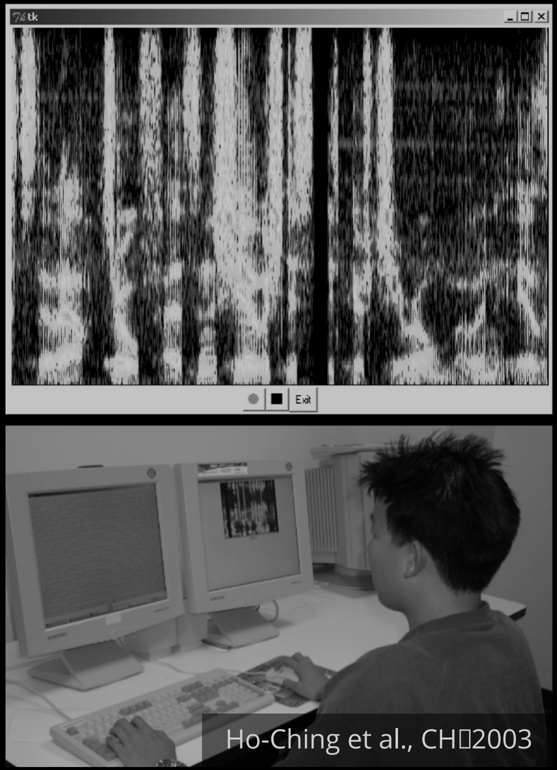


Sicong et al., IMWUT 2017

Smartphone/ handheld

Introduction

Sound Awareness Tools



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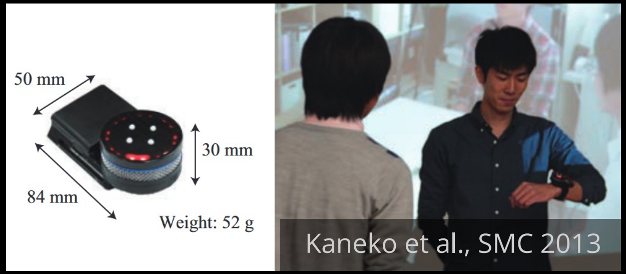
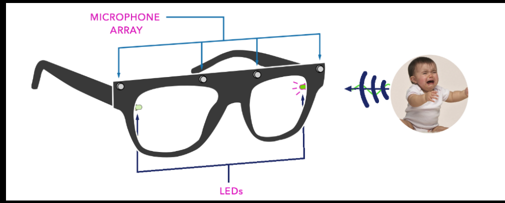


Kaneko et al., SMC 2013



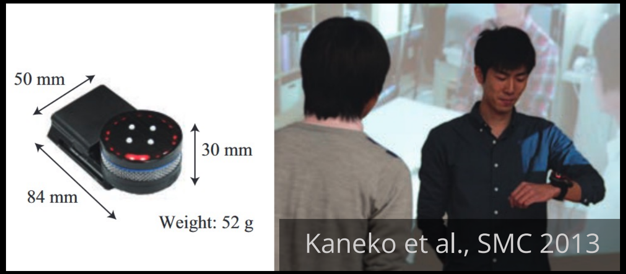

Gorman, ASSETS 2014

Wearable

Sound Awareness Tools

Most wearable devices have only displayed sound information through a single visual or vibrational modality.

In user evaluations of prototypes that have combined both, vibration has been limited to notifications that draw attention to the visual information.



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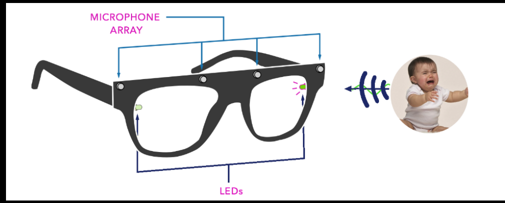



Gorman, ASSETS 2014

Wearable

Introduction

Findlater et al. (CHI 2019)

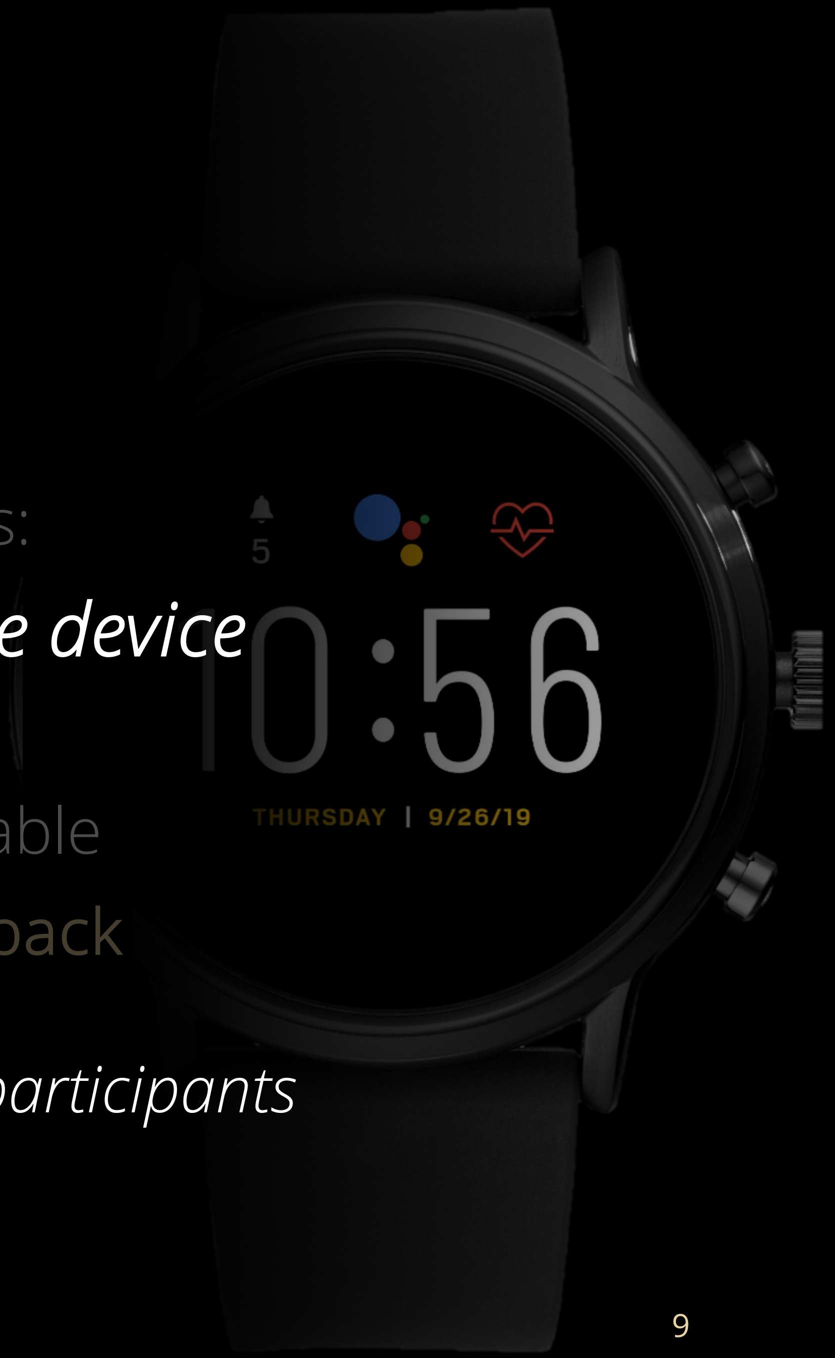
Survey of 201 Deaf and Hard of Hearing participants:

Smartwatches are the most preferred portable device for sound awareness

- Seen as useful, socially acceptable, and glanceable
- Advantageous for both haptic and visual feedback

Prior work is limited to a short, lab-based study of six participants

(Mielke & Brück, 2015)



Research Questions

1. How can a design most effectively combine visual and haptic feedback on a smartwatch?

2. Is there a role for haptic feedback that is more complex than simple vibration?

3. How should sound filtering be designed, and what are the implications for filtering in different contexts?

Method

- Single-session study employing design probe methodology
- Recruited 16 Deaf and Hard of Hearing participants
  - Average age: 56 years old (SD=17.7, range=19-85)
  - Choice of ASL interpreter (n=6) or real-time captioner (n=2)

Method

Study Procedure

Lab-based Design Probe (30 min)

- Wizard-of-Oz evaluation

Contextual Design Probe (25 min)

- Exploration of three campus locations

Semi-Structured Interview (20 min)

- Reflection on overall experience

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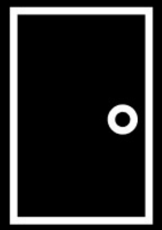
Lab-based Design Probe

1. Discussed reactions to watch-based sound feedback
2. Presented different sound feedback designs by performing three example sounds around the room:



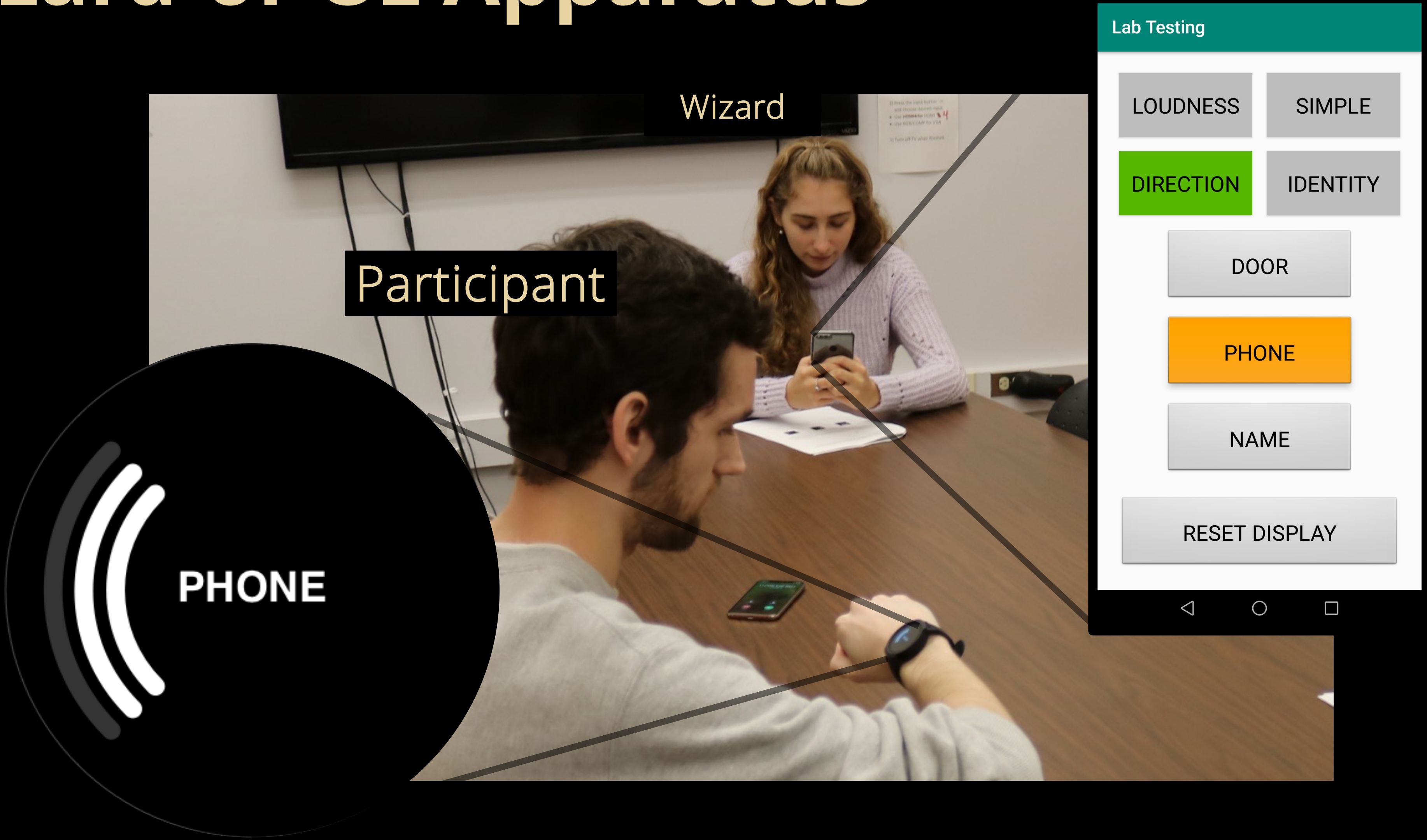
Door knock

Phone ring

Name call

Lab-based Design Probe

Wizard-of-Oz Apparatus



Lab-based Design Probe

Sound Feedback Designs

Each design included visual feedback designed with a high-contrast, glanceable aesthetic

Lab-based Design Probe

Sound Feedback Designs

We presented the visual alone, and with two haptic designs:

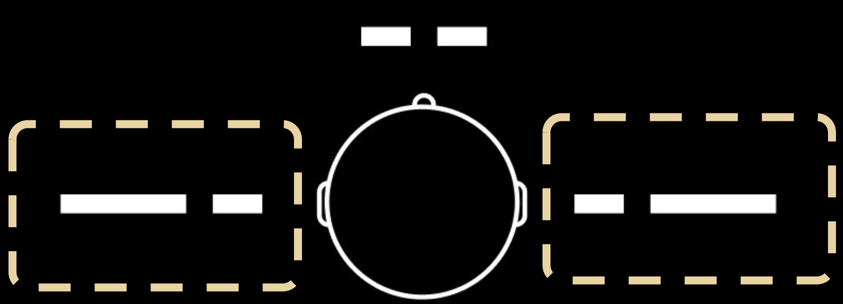
1. Simple vibration: a single vibration to notify the user a sound had occurred
2. Tactons: vibrational pattern to convey sound information.

Lab-based Design Probe

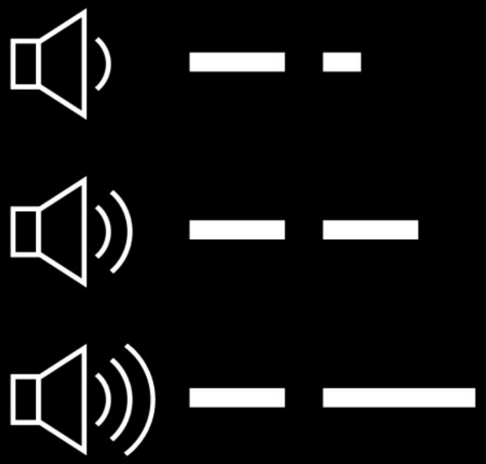
Sound Feedback Designs

Tactons: vibrational pattern conveying sound information

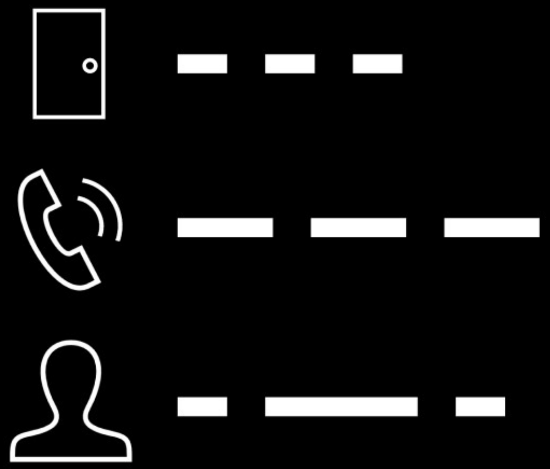
- On-and-off vibrations at a constant intensity



Direction



Loudness



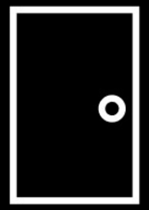
Identity

Lab-based Design Probe

Summary

Using three example sounds in the lab, we presented sound feedback designs in order of increasing haptic complexity:

1. *Visual alone*
2. *Visual + simple vibration*
3. *Visual + tacton*



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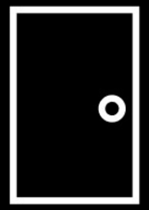
Name call

Lab-based Design Probe

Summary

1. *Visual alone*
2. *Visual + simple vibration*
3. *Visual + tacton (vibration pattern)*
   a) *Tacton for direction*
   b) *Tacton for loudness*
   c) *Tacton for identity*



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Contextual Design Probe

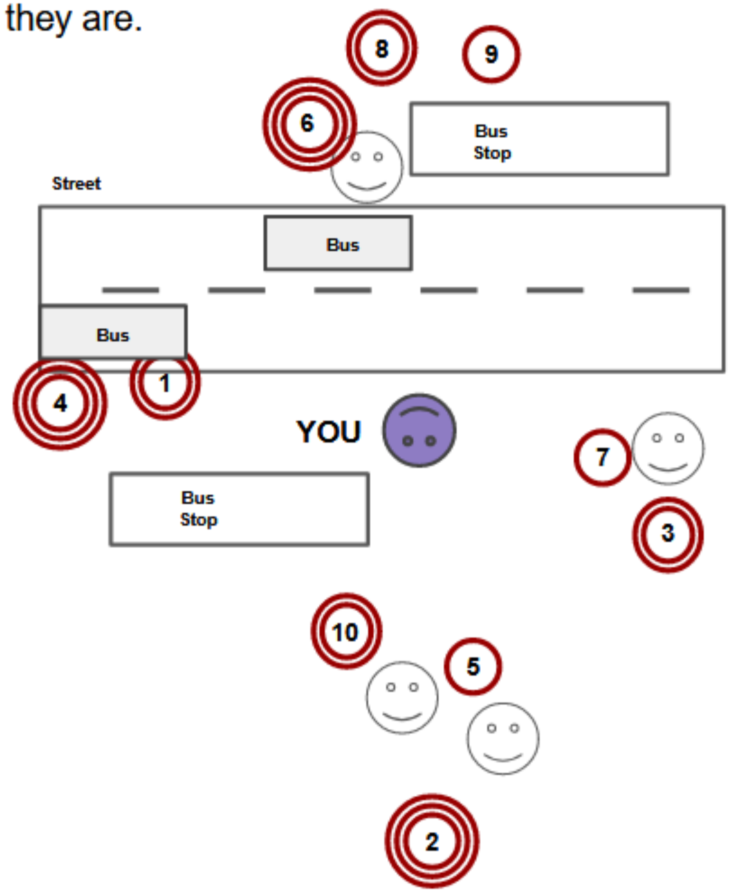
In situ scenario:

*Imagine you are on your way home but forgot your water bottle in the **student lounge** upstairs. After you pick it up, you go to [**the cafe**] in the building next door to pick up some coffee and then go to the **bus stop** to catch the next bus home.*

Contextual Design Probe

LOCATION #3

Imagine you are here to wait for the next bus to go home. The map below shows you where around you different sounds could POTENTIALLY happen (**red circle**). The list on the right is telling you which sounds they are.



List of sounds:

1. Bus arriving
2. Siren
3. Bird chirping
4. Honking
5. People talking
6. Person shouting for the bus to stop
7. Footsteps
8. Dog barking
9. Plane passing
10. Bike bell

Contextual Design Probe

Feedback Simulation

Contextual Design Probe

Sound Filtering

To spur participants to consider different sound filtering options, we explored filtering vibrational feedback.

We added a single vibration to:

- the three loudest sounds
- three sounds occurring behind the participant
- three sounds the watch deemed most important

Contextual Design Probe

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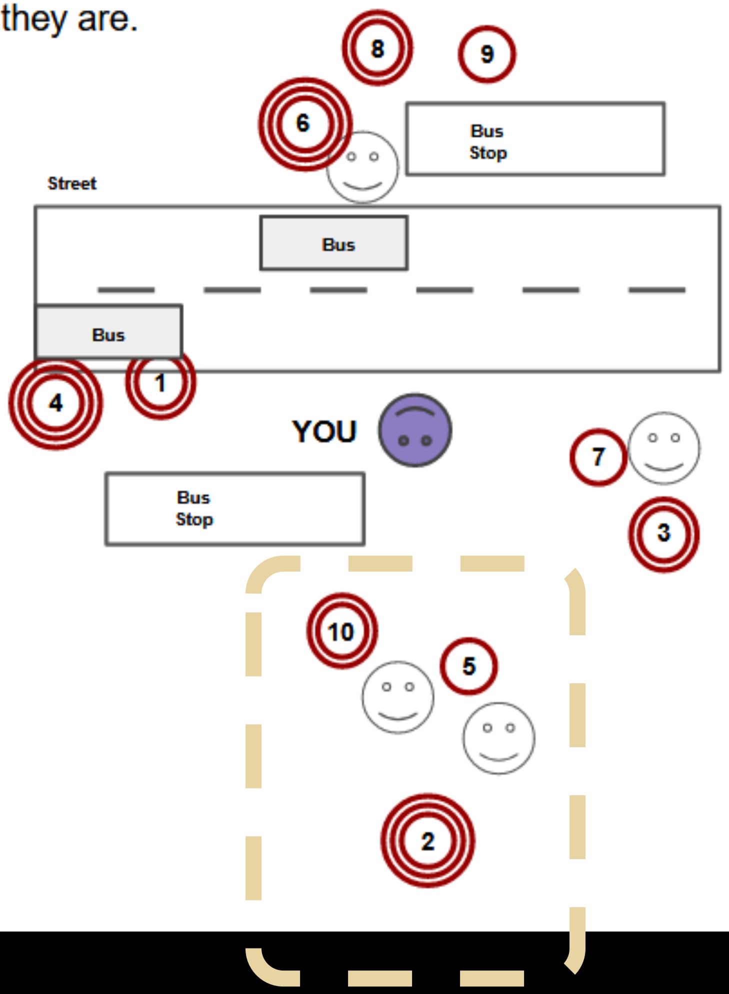

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Semi-structured Interview

We probed for: contextual factors, filtering options, social acceptability, and privacy issues.

We analyzed session transcripts using an iterative coding approach. [Braun, 2006]

- Two researchers developed a codebook to apply holistically

Findings

1. Visual and haptic feedback have complementary roles in sound awareness.
2. Haptic patterns have potential to convey sound information.
3. Sound filtering may mitigate perceived awareness issues in complex soundscapes.

Findings

Complementary Modalities

- Overall, participants responded positively to the idea of smartwatch-based sound feedback.
- Participants desired visual feedback across all conditions:
    - *"It's nice to have visual and the sensory input as well [but] I mean without the visual, I feel like there's not really a point."* (P10)
- Designs <u>with</u> vibration were more useful than <u>without</u>:
    - For example, most participants (*n*=13/16) were concerned they would miss sounds without vibration

Complementary Modalities

Visual and haptic feedback have different, but complementary, functions.

- Visual feedback provides information at a higher throughput than haptic feedback (*n*=8)
- Haptic feedback was appreciated for “alerting to a situation” (P9) and “trigger[ing] you to look at your watch” (P5)

Findings

Complementary Modalities

Past work shows Deaf and Hard of Hearing people make strong use of visual cues for environmental awareness [Matthews 2006]

Haptic feedback (simple or tactons) gets the users attention without interfering with visual awareness strategies:

- The user can respond to the environment immediately
- Or turn to the watch’s screen for more information

Findings

1. Visual and haptic feedback have complementary roles in sound awareness.
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Findings

Tactons’ Potential

Participants’ overall response to tactons was **positive**.

- Primary benefit was **minimizing the need to look** at the watch face
- Several participants (*n*=8) liked to improve their **sound response time**.

Potential for socially acceptable support:

> *“Let’s say I’m at a meeting, and I’m trying to listen to somebody, but I don't want to be rude and look at my watch when they're talking. […] ‘Ah-ha!’ Somebody is calling my name, and then I don't have to look [at the watch]”* (P3)

Findings

Tactons’ Potential

Tactons were not without areas of concern.

- Several (*n*=8) participants were concerned about time required:

  “I had to wait and wait and then the vibration had finished and by the time I finished decoding what it was […] I’d missed whatever happened.” (P6)

- Some (*n*=9) were concerned about effort required to learn each tactons meaning
  - Some were prepared to undertake this process
  - Others felt visual feedback would provide them with the same info

Findings

Tactons’ Potential

To mitigate temporal issues and learning difficulty, participants recommended:

- Limiting tactons to a small, simple set.
- Designing more intuitive patterns, such as a set with semantic representations of sound.

Findings

1. Visual and haptic feedback have complementary roles in sound awareness.
2. Haptic patterns have potential to convey sound information.
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Findings

Filtering & Soundscape Complexity

- Following our visits to different locations on campus, most participants (n=11/16) mentioned new use cases or increased interest in watch-based sound awareness
- This often pertained to use complex soundscapes: areas with frequent, overlapping sound events
  - Experienced in the café and bus stop

Filtering & Soundscape Complexity

P14 returned feeling far more positive about the idea:

> *“The [café] is just phenomenal because it's the thing that really gives people anxiety. “Are they going to hear me? Am I going to hear them?” There's so much ambient noise.*
>
> *In a place like [the student lounge] or in your house with the microwave and whatever, okay, it’s quiet.*
>
> *But when you go to a place outside, bus stop, [café], outside your home, this is just… and again in your car, this is just incredible.”* (P14)

Filtering & Soundscape Complexity

- Quotes like P14’s highlight the challenges, and necessity, of sound awareness in complex soundscapes.
- One strategy for awareness may be through filtering sound.
  - All participants in our study desired filtering due to exposure to realistically complex soundscapes.

Findings

Filtering & Soundscape Complexity

- Responses we split on how to implement filtering effectively.
- Idea: visual always, but vibration only added to some sounds.

  "[Hearing people] have the ability to screen out the sounds because you guys are used to hearing. […] The vibration, I think, could be a lot for me because it doesn't actually have the ability to filter out the sounds , which is why I prefer to see the visual and I can pay attention to it and then decide." (P7)

Findings

Filtering & Soundscape Complexity

Questions also arose over the system making automatic decisions and whether to trust them.

> *"You might be filtering out other awareness that you have built up over the years in favor of, 'Well, this thing knows, and in fact this thing might know better than me, so I'm just gonna ignore my instinct, I'm not going to bother looking because this will tell me.' […] I want to hear it all, and I want my own, I want to be able to choose what's more important."* (P4)

Findings

Summary

- While past work has highlighted a preference for combined visual and haptic feedback, we identify the complementary benefits they provide for environmental awareness.
- We provide evidence of the potential for small sets of haptic patterns (tactons) to convey sound information.
- We characterize perceived issues with sound awareness in complex soundscapes and provide potential means of managing them through sound filtering.

What’s Next?

- A note on participant diversity: our results may be biased toward individuals who want sound awareness technology.
- Collecting longitudinal data through a field evaluation of a working prototype.

Concluding Quote

"There's a huge variety of things that you could need to be aware of. [...] You're out there, you don't think about them. But in designing something that could be useful, you do have to think about it. And the complexity of it, of what the environment is, this is eye-opening." (P15)

Questions?

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Thank You

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