Visualizing Non-Speech Sounds for the Deaf

Tara Matthews                Janette Fong, Jennifer Mankoff
U.C. Berkeley                                        Carnegie Mellon

Motivation

• Ambient sounds give people an understanding of sounds relevant to their current situation or location:
  – serendipitous events (children playing in another room)
  – problematic things (faucet dripping)
  – critical information (fire alarm, knocking on the door)

• Maintaining this awareness can be difficult for people who are deaf

Overview

• Study of peripheral, visual displays to help people who are deaf maintain an awareness of non-speech sounds

Background

• Ho-Ching, Landay, Mankoff [CHI ’03]
  – Gathered initial knowledge on visual displays of ambient sounds
  – Did almost no visual design exploration with users before implementing prototypes
  – Focused on quantitative comparison of two displays
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Spectrogram Positional Ripples (Map)

Study Outline

- Design interviews (8 participants who are deaf)
  - Formal interview
    - Understanding of user needs (sounds of interest, places of use, display size)
  - Design sketch interview
    - Feedback on 10 sketches
    - Visual design preferences & functional requirements

Study Outline

- Implemented 2 fully-functional prototypes
  - Embody preferences & requirements found in interviews

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- Prototype evaluation (4 participants who are deaf)
  - In-lab prototype usage
  - Interview for feedback on prototypes

Formal Interview Topics

For people who are deaf, what are their preferred...

- Sounds to know about?
  - E.g., presence of others, phones, etc.

- Place for more sound awareness?
  - E.g., home, work, while mobile

- Display size?
  - E.g., PDA, PC monitor, large wall screen

...in a visualization of non-speech sounds
Formal Interview Results

• Users discussed a variety of sounds they wanted to know about…

Results: Sounds of Interest

Home
– emergency alarms
– wake-up alarms
– doorbell and knocking
– phone ringing
– people shouting
– intruders
– children
– items falling over
– appliances (faucets dripping, water boiling, garbage disposal, gas hissing, etc.)

“I need a [wake-up] alarm. Before an early flight, I will stay up all night.”

“Once I left the vacuum cleaner on all night.”

“I have trouble hearing my husband calling me… when I’m in another room.”

Results: Sounds of Interest

Work
– presence & activities of coworkers
– emergency alarms
– phone ringing
– coworkers trying to get their attention
– faxes/printers

“My office is not ADA Compliant and I worry about missing the fire alarm.”

Results: Sounds of Interest

Walking / running outside
– dogs barking
– honking
– vehicles
– bikes or people coming up behind them
– if blocking another person

In vehicle
– cars honking
– sirens
– sounds indicating problems with the car

“When I first moved to L.A. I was surprised at how some drivers are aggressive on the roads and at intersections. I had some close calls.”

“When there is something wrong with the car… it tends to go unnoticed until it is very expensive to fix.”

Formal Interview Results

• Places for more sound awareness
  – Wanted to be more aware of sounds in all places
  – Especially at home, work, in the car, & while walking

• Display size
  – Preferred small displays (PDA or part of a PC screen)
  – Large wall screens also valued at home (better visibility)

Design Sketch Interview Topics

For people who are deaf, what are their preferred…

• Information about sounds?
  – E.g., sound recognition, location, characteristics (volume & pitch)

• Visual design characteristics?
  – E.g., shapes & colors, pictorial, text-based, graphs

• Functions?
  – E.g., customization, etc.

…in a visualization of non-speech sounds
Design Sketches

• Designs varied in visual design and information conveyed
  • recognized sounds, location, volume & pitch

LED Panels  Directional Icons  Map

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Results

"I think using the Spectrograph will be useful, so I can glance at it and figure out the sound."

"It looks like a piece of art on the walls... I wouldn't mind having it hanging in the living room."

"I'd have to practice and learn this to understand it."

"It doesn't identify WHAT noise is being made and if it's an important noise... I would prefer some sort of identification of the noise that is being made."

Spectrograph with Recognition  Ambient  Bubbles Sidebar

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Design Sketch Interview Results

- Information about sounds
  - sound recognition
- Visual design characteristics
  - easy to interpret
  - glanceable
  - appropriately distracting
- Functions
  - identify what sound occurred
  - view a history of displayed sounds
  - customize the information that is shown
  - determine the accuracy of displayed information

Using Interview Results: Prototypes

- Prototyped two designs
  - Single Icon, Spectrograph with Icon
- Incorporated support for desired functions
  - sound identity, customization, accuracy, history
- Sound recognition
  - Used existing, state-of-the-art recognition system [Robert Malkin, HSCMA '05]
  - Used audio only to detect and classify events based on training

Single Icon

- Identity: icon shows recognized sound; rings for unrecognized
- Customization: select sounds to show in menu
- Accuracy: icon opacity and text indicate sureness of recognition system
- History: graph of past sounds
- Size: small (55 x 93 pixels)
Single Icon

- **Identity**: icon shows recognized sound; rings for unrecognized
- **Customization**: select sounds to show in menu
- **Accuracy**: icon opacity and text indicate sureness of recognition system
- **History**: graph of past sounds
- **Size**: small (55 x 93 pixels)

History Display

- Colored bars represent recognized sounds
  - Sound ➔ color
  - Volume ➔ bar height
  - Time ➔ x-axis position

Spectrograph with Icon

- Combines Single Icon with a Spectrograph
- **Identity, customization, accuracy, history**: same as Single Icon
- Adds ability for in-depth interpretation of sounds:
  - amplitude ➔ darkness
  - frequency ➔ y-axis
  - time ➔ x-axis
- **Size**: small-medium (263 x 155 pixels)

Prototype Evaluation

- Evaluated with 4 users who are deaf
- Recognition system set-up
  - Trained with office sounds
    - phone ringing, voices, door opening/closing and knocking.
  - Filtered out background noises
    - typing, mouse clicks, chair creaks, and continuous background noises (e.g., heaters & fans).
  - One high-quality microphone (Sony ECM 719), mounted on wall, above & behind the desk/PC
- **In-lab prototype usage**
  - User checked email & monitored display on PC
  - Researcher created sounds:
    - phone ringing, door opening/closing, coughing, pen clicking, shuffling papers, knocking on the door, voices, banging a plastic toy against the table, and hitting a metal bookcase
- **Interview for feedback on prototypes**
Prototype Evaluation Results

User preferences, in order:
1. History Display (as a stand-alone interface)
2. Single Icon
3. Spectrograph with Icon

Results: History Display
- Enabled users to know what sounds occurred w/o constantly watching display
- Alerted users to interesting sounds
  - louder sounds made bigger bars, attracting attention

Results: Single Icon
- Overall, positive reactions:
  - enabled users to recognize sounds
- Suggested improvements:
  - better visual distinction between important and unimportant sounds
  - rings not sufficient for unrecognized sounds: needed more information (e.g., location)

Results: Spectrograph with Icon
- Mixed reactions:
  - confusion
  - difficult to interpret spectrograph
  - hard to distinguish important sounds
- Interest
  - exploring shapes caused by sounds
- Suggested improvements:
  - display icon or text over the spectrograph

Summary
- Study of peripheral, visual displays to help people who are deaf maintain an awareness of non-speech sounds
- Contributions:
  1. Understanding of user needs
     - sounds of interest, places of use, display size
     - Visual design preferences
     - easy to interpret, glanceable, appropriately distracting
     - Functional requirements
     - sound identity, customization, accuracy, history
  2. Two fully functioning prototypes
     - designed, implemented, and evaluated
     - embody preferences and requirements in (2)

Questions?
For more information:
tmatthew@cs.berkeley.edu
www.eecs.berkeley.edu/~tmatthew/projects/ic2hear.html

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Recognition System Accuracy

- Phone 100%
- Voices 100%
- Door knock 100%
- Door open / close 76%