Exploring Sound Awareness in the Home
for People who are Deaf or Hard of Hearing

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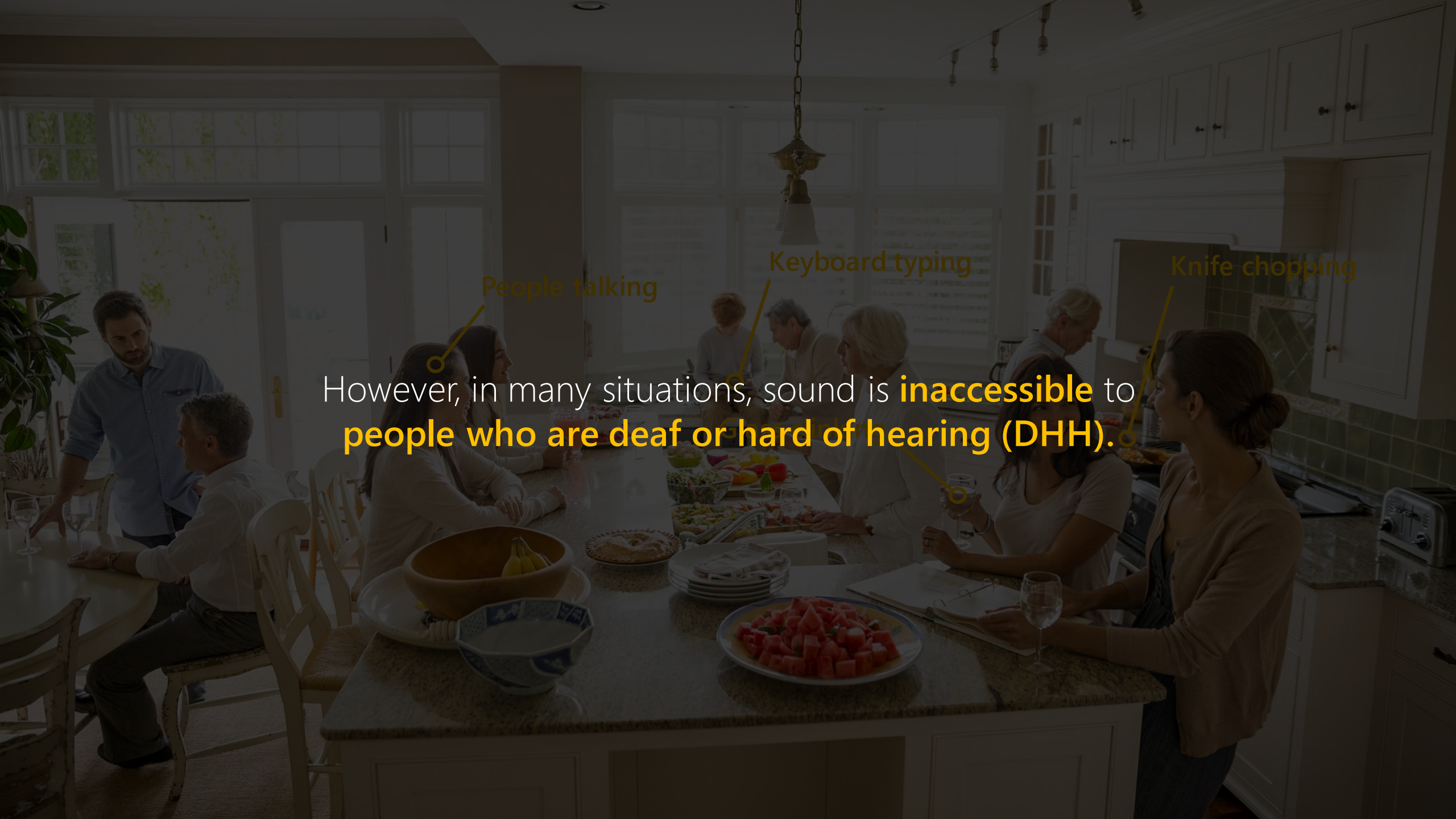
University of Washington, Seattle


The home environment is filled with a
rich diversity of sounds

These sounds inform us about the **home** and the **occupants** within it.



However, in many situations, sound is **inaccessible** to **people who are deaf or hard of hearing (DHH).**

Fortunately, DHH people use **visual** or **vibratory** alternatives…

FLASHING DOORBELL

VIBRATORY BED ALARM

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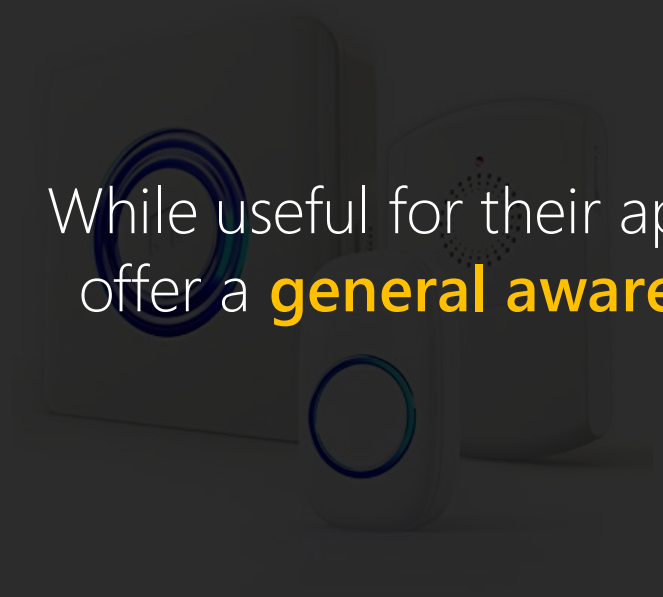


While useful for their applications, these products **do not** offer a **general awareness** about sounds in the home.

FLASHING DOORBELL

VIBRATORY BED ALARM

Recent proliferation of **screen-based** smarthome devices and advances in **machine learning for sound** offer a new opportunity to design for DHH people...

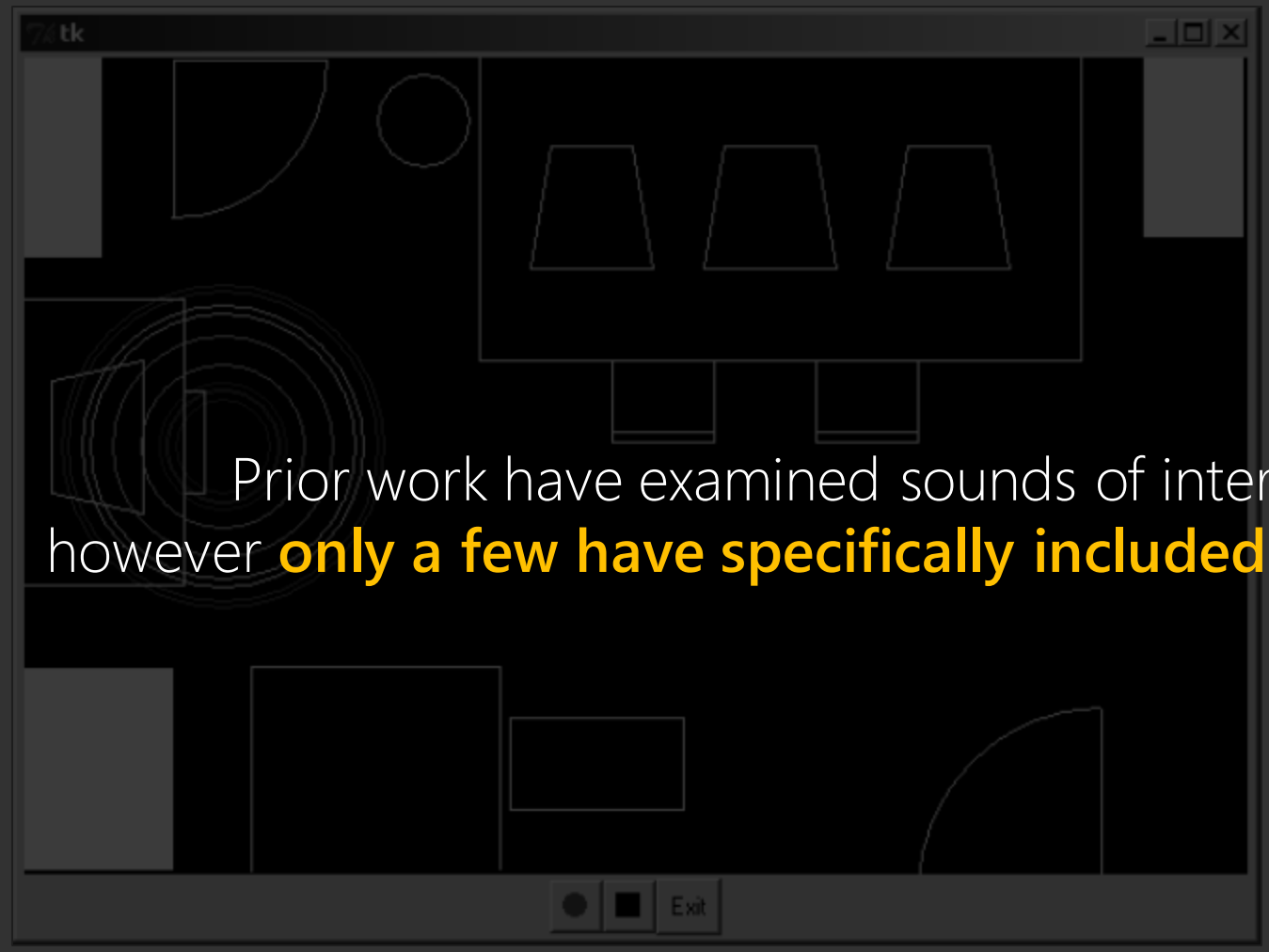
Questions

What **information** about sound do DHH people want in the homes?

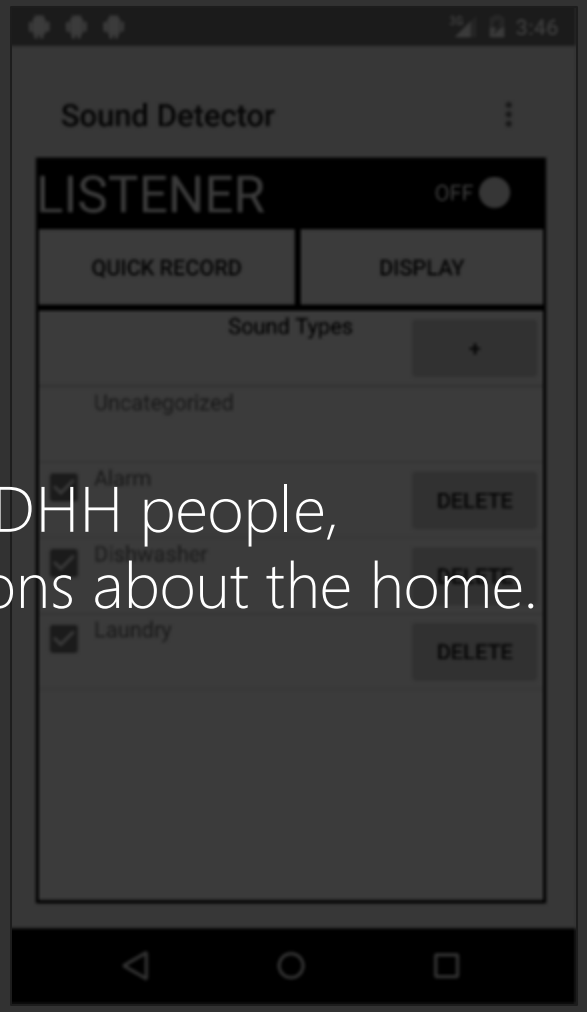
How do they want this information to be **conveyed**?

How would a sound awareness system **integrate** into the homes of DHH people?

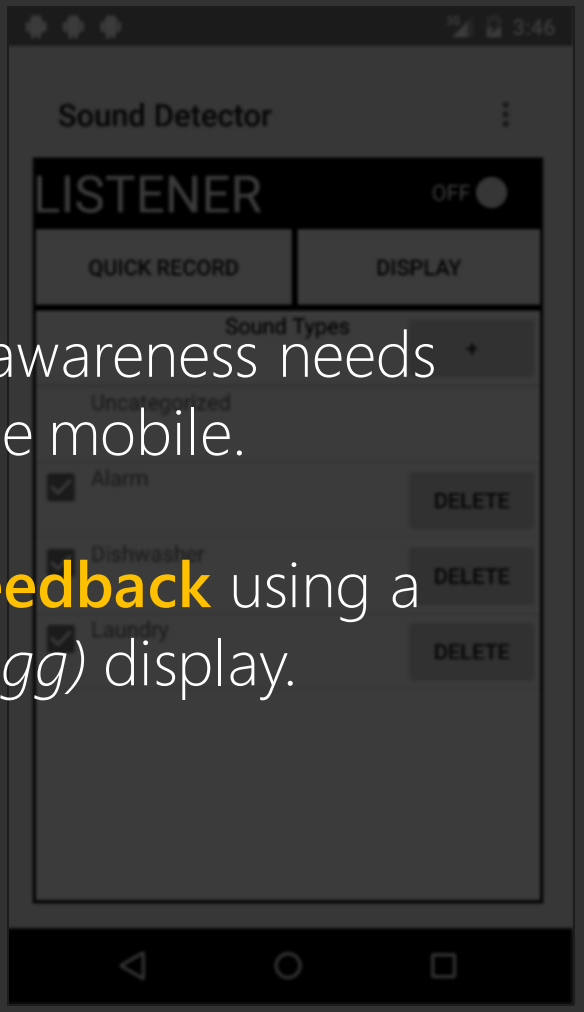
What **concerns** may arise when using such a system in the home? (e.g., privacy)



Prior work have examined sounds of interest for DHH people,
however **only a few have specifically included** questions about the home.



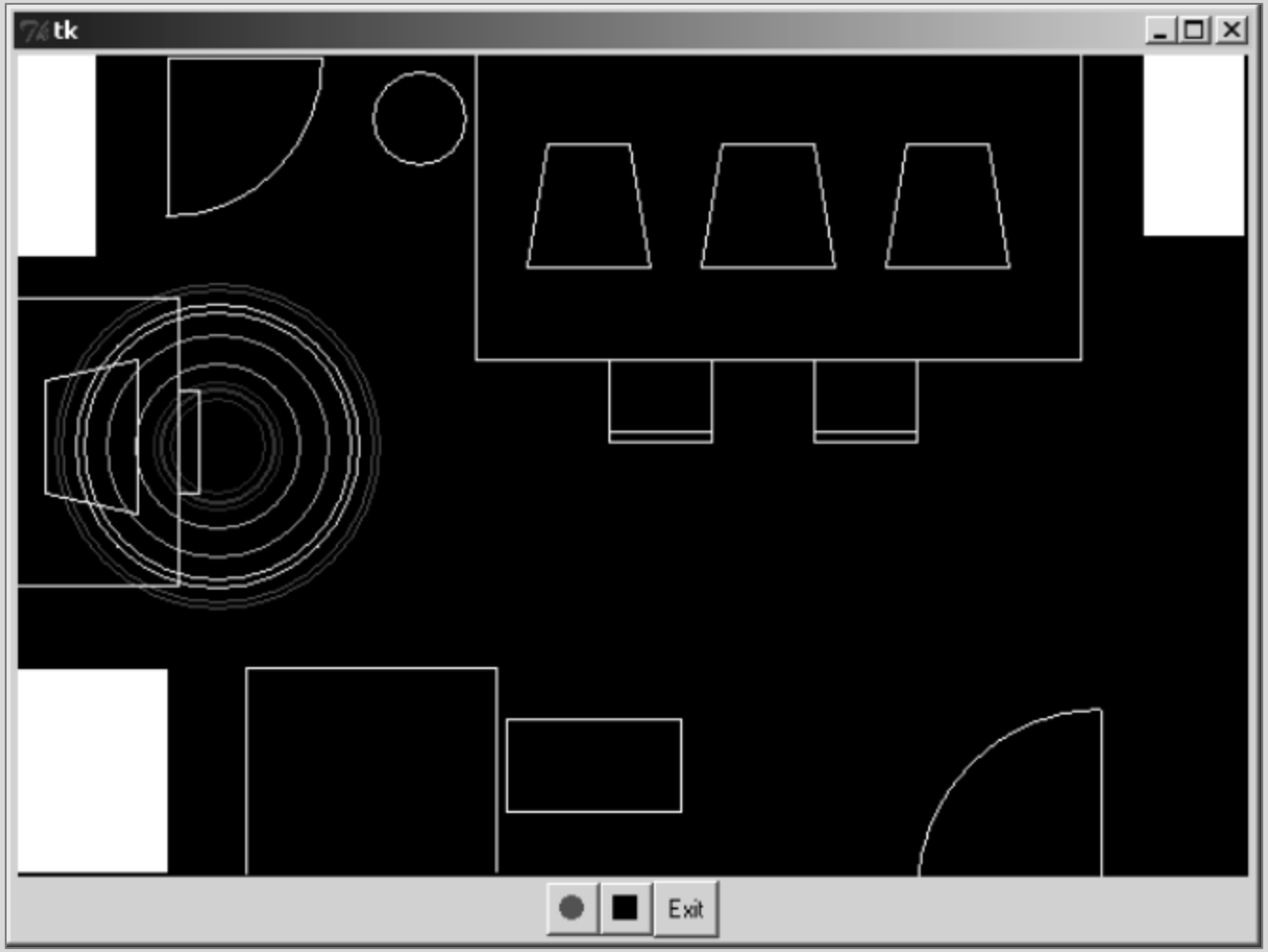
(Matthews *et al.*, *ASSETS 2007*)



(Bragg *et al.*, *ASSETS 2016*)

Matthews *et al.* and Bragg *et al.* investigated sound awareness needs in **three contexts**: at home, at work and while mobile.

They also evaluated providing **sound awareness feedback** using a **desktop** *(Matthews)* and a **mobile phone** *(Bragg)* display.



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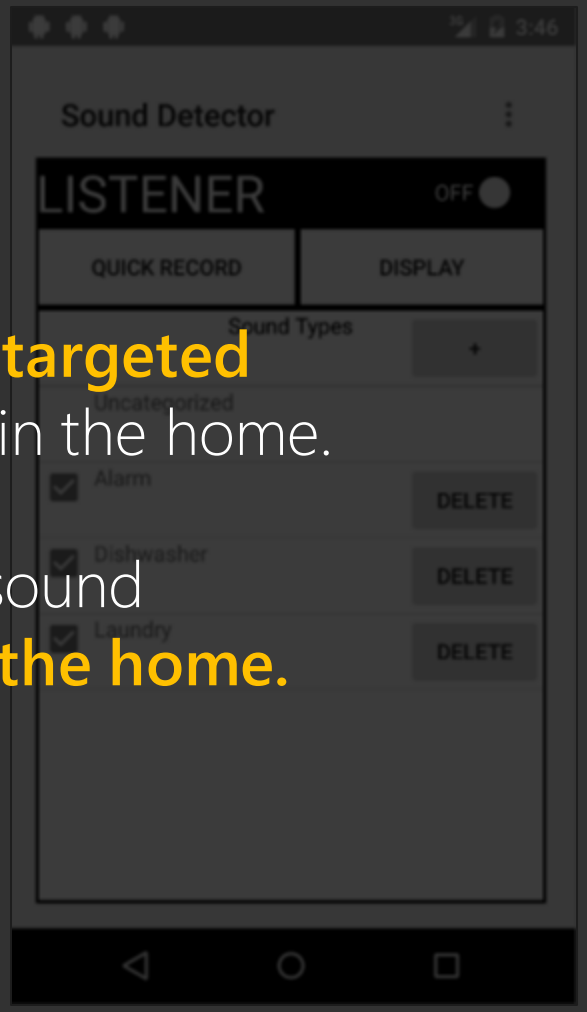
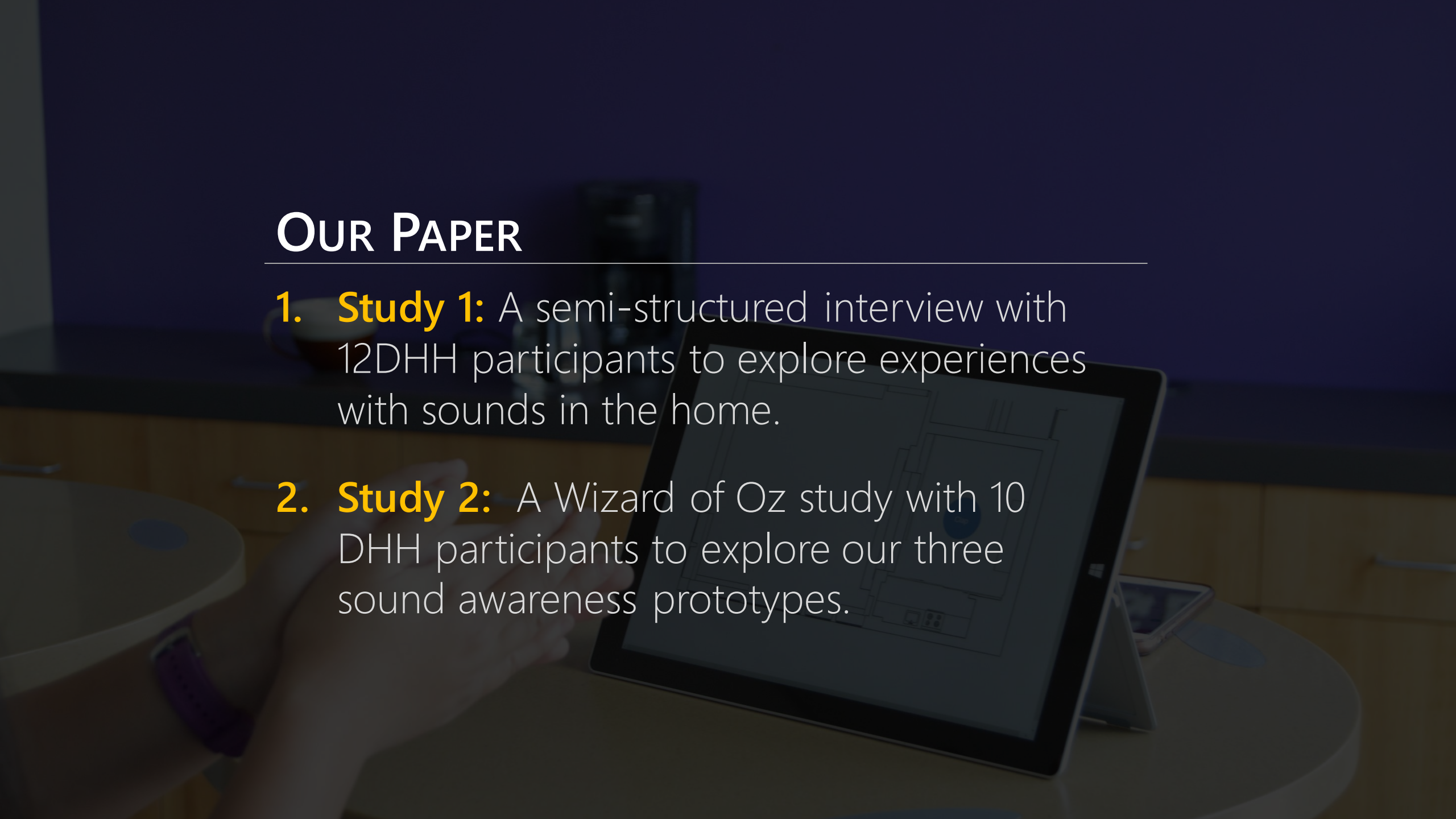


(Bragg *et al.*, *ASSETS 2016*)

We conducted a **more comprehensive and targeted investigation** of needs, concerns and solutions in the home.

We also introduced and evaluated initial sound awareness prototypes **specifically design for the home.**



Our Paper

1. **Study 1:** A semi-structured interview with 12DHH participants to explore experiences with sounds in the home.

2. **Study 2:** A Wizard of Oz study with 10 DHH participants to explore our three sound awareness prototypes.

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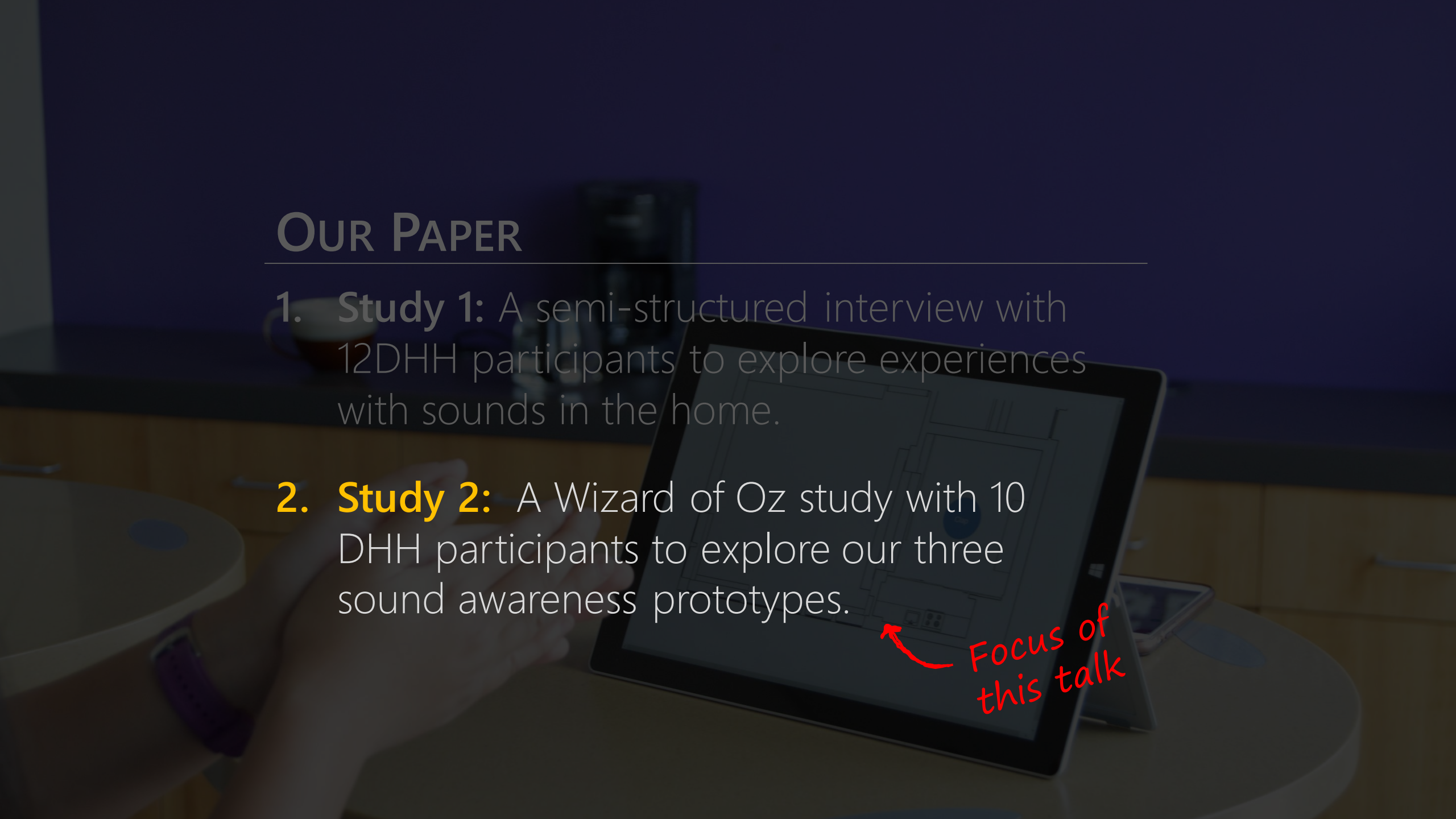


Outline

A brief overview of **Study 1** → **Study 2**

Design of sound awareness prototypes → Wizard-of-Oz evaluation → **Findings**

Outline

A brief overview of **Study 1** (Formative interview) → **Study 2**

Design of sound awareness prototypes → Wizard-of-Oz evaluation → **Findings**

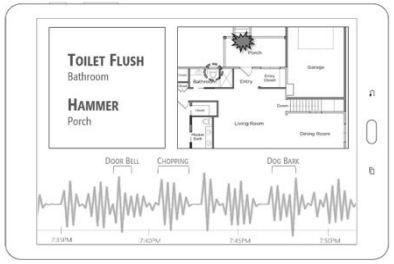
All participants emphasized the **need for a sound awareness system** in the home.

Design Space for In-Home Sound Awareness

Form Factor

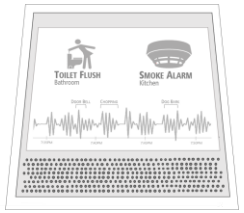
Smart Watch

Smart Phone



Tablet

Head Mounted



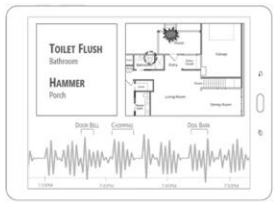
Smart Home

Ambient

Output Modality

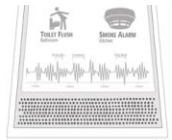
Smart Watch

Smart Phone



Wall Mounted

Head Mounted



Smart Home

Ambient

Visual

Vibration

Display elements

1. Sound type,
2. Sound location
3. Temporal history
4. Length of occurrence
5. Physical characteristics of sound
6. Importance of sound

Sound location specificity

Very specific

Moderate Specific

General

Sound type specificity

Very specific

Moderate Specific

General

Design Space for In-Home Sound Awareness

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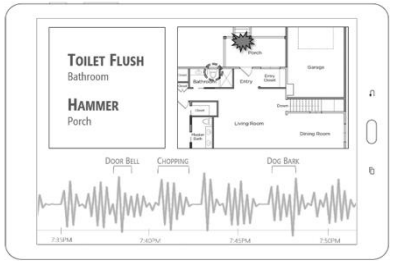
Smart Watch

Smart Phone



Tablet

Head Mounted

Smart Home

Ambient

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1. **Sound type,**
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6. Importance of sound

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Very specific

Moderate Specific

General

Outline

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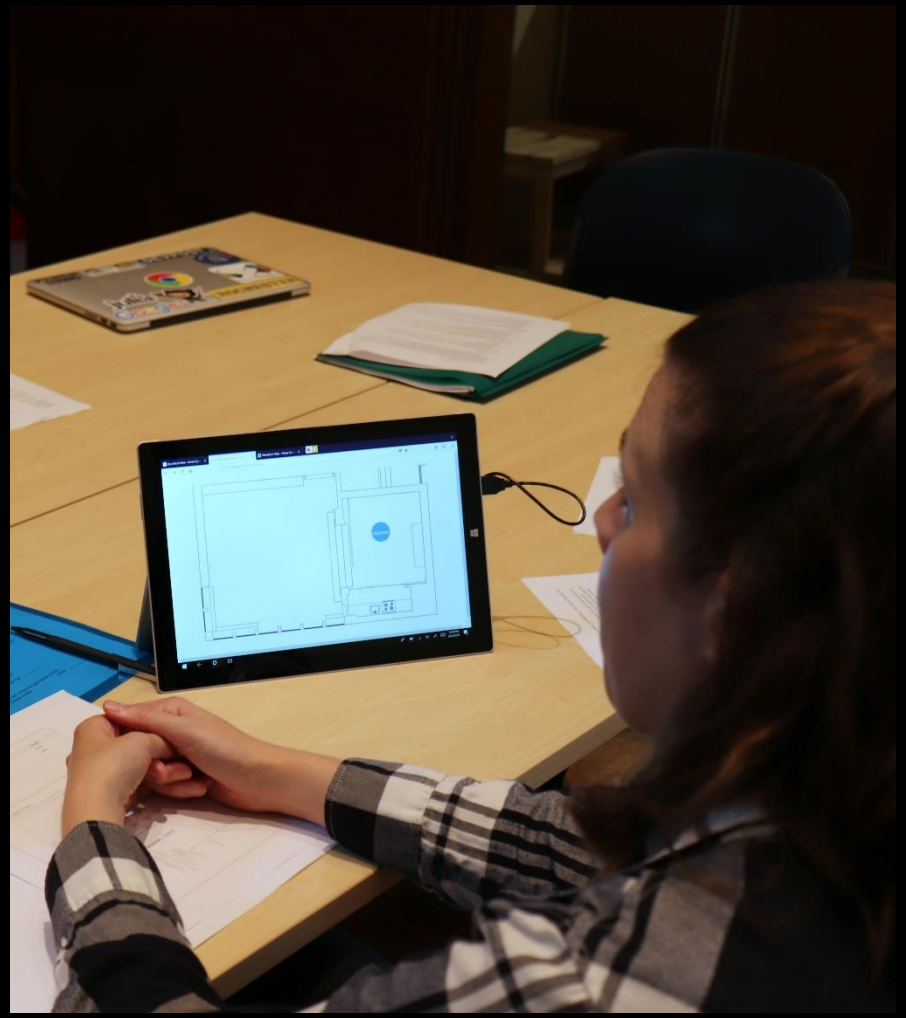
Design of sound awareness prototypes → Wizard-of-Oz evaluation → **Findings**

Study 2



Goal

- To gain further insight into in-home sound awareness, particularly to investigate themes that are central to the home (*e.g.*, privacy, issues with activity tracking)

Participants

- 10 DHH individuals
- Recruited through email and snowball sampling

Study Method

- Built three sound-awareness prototypes
- Evaluated the prototypes using a scenario-based Wizard-of-Oz study

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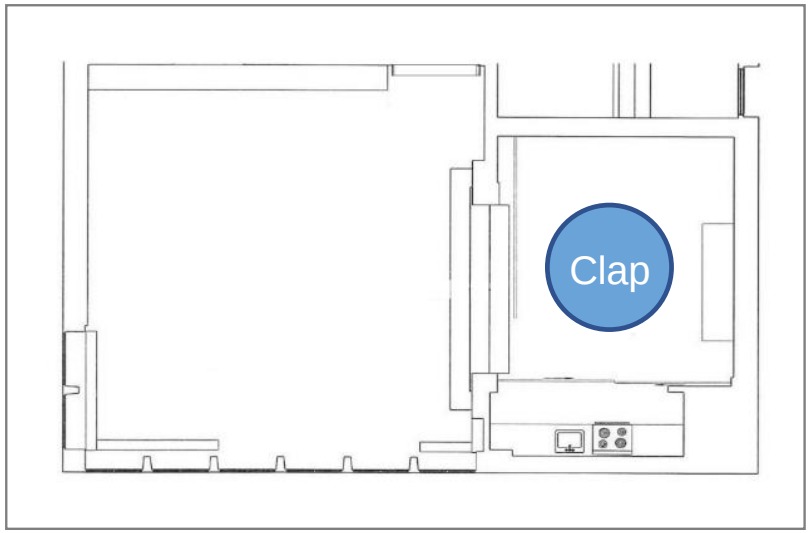
THREE INITIAL PROTOTYPES

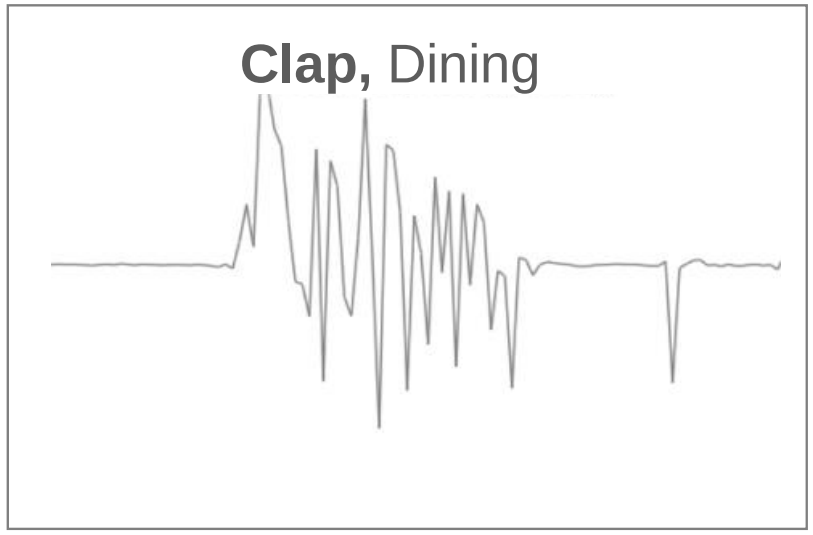


Floorplan

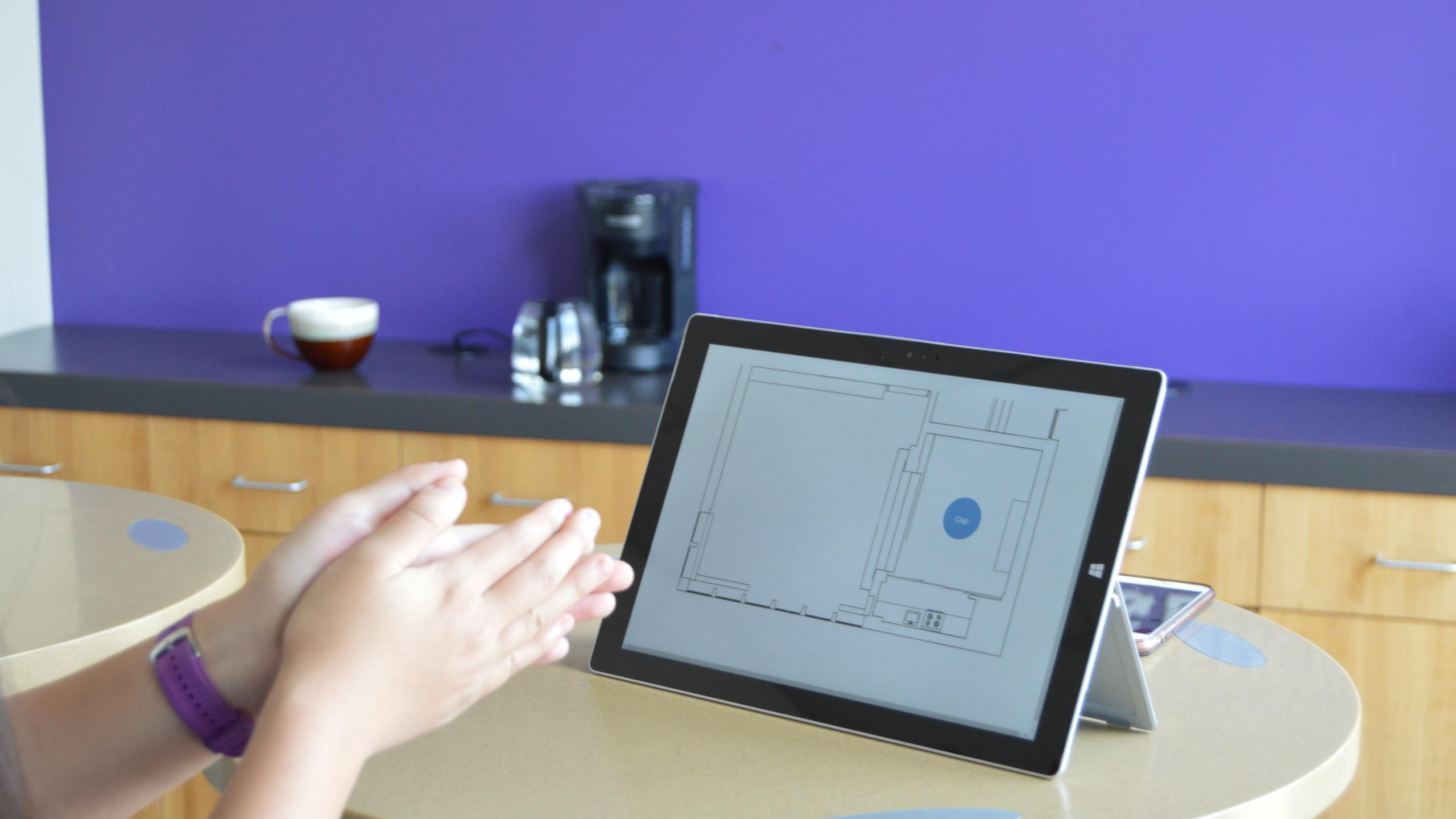
Search for sounds...

Time	Sound	Location
10:07:45	Microwave beep	Kitchen
10:08:01	Bird chirp	Outside
10:08:32	Clap	Dining

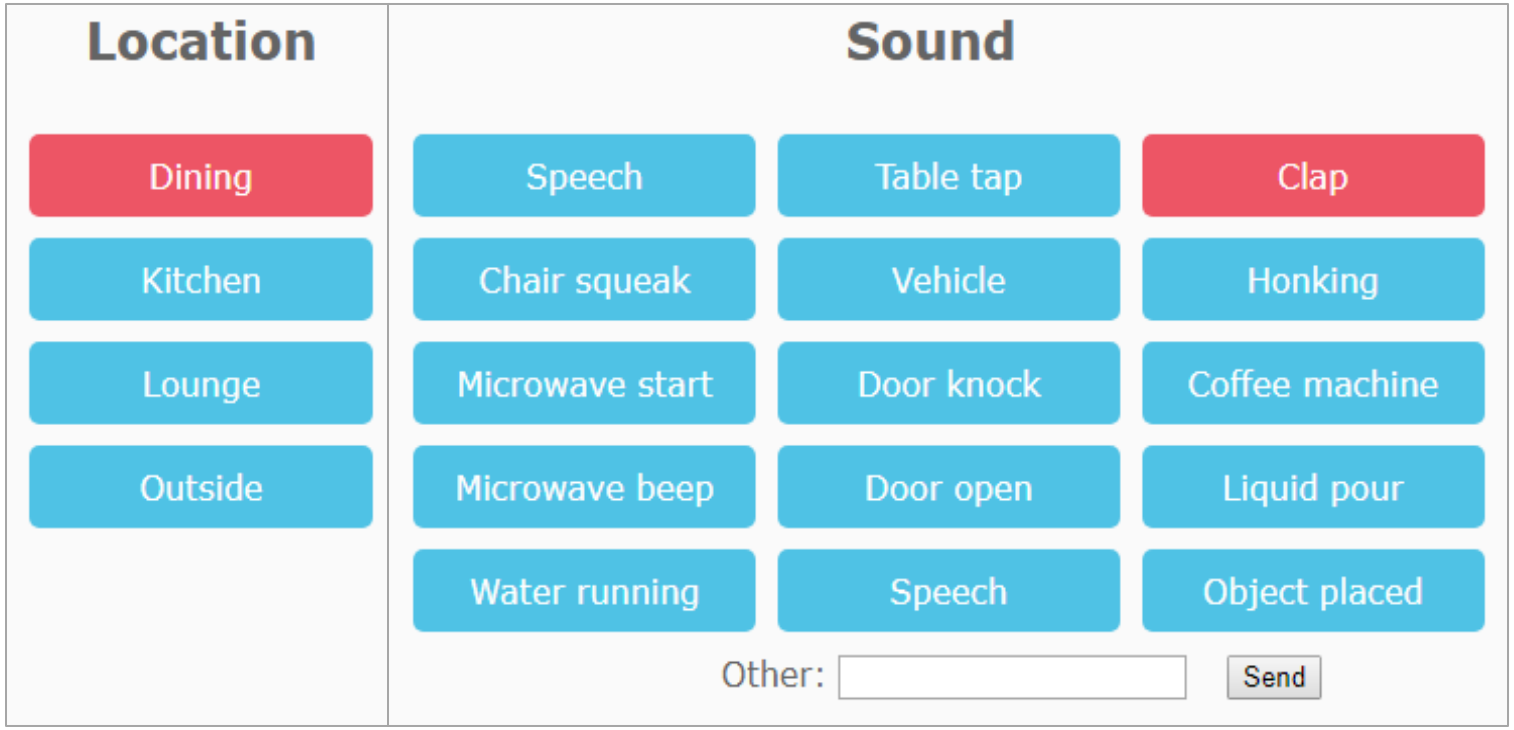
List



Waveform


Clap

WIZARD'S INTERFACE



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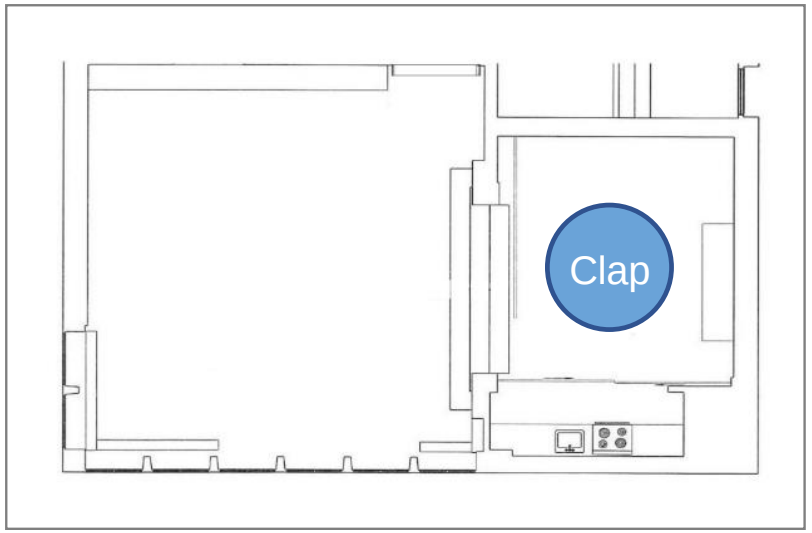

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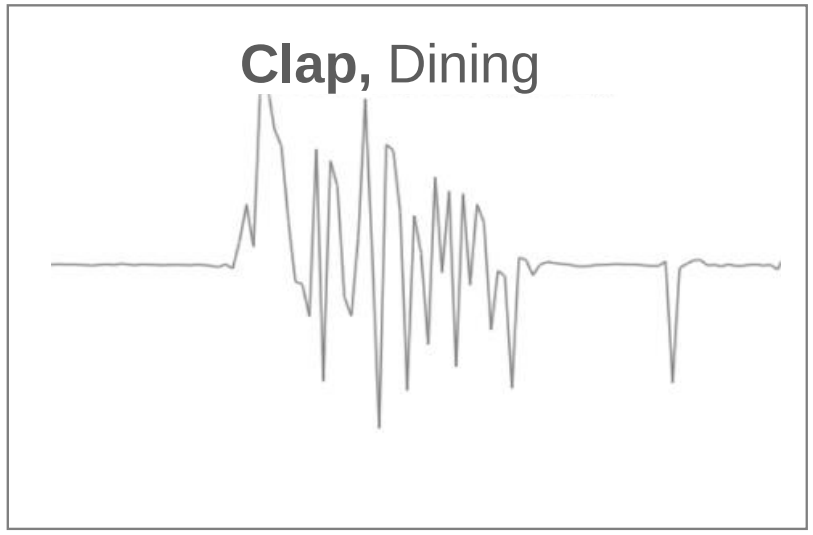
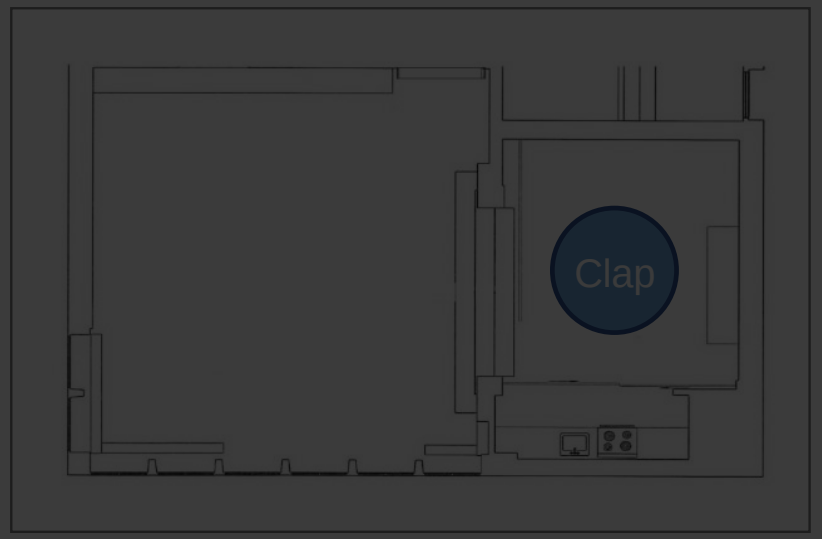
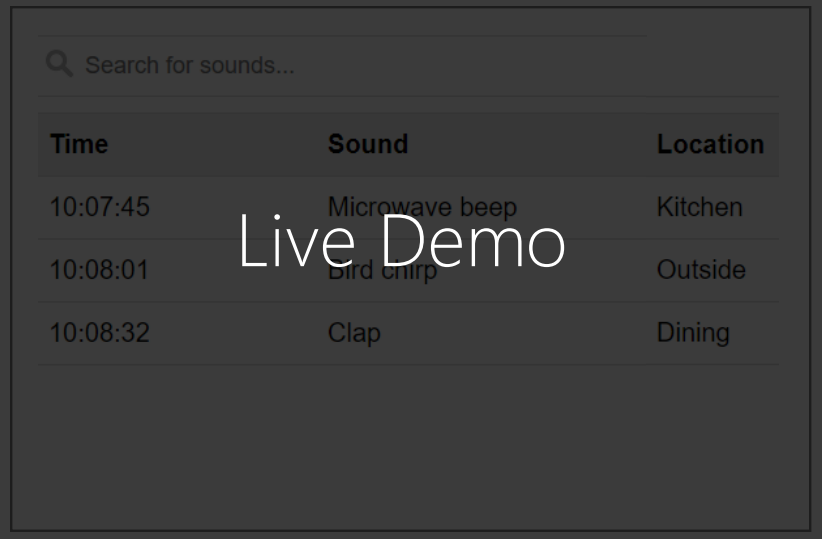


Waveform

Three Initial Prototypes



Floorplan



Live Demo

List

Waveform

Questions

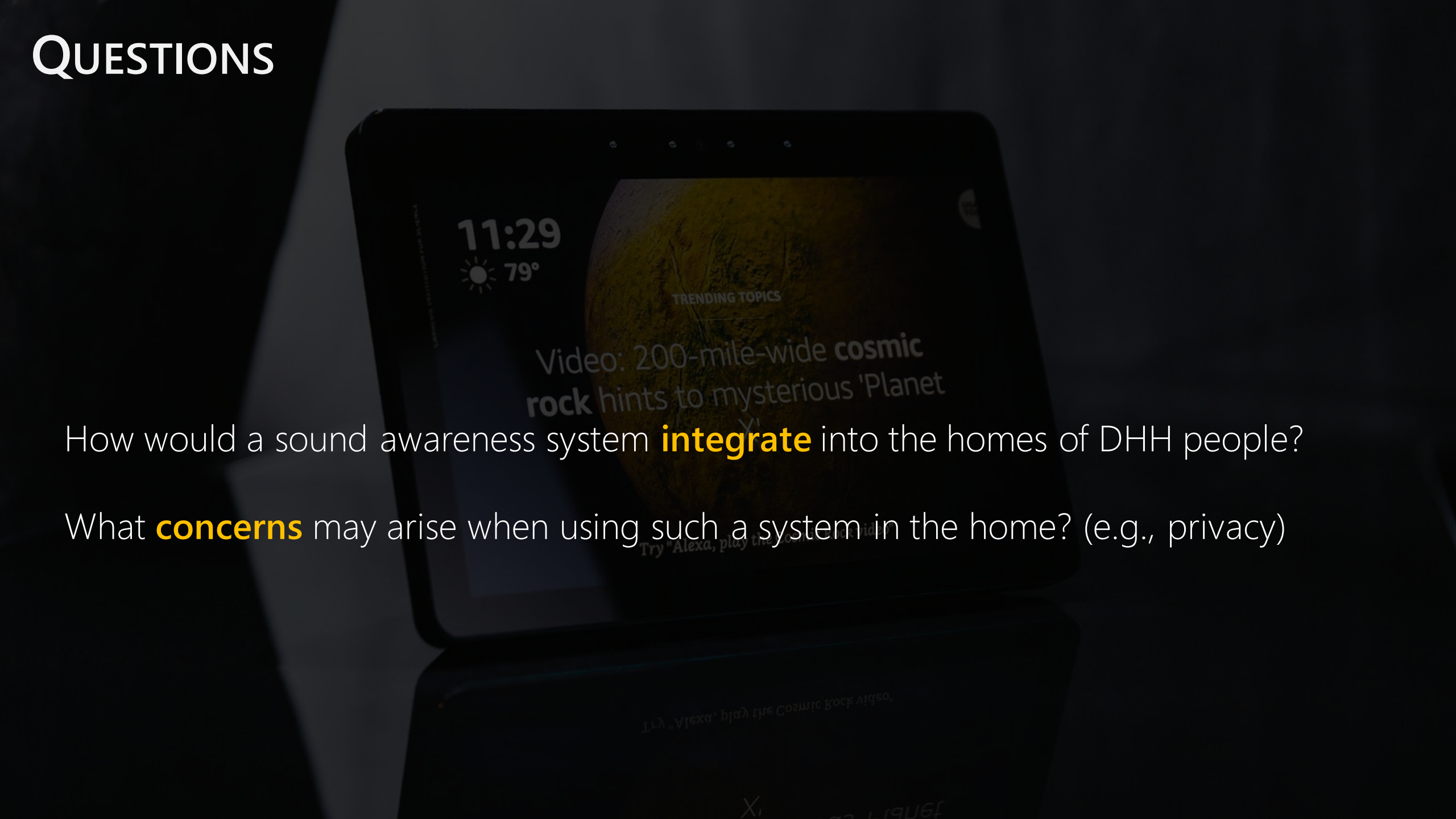
What **information** about sound do DHH people want in the homes?

How do they want this information to be **conveyed**?

How would a sound awareness system **integrate** into the homes of DHH people?

What **concerns** may arise when using such a system in the home? (e.g., privacy)

Questions



How would a sound awareness system **integrate** into the homes of DHH people?

What **concerns** may arise when using such a system in the home? (e.g., privacy)

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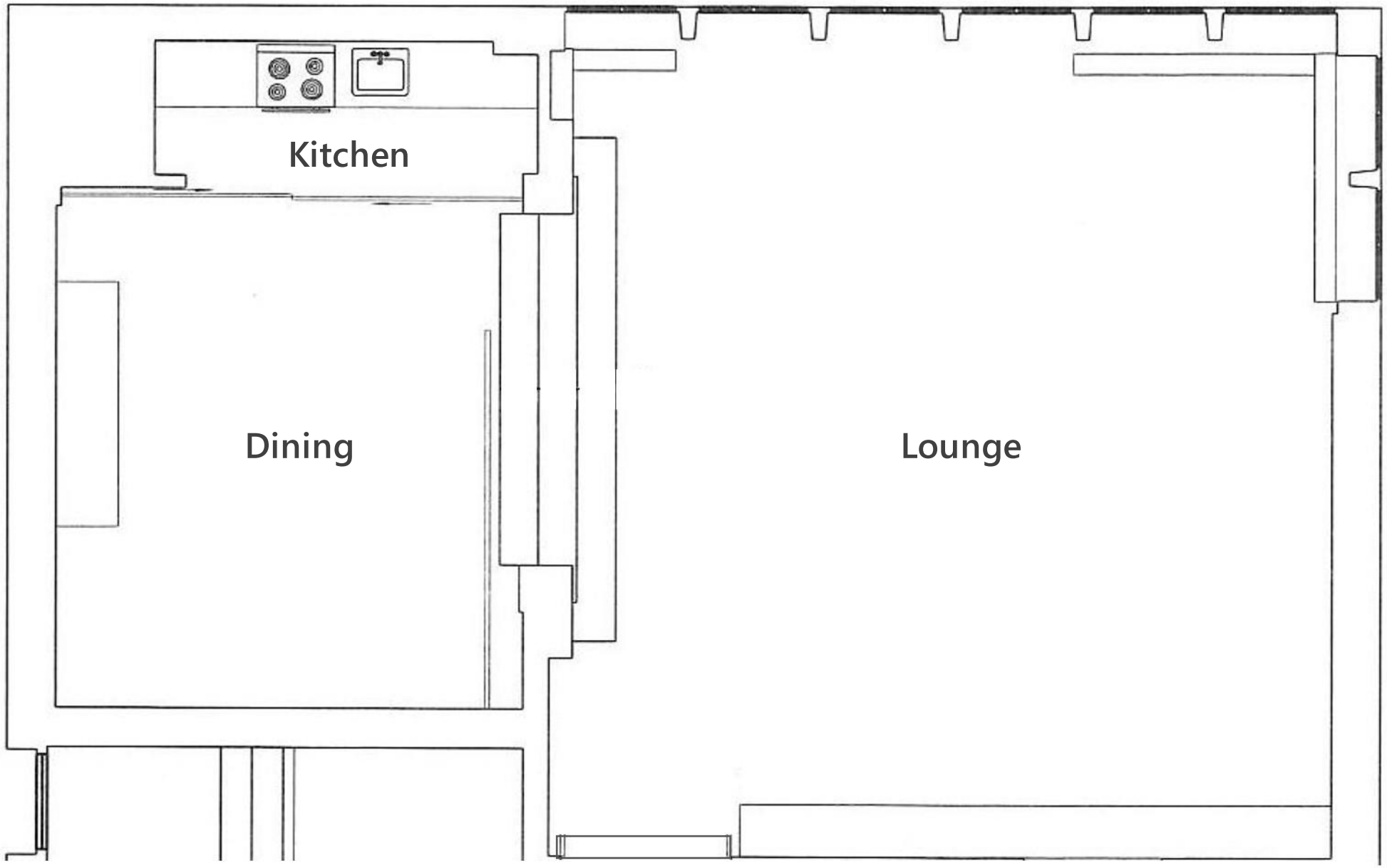
Wizard Of Oz Evaluation

(conducted in a studio on campus that looked like a home)



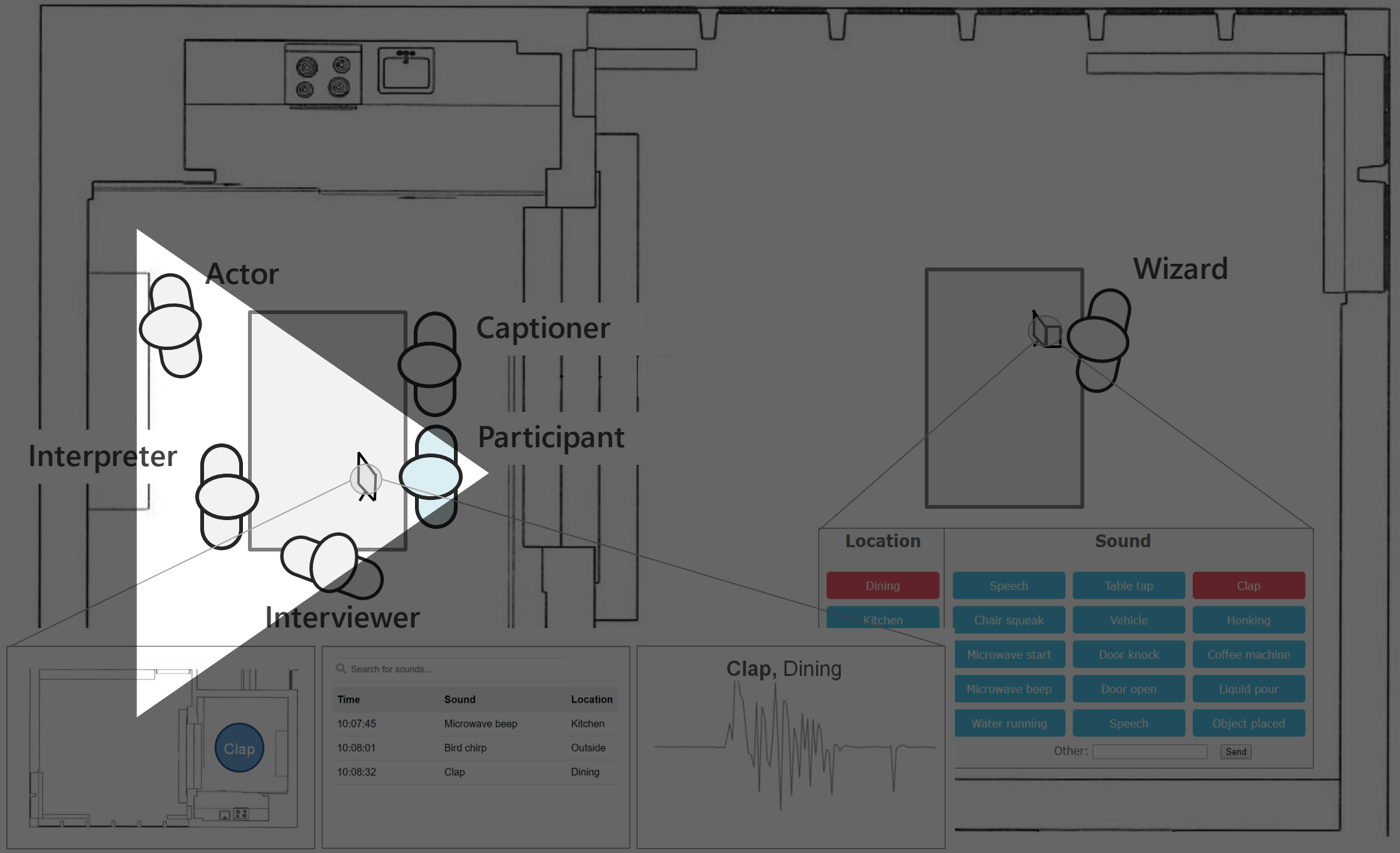
1. Introduced prototypes

Using short demos of some example sounds (*e.g.*, coffee pouring, door knock)

2. Scenarios-based evaluation

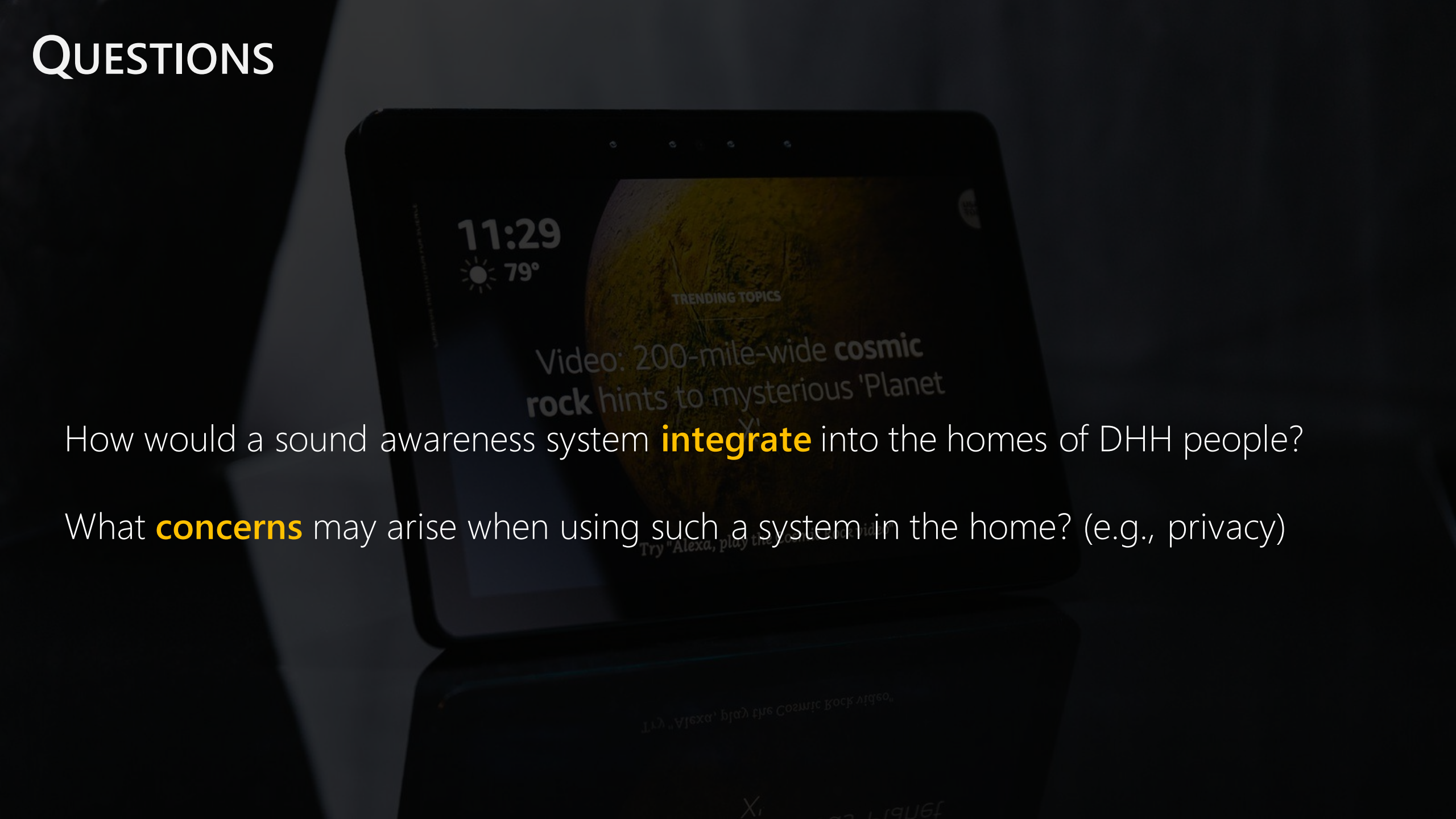
Three scenarios to explore themes central to the home.

Each scenario was in-acted by an actor who made sounds. The wizard then listened to those sounds and clicked on the interface to transmit the sound information to the participant's screen.


Actor
Captioner
Participant
Interpreter
Interviewer
Wizard
Location
Sound
Dining
Kitchen
Speech
Table tap
Clap
Chair squeak
Vehicle
Honking
Microwave start
Door knock
Coffee machine
Microwave beep
Door open
Liquid pour
Water running
Speech
Object placed
Other:
Send
Clap
Search for sounds...
Time
Sound
Location
10:07:45
Microwave beep
Kitchen
10:08:01
Bird chirp
Outside
10:08:32
Clap
Dining
Clap, Dining


Participant
Actor
Coffee Pour

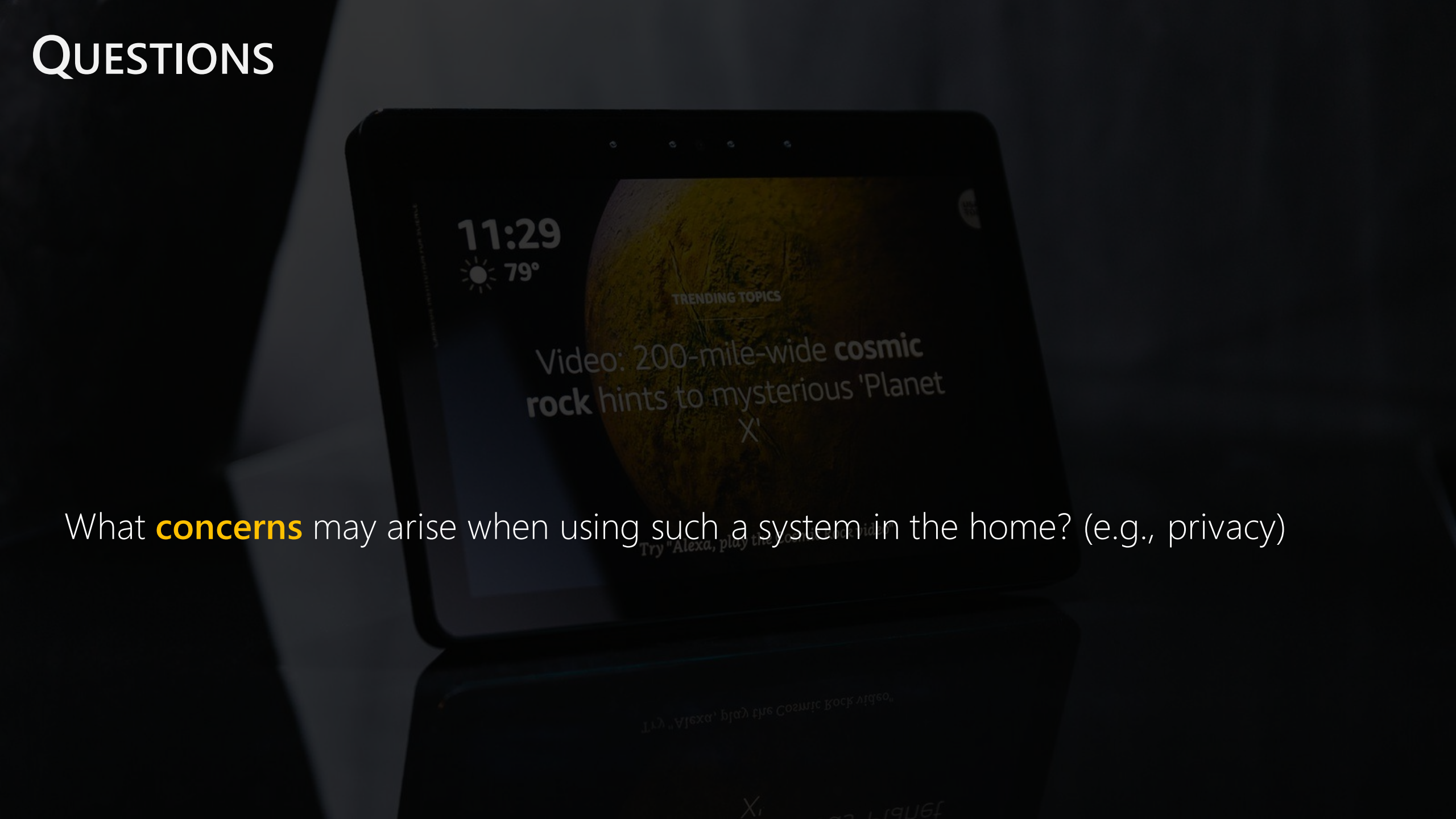
Questions



How would a sound awareness system **integrate** into the homes of DHH people?

What **concerns** may arise when using such a system in the home? (e.g., privacy)

QUESTIONS



What **concerns** may arise when using such a system in the home? (e.g., privacy)

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2. Scenarios-based evaluation

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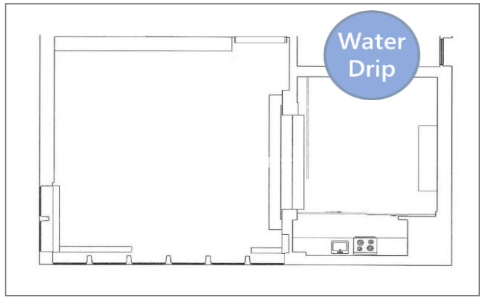
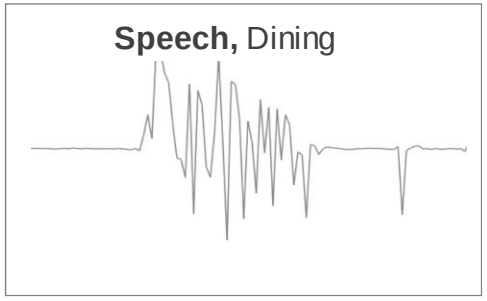
A. Bathroom → Privacy →



B. Babysitter → Activity Tracking →

Time	Sound	Location
16:01:21	Baby crying	Bedroom
16:01:32	Speech	Bedroom
16:02:42	Child playing	Living room
16:05:41	Refrigerator open	Kitchen
16:05:57	Refrigerator close	Kitchen
16:06:14	Liquid Pour	Kitchen

C. Movie → Information Overload →



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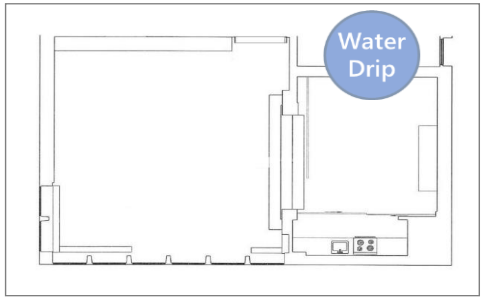

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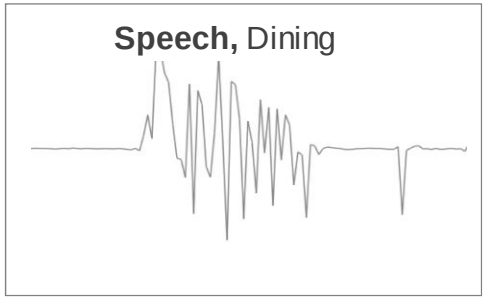

3. Interview on the experience

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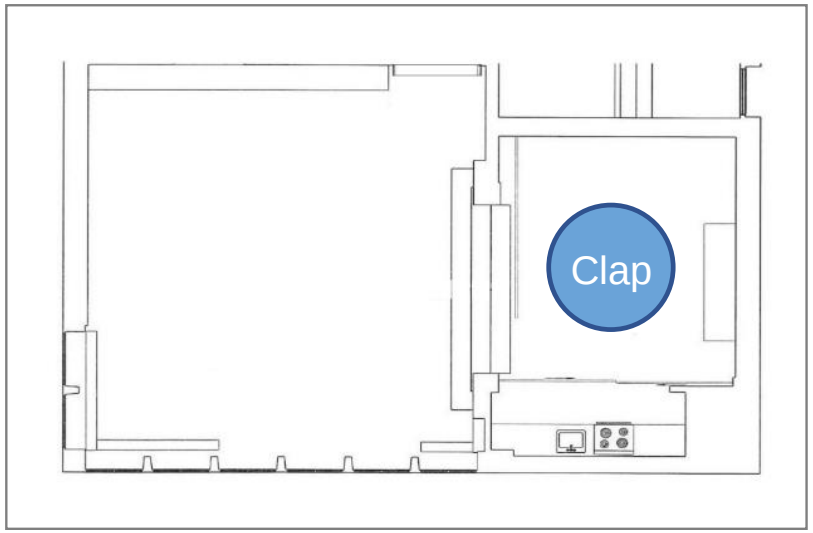
PROTOTYPE PREFERENCE



Most preferred

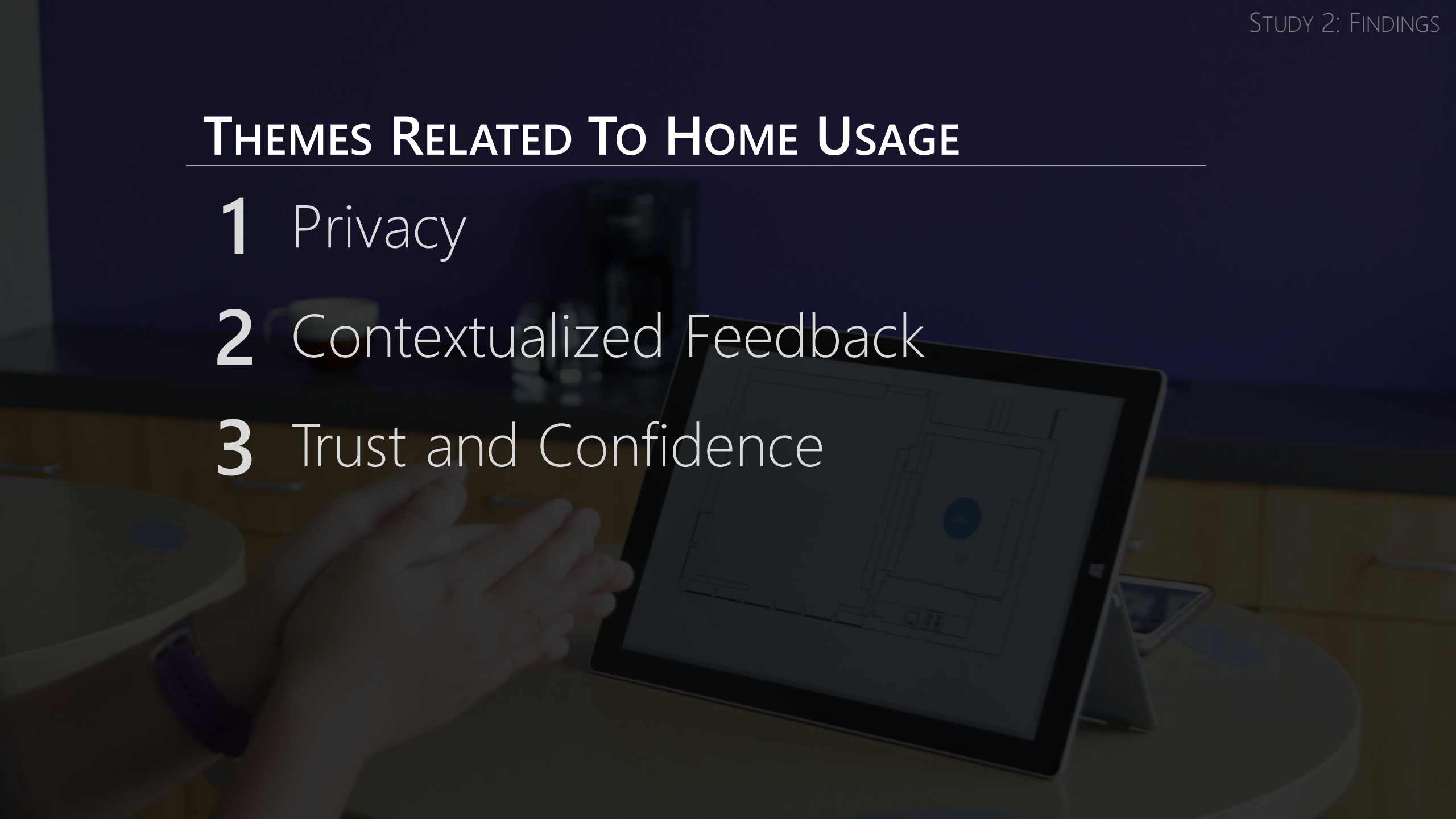
Search for sounds...

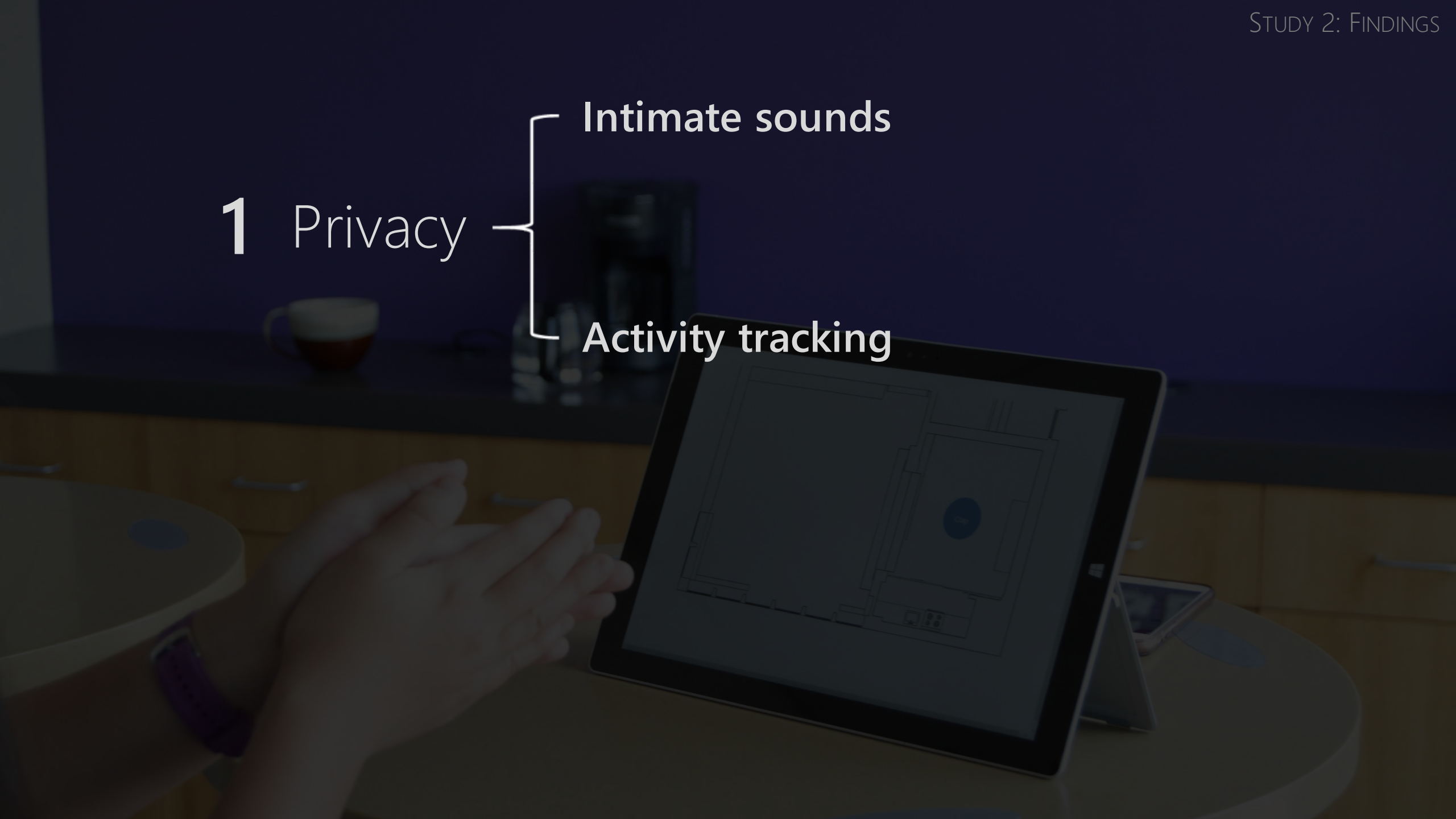
Time	Sound	Location
10:07:45	Microwave beep	Kitchen
10:08:01	Bird chirp	Outside
10:08:32	Clap	Dining

Least preferred

Themes Related To Home Usage

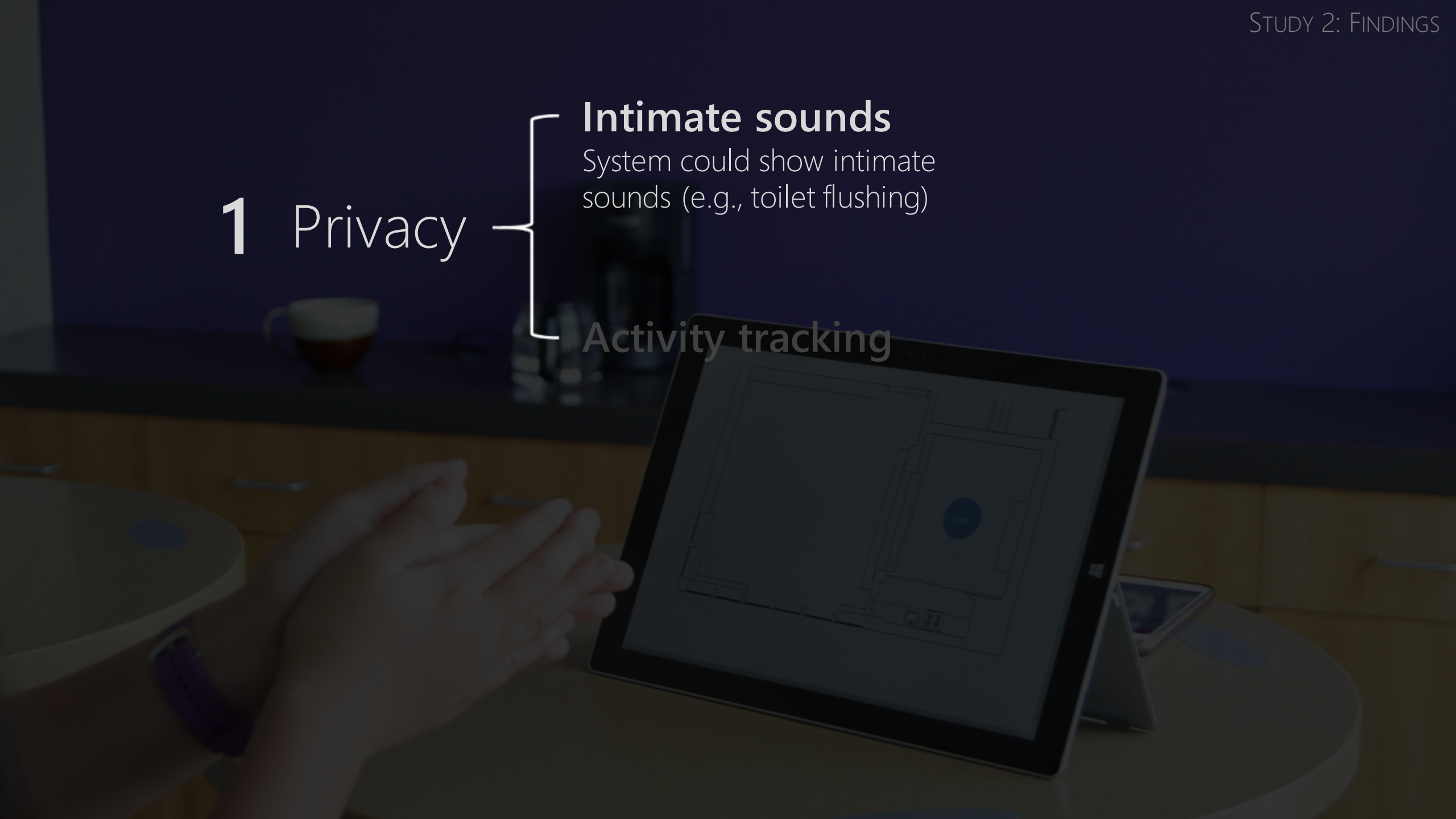
1. Privacy
2. Contextualized Feedback
3. Trust and Confidence





1 Privacy

- Intimate sounds
- Activity tracking

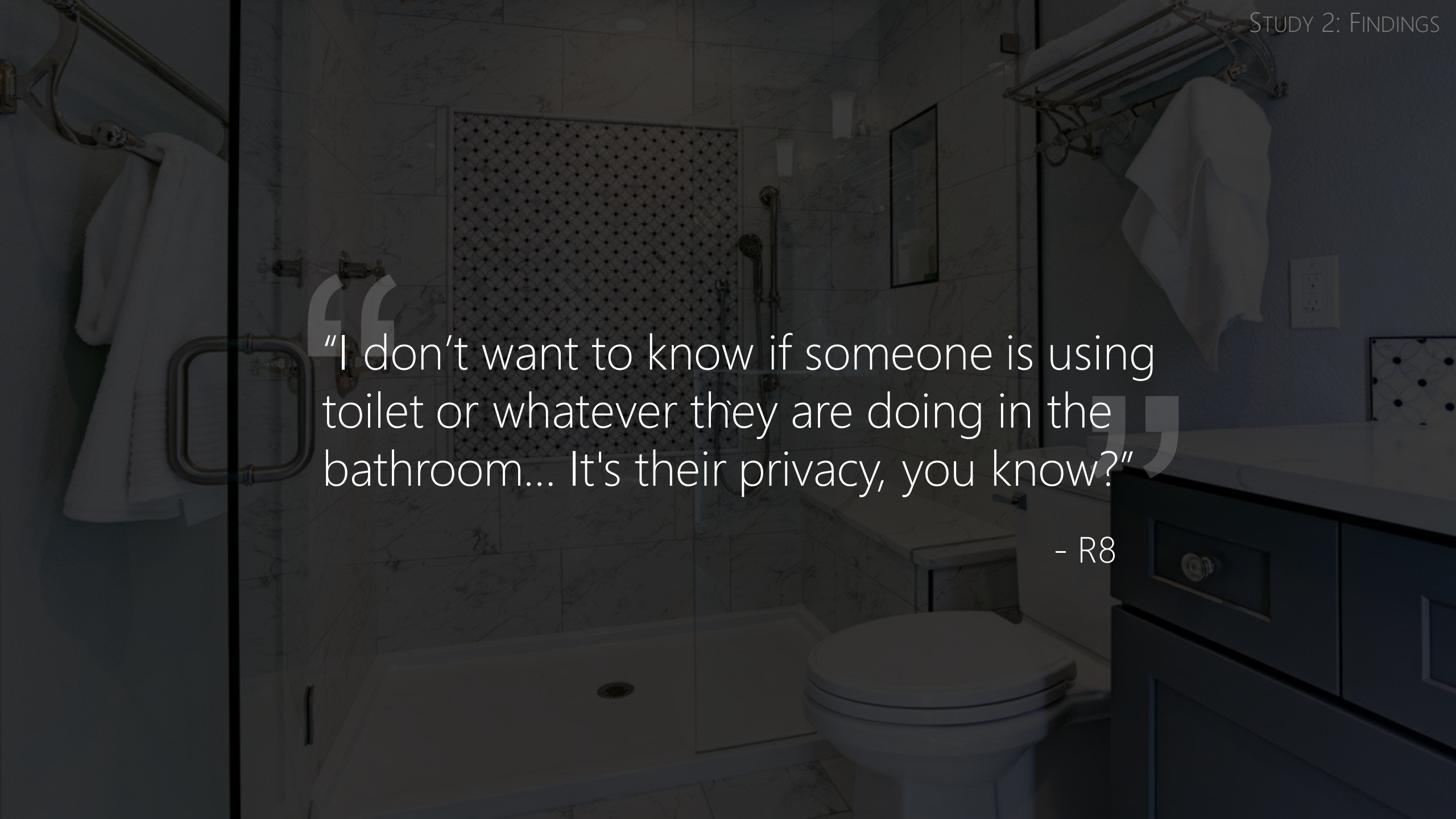


1 Privacy

Intimate sounds

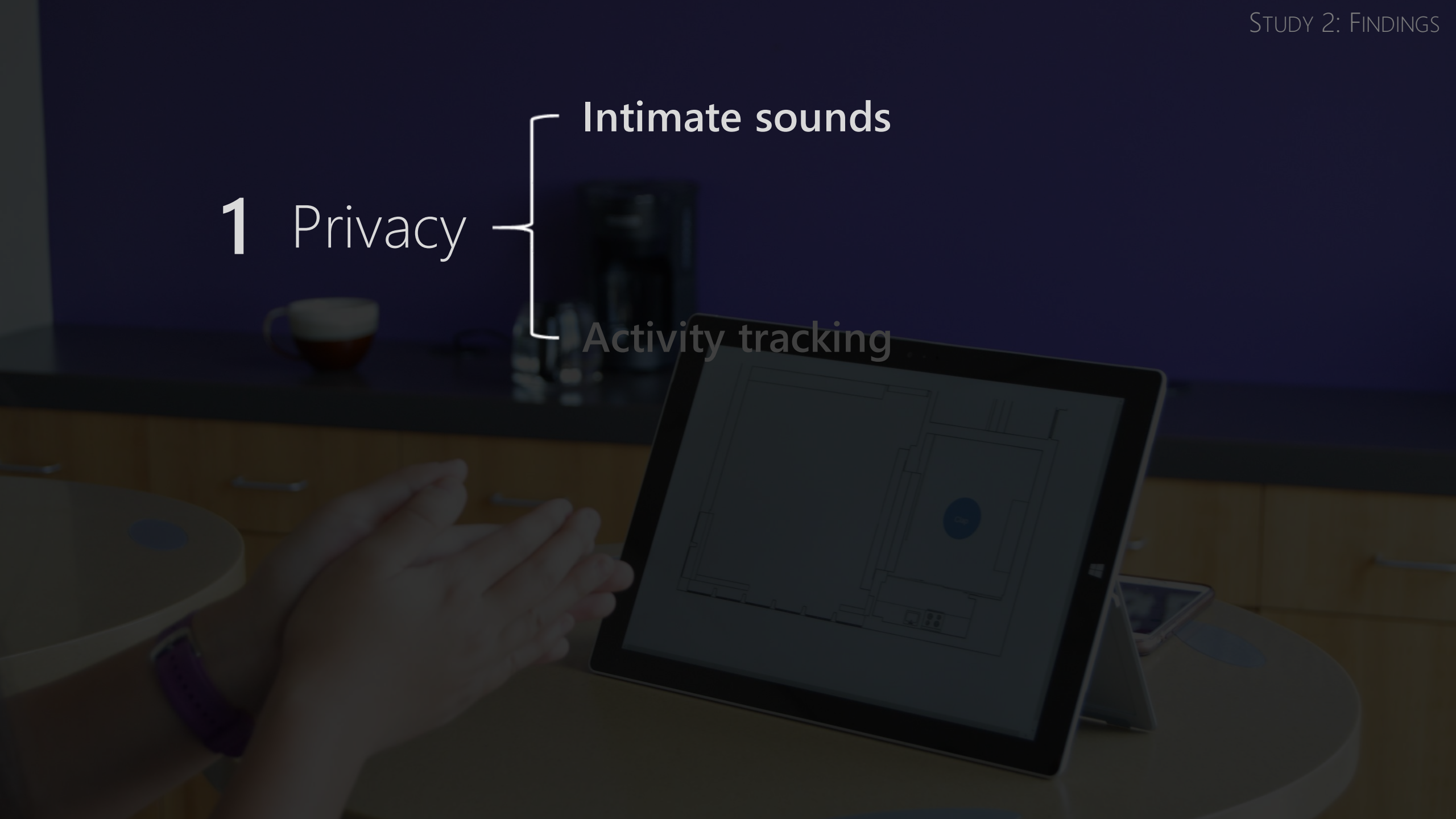
System could show intimate sounds (e.g., toilet flushing)

Activity tracking



“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?”

- R8


1 Privacy
Intimate sounds
Activity tracking

1 Privacy

Intimate sounds

Activity tracking

System may provide insight into other household members' activities

"People [would] avoid coming to my house because they're been monitored each and every moment…"

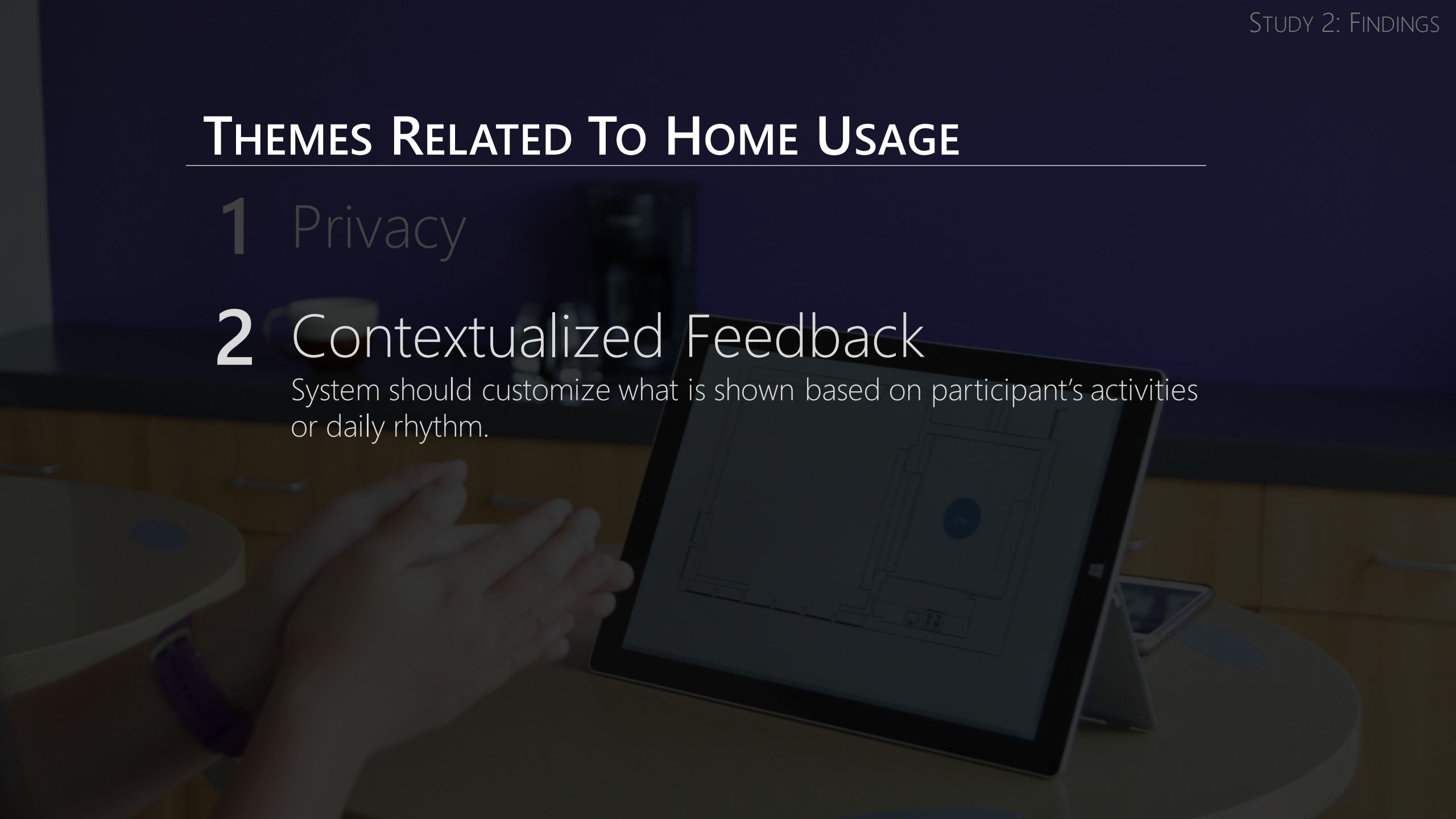
- R10

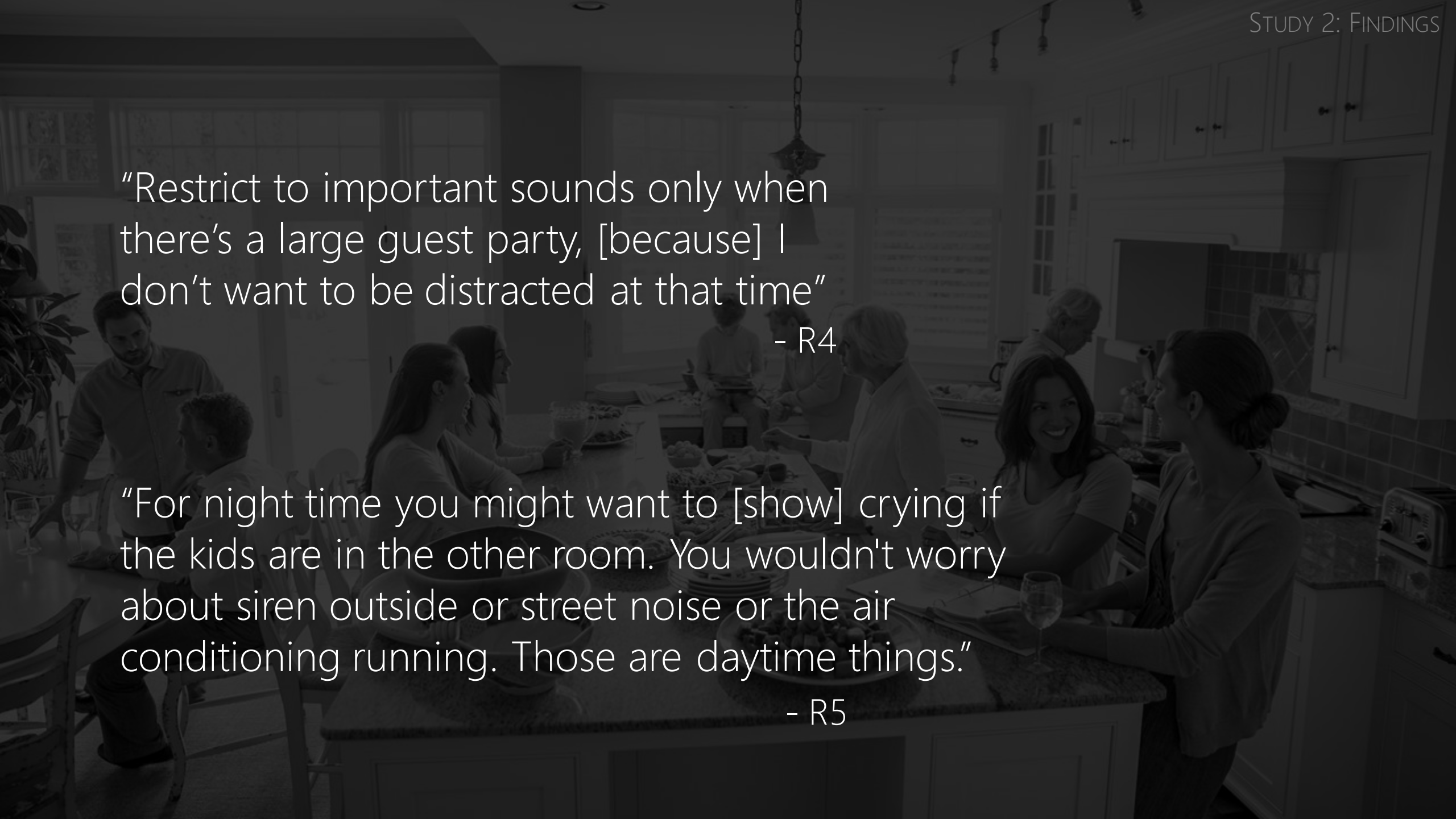
Themes Related To Home Usage

1 Privacy

2 Contextualized Feedback

System should customize what is shown based on participant's activities or daily rhythm.





"Restrict to important sounds only when there's a large guest party, [because] I don't want to be distracted at that time"

- R4

"For night time you might want to [show] crying if the kids are in the other room. You wouldn't worry about siren outside or street noise or the air conditioning running. Those are daytime things."

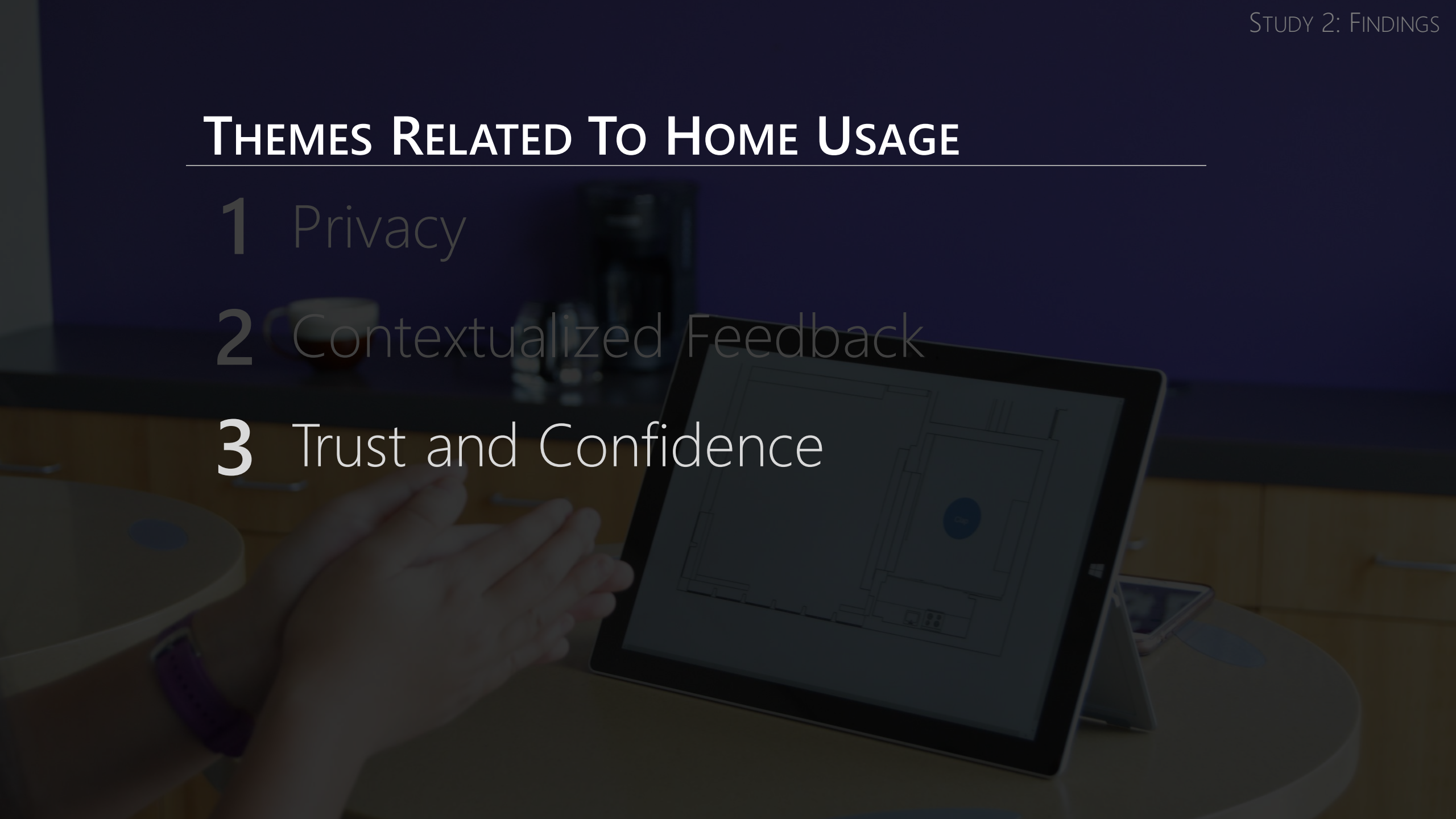
- R5

Themes Related To Home Usage

1 Privacy

2 Contextualized Feedback

3 Trust and Confidence



Themes Related To Home Usage

1 Privacy

2 Contextualized Feedback

3 Trust and Confidence

Because sound classification algorithms are probabilistic, we also asked participants about **possible ways to handle uncertainty in sound detection.**

Themes Related To Home Usage

1 Privacy

2 Contextualized Feedback

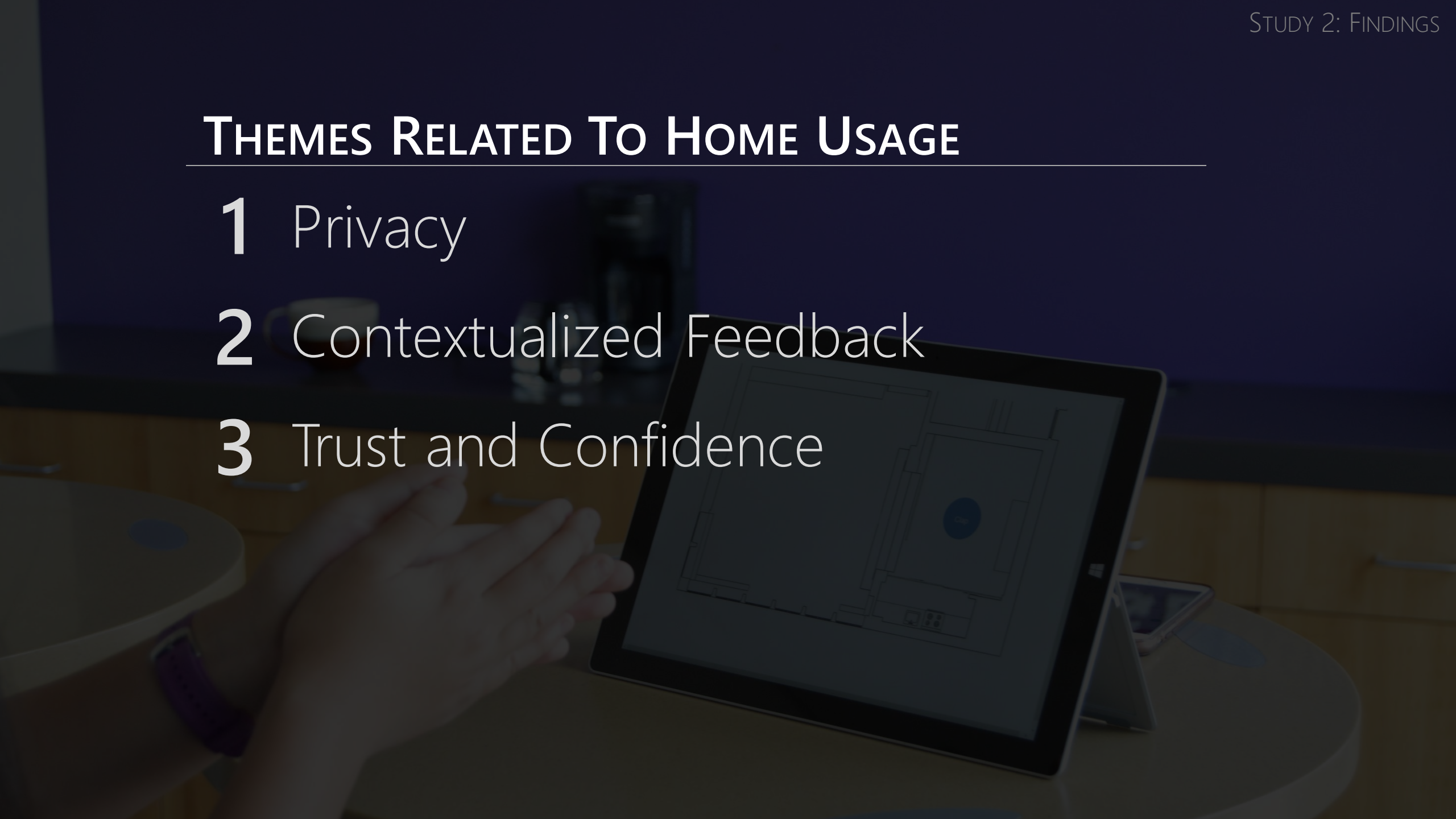
3 Trust and Confidence

All participants said they would use the system even if it **just shows the sound's location** but not its identity (e.g., bathroom but not toilet flush).

Most participants also felt that other uncertain information can be useful as well such as a **general category** (e.g., "an alarm-like sound", R8) or a **list of possible sounds** (e.g., "this sound could be a clock alarm or a microwave beep", R4).

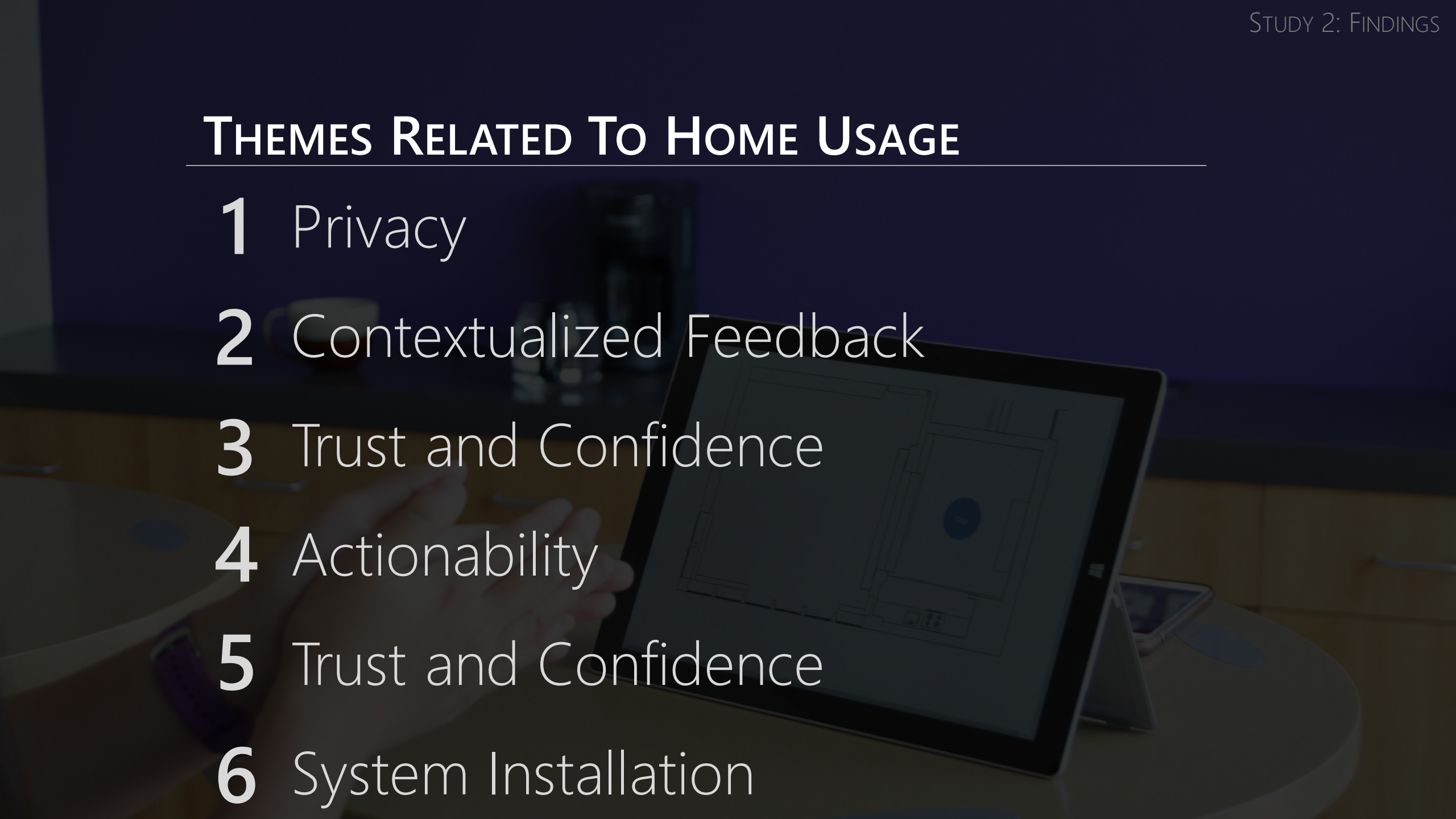
Themes Related To Home Usage

1. Privacy
2. Contextualized Feedback
3. Trust and Confidence



Themes Related To Home Usage

1. Privacy
2. Contextualized Feedback
3. Trust and Confidence
4. Actionability
5. Trust and Confidence
6. System Installation



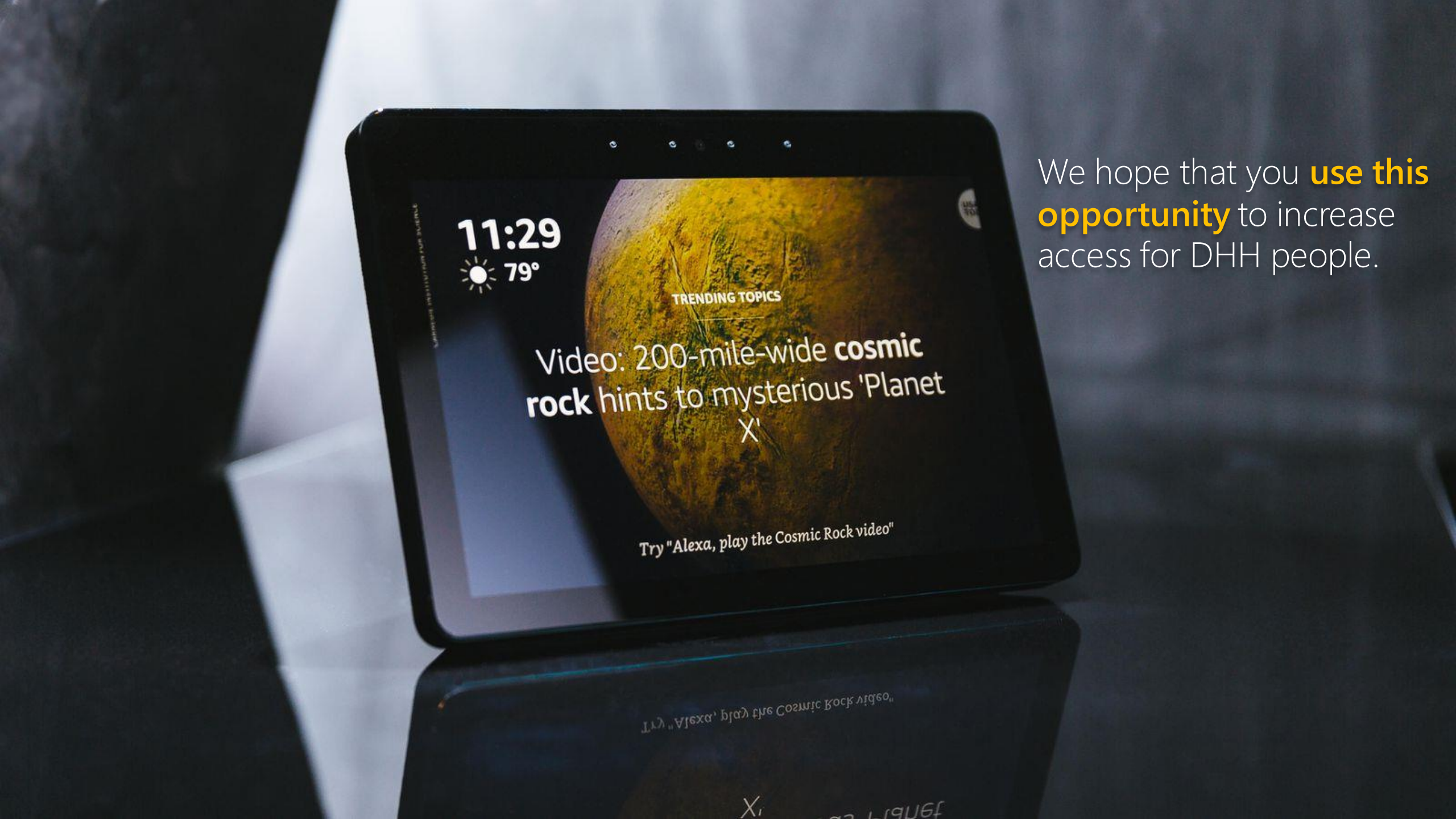
Themes Central To Home Usage

1. Privacy
2. Contextualized Feedback
3. Trust and Confidence
4. Actionability
5. Trust and Confidence
6. System Installation

These considerations give **direct guidance** for design for future in-home systems for the DHH people.

Reflections

Recent proliferation of **screen-based** smarthome devices offer a new opportunity to design for DHH people...



We hope that you **use this opportunity** to increase access for DHH people.

Considerations

1 **Home is a shared space.** Be mindful of *what* sound information is being listened to, and *where* the displays are installed.

2 **System should interweave into the domestic lives of people.** Use context cues such as daily rhythm (*e.g.*, night vs. day), user's location and activity (*e.g.*, not doing high-focused tasks) to select what to record and display.

3 **Handle uncertainty of sound recognition** by displaying additional cues such as location, possible list of sounds, or a general category (e.g. alarm-like sound).

Exploring Sound Awareness in the Home for People who are Deaf or Hard of Hearing

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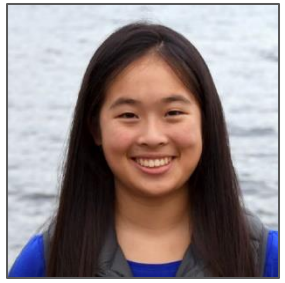

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