A Better User Interface for the Visually Impaired

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Abstract. As a Visually Impaired (VI) person, I find challenges in many tasks that a fully sighted person may not. Therefore, there is a large problem-space for task selection for my context. However, although the problem-space is extensive, it's not necessarily rich. That is, some of the tasks are simply out of scope for my condition, e.g., multi-tasking two or more visually intensive tasks. In selecting a task for this research, consideration was given to audiences that have a visual disability as well as those that do not. My research will involve evaluating an interface that offers users more than just pure visual interaction. This will include the interplay of haptic [1] and audible technologies for interface design.

1 QUALITATIVE EVALUATION

To obtain qualitative data, I evaluated a verbal prototype, which is a low-fidelity prototype for exploring the feasibility of a design. The objective is to evaluate the relative function of the interface early in the design lifecycle to verify the design with respect to user expectations. The evaluation will answer the question: *Does the interface have the potential to meet user goals?*

1.1 Qualitative Evaluation: Execution of Plan

Qualitative research was conducted with audience comprised of family *(two participants)* and friends *(two participants)*. The data was *synchronous*, *think aloud feedback* obtained in a *field* setting. In this case, *field* is loosely defined as my residence. The results were recorded by *notetaking* during the individual sessions with each subject. Since the number of participants in this study was small, to reduce discussion among participants, I chose to interview each in consecutive order over a single day. As I interviewed a participant, subjects waiting to be interviewed were secluded comfortably in another room. Each interview was completed within ten minutes.

[1] Haptic Technology

Future evaluations would include a larger set of participants with interviews organized over multiple-days. I would also revise the prototype to provide qualitative data for usability testing. For example, giving users the rapid wireframe, or even the paper prototype and having them *think aloud* could provide stronger insight into the user experience for interface design.

1.2 Qualitative Evaluation: Results from Think Aloud User Feedback

Refer to Think Aloud Feedback: Results for results of interview questions and responses for *think aloud feedback*. The question will be in bold, followed by the response of each participant in italic text. In summary, the four participants tended to agree in their thoughts. Most used the microwave for cooking and were able to grasp the concepts of my novel design, see figure 3a on page 6 for programming the **Cook, Defrost** time for the microwave. Most participants looked for distractions, mostly sub-tasking with a smartphone device while the microwave was performing their main goal of **cooking**. These participants mostly agreed that having just two options **COOK, DEFROST** were sufficient to accomplish their goals, and that my design may make the task of programming a microwave easier. Recall, the object of this interface is to make it **equitable** for all users, including those with a visual disability.

1.3 Qualitative Evaluation: Analysis and Future Work

This section will further explore and analyze the results from the *Think Aloud* evaluation data. I'll then discuss how the qualitative evaluation will feed back into the design lifecycle for future needfinding and prototyping.

When conducting *Think Aloud* studies, selection and confirmation biases [2] were considered. These biases can be introduced as participants become more thoughtful while experimenting with prototypes and thinking about responses. Thus, they will become more of an expert during the evaluation. To address this, there were more questions than answers during the evaluations. It should be noted that most users are *experts* with microwave interfaces and, although the interface I'm designing is novel, the learning curve for the subjects will follow a Sigmoid Function [3] and become more rapid after a warm-up period.

[2] Biases
[3] Sigmoid Function

The feedback from having the subjects *draw the interface* based on my verbal description was useful in gauging user perception of the interface, see figure 5 and figure 6 on page 12. The results were most interesting and gave me potential ideas for evaluating other design alternatives (see figure 2a on page 5. Also interesting was that most users could not *visually* program the microwave in the dark, implying a need for varied feedback such as *audio* or *haptic*.

Lastly, the qualitative analysis helped fill in *user subtasks* as defined during requirements gathering/needfinding and captured in the in the data inventory. Refer to the **Data Inventory** shown in figure 4 in APPENDIX. From this small set of users, I found that users tended to look for distractions when operating a microwave. Most users sought smartphone applications, which aligns with making my interface accessible from a smartphone application.

2 PREDICTIVE EVALUATION

A hand drawn paper prototype, refer to figure 1 was created for *predictive evaluation*. To reduce bias during predictive evaluation from qualitative evaluation, I performed predictive evaluation first. Since I am the user for predictive evaluation, any knowledge gained from *think aloud* qualitative analysis could influence predictive evaluation.

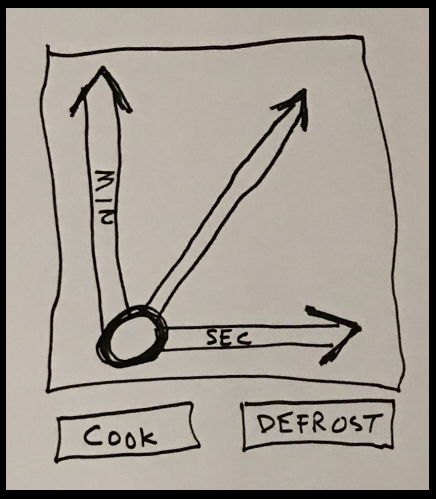


Figure 1: Paper Prototype: Touchscreen Interface

This paper prototype served as a *card based cognitive walkthrough* for *predictive evaluation*. To perform this evaluation, I stepped through the process of interacting with the paper prototype, mentally simulating a *novice user* interacting with the interface to accomplish the goals of programming the microwave to *cook* and *defrost*. Tasks associated with the goals will be explored in the context of bridging the users *gulfs of execution and evaluation*.

2.1 Predictive Evaluation: Cognitive Walkthrough

1. **Program the microwave to cook an item for 12:35 minutes.**
   ***Gulf of Execution**: A user will consider how to enter the time. They may touch the arrows, or even the disk at the origin of the second/minute axis. As this is a novel interface for entering cook time, the design is not consistent with other interfaces. Thus here is a risk that this interface will initially increase the gulf of execution for the user. In order to bridge the gulf of execution, the user will be allowed to experiment in order to discover operations to execute the task. After entering the time, a user will then hit the **Cook** button. This action will be invisible to most users, as this button has **affordances** that tell a user what to do.*
   ***Gulf of Evaluation**: While entering time, a user will look for feedback on the time duration they entered. Audio feedback when pausing over buttons can notify the user of potential actions and definitions. The varied audio and visual feedback combined with direct manipulation (pause-over) will help to lessen the gulf of evaluation for the user.*
   ***Design Principles and Heuristics**: This design will not be **consistent**, and may lack in **mapping** relations, or in "speaking the users language". However, the design is **simple** well **structured** without clutter. Another goal is to make the interface more **equitable** for visually impaired users.*

2. **Program the microwave to defrost an item for 8 seconds.**
   ***Gulf of Execution**: Similar to **Cook**, a user will consider how to enter the time. In this case, to enter seconds, the user will need to drag the disk along the **x-axis**. As this action is not intuitive, the gulf of execution for the user will likely be larger than entering **Minute: Second**. In order to bridge the gulf of execution, the user will be allowed to experiment in order to discover operations to execute the task. A user can drag the disk around, observing or listening to the time. After some initial time experimenting, the user can discover how to enter seconds and then hit the **Defrost** button to complete the task. The Defrost button has **affordances** that tell a user what to do, thus bridging the gulf of execution. **Gulf of Evaluation**: While entering time, a user will look for feedback on the time duration they entered. Audio feedback to notify the user of potential actions as well as button functionality could help to bridge the gulf of evaluation.*
   ***Design Principles and Heuristics**: This design will not be **consistent**, and may lack in **mapping** relations, or in "speaking the users language". However, the*

*design is **simple** well **structured** without clutter. Another goal is to make the interface more **equitable** for visually impaired users.*

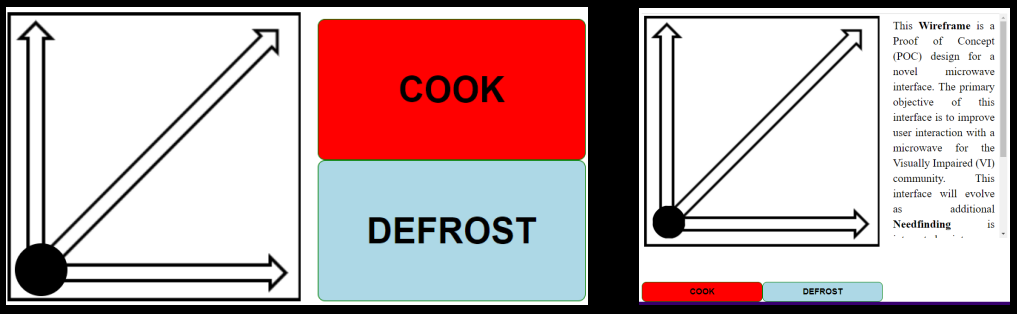
3 EVALUATION SUMMARY

Recall the rationale for choosing these forms of User Evaluation:

- **Qualitative evaluation can provide formative, early cycle evaluation of what the user *thinks* about the interface.**
- **Predictive evaluation can provide insight on user operations to accomplish goals using the interface in order to bridge the users gulf of execution. Feedback can also be simulated and analyzed to bridge the gulf of evaluation.**
- **At this stage of the design process, the physical prototype is not developed enough to support empirical evaluation.**

The information obtained from qualitative and predictive evaluation provided insight for future needfinding efforts. I'd like to explore more deeply into **how?, when?, why?** users employ varied feedback to accomplish goals. I would also like to better understand subtasks that users undertake when using a microwave. Lastly, I'd like to know what a users favorite application is and why. This information would provide greater appreciation of how users perceive interfaces to make my interface more *consistent* with other designs.

In considering results from these evaluation, I decided to tweak the design ever so slightly by making the **COOK, DEFROST** button form-factor larger and closer to the timing grid. I also added audio feedback to the wireframe [4]



(a) Revised Microwave Prototype **(b)** Initial Microwave Prototype

Figure 2: Microwave Prototypes

[4] Wireframe hosted on GitHub

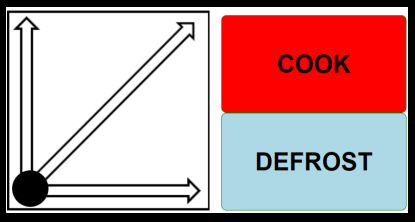
Qualitative evaluation suggested users may prefer a single, multi-functional dial as an interface to **[program time, set for cook, set for defrost]**, see figure 5 and figure 6 on page 12. Based on additional needfinding, some of these concepts may find their way into future design alternatives.

3.1 Future Work: Evaluation Plan

The next round of evaluation would put the wireframe in front of both visually impaired and non-visually impaired audiences for both qualitative (*think aloud feedback*) and empirical evaluation using a wireframe prototype. Employing an interactive wireframe will enable more accurately measurements for user tasks, while also providing a valuable usability engineering method for evaluating human factors.

3.1.1 *Empirical Evaluation*

In order to gauge user efficiency in programming a microwave interface, participants will be asked to program a microwave to cook an item for 12:35 and 7:00 minutes and to defrost an item for 49 and 8 seconds. The time for cook and defrost are deliberately chosen for values containing unique integers of different length [12:35, 49] as well as a single integer to the exact minute and second [7, 8] respectively.



(a) Treatment 1

(b) Treatment 2

Figure 3: Treatments: Prototype vs. Standard Microwave Interfaces

As previously mentioned, participants will be recruited from both visually and non-visually impaired audiences and will participate in two treatments, one employing a *standard* microwave interface, while the second will utilize the wireframe prototype.

The choice for the amount of time a user will enter is a *control variable* designed to minimize the effects of variables that are dependent on the interface, i.e., the difference in the timing controls between the two treatments. This approach

will also serve to minimize biases when programming the interface. Entering a time with a single integer, e.g., **7:00** minutes may introduce a bias to the treatments. Indeed, entering a time with unique integers, e.g., **12:35** may also introduce a bias. Conversely, utilizing both time formats will negate the effects of using either alone, thus, minimizing bias between the treatments.

1. **Treatment 1, Microwave Interface Wireframe Prototype** [5] **hosted on GitHub:**
   How long does it take a participant to cook an item for 12:35 minutes?
   How long does it take a participant to cook an item for 7:00 minutes?
   How long does it take a participant to defrost an item for 8 seconds?
   How long does it take a participant to defrost an item for 49 seconds?
2. **Treatment 2, Standard Microwave Interface:**
   How long does it take a participant to cook an item for 12:35 minutes?
   How long does it take a participant to cook an item for 7:00 minutes?
   How long does it take a participant to defrost an item for 8 seconds?
   How long does it take a participant to defrost an item for 49 seconds?

3.1.2 *Empirical Evaluation: Hypothesis Testing*

The *null hypothesis* is that the time to program a microwave will be *equal* for the two treatments. The *alternative hypothesis* is that the time to program a microwave for treatment 2 will be shorter than that of treatment 1. Thus, the proposed design will allow users to be more efficient in programming a microwave. The *alternative hypothesis* will be accepted if the results are *statistically significant*, i.e., there is less than a five percent chance that the difference in efficiency between the treatments could have arisen by random chance.

3.1.3 *Empirical Evaluation: Conclusion, Lurking Variables and Bias*

A *lurking variable* is a variable that is unknown and not controlled for. It may have a significant effect on the variables of interest, e.g., the amount of *time* it takes to program the interface. The experimental control that was defined in Empirical Evaluation can address lurking variables that may arise from a user programming the interface. For example, programming single integers for a *cook time* may introduce a lurking variable where the buttons of the interface may *stick or jam*.

[5] Microwave Wireframe

Some potential lurking variables that may be introduces are:

- **Treatment order for subjects participating in a within subjects design. Consistently assigning subject to experience one of the treatments first can introduce a lurking variable based on a static ordering of treatments.**
  *Account for this lurking variable by **randomly assigning the order** for participation in treatments.*
- **The differences in *human abilities* for each participant, i.e., vision, haptic dexterity and human cognition.**
  *Account for this lurking variable by **randomly assigning the order** for participation in treatments.*
  *Account for this lurking variable by **randomly assigning** participants to treatments.*

To moderate the effect of lurking variable, regression analysis will be utilized to analyze the data.

4 APPENDIX

4.1 Data Inventory

Data Inventory	Needfinding 1	Needfinding 2	Needfinding 3
Who are the users [age, gender, hobbies]?	Survey response show that most users prefer to visually intact with microwave interfaces: Visual: 16, Haptic: 9, Audible: 0 and have an average age of 33.88 +- 8.86485194462	I was not able to observe enough participants to qualitatively answer this question	This was not part of the data inventory for this needfinding plan
Where are the users?	This was not part of the data inventory for this needfinding plan	This was not part of the data inventory for this needfinding plan	This was not part of the data inventory for this needfinding plan
What is the context of the task?	From the survey responses, the user context is to Re-Heat or Cook food using the Microwave control panel as their preferred interface	This was not part of the data inventory for this needfinding plan	I was not able to observe enough reviews to qualitatively answer this question
What are the user goals?	User goals are to cook/heat/defrost food by interacting with the "native" microwave interface	This was not part of the data inventory for this needfinding plan	I was not able to observe enough reviews to qualitatively answer this question
What does the user need?	The survey response did dhow some level of dissatisfaction with existing microwave interfaces. From this data, I can cycle through additional needfinding, requirements and prototyping	I was not able to observe enough participants to qualitatively answer this question	User reviews corroborated dissatisfaction with programmable microwave interfaces. Conversely, some reviews preferred a more simplistic interface.
What are the user tasks?	Data from the survey show user tasks: Cooking: 14, Defrosting: 10, Re-heating: 21, Timer: 4	This was not part of the data inventory for this needfinding plan	This was not part of the data inventory for this needfinding plan
What are the user subtasks?	NA for this needfinding plan	NA for this needfinding plan	NA for this needfinding plan

Figure 4: Data Inventory

4.2 Think Aloud Feedback: Results

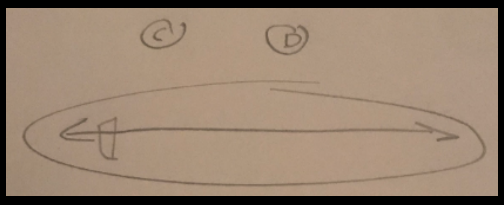
1. **Let's discuss cooking with a microwave.**
   - **What task you most often use a microwave to perform?**
     [P1: Cook, P2: Cook, P3: Cook, P4: Reheat]
   - **Do you ever get frustrated when performing this task?**
     [P1: No, P2: Yes, P3: No, P4: No]
   - **While using a microwave, are there any other tasks you perform?**
     [P1: Cook on a Stove, prepare menu items,
     P2: Fiddle with smartphone,
     P3: Fiddle with smartphone,
     P4: No other tasks]
   - **Can you program your microwave in the dark?**
     [P1: No, P2: No, P3: No, P4: No]
   - **What are you thinking about as you program the microwave? Do you have to think about how to program the microwave, or is this intuitive?**
     [P1: Thinking about the amount of time to enter,
     P2: Thinking about the amount of time to enter,
     P3: Thinking about social media,
     P4: Its easy, always enter one-minute.]

2. **I'm considering a microwave interface that will be used to program the microwave for cook and defrost and have a way to set the time duration for either of those two options. Do you feel like those two options are enough to accomplish your needs for using the microwave?**
   [P1: Yes, those options are sufficient. I almost always use the cook option and program the time,
   P2: Yes, although sometimes I like to quick cook by hitting "cook for one-minute",
   P3: I think that's all I need,
   P4: I suppose, but not sure when to use cook or when to defrost]
   - 2a. **Cook and defrost are the only options. Is this sufficient, or do you prefer more options?**
     [P1: Yes, P2: Yes, P3: No, P4: No]
   - 2b. **Would the addition of more options make this interface easier or more challenging for you to perform your favorite task?**

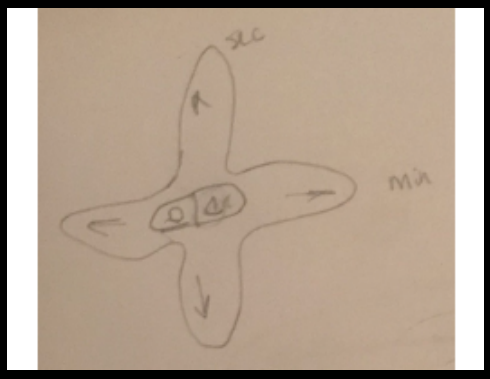
[P1: More challenging, P2: No difference, P3: No difference, P4: No difference.]

3. **The concept for setting the time is novel. It will not use digits [0-9] to enter the duration. Think about setting the volume on a YouTube video. You drag the volume button left or right to decrease or increase the volume respectively. Similar to setting the volume on a YouTube video, this interface will have a button that can be dragged to set the time. However, where the YouTube volume selector only moves in the horizontal plane, this interface will have a button that moves both horizontally and vertically, as well as any angle between 0 and 90 degrees. Consider your high school math class, the Cartesian coordinate system. This application will have a button at the origin [0, 0] which can be moved**:
   - **In a positive horizontal direction to increase the time by seconds**.
   - **In a positive vertical direction to increase the time by minutes**.
   - **In a negative horizontal direction to decrease the time by seconds**.
   - **In a negative vertical direction to decrease the time by minutes**.
   - **With a positive slope to increase the time by minutes/seconds. The steeper the slope, the greater the increase by the minute**.
   - **With a negative slope to decrease the time by minutes/seconds. The steeper the slope, the greater the decrease by the minute**.

     3a. **Please use this pen and paper to draw the interface I've just described.**

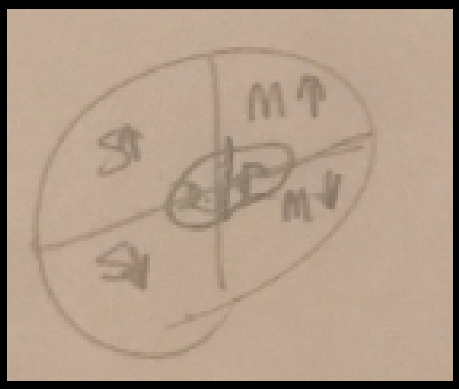


(a) Microwave Interaction Sketch: Participant 1

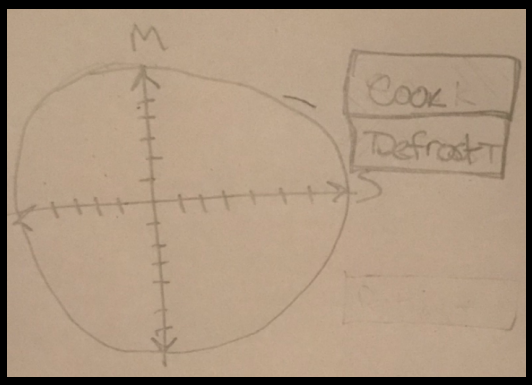


(b) Microwave Interaction Sketch: Participant 2

Figure 5: Microwave Interaction Sketches: Participants 1 and 2



(a) Microwave Interaction Sketch: Participant 3



(b) Microwave Interaction Sketch: Participant 4

Figure 6: Microwave Interaction Sketches: Participants 3 and 4

3b. **Using the diagram you've depicted, can you show and tell me how you would set the time using this interface?**
[P1: Drag the button in the oval disk to set the time,
P2: Enter the time by hitting the right side of the x-axis to increase the minutes, hit the left side of the x-axis to decrease the minutes. Hit the top of the y-axis to increase the seconds, hit the bottom of the y-axis to decrease the seconds.
P3: Touch inside the disk to set the time by minutes/seconds,
P4: Hit the COOK or DEFROST button and enter the time, minutes on the x-axis, seconds on the y-axis.]

3c. **Does this seem easier or more difficult that using a [0-9]**

keypad to program the time?

[P1: Once I get used to it, could be easier,

P2: Not sure,

P3: Easier,

P4: Not sure.]

3d. **We're concluding this session. before we part, and we're all warmed up - pun intended, tell me about your goals for a microwave interface?**

[P1: For the machine to last and be dependable,

P2: I'd like it to cook food quickly,

P3: To cook food,

P4: To cook food.]

3f. **Thanks for your time today, do you have any other thoughts or questions for me?**

[P1: Good luck with the project,

P2: Are you going to publish my sketch?,

P3: Nothing,

P4: Nothing.]