Should Heating up Leftovers be this Hard?

Evaluation and Redesign of a Microwave Oven Interface

Lakna Jayasinghe

University of Idaho

Abstract

        Since its introduction, microwave ovens have become a mainstay in the American household. For 52 years, consumers have been using the microwave oven to quickly and conveniently heat and prepare food and drink items. However, the design of microwave oven interfaces has scarcely changed over the past few decades. Present day microwave oven interfaces are still awkward to use due to reasons such as; (a) lack of meaningful feedback about the state of the item being heated in the microwave; (b) lack of discoverability of frequently used functions due to clutter in the interface; (c) feedback is loud and obtrusive. In this paper, I analyzed and redesigned the interface of the Mainstays 700W Stainless Steel microwave oven. Redesign elements were informed by user data collected through an online questionnaire (n = 257), as well as principles of engineering psychology. The redesign; (a) incorporates temperature of item being heated as meaningful feedback to the user; (b) minimizes number of buttons to increase discoverability of important time-based buttons; (c) allows users to mute loud and obtrusive audio feedback. Future steps include further examining the use of the auditory display as a means of providing meaningful feedback about the temperature of the item. Integrating smart phone and smart home devices may also help in providing user with more meaningful feedback about the heating process, and thus make the process more convenient.

Should Heating up Leftovers be this hard?:

Evaluation and Redesign of Microwave Oven

In 2011, 97% of households in the United States owned a microwave (Siebens, 2013). Since the introduction of the Microwave oven as an affordable household appliance in 1967, the device has been used for quick and convenient heating purposes to fit a fast-paced lifestyle. Although the appliance has become a mainstay in the American household, it is often considered awkward and bulky to use. Little has changed in the interface of the microwave oven in the last 52 years.

Microwave ovens often have an analog dial or a digital touch panel through which users may select the duration for which they would like to heat an item. Over the years, the number of options for selecting the duration of heating time has increased. Modern microwave interfaces provide various preset options that allow users to select heating options for specific food types such as popcorn or frozen vegetables, or defrosting options for thawing purposes at a lower power. Manufacturers have attempted to enhance the fulfillment of the appliance's main purpose, convenience, by introducing more and more heating selection options. However, the introduction of such options has lead to even more confusion about the heating process for users. Since the only information provided to the user about the heating process is the number of minutes of heating, users have to adopt a trial and error process to effectively heat an item in a microwave. When heating an item in a microwave oven, users typically select the duration of heating by guessing how much time is needed for the item to be heated effectively. Users rely on previous experiences of heating similar items in microwaves, or by following instructions given by the manufacturer of the item being heated. Often times the initial attempt of heating the item is inadequate, either because the heating duration was too short and the item has not reached the desired temperature, or because the heating duration was too long and the item is no longer edible. In the case of the former situation, users have to assess the temperature of the item by poking the food with a finger or utensil, insert the item back into the microwave, and restart the

process of estimating the duration for which to heat the item. This process increases the user's

time spent heating items and reduces the convenience of the appliance.

Project Goals and Requirements

In this project, I attempted to address the main issue of users having to adopt a trial and

error approach when heating items in a microwave to a desired temperature. I aimed to eliminate

the uncertainty around; (a) selecting the appropriate heating duration; (b) whether the item has

reached the state that the user desires for consumption. I will be analyzing and redesigning the

interface of the Mainstays 700W Stainless Steel microwave oven, as shown in figure 1.

Figure 1. Mainstays 700W Microwave Oven.

Features of the Microwave Oven Model

This model falls within the affordable range of microwave ovens. It has a small LED

screen used to indicate; (a) the current time; (b) heating time entered by the user; (c) weight of

item entered by the user; (d) any other feedback such as when the item is heated and ready. It

also has the standard time cook, time defrost, power, clock, timer buttons, and number pad found

on all microwaves. The interface of the microwave also consists of preset buttons that allow

heating for specific food such as popcorn, potato, pizza, frozen vegetables, beverage, and dinner

plate. The microwave also includes a start button that functions as the add 30 seconds button, as

well as a stop button that functions as a cancel button (See Figure 2). The microwave provides

auditory feedback in the form of beeps when heating duration is complete.

Figure 2. Interface of Mainstays 700W Microwave Oven.

User Research and Online Questionnaire

        To gain more information about how users typically interact with a microwave oven

appliance, I created a survey through Google forms. The questionnaire included multiple-choice

questions and open-ended text entry questions about the participants' microwave usage habits,

which features on their microwave oven they use most often, which features they like, and which

features they do not like. I was able to gather data from 257 respondents through the online questionnaire.

With the data that I collected, I was able to determine the following observations:

- Out of the 257 responses, 95.3% of participants indicated that they had a microwave in their homes (See Figure 3).

- Participants specified that the main purpose for which they used the microwave was to complete quick and simple actions such as reheating food and drinks (n = 192), rather than for purposes such as complex meal preparation tasks, as a clock, or as a timer.

- Most users indicated that they used a microwave between one to four times a week, or everyday (See Figure 4).

- Just over 81% of participants indicated that they used the microwave for heating tasks that lasted less than three minutes (See Figure 5).

- When asked to rank the buttons that participants most frequently used, 98 of the participants stated that they most frequently used the add 30 seconds button to carry out these heating tasks. Participants also selected the time cook button as the most frequently button (n = 76), while 71 participants selected the quick start keys on the number pad as the buttons they use most frequently.

- The data showed that many participants (n = 149) do not use the preset keys for specific food such as popcorn, frozen vegetables etc.

- When participants were asked which button they would look for when using a microwave they haven't used before they specified the time cook button.

- Participants also specified that they most often underestimate the time needed to heat adequately an item and have to reheat the item in a second attempt (n = 153).

- Additionally 61.1% of the participants mentioned that they stay close and try to complete other activities near the microwave while waiting for an item to be heated (See Figure 6).

The observations from the data, and their corresponding research insights are listed in Table 1.

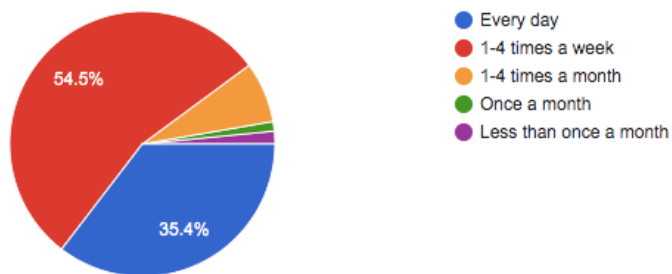## Do you have a microwave in your home?

257 responses
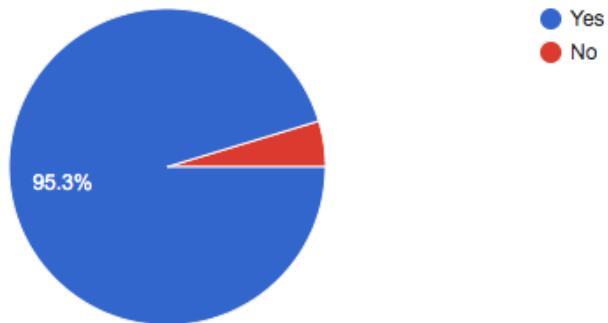
Figure 3. Observations from questionnaire about microwave usage. This figure illustrates the

percentage of participants that own/do not own a microwave.
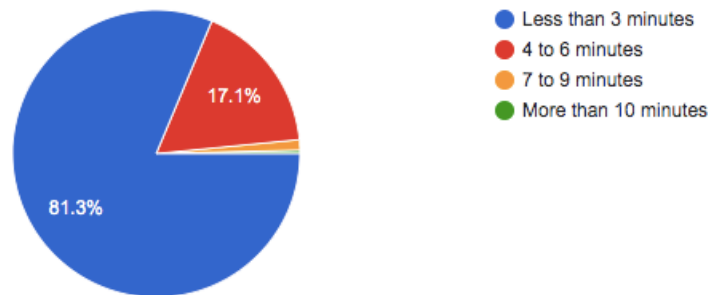
How often do you use a microwave?

257 responses

Figure 4. Observations from questionnaire about microwave usage. This figure illustrates how

often participants use microwaves.

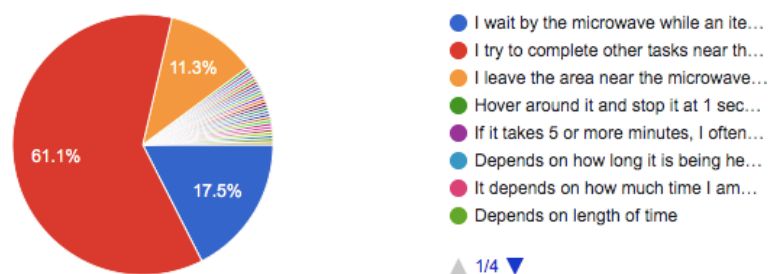## How much time do you most often heat your food or drinks for?

257 responses

- ● Less than 3 minutes
- ● 4 to 6 minutes
- ● 7 to 9 minutes
- ● More than 10 minutes

17.1%

81.3%

Figure 5. Observations from questionnaire about microwave usage. This figure illustrates the heating times participants use most often.

When heating food/drinks, do you usually wait by the microwave, or do you leave to complete another task in the meantime?

257 responses

- ● I wait by the microwave while an ite...
- ● I try to complete other tasks near th...
- ● I leave the area near the microwave...
- ● Hover around it and stop it at 1 sec...
- ● If it takes 5 or more minutes, I often...
- ● Depends on how long it is being he...
- ● It depends on how much time I am...
- ● Depends on length of time

△ 1/4 ▽

11.3%

61.1%

17.5%

Figure 6. Observations from questionnaire about microwave usage. This figure illustrates the activities users engage in while waiting for an item to be heated.

Table 1

Observations and Research Insights

Observations from Data	Insights
81% use microwave for heating tasks <3 minutes	Short increment time controls important
Most frequently use +0:30s button (n = 98)	+0:30s button is very important
Don't use preset keys (eg: popcorn) (n = 149)	Preset keys don't help – get rid of them
With unfamiliar microwave, first button to look for is time cook (40.9%)	Time cook button should be highlighted
Underestimate heating time on first try and heat (n = 153)	Feedback should be meaningful
While heating, 61% stay close by but do other tasks	Feedback must be multimodal (visual + auditory)
When deciding heating time, users rely on previous experience, or use trial and error approach	Improve information given to user about heating times
Beeping feedback can be loud, annoying & not very meaningful	Give users option to change feedback quality

Table 1

The data confirms that most users own and use a microwave quite frequently. Thus, it is important to streamline the heating process to ensure that users spend minimal time when heating items. Most of the heating tasks are quick and simple tasks of convenience. Hence, users should be able to access the controls for these quick tasks such as time cook button, add 30 seconds button, and quick start buttons easily. Users also tend to use buttons that involve time input more often than the preset keys. Furthermore, many users concentrate on other tasks in the vicinity of the microwave when waiting for an item to be heated, therefore any feedback should take advantage of the auditory modality that does not require physical shifts to gain attention.

The questionnaire also included several open-ended questions about the steps users take in the heating process, what they like or dislike about their microwave, and what they would like to see improved. Using the text analysis software of NVivo, I was able to examine word frequencies in the open-ended responses. Many participants stated that deciding the heating duration was based on previous experience, or a process of trial and error (See Figure 7 and 8).
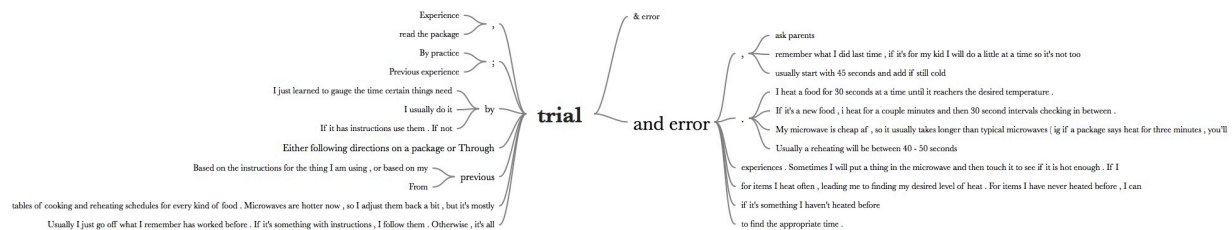
Figure 7. Word tree for "trial". This figure illustrates the most frequent words and phrases with which the word "trial" was used.

Figure 8. Word tree for "experiences". This figure illustrates the most frequent words and phrases with which the word "experience" was used.

I documented the most frequently mentioned concerns of the participants indicated in the open-ended text entry questions of the online questionnaire. Afterwards, I created an affinity diagram to group and examine the users' concerns in terms of various aspects of the microwave (See Figure 9). I grouped the responses in terms of the usability of the microwave, feedback received from the microwave, the functions and performance of the microwave, cleaning issues, and physical features of the microwave.

Usability

- I do like how mine uses dials for wattage and time instead of buttons. Buttons sometimes confuse me and look complicated.
- I guess the button types are too complicated for me. I just need strength of heat + time to heat or cook my food properly.
- Less buttons for random things
- I don't like that the buttons are not exceptionally easy to press. Flat buttons that are sensitive to the touch (more like tapping a phone screen than pressing a button) would be preferable
- My absolute most necessary feature is the 30 second button. One press and it starts. Simple.
- Fewer unnecessary buttons (do people actually even click the 'potato' etc. buttons?)
- Integrate with OK Google so I can yell at the microwave from my couch.
- Maybe your own custom preset options, like how you can preset your car radio stations.
- When the microwave asks for input, it never specifies the unit. Because they use the same 7-segment display, you never know if it's asking for pounds, time, power, or what.
- I also wish it was easier on all microwaves to change the power setting! It's always so confusing and it's unclear if I've actually properly done it or not, so more often than not I avoid it.
- I would like to measure food temperature
- Digital display so I can choose accurate timings

Feedback

- Oh! another thing: is there a reason why microwaves can't be silent??? or at least have that option. I don't like sounds when pressing buttons. But all of them have that.
- Volume button/dial for the beep would be nice, as mine is way too loud - to the point of me worrying about waking the neighbors if I use it during the night.
- A small screen showing stuff like temp, time, etc.
- Maybe auto clear the timer once a certain time has passed since the microwave has been in use.
- The beeping gets really annoying, but it is easily identified which is good.

Functions

- It doesn't heat evenly and I don't usually know how it works except for the 30 seconds button
- I wish there was more options to accurately change the temperature
- I hate the rotating tray, that requires removal and cleaning, v. our old microwave that had no spinning plate inside
- Stop the microwave when something goes wrong, like your food cooking over the bowl, because that is such a mess.
- Some magic way to heat the contents evenly so for things like leftovers I don't have to stir it and put it back in to avoid the inside being like ice and the outside like lava.
- Inconsistent power ratings. My childhood microwave cooked frozen veggies really well, but my apartment microwave nukes the ever living heck out of them. Same power rating on both.

Cleaning

- I wish they were easier to clean, also there's like a bazillion different buttons and that's annoying

Physical Features

- The ebonite door hook which locks the door; this is liable to break if entangled or hit by hand or a utensil.
- I wish my microwaves have had lighted buttons so they're easy to see in the dark

miro

Figure 9. Affinity diagram. This figure illustrates the most frequently mentioned concerns grouped in terms of usability, feedback, function, cleaning, and physical features

For this project I chose to focus on the usability and feedback issues of the microwave interface. Based on the usability of the microwave, the most prominent issue participants are facing is the complicated nature of the input methods available on the microwave interface. The multitude of buttons, as well as the ambiguity of the functions of the buttons appears to cause confusion to the user. Participants specified that the little feedback provided by the microwave in the form of beeps was intrusive at times. Additionally respondents mentioned that current feedback did not provide any specific information about the state of the item being heated, other than when the heating duration entered by the user is complete.

Analysis based on Engineering Psychology Principles

1. **Levels of Representation and Mental Models.** Levels of representation are important to consider when designing displays. The three levels of representation are; (a) physical level; (b) internal level; (c) display representation. The utility of the display that incorporates levels of representation lies in the compatibility between these levels of representation. When the properties of the display are compatible with the constraints of the natural physical system it represents, there is high ecological compatibility. Displays with high ecological compatibility are designed not just in terms of the physical aspects of the system, but also the purpose of the system. The main purpose of the microwave is to conveniently heat items to a desired temperature. Although the use of microwaves to heat items is a method different to other cooking appliances such as the conventional oven and stovetop, the user's goal of using these appliances is to heat the item and increase the temperature of the food or drink item being prepared. Conventional ovens and stovetops incorporate the representation of the physical system of kinetic energy through the standard measurement of temperature.

   Microwave ovens do not make use of temperature as a method of representing the state of the item being heated. The controls and display of the microwave do not correspond to the physical level of representation, as there is no indication of the temperature. Furthermore, it is challenging to build a mental model based on the current microwave interface as the outcome of using a microwave (state of the item heated) varies greatly for each microwave because of Wattage differences, and power selection differences. Thus users' expectancies of the state of the item being heated may not be met from one microwave to another. I suggest incorporating temperature as a standard representation of the physical system to the user to help users build better quality mental models of the microwave. Users can then develop an internal level of representation that is compatible with the physical system that will help users form more accurate expectancies of the outcome of the system. By providing the user information about

established temperature ranges for safe food handling in combination with temperature information, the user's mental model can be further improved.

2. **Direct Retrieval Strategy – Heuristics and Biases in Uncertain Choices.** According to the data obtained through the online questionnaire, users rely on previous experience with microwaves to make choices about the number of minutes to heat an item in a microwave. This strategy may turn out to be unsuccessful when trying to heat an item to the desired temperature in a microwave on the first attempt, due to the variation in the outcome because of performance differences in microwaves. Due to these performance differences, mental simulations may not accurately predict the outcome of the choice.

3. **Lack of Meaningful Feedback - Expertise and Experience in Decision Making.** Most individuals have used a microwave to carry out heating tasks and have gained practice by interacting with a variety of microwaves, yet users still cannot effectively decide the duration for which an item should be heated in a microwave and whether the item has reached the desired temperature. This is due to the lack of meaningful feedback about the item being heated provided by the microwave to the user. The feedback provided by current microwaves, in the form of simple beeps, provides very little information about the state of the item being heated. The beeps are used to indicate that heating time has ended, and even act as feedback when pressing buttons on the interface. However, users found the poor form of auditory feedback to be annoying, loud, and obtrusive.

Although selecting a specific duration to heat an item would be successful in a specific microwave, the same actions may not yield the same result when attempted on a different microwave. Thus, when redesigning the microwave interface I would like to incorporate temperature into the display as way of providing meaningful feedback. Providing interpretable information about the temperature of an item in the display of the interface may act as a decision support tool that would allow users to effectively estimate

how much longer the item needs to be heated to get to the desired temperature, without having to take the item out of the microwave to assess the temperature.

4. **Seven Principles of Design – Discoverability.** According to the data I collected through the online survey, most users tend to focus on the time-based buttons when selecting a heating time. The time-based controls that are typically found on a microwave interface are; (a) the time cook button which, after pressed, allows users to select the exact heating time using the number pad; (b) the quick time buttons that allow users to press a button on the number pad once to start the microwave for the specified minutes (this functionality is usually added to the one to six buttons on the number pad); (c) the add 30 seconds button that allows users to add 30 seconds to the current heating time. Although these time-based buttons are the most frequently used buttons, their discoverability is low. In the questionnaire, majority of users (40.9%) indicated that the first button they look for when interacting with an unfamiliar microwave is the time cook button. However, the time cook button blends in with the other preset buttons in the current microwave interface and is not immediately discoverable to the user. The quick time buttons embedded in the numbers one to six in the number pad are also not discoverable to the user. There are no visual indicators that show that these number buttons can carry out different functions within the microwave interface.

Redesign of the Interface

When redesigning the interface I attempted to address the following issues,

1. Heating process is inconvenient and takes longer when items are not heated to the desired temperature in the first attempt.

2. Current interface consists of complicated number of buttons that often go unused.

    a. Preset buttons are usually unused.

    b. Users most frequently used time-based buttons.

3. Feedback given by current interface is not meaningful, loud, and obtrusive.

Streamlining the Heating Process. When addressing the issue of the inconvenience of the heating process, I attempted to streamline the heating process by eliminating the additional step of having to take the item out of the microwave to assess its temperature and reheating it. I incorporated information about the temperature of the item obtained from an infrared thermopile sensor into the display. This would allow users to effectively estimate how much longer the item needs to be heated for without having to extract the item from the microwave. The display will also provide temperature information while the item is being heated, thus allowing users to observe the current temperature and add heating time without stopping the current heating cycle. The microwave display will also have guidelines indicating the typical temperatures that are recommended for safely heating food by the USDA (2019). The temperature guidelines I incorporated are the following; (a) temperature of items that is cold/refrigerated will be at around 48°F; (b) items at room temperature will be around 68°F; (c) items at hot temperatures will be at a minimum of 165°F; (d) items (specifically beverages) at boiling temperature will be around 212°F (See Figure 10). The guidelines are also **color-coded to represent specific qualitative information**. For example the guideline for the cold temperature is blue as the color has the cultural meaning of cold temperature, whereas the guideline for the hot and boiling temperatures are orange and red as these colors are culturally associated with hot temperatures. The redesign also takes advantage of **emergent features**, by incorporating the different colors of the temperature guidelines into the color of the circular progress bar as the item increases in temperature (See Figure 11 and 12).

Emphasizing Time-Based Buttons on the Interface. According to the data I obtained through the online questionnaire, users rarely use the preset buttons that are specifically for certain types of foods such as popcorn. To address the clutter of heating options in the interface, I eliminated the preset buttons from the interface and emphasized the time-based buttons such as the time cook button, the quick time buttons of one, two, and three minutes, and the add 30 seconds button. I also enhanced the **discoverability** of the time cook button by increasing the size of the button to make it more prominent. I also increased the discoverability of the quick

time buttons of one, two and, three minutes by changing the color of the background of these

buttons.

Ability To Change Auditory Feedback. Respondents of the questionnaire also indicated

that the current auditory feedback given in the form of beeps is loud and unpleasant. I attempted

to resolve this issue by adding a mute button that gives users the option to turn off the auditory

feedback when desired. The integration of temperature into the display addressed the issue of

providing meaningful feedback.
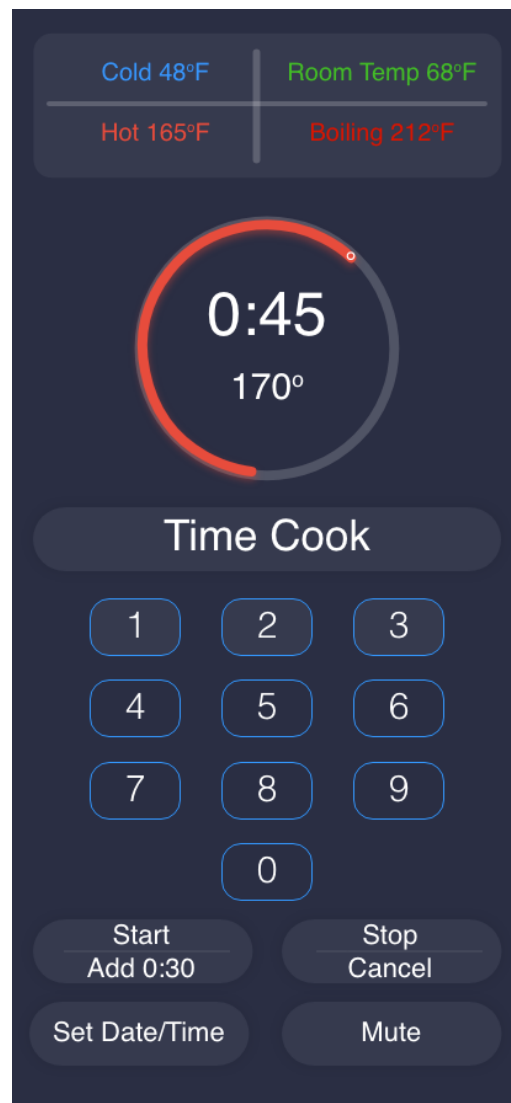
Figure 10. Prototype for microwave interface. This figure shows the microwave interface when
an item has reached the temperature range that is above the "Hot" temperature guideline.
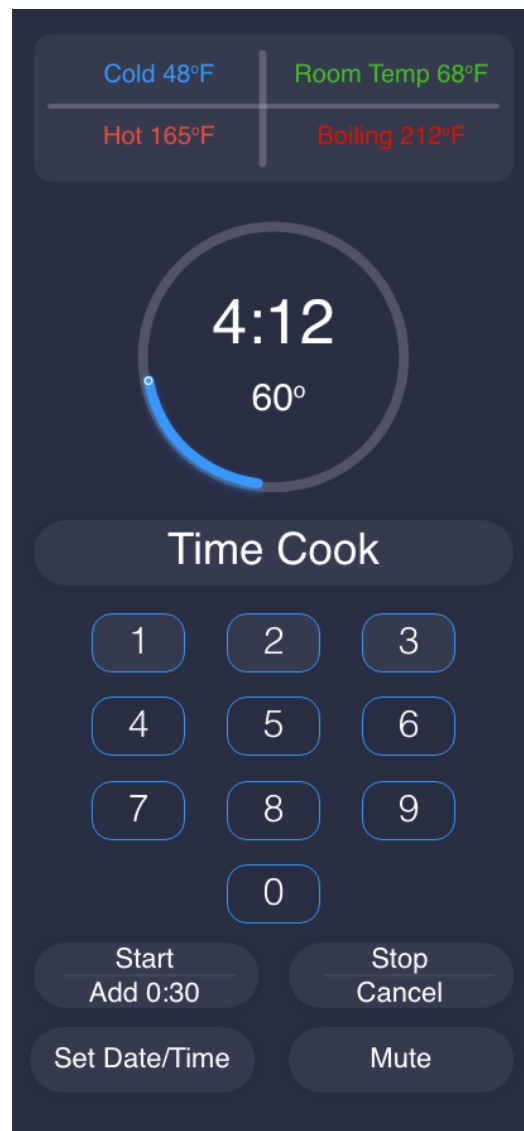
Figure 11. Prototype for microwave interface. This figure shows the microwave interface when an item has reached the temperature range that is between the "Cold" and "Room Temp." temperature guidelines.
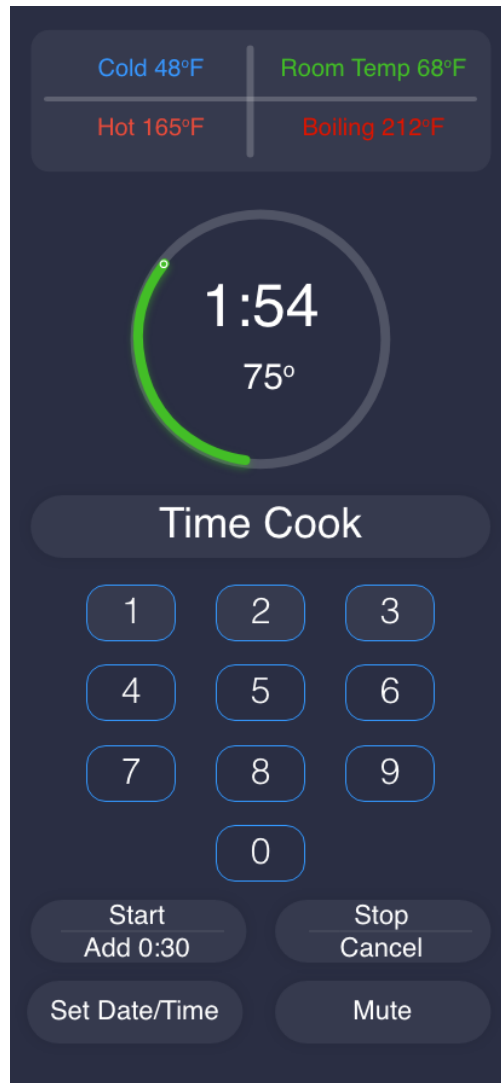
Figure 12. Prototype for microwave interface. This figure shows the microwave interface when

an item has reached the temperature range that is between the "Room Temp." and "Hot"

temperature guidelines.
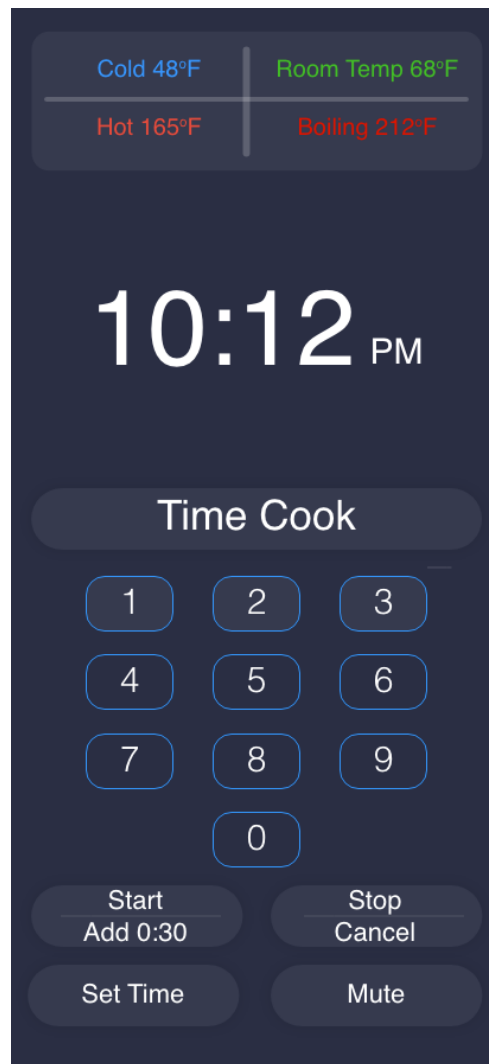
Figure 13. Prototype for microwave interface. This figure shows the microwave interface in

resting state and time is indicated.
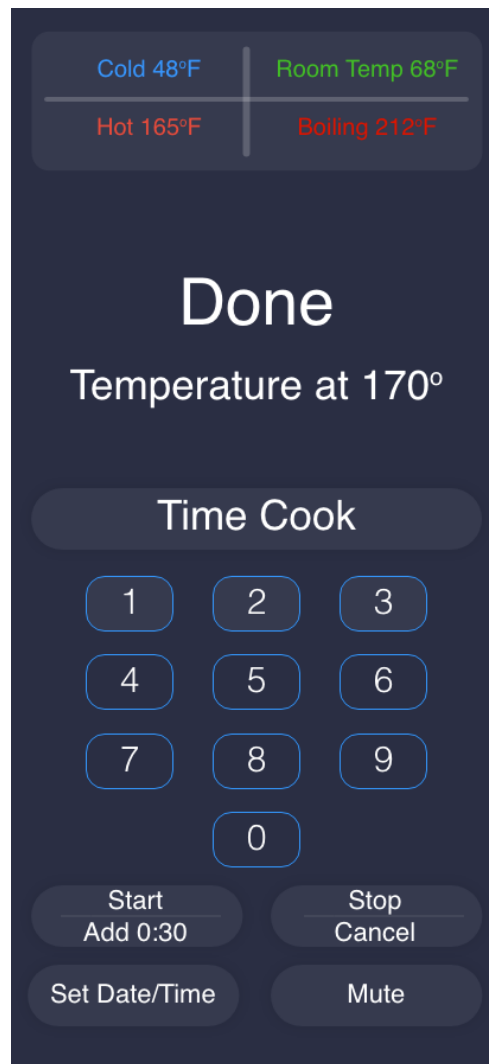
Figure 14. Prototype for microwave interface. This figure shows the microwave interface when the specified heating time is completed.

Future Steps

In the future I would like to further examine how to use an auditory display to provide feedback about temperature. Since majority of the participants of the online survey indicated that although they tend to stay near the microwave when waiting for items to be heated, they concentrate on other tasks while waiting. Transforming the temperature information into auditory feedback will grab the user's attention and awareness about the state of the item being heated without the need for the user to break away from their current task. I would also like to look into

integration with smart phone applications such as Ok Google and smart home devices. Syncing the microwave to a smart phone can allow for the provision of more meaningful feedback and the ability to control microwave functions remotely. This would further eliminate the guesswork and the inconvenience of using a traditional microwave oven.

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