

The Design and Evaluation of User-Interface Prototypes for a Next-Generation Dishwasher Mobile Application

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Abstract—Dishwashers have become an integral part of most American households and with the advent of technology, there is an opportunity to integrate smart features such as Wi-Fi connectivity, new user interfaces, and autonomous operation. The focus of our work is to inform the design of a next generation dishwasher. Here we provide research on how the smart technologies may change the paradigm in which users interact with their dishwasher and present an initial mobile prototype based on our research to improve the dishwashing experience. This study included three phases. For phase 1, we gathered data to inform the design of a mobile application prototype that included data information gathering from 31 user interviews, seven user daily-use diary interviews, and 164 questionnaires. For phase 2, we developed a mobile application prototype. For phase 3, we evaluated the mobile application prototype with 10 users. Our results thus far have shown that users are frustrated with the lack of transparency and understanding of all the functions available with their dishwasher, but have positively responded to using a mobile application to improve their understanding of their dishwasher. Overall, we believe that smart technologies have a potential to revolutionize the dishwashing experience; however, we believe that an effective UI design is critical towards that goal.

Keywords—*user interface, design, smart home appliance*

I. INTRODUCTION

Smart household appliances have become increasingly popular and affordable. For example, dishwashers have become an integral part of most American households and users expect the appliance to adapt to their necessities. Major appliance companies are in the process of creating the next generation dishwasher that will have features such as Wi-Fi connectivity,

new user interfaces, and autonomous operation. The objective of this project was to develop a prototype of a mobile application to improve the user dishwashing experience. To this end, we conducted additional research on the current dishwasher landscape and similar markets, user interviews, surveys for potential users, created a prototype based on the information from the past activities, and conducted usability testing sessions.

II. BACKGROUND

A. Usage of Dishwashers

A study from the U.S. Energy Information Administration (EIA) found that, out of 80 million households with dishwashers, 54% of households use a dishwasher at least once a week [1]. Improving the dishwashing experience could potentially benefit many people across the United States and the world. The next generation of consumers are comfortable with technology and may expect more features to be present in their devices and appliances. The rapidly growing demographic of tech-savvy consumers require a new approach to determine how best to integrate technology in people's lives.

Smart technologies have been rapidly emerging and pervading throughout a multitude of industries such as the connected home device industry, and increasingly, the household appliance industry. For example, there has been a positive reception to smart washing machines that add enhanced features to standard dishwashers such as Wi-Fi connectivity and smartphone controls [2].

B. User Interface Components

Our goal is to extend the aforementioned concepts to the design of a next generation dishwasher and begin to consider how to integrate smart technologies that include advanced sensors, Wi-Fi connectivity, and autonomous features and how this may change the paradigm of how people interact with dishwashers. To create an effective user interface, it is important to consider factors that influence user behavior ranging from the size of the household to typically overlooked personal characteristics like age, sex, and religion [3]. The usability of a user interface (UI) is important because limited functionality would result in user dissatisfaction and a UI that is too technologically advanced can become unusable to the user. Fig. 1 provides a visualization of the primary UI components for a dishwasher that would need to be considered in a futuristic dishwasher. Based on the findings from Jin, Ji, Choi, and Cho (2009), Fig. 2 provides an overview of how different design factors influence people’s preference towards dishwashers. The findings based on 200 in-house consumer surveys showed major factors include: label icon, size, rack size, shape of the knob, and LCD size. A major finding from this study shows that most users do not fully comprehend the capabilities and user interface of their dishwashers [4]. Therefore, this project aims to ensure that the user interface—namely a mobile app interface—is intuitive for the consumer and allows the consumer to be cognizant of the dishwasher’s operational capabilities.

As part of this line of work, we aspire to develop a UI that would provide the features and experience that address current pain points in the dishwashing process, improve usability, and provide the features that are expected by consumers for a 21st-century technology.

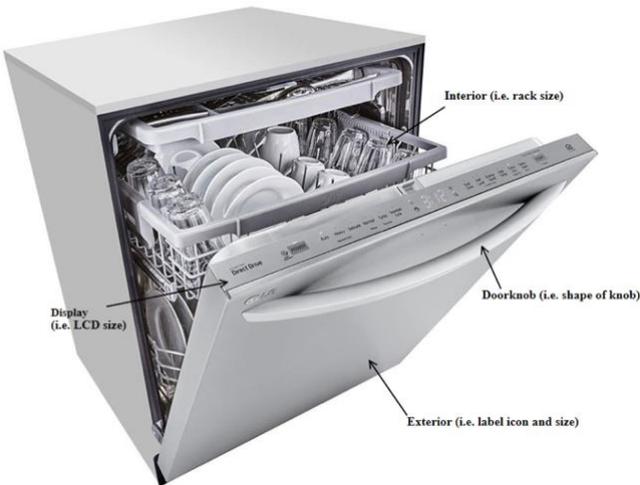


Fig. 1. The labeled dishwasher identifies the primary physical counterpart to the terms used to describe influencing features which contribute to consumer behavior.

Component of Dishwasher	Physical Design Factor	Degree of Influence (%)
Exterior	Label icon	21.50
	Size	21.64
	Button shape	15.82
	Color	10.44
	Panel size	9.95
Interior	Button color	8.23
	Rack size	41.47
	Bar	32.11
	Strength of bar	17.95
Doorknob	Distance between racks	8.47
	Shape of knob	67.40
	Thickness	32.60
Display	LCD size	26.56
	Display font type	22.16
	Color	20.47
	Control sound	14.91
	LCD font size	9.02

Fig. 2. The generated dishwasher’s physical design factors and the degree of influence. There are four main dishwasher components (e.g., exterior, interior, doorknob, and display) with a percentage breakdown of each physical design factor’s influence on consumer behavior. The highlighted components indicate the physical design factors with the greatest influence on consumers based on the various components of the dishwasher [5].

III. METHODS AND DESIGN

Our approach included three phases: (1) user research, (2) mobile application prototype development, and (3) user evaluation. For phase 1, research included gathering information about user experiences. For phase 2, prototype designs were developed in Figma (a web-based wireframing/prototyping tool) based on the findings from phase 1. For phase 3, the prototype was evaluated with potential users. The findings from phase 3 will be used to refine the usability of the initial prototype.

A. User Research

Our initial industry research was to gather information on the current dishwasher market and similar markets to see how smart technologies have been implemented. The findings here were mainly to inform the design of questions to be asked during interviews and in the surveys. We visited home improvement and appliance stores such as Lowes, to get hands-on experience with different dishwashers and to get a better understanding of how they looked and operated. We also interacted with the sales staff who were helpful in providing insights about which brands were most popular and what features customers have questions regarding.

Next, we conducted user interviews where the goal was to have conversations/semi-structured interviews with current dishwasher users. In total, 32 people were interviewed and the full histogram of the ages of interviewees is shown below in Fig. 3. The mean age of interviewees was 33 years old, and 33% were male and 67% were female. The age range is heavily skewed to the younger region of students and recent graduates as the goal market was initially given as people who would be looking to purchase a home in 5-10 years. In addition to the conversational interviews, we asked seven participants to complete diary interviews, where they would write whatever they were thinking while in the process of using their dishwasher for one continuous week.

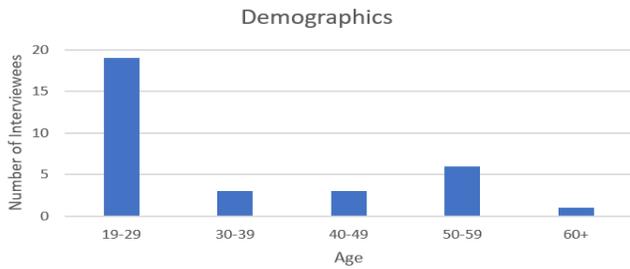


Fig. 3. The age distribution of the sample population interviewed.

The responses to the interviews could be categorized into three general categories: (1) comments regarding their current dishwashing routine, (2) improvements that could be made to their dishwashing routine, and (3) sentiments about a possible mobile application.

For comments regarding their current dishwashing routine, we found that respondents generally: use one cycle (e.g., ‘Normal’ or ‘Regular’), do not know the length of a typical cycle, have issues with dishes not drying properly, and often rinse their dishes before loading them into the dishwasher.

- For comments regarding improvements that could be made to their dishwashing routine, respondents were interested in the following improvements: water and power efficiency of their dishwasher, recommendations to fit more dishes in a cycle, and a notification of the time remaining in a cycle.
- With respect to sentiments about a possible mobile application to run the dishwasher, we found that many respondents viewed the application as unnecessary and did not have major issues with the current user interface on the dishwasher itself that are typical of most standard dishwashers.
- For the diary interviews, some key findings included: some frustration running the dishwasher multiple times due to its limited capacity, dishes still being wet after running the dishwasher, and having to re-run the dishwasher if dishes were dirty after running it an initial time.

Based on these results we developed hypotheses about features users would find useful in the mobile dishwasher application and developed a survey to collect more data. We created a survey that consisted of 22 questions and covered topics regarding the user’s daily use of their dishwasher, method of choosing which cycle to use, and exposure to smart home technology to get a sense of the consumer’s needs and how a mobile application could address some of these needs. 164 participants completed the survey: 29% of the participants are male and 71% are female. Around 70% of the respondents were homeowners and 62% of the respondents fell in the age range of 25-54 years. The major findings of the survey included the following: 65% of users have already adopted smart technology, users over the age of 44 are more likely to be unsure about if they would use an automatic cycle, most users feel they only have a “moderate” understanding of their dishwasher, users under the age of 44 are more likely to feel that they do not know the best way to load a dishwasher while

users over the age of 44 are more likely to feel like they know how to properly load the dishwasher, and users tend to have a preference for a simpler user interface.

B. Prototype Development

The results of the user research led us to focus on addressing the following questions with the design of a mobile dishwasher app:

- How can we provide users guidance of which cycle to use?
- How can we give users advice on how to resolve poor cleaning from the dishwasher?
- How can we give users more information on their water and power usage?
- How can we give users more information on what the dishwasher is always doing?

To provide users guidance on the best cycle to use, we created two features within the mobile app: ‘Onboarding’ and ‘Quick Start’. ‘Onboarding’ is a series of questions the user would fill out the first time they open the mobile app to find the best default cycle based on their routine. The notification a user would receive to start ‘Onboarding’ is shown in Fig. 4 (left-hand side). A popup would start the short process for the app to gather information about how the user typically uses a dishwasher as a baseline. For situations where users are unsure of the correct cycle to use, we created the ‘Quick Start’ feature which allows users to find the recommended cycle for a specific load (Fig. 4, right-hand side). These cycles could include automatic, half-load, normal, heavy, delicates, and rinse and load.



Fig. 4. ‘Onboarding’ Feature (left) and ‘Quick Start’ Feature (right). The ‘Onboarding’ feature allows users to select a default cycle after a given set of questions, which are tailored to asking about their daily needs, that will output to the preferred cycle. The ‘Quick Start’ feature allows users if they are unsure of which cycle to use.

To help users diagnose poor cleaning results, we developed a feature that could be accessed through the ‘Help’ menu. Here the mobile app allows users to answer questions about the problems they are encountering as well as their current usage habits as shown in Fig. 5. From their responses, the mobile app generates tips for possible methods to resolve the issue, for example changing the loading habits to ensure sprayer arms are not blocked.

To give users more information on their water and power usage, the ‘Water/Power’ feature allows users to see how much water their dishwasher has used each day over different time periods. Water usage is also compared to their average water usage from the previous month as shown in Fig. 5. Tips for water conservation are also included in this section to encourage users to develop efficient dishwasher habits as well as fun facts for how much water they have saved by using an Energy Star dishwasher.



Fig. 5. ‘Troubleshooting’ Feature (left) and ‘Water/Power’ Feature (right). The ‘Troubleshooting’ feature allows users to answer a survey of issues they are experiencing with their dishwasher leading to tips to improve their experience. The ‘Water/Power’ feature allows users to monitor and compare their water and power consumption over different time frames.

To give users more information on what the dishwasher is always doing, the ‘Cycle Status’ feature aims to give users insight into the “black box” as to how most people see their dishwasher upon starting a cycle. This feature is intended to be only accessible when the dishwasher is running. The major stages the dishwasher goes through during a cycle are displayed, what stage the dishwasher is currently in, estimated time for each stage, and the total time remaining in the cycle as shown in Fig. 6.

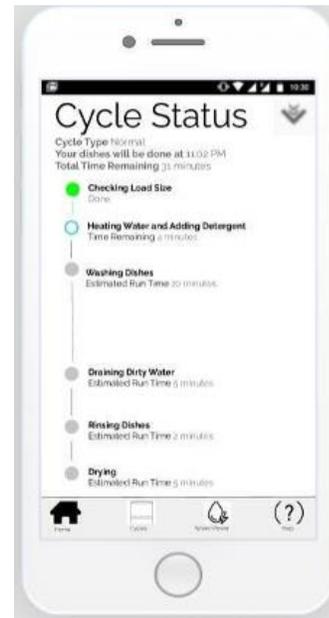


Fig. 6. Example of an Active Cycle Status Monitoring Screen. Cycle Status Feature that shows the status of the current running cycle including the time remaining and the part of the cycle that is currently active.

C. User Testing

We conducted a preliminary user evaluation study testing of the Figma prototype of our dishwasher mobile app with ten participants who are homeowners between the ages of 25 and 50 years old and regularly use a dishwasher. Here we present the results based on the initial five participants. After the first round of interviews, we plan to use the findings to refine the design of our prototype.

Our first round of evaluations was all conducted through video chat using Zoom. Each interview was conducted by two members of our capstone group—one of whom moderated the evaluation, while the other took notes. Participants were walked through each feature of the mobile app prototype one by one and were asked questions throughout by the moderator. For the ‘Troubleshooting’ and ‘Quick Start’ features, we used a think aloud study where participants were asked to say what they notice, their thoughts, and any questions that arise while completing a task in the app based on a given scenario. All participants will be compensated \$200 upon completion of the study.

During user testing, our goal is to determine which features users have interest in. The features outlined in section B is accessible from the bottom bar of tabs shown on each of the wireframes. The home screen shown in Fig. 7 allows for quicker access to each of the features.

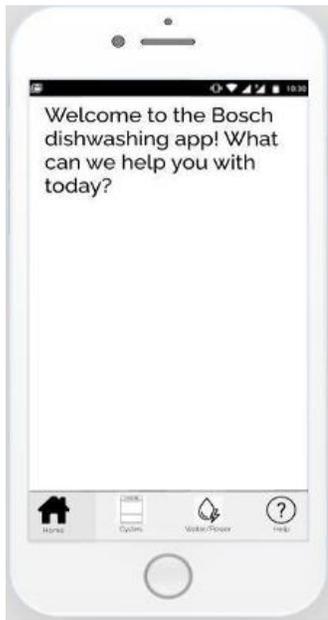


Fig. 7. Home Screen of Dishwasher App. Image capture that shows the home screen that the user would see upon opening the application.

We have found thus far that the users liked the mobile app prototype. Several of the participants noted that the app could improve their dishwashing experience and that, if they had the opportunity, they would definitely use the app if it becomes available in the future. Most notably, users enjoyed both the ‘Cycle Status’ and ‘Quick Start’ features. One user liked the cycle status feature as they felt like the feature gave the dishwasher more transparency. A participant mentioned that they, “just load the dishwasher and the soap and press start, and the rest just magically happens.” With the ‘Cycle Status’ feature however, the user felt that they were able to know exactly what was going on inside the dishwasher at all times and knew exactly when the cycle was going to be finished. The ‘Quick Start’ feature was also praised by a different user, who mentioned that the feature would be great for their children, who often asks her what cycle to use. With the ‘Quick Start’ feature, she would not need to go through this hassle every time her children had to do the dishes.

The users also had feedback for improvements for parts of the prototype. For example, several participants recommended changing the theme of the home screen to include more color and pictures. Adding more information about cycles in the ‘Quick Start’ and ‘Onboarding’ features of the prototype were some examples of changes that users thought would help improve the app to best meet users’ needs. Also, some participants indicated that they would like more explanations for certain features included in the mobile app and its purpose. Participants had suggestions to make the app more accessible for older users such as including larger buttons and to get them more mobile app training as they may not be as familiar with using a smartphone interface. Our future iterations will focus on these sorts of changes to make the mobile app more accessible for all target users.

IV. DISCUSSION

The development and testing of the mobile dishwasher app prototype can improve the many frustrations that users have with the dishwashing experience. It is possible to target frustrations in ways that may not have been possible without the advent of these new technologies. Namely, a lack of understanding of the “black box” that the dishwashing process represents. Through our research of user interviews, diary studies, and surveys, a common theme of users echoed was that they do not fully understand how their dishwasher operates. Users knew how to load their dishwasher with dishes and soap and press start, but had no idea what happened afterwards. A common response in our survey was that users often defaulted to the normal cycle on their dishwasher because they did not know which cycle would be optimal under different circumstances and the difference between cycles. When dishes still came out with residue on or when dishes came out still wet, users often did not know the reason why this was the case, instead just blaming the dishwasher itself leading to unhappy and frustrated users.

Our mobile app prototype built on these findings in attempts to improve the dishwashing experience. Through the features as part of our mobile app, users could see exactly what the dishwasher cycle they chose entailed, what part of the cycle is currently happening, how long the cycle will take, and how much water and power the cycle would use. By allowing the users to see exactly what their dishwasher was doing, we hope that users would feel more confident in their knowledge of how their dishwasher operates. Further, features such as the ‘Quick Start’, ‘Onboarding’, and ‘Cycles’ gave users more knowledge on the difference between the many cycles that their dishwasher has and when it would be best to use the feature.

Lastly, through our ‘Troubleshooting’ feature, we aim to provide users with information on why they might be having any issues with their dishwashing experience, giving succinct information on exactly what may be going on. Through this feature, users can know that their frustrations might be misplaced at the dishwasher technology without the need to go through the long and annoying process of calling customer support. By taking advantage of smart technology, we attempted to leverage the uniqueness of a smartphone interface to improve the dishwashing experience for users in ways that a traditional dishwasher interface cannot.

V. CONCLUSION AND FUTURE WORK

Smart technologies—i.e., sensors, Wi-Fi connectivity, and autonomous features—can change the paradigm in which users interact with dishwashers. Here we aspire to develop a mobile app UI that would provide the features and experience that addresses current problems in the dishwashing process, improves usability, and offers features that are expected by consumers for 21st-century technology.

Future work for this project will require a second iteration of user testing, so that critical usage concerns can be addressed. This second iteration process will involve altering specific designs and functionalities within the dishwasher application.

After improvements to the application are completed, the same set of participants from the first round of user testing are tested again with the same method. By using the data collected we can create a design of a mobile dishwasher app prototype that users will want to use and result in a positive user experience.

REFERENCES

- [1] B. McNary, "Dishwashers are among the least-used appliances in American homes", *Eia.gov*. [Online]. Available: <https://www.eia.gov/todayinenergy/detail.php?id=31692>.
- [2] "Smart Dishwasher Market Size, Share & Trends Analysis Report By Product, By Application (Household, Commercial), By Distribution Channel (Offline, Online), By Region, And Segment Forecasts, 2020 - 2027," June, 2020. [Online]. Available: <https://www.grandviewresearch.com/industry-analysis/smart-dishwasher-market>. [Accessed: April 12, 2021].
- [3] D. Assadi, "Do religions influence customer behavior? confronting religious rules and marketing concepts", 2003. [Online]. Available: https://www.researchgate.net/profile/Djamchid-Assadi/publication/242109368_Do_Religions_Influence_Customer_Behavior_Confronting_religious_rules_and_marketing_concepts/links/549db7ab0cf2fedbc311989d.pdf.
- [4] C. Richter, "Usage of dishwashers: observation of consumer habits in the domestic environment", *International Journal of Consumer Studies*, vol. 35, no. 2, pp. 180-186, 2011. Available: 10.1111/j.1470-6431.2010.00973.x.
- [5] B. Jin, Y. Ji, K. Choi and G. Cho, "Development of a usability evaluation framework with quality function deployment: From customer sensibility to product design", *Human Factors and Ergonomics in Manufacturing*, vol. 19, no. 2, pp. 177-194, 2009. Available: 10.1002/hfm.20145.