Nurse AMIE: Using Smart Speakers to Provide Supportive Care Intervention for Women with Metastatic Breast Cancer

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Women with metastatic breast cancer (MBC) face serious physiological and psychosocial challenges. The management of this chronic, incurable condition requires long-term care coordination. Traditional clinical methods do not often provide adequate and personalized support for these individuals. In this project, we aim to use smart speakers to provide supportive care interventions to improve the quality of life for women with MBC. Specifically, we have developed Nurse AMIE (Addressing Metastatic Individuals Everyday) by leveraging the Amazon Alexa to remotely deliver validated interventions. We believe that voice interactions can significantly lower the barrier to interact with remote intervention technologies for this population. In a pilot study, we deployed Nurse AMIE for 14 days over 6 women with MBC. Based on the collected data, this paper discusses the feasibility, acceptability, and future directions of Nurse AMIE. To the best of our knowledge, this is the first study to use smart speakers to support women with MBC.

CCS Concepts: • **Human-centered computing**; • **Smart speakers**; • **User studies**;

Additional Key Words and Phrases: Smart speakers, Conversational agents, eHealth, Metastatic Breast Cancer

ACM Reference Format:
Ling Qiu, Bethany Kanski, Shawna Doerksen, Renate Winkels, Kathryn H. Schmitz, and Saeed Abdullah. 2021. Nurse AMIE: Using Smart Speakers to Provide Supportive Care Intervention for Women with Metastatic Breast Cancer. In *CHI Conference on Human Factors in Computing Systems Extended Abstracts (CHI '21 Extended Abstracts), May 8–13, 2021, Yokohama, Japan.* ACM, New York, NY, USA, 10 pages. https://doi.org/10.1145/3411763.3451827

1 INTRODUCTION

Metastatic breast cancer (MBC) — also known as advanced or stage IV cancer — occurs when cancer cells spread to other parts of the body [6]. It is estimated that more than 150,000 women are now living with MBC in the United States [23]. MBC can seriously impact the quality of life causing both physiological and psychosocial challenges. For example, bone metastasis can result in severe pain and the inability to move [15]. MBC also leads to significant societal costs. In 2015, the productivity costs associated with MBC was estimated to be $18.2 billion in the US [34].

MBC is not curable [12]. Current treatment methods focus on enhancing the life length and quality of life by minimizing the physical and psychological impacts of MBC [3]. This requires significant lifestyle changes as well

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Manuscript submitted to ACM

as continuous and personalized care coordination. However, the traditional clinical methods are often inadequate to facilitate long-term, dynamic, and personalized support for women with MBC [21]. The resultant barrier to access care (e.g., clinical visits, wait times) can significantly impact their quality of life as well as worsening survival rates. The need for flexible and remote delivery of MBC interventions has been particularly acute during the COVID-19 pandemic [27].

A number of recent studies have explored the use of technology-driven supportive interventions for individuals living with cancer. For example, Greer et al. [14] developed a chatbot to provide positive psychology skills for young adults with cancer. Recent work has also leveraged smartphone apps to support individuals living with breast or prostate cancer [29]. Our team has previously developed Nurse AMIE for a tablet platform [30]. However, there is a lack of rigorous findings regarding the efficacy of these systems [29]. Furthermore, current technologies have mostly focused on physical interactions (e.g., touch screens, clicks) without leveraging the recent advances in hands-free voice modality.

We believe voice-based interactions are particularly well-suited to deliver supportive interventions for women living with MBC. The median diagnosis age for female breast cancer is 62 years and the diagnosis risk is highest for women in their 70s [9]. Given their age, women living with MBC can have difficulty understanding and interacting with digital technologies. Case in point, 50% of women approached to participate in the tablet-based Nurse AMIE [30] declined because they were overwhelmed by the technology. Furthermore, the manual dexterity or vision issues can make it particularly challenging to use physical interactions (e.g., clicking buttons on a screen). Voice interactions can significantly improve accessibility of technologies for such "digital non-natives" [13]. Indeed, older adults have been an early adopter of smart speakers. A study by NPR found that older adults (age > 55) constitute the largest group of "first adopters" in the US — they account for 33% of all users who have owned smart-speakers for a year or more [25]. Older device owners (age >= 60 years) are also likely to interact with voice assistants daily[7, 18, 19]. Irrespective of their increased adoption by older adults, no prior work has explored the feasibility of using smart speakers to provide supportive interventions to women with MBC.

This project aims to address this gap. Specifically, we have leveraged Amazon Alexa ecosystem to translate Nurse AMIE from the tablet to a smart speaker platform to deliver supportive interventions to women with MBC. Following previously validated methods [30], Nurse AMIE aims to record relevant symptoms (e.g., level of pain), provide customized interventions (based on metastasis location and symptoms), and deliver nutrition tips. Users can interact with Nurse AMIE using voice interface enabled by Alexa. Some intervention components use videos (e.g., how to conduct a specific exercise) and web resources (e.g., recipes). We leverage the display in recent Alexa devices (e.g., Echo Show) to deliver these intervention components. Following the implementation, we have conducted a preliminary study by deploying Nurse AMIE over 2 weeks among 6 women with MBC.

In this paper, we will first describe the overall system design of Nurse AMIE, including different architecture and interface design decisions to leverage the strength and address the current limitations of smart speakers. We will then use the data from the preliminary study to discusses the feasibility, acceptability, and future directions of using smart speakers to effectively deliver interventions for women with MBC.

2 RELATED WORK

Many cancer patients may not visit their healthcare providers for a relatively long time after returning home from hospital [11]. Recent studies have leveraged digital technology including smartphone apps (e.g., [16, 17, 32]) and online platforms (e.g. [10, 20, 35]) to support cancer patients. Jacobs et al. [16] designed a mobile application, MyPath, to provide personalized, dynamic, and trusted health information to facilitate patients' proactive health management. Eschler et al. [10] investigated the use of online collaborative spaces to support young adult cancer survivors during and

after cancer treatment. However, the adoption and utilization of these systems remain low, specifically for older patients [33]. Given women with MBC tend to be older (median diagnosis age: 62 years [9]), the use of digital technologies to support MBC interventions can be particularly challenging.

In recent years, there has been an increased interest in using conversational agents (CAs) to deliver health interventions. For example, Greer et al. [14] developed Vivibot to deliver positive psychology skills for young adults after cancer treatment. CAs can also help to easily collect clinical information and medical history [8]. In this project, we focused on developing a smart speaker based CA to deliver MBC interventions. Given the increased adoption of smart speakers by older adults [25], we believe that smart speaker based CAs can lower the barrier of access for women with MBC.

3 NURSE AMIE DESIGN

To develop Nurse AMIE, we leveraged a previous tablet-based remote intervention delivery system [30]. Nurse AMIE is designed to deliver a 12-week long evidenced-based self-management intervention package. This includes implementing a wide range of intervention strategies (e.g., psycho-education, cognitive behavioral therapy, mindfulness meditation, physical activity, soothing music). Nurse AMIE collects daily symptoms (sleep, distress, fatigue, pain) and status (number of steps) data from participants. It then uses the collected data to recommend a self-management intervention strategy. Based on our prior work [26], we identified there is a strong need for diet and nutrition support for women with MBC. To address this need, Nurse AMIE also includes a nutrition module with a daily nutrition tip and recipe.

3.1 Architecture

We used Alexa Skills Kit SDK to implement voice interface and dialogue models in Nurse AMIE [2]. Given some interventions include videos (e.g., exercise instructions), we selected Echo Show devices for development and deployment — it has an 8-inch touch LCD with 1280 × 800 resolution. The visual user interface of Nurse AMIE is implemented with the Alexa Presentation Language (APL) [1]. For deployment, we used the AWS Lambda service. We also collected user interaction data with Nurse AMIE. For data storage, we used AWS DynamoDB.

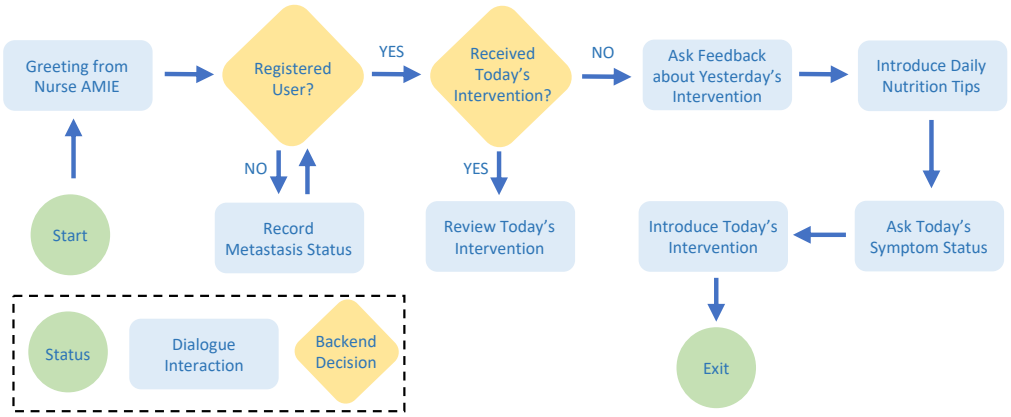

Fig. 1. Nurse AMIE User Flow Diagram

3.1.1 User Flow. To develop the voice interface, we identified turn-taking points and established branching logic reflecting user inputs and selected intervention strategy. The user flow diagram of Nurse AMIE is shown in Figure 1. When the user starts the interaction, she first receives a friendly verbal greeting. For an unregistered user, Nurse AMIE asks her about the presence and location of bone metastases. It uses this information to filter out potentially risky exercise interventions to avoid any serious injury to the participant. Nurse AMIE engages registered users in a set of daily activities. It first asks the user to provide feedback about the recommended intervention from the previous day. If the suggested intervention involved exercise, the user can ask Nurse AMIE to adjust the difficulty levels for future suggestions. Then, Nurse AMIE introduces a daily nutrition tip centered around a weekly nutrition topic. After the nutrition tip, Nurse AMIE asks the user about her symptom (level of pain, sleep, distress, and fatigue) as well as the number of steps taken yesterday (all participants had access to pedometers). Based on these data, it then selects a tailored self-management intervention strategy (e.g., resistance exercises) for a given participant. The algorithm for selecting intervention strategy uses published guidelines for symptom management [30]. If a user has already received the daily intervention, Nurse AMIE will ask her if she would like to review the intervention contents or explore the Pink Ribbon Menu.

3.1.2 Pink Ribbon Menu. The Pink Ribbon Menu enables users to easily access all intervention strategies and educational content in Nurse AMIE. The user can either use voice or touch screen to interact with the Pink Ribbon Menu. The content of the Pink Ribbon Menu includes: Movements (exercise videos), Coping with Symptoms (educational videos), Guided Relaxation (meditation audio), Soothing Music, Nutrition (daily nutrition tips and recipes), and Resources (useful websites for cancer treatments).

3.2 User Interface

3.2.1 Voice User Interface. We specifically focused on designing the voice user interface (VUI) in Nurse AMIE to be easy to navigate and sustain engagement with women living with MBC. First of all, we generated nearly one hundred different cheerful and engaging greetings. We believe the diversity of the messages will ensure better engagement with the personification of the Nurse AMIE and the cheerful nature of greetings will lead to a positive interaction experience for our participants. Every time a user invokes Nurse AMIE, she will receive one of the greetings randomly drawn from the pool. In addition, we made the dialogue throughout the skill as informal and engaging as possible. We make sure that interactions are brief — users can answer most of the questions only within a few words. We also decided to reduce the standard speaking rate in our VUI following user feedback. Lastly, we programmed to ensure that Nurse AMIE asks a question the second time if the user did not answer or Alexa could not capture or recognize the response the first time. The is due to the fact that Alexa would stop listening if a user does not respond to a question within around 7 seconds.

3.2.2 Graphical User Interface. One of our key goals is to ensure the ease of access and interaction with remote supportive interventions for women with MBC, who might not be very familiar with digital technologies. Toward this goal, we also leveraged the graphical user interface (GUI) available in recent Alexa devices (e.g., Echo Show). The use of GUI can complement VUI to further improve the user experience of Nurse AMIE.

On the welcome page (Figure 2 (a)), the figure of Nurse AMIE (an oncology nurse in a white lab coat) is pictured on the left side of the screen. The presentation of a medical professional from the healthcare provider could potentially increase the credibility of the skill. The design of VUI should follow the rule of minimization such that the CA's utterances should be as short as possible [24] to make the information easier to grasp. However, in some situations, Nurse AMIE could not avoid lengthy utterances, e.g. nutrition tip of the day and the question of asking which activity to select

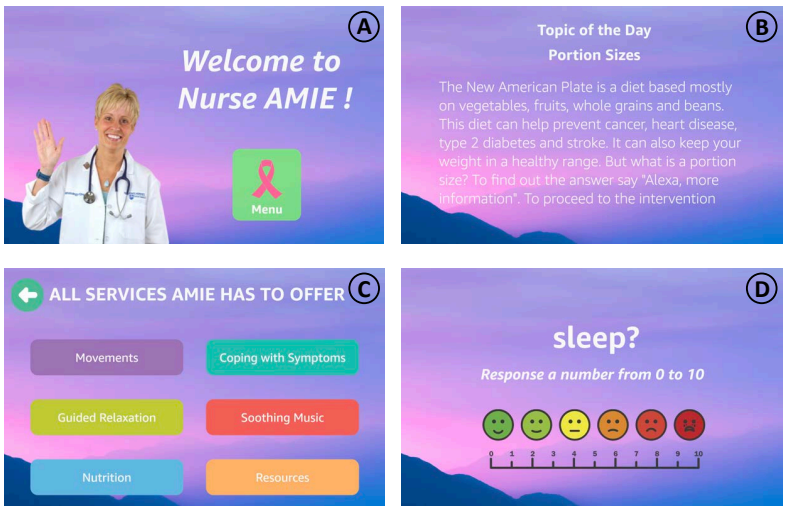

Fig. 2. Nurse AMIE Graphical User Interface Examples. A: Welcome Page. B: Nutrition Tip of the Day. C: Pink Ribbon Menu. D: Asking for Sleep Level.

in the Pink Ribbon Menu. We designed that such voice information's visual outputs are displayed on the screen as shown in Figure 2 (b) and (c), which could alleviate this issue and augment the hearing experience. The illustration of the pain scale shown in Figure 2 (d) also serves the same purpose of complementing the voice interaction. Overall, we aimed to ensure that all user inputs can be delivered through voice interactions while responses are delivered through a combination of VUI and GUI elements to help with information comprehension and retention.

4 EXPLORATORY STUDY

4.1 Study Design

We recruited 6 women with MBC for the preliminary study (see the supplementary document for demography data). We recruited the participants within the Penn State Cancer Institute. For recruitment, we approached physicians treating women with MBC. We excluded participants who have a life expectancy less than 6 months and other medical or psychiatric concerns that might make it unsafe for them to use Nurse AMIE.

For the usability test, we conducted a single-group, quantitative and qualitative evaluation that includes a baseline evaluation of the Nurse AMIE followed by 2 weeks of use at home and a follow-up phone interview. During the orientation session, we collected basic demographic and health information from participants. We then introduced Echo Show devices and Nurse AMIE to them. We instructed the participants to complete different tasks using smart speakers/Nurse AMIE while "thinking aloud" so that we can hear and record their comments and feedback. After they had completed the tasks, we conducted a semi-structured interview to collect their feedback and assess their initial experience with the Nurse AMIE. After the interview, we gave each participant an Echo Show, a pedometer (for step counting), resistance bands (for exercise interventions). We also provided instructions on how to set up and use Nurse AMIE at home. After two weeks, we conducted follow-up phone interviews with participants. The study protocol was approved by the relevant institutional review board (IRB).

4.2 Quantitative analysis

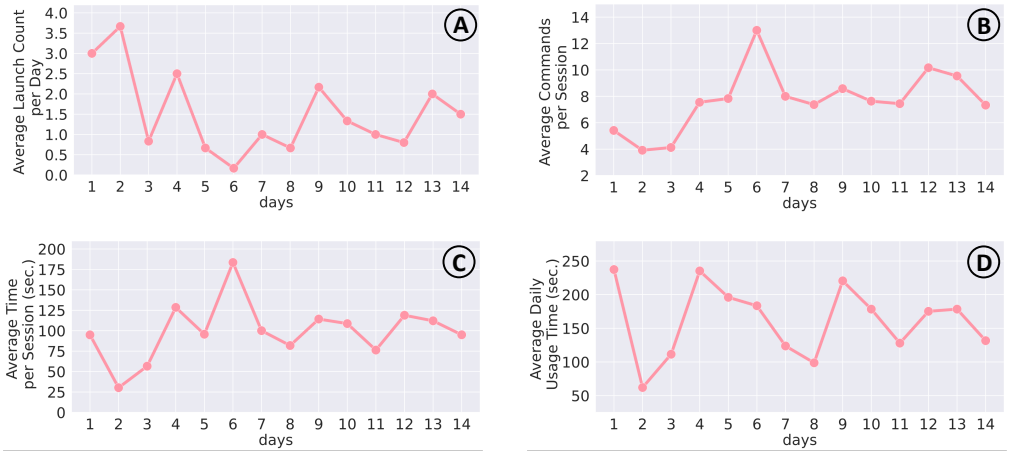

Fig. 3. Nurse AMIE usage patterns. A: average daily number of launch count per user. B: average number of commands per session per active user. C: average session duration per active user. D: total usage time per day per active user

Figure 3 shows how participants interacted with Nurse AMIE over the study duration. The y-axis is the number of days since their first interactions with Nurse AMIE. The average daily frequency of users initiating ("launching") Nurse AMIE (Figure A in 3) was at the highest during the beginning of the study, potentially reflecting novelty factors. The average launch count then reaches a relatively steady trend starting from the 2nd week. Figure B in 3 shows the average number of commands used by an active participant per session over the study duration. An active participant is a participant who launched Nurse AMIE on that day. A session starts with a user initiating Nurse AMIE and ends when it is closed (e.g., the end of a video intervention, timeout caused by inactivity). A command indicates a user input or interaction (e.g., opening Pink Ribbon Menu, answering the sleep question) with Nurse AMIE. As shown in Figure 3 (B), the average number of commands per session gets higher over time and then becomes relatively steady. We speculate that it is due to users becoming more familiar with Nurse AMIE over time while exploring different modules.

We also calculated the average time spent by an active participant per session over the study duration. We excluded the time spent playing media (e.g., exercise video, relaxation audio) for this calculation as we were interested in the active user interaction duration. Similar to the frequency of usage, the session duration reaches a relatively stable trend from the beginning of the second week, with each session roughly lasting about 100 seconds. Figure 3 (D) shows the average usage duration per day per active participant over the study duration. The daily usage duration depends on both the number of sessions per day and the duration of these sessions. We note that the trend in this figure roughly follows the average launch count pattern (Figure A in 3) from the second week.

4.3 Qualitative analysis

The qualitative analysis involved two phases. In the first phase, one researcher transcribed the phone interview data and identified different themes in the transcribed data. In the second phase, other team members iteratively examined, discussed, and merged common themes to ensure correct interpretation and consistency.

4.3.1 Ease of access and integration to daily routine. Overall, the participants were highly interested in using and routinely engaging with Nurse AMIE. A number of participants mentioned that daily interactions with Nurse AMIE helped them to be more mindful of their symptoms and illness management. One participant noted the benefit of daily interactions with Nurse AMIE: "*I definitely do think it would be a good thing to do every day. I think it is grounding for me because we are so busy and we forget to reflect on things like sleep. I would start it before I did work so it fit into my routine*".

The easy access and flexibility afforded by Nurse AMIE were also highly convenient — participants could follow these interventions at their own schedule in their home. This was particularly important during the COVID-19 pandemic as noted by one of the participants: *"I started working more using the Nurse AMIE seated exercise videos at home because they were less strenuous than physical therapy. I was also becoming uncomfortable with the number of people in the physical therapy office due to COVID."*

4.3.2 Perceived usefulness of delivered interventions and nutrition tips. The participants were also satisfied with the customized interventions and nutrition tips delivered by Nurse AMIE. They perceived these tips as informative, interesting, and a good way to make small changes to improve their health condition. This is consistent with the findings from Suh et al. [31] that cancer patients are often overwhelmed by information and as such, they prefer frequent reminders rather than one-time information and notification. One participant commented: "*I liked the daily tips and reminders like drinking water, eating more fiber, things like that. I really appreciated daily tips.*" Another participant commented on how information from Nurse AMIE can help her to sustain a healthy lifestyle: *"I did like understanding the tips of the day. Like yeah my sugar intake isn't as good as having a healthy fruit so awareness of that was good.*"

Similarly, participants thought the interventions suggested by Nurse AMIE can be useful in managing their symptoms. The suggested interventions also enabled them to explore new healthy habits. For example, one participant mentioned how Nurse AMIE helped her to try different physical activities: "*I feel like I should stretch, but not sure what to do. I now know how to do a wall push up. I could not get up and down from the floor like they instructed, but I do like that they taught that. It helped me to get moving which I know will be huge for a lot of people.*"

4.3.3 Facilitating self-management. The daily checkup routine by Nurse AMIE can help participants to identify patterns and raise self-awareness. This can lead to active symptom management and better care coordination as shown in prior work [5, 22]. One participant commented that Nurse AMIE helped her to examine her everyday health status: "*I think the intervention makes me think more about how I'm really feeling. It did make me see my own pattern from day to day. A couple times I had to stop and think about it and brought my attention to some things*". Another participant revealed that this self-examination brought her attention to the level of inactivity: "*I liked the fact that it made me check in with something. It kept accountable about my steps. It also caused me to analyze myself, like did I sleep well? I learned that I need to move more out of the interventions.*"

4.3.4 Need for more customization. While participants in general found the interventions and nutrition tips to be useful, some users (n=4) also suggested options for more individualized and customized information tailored to their health conditions. For example, a participant noted she would be interested in learning more about her specific diagnosis (HER2+ with metastasis to the liver) instead of just MBC in general. Another participant with a long history of diagnosis (13 years) also pointed out that cancer patients who have just been diagnosed might require different levels of support.

Some participants (n=3) also suggested to include a broader range of tips and health information in Nurse AMIE. One participant suggested that Nurse AMIE should aim to provide answers to illness-related questions that she is not comfortable asking her oncologist (e.g., questions related to sexual health). One participant suggested having a wider

range of interventions from Nurse AMIE:"*I was offered mostly walking as an activity and that is taxing on my knee. I have had to start using my wheelchair a little more at home. The exercises I was offered are similar to my PT exercises.*" Similarly, another participant suggested to make nutrition tips to be more diverse: "*The nutrition info was somewhat repetitive. I did not find anything that I could not look up on my own. At the same time, I was really just getting acquainted with the Nurse AMIE program.*"

4.3.5 Addressing interaction challenges. Voice interfaces in smart speakers can help to lower the barrier of interactions [4] and our participants considered Nurse AMIE to be user-friendly in general. However, we also noted some common issues stemming from their unfamiliarity with these devices. One participant had difficulty remembering the "wake" word to initiate interaction: "*I had trouble with the correct language for opening Nurse AMIE. I had to look [into the training manual] each time.*" Some participants also mentioned that they sometimes had difficulty in identifying the correct action word for a given interaction. For example, a participant might say "Alexa, stop" to pause current interaction (e.g., intervention for guided relaxation). However, it will result in closing Nurse AMIE and ending the session as "stop" is a system-defined keyword. Similarly, participants might say "close" to end an interaction, however it is not a defined keyword and therefore could not be recognized by Alexa unless it is manually pre-specified in Nurse AMIE.

Some participants also mentioned timing issues when taking turns and communicating with Nurse AMIE. To indicate Nurse AMIE is ready to listen and process voice inputs, Echo Show devices show a blue bar at the bottom of the screen. Some participants were not aware of this visual indicator and sometimes they spoke too early (before the blue bar is shown) or wait too long to respond (after the blue bar disappear). This resulted in Nurse AMIE not capturing these responses. When Nurse AMIE did not receive the expected user response for an extended period of time, it resulted in a system timeout. In that case, the participants had to reinitiate Nurse AMIE using the wake word, which can be confusing for users. Future work should aim to provide more informative responses and train users to avoid such confusion [28].

The way Alexa devices process graphical and voice interactions resulted in confusion in some cases. For example, if a user touches the screen while Alexa is listening to voice input, Alexa will promptly stop listening. In that case, the user needs to reinitiate the interaction by saying the wake word. This default act to stop listening in case of a touch action was unexpected for some participants. Similarly, if a video is paused for more than 10 seconds without any voice or touch interaction, it will result in a timeout and Nurse AMIE will be automatically closed. Such timeout created confusion for the participants. One participant mentioned: "*I tried to pause the exercise video to set up [exercise] bands and then had to go back to the beginning of the video because it closed out. I could not get it to unpause.*"

While these issues occasionally interrupted user interactions with Nurse AMIE during the preliminary study, we believe that these are not major challenges. For the next iteration, we plan to address these challenges by providing adequate training as well as detailed manuals to participants.

5 CONCLUSION

In this paper, we described the architecture and interface design of Nurse AMIE — a smart speaker based interventions for women with metastatic breast cancer. We deployed Nurse AMIE for 2 weeks over 6 women with MBC. Based on this preliminary data, we presented the quantitative and qualitative analysis of usage patterns, feasibility, future interaction design challenges for Nurse AMIE. To the best of our knowledge, this is the first study to use smart speakers to deliver MBC interventions. We are planning to conduct a Randomized Controlled Trial (RCT) to further assess the acceptability and efficacy of Nurse AMIE. We believe that the voice interfaces in smart speakers can help to lower the barrier of entry and significantly advance the current state-of-the-art to deliver remote interventions for women with MBC.

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ACKNOWLEDGMENTS

We would like to thank the American Institute for Cancer Research and the Tronzo Medical Informatics Endowment for supporting this project.