

## ***BreMo: A Mobile Application to Promote Primary Knowledge About Breast Cancer***

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### **Abstract**

To promote early diagnosis - an essential pillar of breast cancer management (WHO) - thousands of apps exist on the Google Play Store. Only 13% of all breast cancer apps focus on awareness and self-check and have not been scientifically evaluated. The primary objective of this study was to co-design and develop BreMo for Nepalese women using a participatory approach. The “Theory of change”- based - intervention was also designed to ensure behavior change amongst the target users. An extensive study of breast cancer symptoms (especially those prevalent in Nepal), self-check, and existing apps were done to outline essential features and develop the prototype. A questionnaire-based survey was conducted online to test the UI, UX, and content of the prototype. Feedback from the survey was incorporated into the development phase. A questionnaire-based randomized trial was conducted (15 women) to test BreMo against 5 existing apps. BreMo with its four main features - self-check, symptom recording, symptom tracking, and a reminder was fun to train with according to 67% of the participants. Six (6/8) participants would like to continue using BreMo, and 8/12 would recommend BreMo to their friends and family. To ensure behavioral change, the Theory of change methodology was followed. Behaviour change techniques (BCTs) in the app were identified and other important BCTs were incorporated with added measures. The next step is to test the intervention with the target audience - Nepalese women.

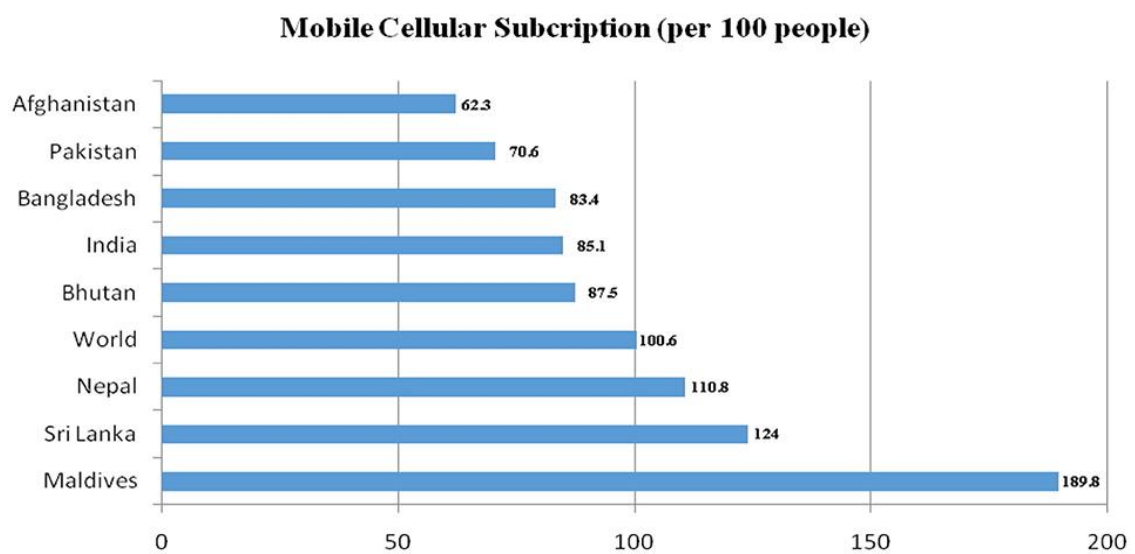
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## Introduction

The number of smartphone users reached around 6.6 billion in 2020 and is predicted to increase to 7.8 billion by 2028 (Mobile Network Subscriptions Worldwide 2028 | Statista, 2023). Around 82% of people in developing countries own a smartphone (Deloitte, 2017). According to Nepal Telecommunications Authority's (NTA) Management Information System (MIS) report, there are 38.21 million mobile users in Nepal as of mid-January 2021 which exceeds the country's total population (29.7 million) by 34.64% (Number of Mobile Phone Users Exceeds Total Population of Nepal, 2021). World Bank's 2016 data (Figure 1) ranks Nepal as having the third highest mobile subscriptions in South Asia with ~110 subscriptions per 100 people (World Bank Open Data, 2021). According to Ncell's latest financial report, smartphone penetration has reached 65% (NepaliTelecom & NepaliTelecom, 2023). With the increase in the number of smartphone users, the number of health-related mobile apps is also increasing.



**Figure 1: Cellular mobile subscribers in developing countries (World Bank, 2016)**

According to IQVIA's Digital Health Trends 2021, there are 3,50,000 health-related mobile apps in popular app markets, with more than 90,000 apps added in 2020 (Digital Health Trends 2021). Despite the advantages mobile health apps offer, only 110 apps out of 3,50,000 were downloaded more than 10 million times accounting for almost half of all downloads (May, 2021). This highlights the need for "quality" tested apps. Such is the case with apps related to breast health and breast cancer too (Collado-Borrell et al., 2016).

There exists a multitude of mobile apps related to breast health (breast cancer and self-check information) as highlighted in our previous work (Categorization and Analysis of Primary Care Mobile Health Apps Related to Breast Health/Breast Cancer: A Review, n.d.). Only 13% (Houghton et al., 2019) of all the available breast health-related apps focus on promoting awareness for all women and these apps have not been scientifically evaluated. These apps provide a range of features and information to help individuals learn about breast health, track changes in their breasts, and take proactive steps to maintain their breast health.

Some of the common features of these apps may include:

1. Breast self-exam reminders and instructions: Many apps provide instructions and reminders for performing a breast self-exam, which can help women detect any changes in their breasts early on.
2. Breast cancer risk assessment: Some apps offer a tool for assessing an individual's risk of developing breast cancer based on various factors such as age, family history, and lifestyle habits.
3. Breast health tracking: Some apps allow users to track changes in their breasts over time, including any lumps or abnormalities they may detect during a self-exam.
4. Education and information: Many apps provide educational content about breast health, including information on breast cancer symptoms, treatment options, and prevention tips.

Unfortunately, a very small percentage of these apps consist of all the above-listed features. Most of them are just educational guides with content on subjects like breast cancer, symptoms, risk factors, and prevention. These apps are verbose and boring, consisting of more than 25 words per sentence on average, not adhering to the IOM guidelines for Health Literate Apps (Categorization and Analysis of Primary Care Mobile Health Apps Related to Breast Health/Breast Cancer: A Review, n.d.; Broderick et al., 2014). Furthermore, most of these apps are monolingual catering to only 17% of the English-speaking population (Categorization and Analysis of Primary Care Mobile Health Apps Related to Breast Health/Breast Cancer: A Review, n.d.; The Most Spoken Languages Worldwide 2023 | Statista, 2023).

Furthermore, it is essential to emphasize in these applications the proper timing for conducting self-checks in relation to the menstrual cycle (if that is the case) specifically, between 5 to 7 days after the commencement of menstruation (Categorization and Analysis of Primary Care Mobile Health Apps Related to Breast Health/Breast Cancer: A Review, n.d.; Breast Self-exam: MedlinePlus Medical Encyclopedia, n.d.; Breast Self-Examination: Knowledge and Practice among Nurses in United Arab Emirates, 2010). Enhancements can be made to the reminder functionality by integrating it with period tracking apps. By prominently displaying the information regarding the start date of the menstrual cycle, users will find it easier and more convenient to select the dates for monthly breast self-examinations (BSE), resulting in a more dependable outcome.

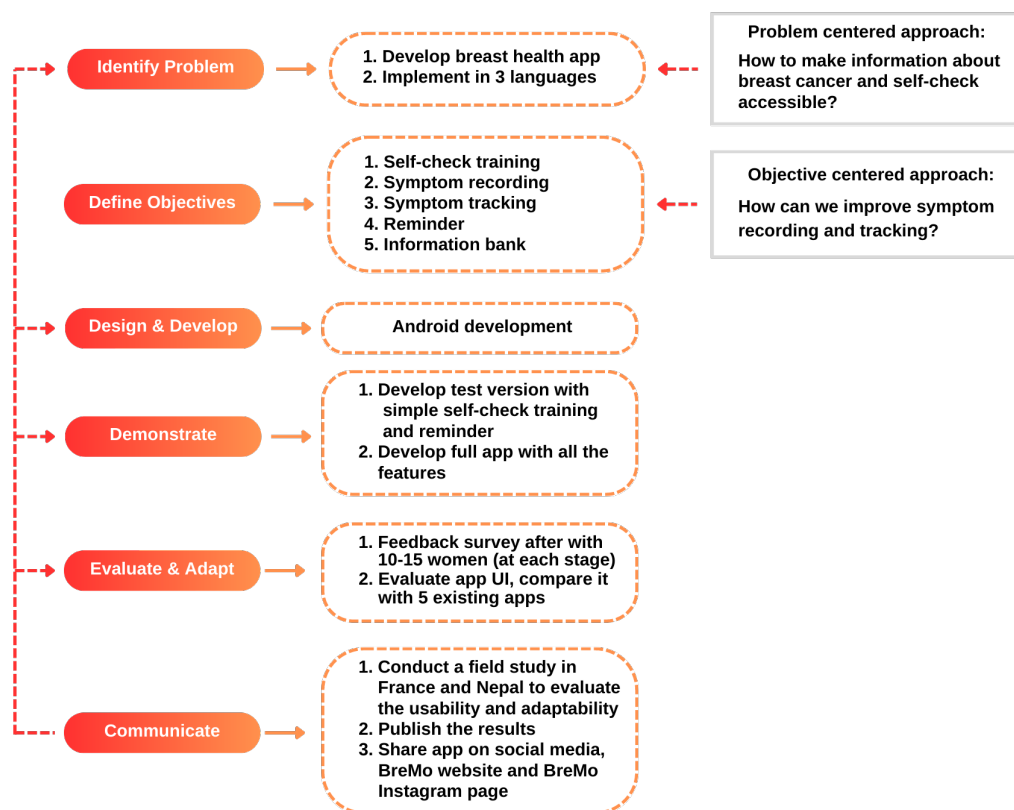
Another crucial addition to these apps could be a well-defined feature for recording symptoms, where all the symptoms are listed as images or graphics. This will simplify selecting symptoms for users, especially those with low literacy levels. Additionally, integrating voice assistant functionalities similar to Siri or Alexa (Hoy, 2018b) can greatly benefit individuals with low literacy by providing apps in regional languages with audio assistance.

Taking these shortcomings into account, and with a motivation to develop an app that can meet all breast health needs, BreMo or Breast monitoring app was designed. A participatory approach was taken to design and develop BreMo to ensure that it met the needs of women. This paper will discuss in detail the design and development of BreMo followed by a study to evaluate the effectiveness of BreMo as opposed to some existing apps which have most of the features discussed above.

## Design and Development of BreMo

### Objectives

As discussed in our previous work (Categorization and Analysis of Primary Care Mobile Health Apps Related to Breast Health/Breast Cancer: A Review, n.d.), most breast health-related apps are lacking and need proper scientific evaluation. Taking the first step in this direction, a wireframe followed by a working prototype of BreMo was designed for Android. User-Centered Design Science Research Methodology (Saparamadu et al., 2021; Venable et al., 2017; Chammas et al., 2015) was incorporated in a participatory research design to design and develop BreMo. Problem-centered - and Objective-centered processes were used as entry points.



**Figure 2: Design Science Research Methodology process model for the BreMo app**

The problem-based aim was to develop an app meeting women's breast needs globally, making breast health information and self-check accessible even for remote communities. This was achieved by implementing an Android app in multiple languages - English, French, and Nepali- to reach as many women as possible, even those living in remotest areas. The objective-centered aim was to design an improved symptom recording and tracking feature as compared to existing apps along with an overall more interactive, engaging app. This aim was achieved by designing a symptom recording screen with a comprehensive list of common symptoms to select from. A novel algorithm was developed to provide users with some conclusions about their symptoms - 'You are healthy', 'Need to follow-up' and 'Visit a doctor; based on the symptoms selected. This algorithm was designed incorporating knowledge from extensive research followed up discussions with a physician and supervisor JCT. These conclusions after every recording will also graphically show how recorded

symptoms have changed over time. These objectives resulted in an app model where users can self-check step-by-step and then record symptoms in their language and at their own pace. This makes the app interactive with feedback from the app.

## Behavior Change Theory

Behavior change theory is fundamental to implementing any evidence-based practice. As defined by Michie et al. (2013) ‘Behaviour change interventions’ are coordinated sets of activities designed to change specified behavior patterns. BreMo's design and development were thus informed by behavior change theory - a taxonomy of behavior change techniques (BCTs) (Michie et al., 2013).

**Table 1: BCTs for BreMo**

Category	Behavior Change Techniques
1. Goals and Planning	<ul style="list-style-type: none"> <li>1.1 Goal Setting (Behavior)</li> <li>1.2 Problem-Solving</li> <li>1.3 Goal Setting (Outcome)</li> <li>1.5 Review Behavior Goal(s)</li> <li>1.7 Review Outcome Goals(s)</li> </ul>
2. Feedback and Monitoring	<ul style="list-style-type: none"> <li>2.2 Feedback on behavior</li> <li>2.4 Self-monitoring of Outcomes of Behavior</li> <li>2.5 Monitoring Outcomes of Behaviour by others without feedback</li> <li>2.7 Feedback on Outcomes of Behavior</li> </ul>
4. Shaping Knowledge	<ul style="list-style-type: none"> <li>4.1 Instructions on How to Perform a Behavior</li> <li>4.2 Information about antecedents</li> </ul>
5. Natural Consequences	<ul style="list-style-type: none"> <li>5.1 Information about Health Consequences</li> </ul>
6. Comparison of Behavior	<ul style="list-style-type: none"> <li>6.1 Demonstration of the Behavior</li> </ul>
7. Associations	<ul style="list-style-type: none"> <li>7.1 Prompts/Cues</li> </ul>
9. Comparison of Outcomes	<ul style="list-style-type: none"> <li>8.1 Credible source</li> <li>8.3 Habit Formation</li> </ul>
10. Reward and Threat	<ul style="list-style-type: none"> <li>10.4 Social Reward</li> </ul>
13. Identity	<ul style="list-style-type: none"> <li>13.3 Incompatible beliefs</li> <li>13.5 Identity associated with Changed Behavior</li> </ul>

**Figure 3: BCTs identified for the BreMo app**

To identify, define and categorize active intervention components designed to foster behavior change, the taxonomy of behavior change techniques have been developed (BCT Taxonomy (V1): 93 Hierarchically-Clustered Techniques, n.d.). This theory defines 93 behavior change techniques categorized into 13 broad categories. Nineteen (19) BCTs were identified and adapted to make BreMo effective, as shown in Figure 3.

## Methods

### Wireframe and Prototyping

App wireframe (Figure A1 in Appendix) highlighting main features was designed on Miro (Collaboration Platform, 2023) a software that allows collaborative work, brainstorming, wireframing, and efficient project management. Elaborating on the wireframe, a working prototype was developed using Figma as shown in Figure 4 (full prototype - Figure A2 in Appendix). The prototype of the app focused on step-by-step, interactive Breast Self-Examination (BSE) training:

1. Explicitly highlight some ‘Do’s and Don’ts’ about the BSE process.
2. Illustrate each step of BSE with images or short animations (GIFs) to help make the process easy and fun.
3. Recording of symptoms after the observation step and palpation step respectively - type (in case of nipple discharge) and intensity of the symptom.

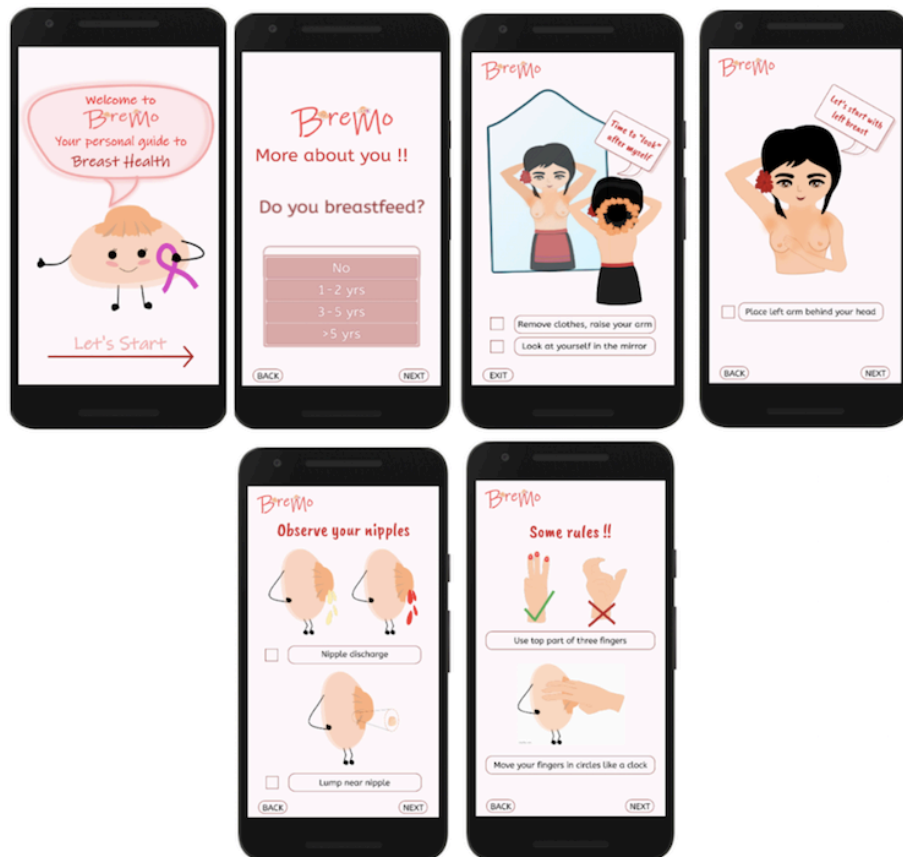


Figure 4: Prototype of BreMo

This design was a result of extensive research of the literature and existing breast cancer apps to bridge the gap in the existing apps.

### **Development of BreMo (Version 1)**

BreMo (Version 1) was developed for Android phones using Dart in Flutter (an open-source UI software development kit (Wikipedia Contributors, 2019)) by SK incorporating the feedback JCT (Physician), and a small group of women. Flat design principles were used to develop this app in contrasting colors. Sans serif fonts were used to ensure good readability amongst all users irrespective of their age (Hou et al., 2022; Rello & Baeza-Yates, 2016).

Version 1 of BreMo included all the features discussed in wireframing and prototyping and some additional features as deemed necessary from the feedback session. A questionnaire-based study was conducted after developing version 1 with 13 participants recruited from non-probability, convenience sampling (non-probability sampling in participants recruited are easily accessible and motivated to participate in the study (Stratton, 2021)). The main objective of this study was to evaluate:

- 1) the usability of BreMo and,
- 2) the time taken to complete the training using BreMo.

At this stage, no limitations on sex, age, and nationality were imposed. Questions on the length and comprehensiveness of the initial survey on BreMo, and BSE training and recording were included (Figure B in Appendices).

### **Evidence-Based Evaluation - BHA (Breast Health Apps) Study**

Based on the results of the previously conducted questionnaire-based study, the app was modified (Version 2). A questionnaire-based blind study was conducted with a small group of women sampled using convenience sampling.

Two objectives of this study included:

- 1) to analyze whether BreMo meets the current standards in comparison to the other apps (Stan Swasthya, Pink Pakistan, Daisy Wheel, Breast Check Now, Dear Mamma - apps were selected from a comprehensive database of breast health apps created by us as discussed in our previous work), and
- 2) to compare BreMo with the other existing apps.

Participants, 15 - 40 years old with no restriction on gender, or age were recruited on a voluntary basis via an enrollment form (Figure C in Appendix). Each participant was assigned to review one of the discussed apps (Stan Swasthya, Pink Pakistan, Daisy Wheel, Breast Check Now, Dear Mamma) and BreMo. To ensure no bias against BreMo, participants were made unaware that they were all assigned to review BreMo (app 2) along with another app. For them, BreMo was one of the existing apps that was randomly assigned to them. The participants were required to test, and review randomly allocated one of the 5 apps along with BreMo and then complete a simple questionnaire (in the appendix). In the end, each app (excluding BreMo) was reviewed by three independent participants and BreMo was reviewed by all of them.

The evaluation of the apps was conducted through a paired comparison approach where each participant was assigned a pair consisting of BreMo and one of the five pre-selected apps. The allocation of app pairs to each participant was randomized to achieve a balanced block design, ensuring fair and unbiased evaluations. This systematic evaluation process was repeated 15 times in total, providing a comprehensive and reliable analysis of the apps' performance.

The questionnaire was designed to evaluate four main aspects (Figure C in Appendices): breast self-examination, recording, tracking, and reminders. The questionnaire also included questions about intrusiveness, language options, UI design, and data usage, some were open-ended. The analysis of the BHA study data encompassed several comprehensive steps to gain meaningful insights and draw robust conclusions, as listed below:

1. **Descriptive Statistics:** Descriptive statistics were used to provide a comprehensive overview of the data. Specifically, the focus was on comparing BreMo with other apps in terms of self-check, remainder, recording, tracking, and some other features.
2. **Preparation of data:** A matrix was constructed with 5 columns representing 4 features (f1 - BSE, f2 - recording, f3- tracking, and f4 - reminder) and Total\_Score across the 4 features. Based on user perception of certain features (i.e., whether it is available or not in the app when the truth is known), each feature is scored 0 (incorrectly identified) or 1 (correctly identified). For 5 apps (excluding BreMo) reviewed by 3 users each, a total of 15 rows were included in the matrix plus another 15 rows for responses by the same 15 users about BreMo resulting in a 30\*5 matrix.
3. **Ordinal regression analysis:** Since the data gathered was transformed into categorical-ordinal data. As described above, it necessitated specific methods to analyze them adequately. An ordinal regression analysis was performed to explore the relationships between various app features. This analysis allowed for a deeper understanding of user perception of some features. Linear Mixed Model Regression (Lmer - lme4 package) was also applied to take into account the correlation between feedback from one participant for two different apps. Cumulative mixed link models were also applied to take into account two responses by one participant for 2 different apps.

### **Development of the Final Version of BreMo (Version 3) and Evaluation**

Based on the results of the BHA study, and feedback from experts in Nepal (doctors and nurses) further modifications were made to BreMo resulting in the current version (Version 3) of the app. The app interface was changed completely to make navigation simpler. Some features were added:

- 1) Symptom recording screen using an in-built algorithm
- 2) Symptom tracking - a graphic representation of symptoms recorded over time
- 3) Knowledge bank - flash cards with information about breast cancer, risk factors, prevention, and myths
- 4) A side menu was added to the app bar with two options: 1) settings and 2) log out



## Results

### Development of BreMo

After the development of the app (Version 1), a small study was conducted using a questionnaire to evaluate the UI of the app. Fifteen (15) people responded to the survey. One (1) response was excluded as it was a duplicate.

Thirteen (13) respondents were female and 1 male. Most of the (78.5%) respondents were young: 20-30 years old. Forty (40%) percent of respondents were French, 40% were Nepali and 20% were Indians. The majority of the respondents (85.71%, Figure 5.a) found visuals helpful to better understand each step of the BSE. Seventy-eight (78.57%, Figure 5.b) respondents agree that GIFs helped them understand different steps of self-examination. Illustrations depicting different symptoms of breast cancer defined each symptom well according to 64.28% (Figure 5.c) of the respondents and 73.3% found recording symptoms easy with BreMo (Figure 5.d). Almost all of them (91.67% of 12 respondents) completed BSE within 10 mins.

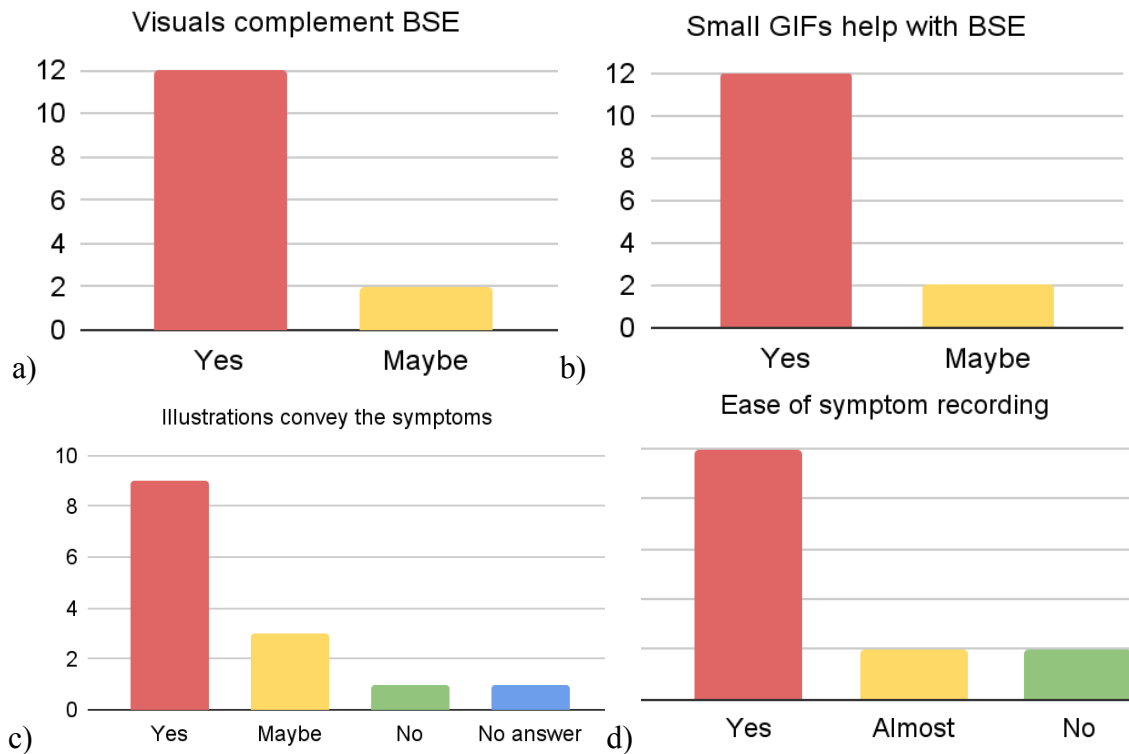
Some very useful feedback was also recorded from the respondents:

‘Could have a progress bar showing percentage of questionnaire done/left.’

‘Maybe adding an arrow of the motion direction.’

‘Now the instructions are scattered in several pages, so that the users can follow them step by step. But maybe at the end of the apps or at the end of the instruction section, you can provide them with a picture that includes all the instructions. Or maybe having a shortcut to the instruction section so that users do not have to go through the questionnaire again in acquiring instruction information.’

‘Instead of scale for recording intensity, a list of options could work better, because I didn't understand what the highest and lowest points in scale correspond to.’



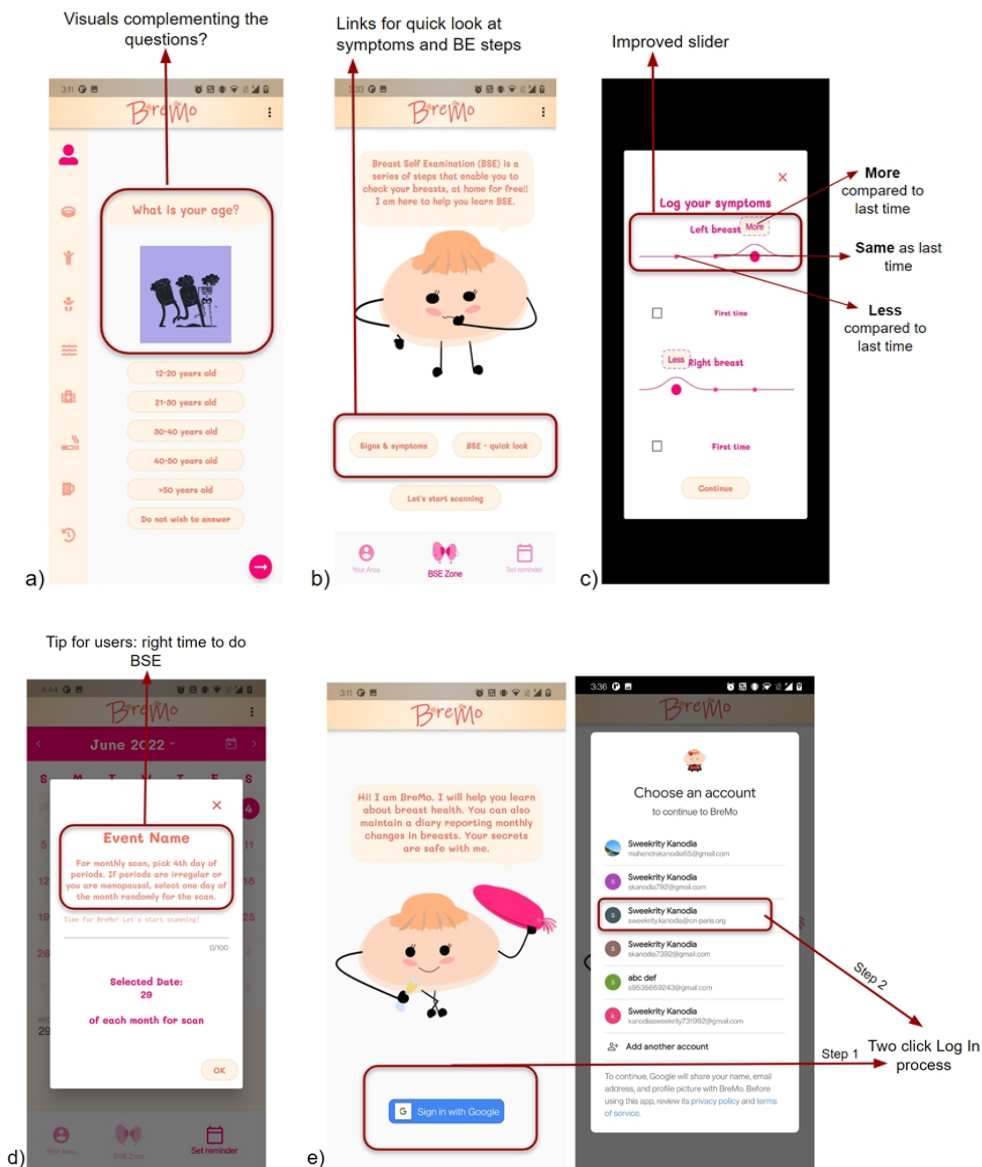
**Figure 5: Feedback on different aspects of the BSE training and symptom recording; a) visuals help in understanding BSE observation steps, b) GIFs help in understanding the BSE palpation steps, c) Illustrations complement the definition of symptoms, and d) ease of recording symptoms.**

Overall, 76.92% of respondents enjoyed training with BreMo and 64.3% would continue using it. Only half of (50%) them found it easy to navigate through the app, highlighting the need for improving it. Eighty-four (84%) respondents were positive about recommending BreMo to their family and friends. Around 87% of the 8 respondents showed a positive learning curve with increased awareness about breast cancer symptoms, steps of BSE, and self-care. Thirty-five (35.17%) of the respondents had no idea about BSE and learned about it from BreMo.

Based on the feedback and results of the UI study BreMo was modified (BreMo Version 2). Some features added to BreMo Version 2 include:

- Visuals accompanying the questions in the initial survey (Figure 6.a)
- A quick look at BSE symptoms (Figure 6.b)
- A quick look at BSE steps (Figure 6.b)
- Easy-to-use slider option, for recording the intensity of the symptom (Figure 6.c)
- Tips on when to do BSE, combined with the reminder (Figure 6.d)

The major changes concerned privacy - providing name and number for Registration and Login. To tackle this, a 'Two-click Gmail login' was incorporated (Figure 8. e) as the majority of Android users have their smartphone linked to a Gmail ID already. To resolve issues regarding the questionnaire's progress indicator, tabs were added for each question to indicate how many questions to expect. Other minor changes included color, display, alert boxes, side menu, and so on (Figure D in Appendix).



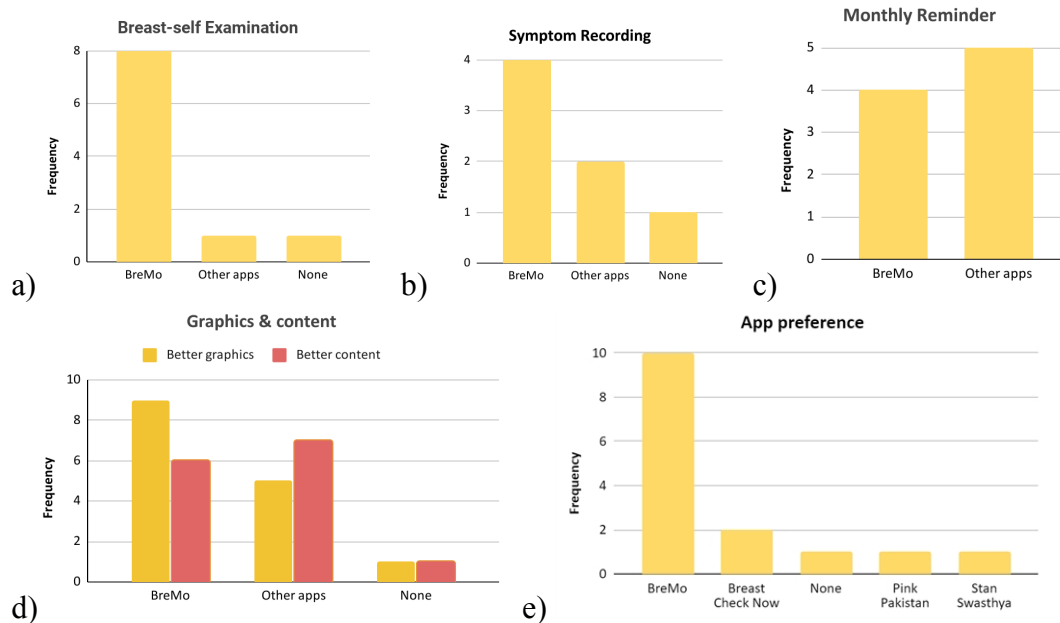
**Figure 6: Screenshots of BreMo version 2: a) Tabs for each question, b) Quick look at symptoms and BSE steps, c) Intensity slider made simpler with just three options - more, less, or same, d) Tip for monthly BSE combined with a reminder, e) two click Login using Gmail ID**

## BHA Study

15 participants completed the study, with a 42% dropout rate. After pre-processing of the data obtained, descriptive statistics were performed. The results of descriptive statistics are provided with respect to BSE (Figure 7.a), recording (Figure 7.b), reminder (Figure 7.c), graphics (Figure 7.d), and content (Figure 7.d). In these graphs, 'Other apps' were cumulative responses by participants for other apps tested except for BreMo. The results suggest that BreMo is comparable to the existing apps and might even be preferred (67%) over other apps, especially for self-check (80%), and graphics (67%).

A mixed model was used to find the effect of fixed variable App\_ID (that is different apps used for the study including BreMo) and the random effect from different participants on the

total score for each app (Table 1). The total score was calculated by summing the score given to each of the four features (self-check, recording, tracking, and reminder) based on if it is available in the app or not. Here, the reference was set to the BreMo app, and all the coefficients of all other apps were calculated with respect to it.



**Figure 7: Features of BreMo compared with other apps: a) self-examination, b) symptoms recording, c) reminder, d) graphics and content, and e) app preference**

User_ID	App_ID	f1	f2	f3	f4	f5	TotalScore	
1	1	2	1	0	1	1	5	3
2	1	1	0	1	1	0	5	2
3	2	2	1	1	1	1	4	4
4	2	1	1	1	0	1	3	3
5	3	2	1	1	1	1	4	4
6	3	1	1	1	0	1	3	3
7	4	3	1	0	0	1	5	2
8	4	1	1	1	1	1	5	4
9	5	3	1	0	0	1	5	2
10	5	1	1	1	1	1	4	4
11	6	3	1	0	0	1	5	2
12	6	1	1	1	1	1	3	4
13	7	4	1	1	1	1	5	4
14	7	1	1	1	1	1	3	4
15	8	4	0	1	1	1	3	3
16	8	1	1	1	0	1	4	3
17	9	4	1	1	1	1	5	4
18	9	1	1	0	0	1	3	2
19	10	5	0	1	0	0	5	1
20	10	1	1	1	1	1	3	4
21	11	5	1	1	0	0	3	2
22	11	1	1	1	1	1	4	4
23	12	5	1	1	1	1	5	4
24	12	1	1	1	1	0	5	3
25	13	6	1	0	0	0	3	1
26	13	1	1	0	1	1	5	3
27	14	6	1	0	0	1	3	2
28	14	1	0	1	1	1	4	3
29	15	6	1	1	0	1	5	3
30	15	1	0	0	0	1	3	1

**Table 1: Table of scores appointed to each feature (0 or 1) based on whether a particular feature (f1 - BSE, f2 - symptom recording, f3 - symptom tracking, f4 - reminder) was correctly identified by the user (User\_ID) for each app of the two tested by each of them (App\_ID)**

Results indicate variance due to random effect to be almost 0. The cumulative link mixed model resulted in similar observations.

```
polr(formula = TotalScore ~ App_ID, data = givendata, Hess = TRUE,
      method = "logistic")

Coefficients:
              Value Std. Error t value
App_ID2  1.215      1.288  0.9433
App_ID3 -2.322      1.143 -2.0323
App_ID4  1.215      1.288  0.9433
App_ID5 -1.997      1.420 -1.4069
App_ID6 -2.395      1.273 -1.8819

Intercepts:
              Value Std. Error t value
1|2 -3.3209  0.8970  -3.7021
2|3 -1.3241  0.5997  -2.2079
3|4  0.4105  0.5133   0.7997
```

**Figure 8: Generalized ordinal regression results using package ‘polr’ in R**

Owing to the negligible random effect from participants reviewing two different apps, the analysis was directed to ordinal regression models using polr package in R, as shown in Figure 8. It is evident from these observations that BreMo (reference) is similar to all the apps except App 2 (Dear Mamma) and App 4 (Breast Check Now) which are significantly different.

### **Development of the Final Version of BreMo (Version 3) and Evaluation**

The final version (Version 3) of the app (prototype in Figure E in Appendix) is an Android app, as shown in Figure 9. It will be made available on Google Play Store after the field study in Nepal. It is available in three languages: English, French, and Nepali.

BreMo has an app bar with a side menu with two options:

- 1) settings and
- 2) log out so that these options are easily accessible to the users.

The bottom navigation bar has 3 options:

- 1) HomePage - with buttons to all main screens for easy navigation,
- 2) Self-check - step-by-step training, and
- 3) Reminder - to set monthly notifications for self-check.

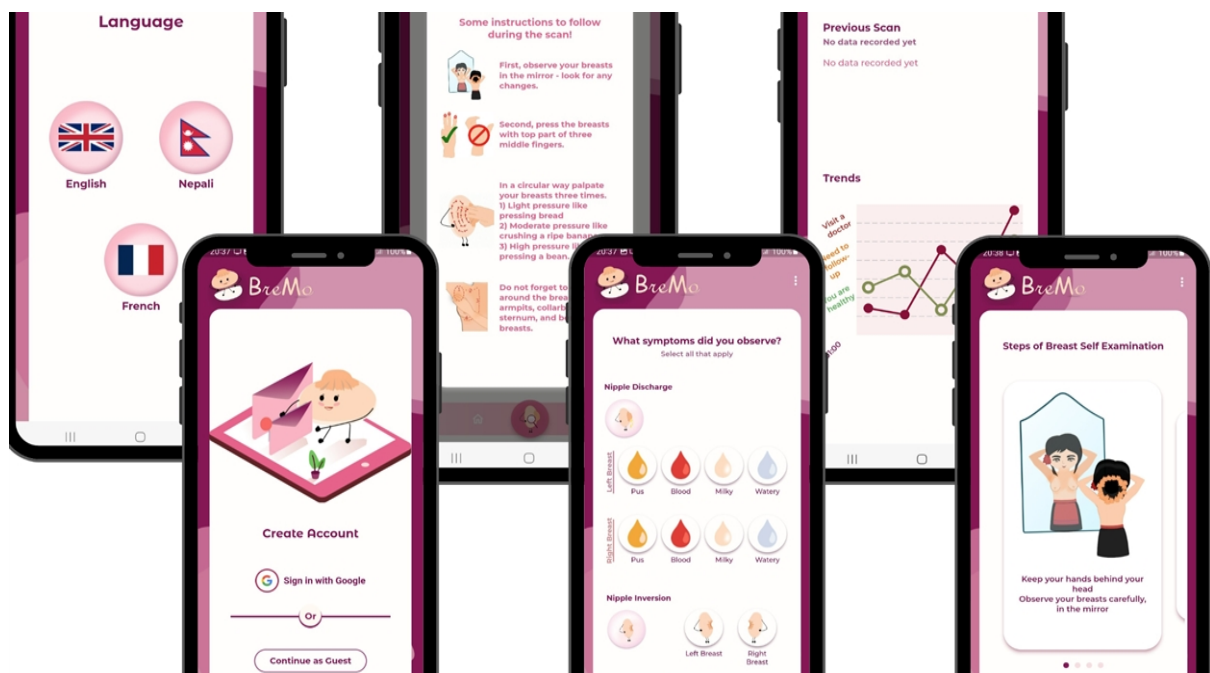
When the app is launched, a flash screen opens followed by a Language screen where users can select the language of interest. Users can also change the language anytime easily while using the app by going to ‘Settings’ in the Appbar side menu. This is followed by one-time intro sliders explaining the purpose and use of the app. Login is fairly simple via Gmail ID that all Android phones are linked to. Additionally, users can continue without logging in by clicking on ‘Continue as a guest.’

The homepage has buttons for :

- 1) Symptom recording,
- 2) Symptom tracking,
- 3) Quick look at symptoms,

- 4) Quick look at self-check,
- 5) Knowledge bank, and
- 6) Personal history.

The symptom recording screen has a list of buttons depicting different symptoms from which users can click and select. Based on the symptoms selected by the users, a small feedback will be provided in a bottom overlay widget. The symptom tracking screen will graphically display the feedback of the recorded symptom over different time points. Screens ‘Quick look at symptoms’, ‘Quick look at self-check, and ‘Knowledge bank’ contain carousel sliders with images and text conveying respective information about breast cancer symptoms, self-check, and knowledge about breast cancer definition, risk factors prevention, and myths. The ‘Personal history’ screen contains a questionnaire that users can fill out to provide some information about their pregnancy, breastfeeding, contraceptives, etc. This information will help BreMo personalize some feedback and information for the users in the future.



**Figure 9: Version 3 of BreMo**

The ‘Settings button’ in the app bar has options to:

- 1) change language,
- 2) understand privacy settings and delete all data from BreMo, and
- 3) button to set app lock (will be activated in future versions).

An overview of the app is presented in Figure 9.

## Discussions and Conclusions

### Main Findings

This study describes the participatory approach to the design and development of BreMo with periodic assessment of BreMo at each stage with a small group of women. BreMo digitizes standard, clinically validated breast self-examination techniques in an engaging and

interactive way along with information about breast cancer from reliable sources. BreMo prototype was designed to also include features like symptom recording and symptom tracking but version 1 of the app was constrained to breast self-check and reminder. Continuous feedback on the design using questionnaires with a small group of women was done to ensure that BreMo meets the requirements of women. Additionally, in the final version, BreMo V3 users can also select symptoms after self-check from a comprehensive list of common ones. Based on the combination of symptoms selected, BreMo provides users feedback either as 'You are healthy,' 'Need to follow-up,' or 'Visit a doctor.' These feedbacks are presented graphically against time on the 'Symptom tracking' screen.

There are buttons to allow users to quickly look at different symptoms and steps of self-check-in case they are in a hurry or already have knowledge about it. Results of the BHA Study show that BreMo meets the current standards of breast health-related apps and might be better than them in some features (self-check, recording), and aspects (graphics). Sixty-seven (67%) of the participants preferred BreMo over other apps. Observations from ordinal regressions further support that BreMo is comparable to the existing apps.

With the increasing burden of breast cancer also in developing countries like Nepal, as estimated by WHO (Cancer Tomorrow, n.d.), there is a need for such apps in regional languages and contexts. BreMo could be a means to bridge the gap in quality to provide users with an engaging, scientifically validated app developed in collaboration with users. BreMo provides useful information and training about breast health and self-check-in in multiple languages. In the future, more language options will be added with more personalized information for the users. Continuous feedback from users will help us make improvements to the app with time.

## **Limitations**

With a dual aim of promoting breast health information and self-check globally (including LMIC), and setting an example for scientifically validated, quality-tested apps on app stores, BreMo was developed. The primary design of BreMo incorporating self-check training, symptom recording and tracking, reminder, and information about breast health was met. Having said that, not all symptoms have been highlighted in the symptom recording screen. Most common symptoms have been highlighted currently but more symptoms will be added in the future as per user recommendations. Additionally, symptom recording will be modified to be more specific to each aspect of a certain symptom, for example - localized or diffused redness or pain, or mobile or immobile lumps. Incorporating these specificities will improve recommendations provided after the recording of symptoms.

Currently, a basic in-built algorithm has been used to provide feedback to users based on the symptoms selected. This also needs to be modified to be more specific depending on the uni- or bi-laterality of symptoms, and the time for which symptoms exist. Additionally, the algorithm needs further review by experts, i.e. medical doctors and nurses. To tackle anxiety arising from symptoms observed, contact with experts and means to telecommunicate with them need to be incorporated. The addition of a detailed list of symptoms recorded over time and its summary in pdf format might be useful when consulting a doctor.

To enhance user engagement and provide a space for women to share their concerns, a chat room will be added like that in menstruation trackers like flo. This space will offer women a platform to talk about their concerns anonymously and learn that they are not alone and

provide support to each other. In the future, personalized recommendations and suggestions will also be provided to women to support them with their problems.

In the next update, the App lock will be activated as desired by users. Based on the feedback from the users, some features need to be modified to improve user experience, including a one-click reminder setting, and more language options. The reminder setting was difficult for a lot of users. They prefer just selecting a date for self-check without being confused about co-relating it with their menstruation start date. This means automatic recommendations of self-check dates based on the start of menstruation start date. Although the app supports this currently, it is difficult to use as apparent from user feedback. More language options will be added as per user demands - Spanish, Arabic, Ukrainian, and Russian along with some languages from developing countries like Hindi, Bangla, and Mandarin to ensure global accessibility.

Since only 15 participants took part in the BHA study, the results cannot be generalized. Dropout rates for the study were around 42% and this is a problem most citizen science studies face. Another limitation of this study due to the low number of participants was that most models could not converge. Hence we had to total scores across different features and run models with that Total\_Score. Also, for descriptive studies, we had to group all other apps (excluding BreMo) in one category and compare it to BreMo for some meaningful results.

### **Future Work**

The need for multilingual apps related to breast health is increasing with the increasing burden of breast cancer globally. Developing countries are experiencing an overwhelming rise in the incidence and mortality cases of breast cancer. In such resource-limited settings, mobile apps like BreMo offer sustainable ways to educate women about breast cancer, and self-check. A participatory approach to designing and developing mHealth apps followed by randomized or cluster-based trials as presented in this paper also provides new avenues for scientifically validating mHealth apps. Work still needs to be done in standardized such protocols for the design and development of quality mHealth apps.

A field study has been planned in Nepal to provide more insights into the needs of women in LMIC with language and knowledge constraints. Results from the study will help us understand the usability and adaptability of BreMo amongst rural, uninformed women.

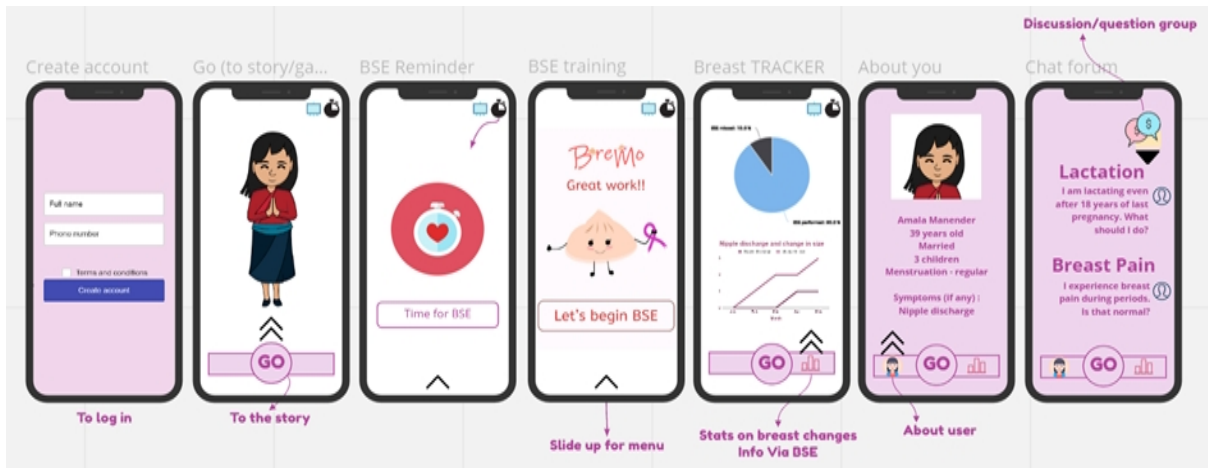
### **Acknowledgment**

The present work is part of the Ph.D. of SK (under the supervision of Prof Fabien Reyal and Pr. Jean Christophe Thalabard, as co-supervisor), for which she benefits from a grant by Université Paris Cite.

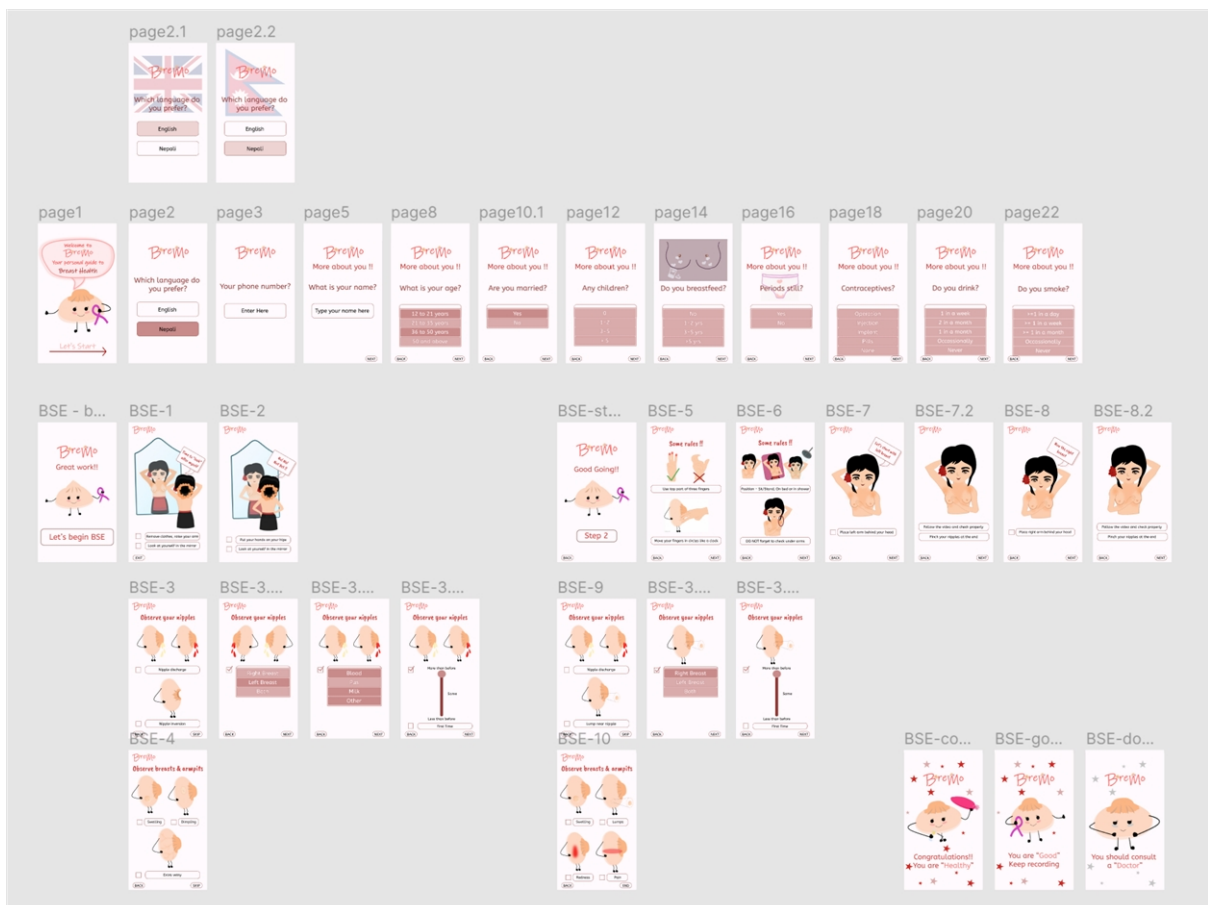


# Appendix

## A. BreMo Version 1 - wireframing and prototyping




**Figure A1: BreMo wireframe depicting the main features: 1) login, 2) visual novel, 3) reminder, 4) self-check training, 5) symptom recording and tracking, 6) user-area**



**Figure A2: BreMo Prototype - Version 1**

## B. Questionnaire for UI study



### "BreMo" - Your personal guide to "Breast Health"

Welcome!  
Since you are on this Feedback Form, you might have played with BreMo - prototype V1 focused on Breast self examination.

I am trying to build an app which is one stop solution to women's "breast care". Education about breast health can help in taking better care of our breasts, especially in remote settings.

Your feedback will help me improve this prototype. So, please feel free to leave suggestions, feedbacks (both negative & positive).

sweekrity.kanodia@icri-paris.org [Switch account](#)

Not shared

\* Indicates required question

Name (only if you wish to provide)  
Your answer

Email (only if you wish to provide)  
Your answer

Are you male, female or other? \*

Female  
 Male  
 Other


How old are you? \*

less than 20 years old  
 20 - 30 years old  
 more than 30 years old

Where do you live (country)? \*  
Your answer


Next Page 1 of 6 Clear form

While recording intensity of symptoms, would you prefer two different scales (as in image below) to record symptoms of both breasts separately when "both" option is selected for symptom in which breast?



Yes  
 No

Did the small gifs help in understanding how to do breast self examination?



Yes  
 No  
 Not very clear  
 Other...

How much time did it take for you to finish the training?

Less than 5 mins  
 5 - 10 mins  
 More than 10 mins

Was it "too" long?


It was just right.  
 It could be smaller.

Any feedback on this section?  
Long answer text

#### Section 1 - Questionnaire

Evaluation of the first section of the app where user information is collected to personalize the training.

Was the questionnaire lengthy/ time consuming?




It can be a little shorter!  
 It was short (more questions can be added if required)  
 It was just right!  
 Other: \_\_\_\_\_

Were the questions "easy to understand"?

Yes  
 No  
 Some of them!  
 Could be clearer!  
 Other: \_\_\_\_\_

Would visuals help in better understanding (like the image below)?



Yes, it would help!  
 Maybe  
 They are just fine as is!  
 Other: \_\_\_\_\_

Any feedback on this section?  
Your answer

Back Next Page 2 of 6 Clear form

#### Section 4 of 6

Overall Experience  
Description (optional)

Did you enjoy training with BreMo?

Least  1  2  3  4  5 Most

How easy was it to navigate through the prototype (I know it is not the best yet :P)

Least  1  2  3  4  5 Most

Would you like to use BreMo to track your breast health?

Not at all  1  2  3  4  5 Definitely

How likely are you to recommend BreMo to friends and family?

Least  1  2  3  4  5 Most

Did you learn anything new from BreMo?  
Long answer text

After section 4 Continue to next section

#### Section 5 of 6

We are almost done!  
Just a min more...

Did you know how to do Breast self examination before using BreMo?

Yes  
 No  
 Have heard about it

Do you perform Breast self examination every month?


Yes  
 No  
 Sometimes  
 I know how to do it but still do not do it

If you chose "I had heard about it" or "I know how to do it but still do not do it" in the previous two questions - what stops you from doing breast self examination?  
Long answer text

#### Section 3 of 6


Breast Self Examination -Step 1 & 2  
Evaluation of second section on Breast self examination - observation

Do the visuals complement the step by step process?



Yes  
 No  
 Maybe  
 Other...

Do the illustrations communicate clearly the symptoms represented?



Yes  
 No  
 Maybe  
 Other...

Was it easy to record your symptoms?

Yes  
 No  
 Almost  
 Other...

#### Section 4 of 6

Do you use any breast self examination tool currently?

Yes  
 No  
 Used a while back!

If you do use an app/website to perform breast self examination, which one?  
Short answer text

Is BreMo better than the app/website you use?

Yes  
 No  
 Maybe

After section 5 Continue to next section

#### Section 6 of 6

You Survived!  
Description (optional)

Figure B: Questionnaire for UI study


# C. BHA study questionnaire

### Section 1 - App features

Great! Let's quickly answer some questions now about different features/functions of these apps.

#### BSE Training feature

Breast self-examination (BSE) is a step-by-step method women can use to examine their breasts. By feeling of the breasts and breasts regularly, you can detect anything that seems abnormal. BSE training refers to helping the females that help in teaching women about BSE.



Which app has "Breast Self Examination (BSE)" training feature? (Check all that applies) \*

Pink Pakistan  
 BreHo  
 None

What do you like about the BSE Training in Pink Pakistan, if any? (Check all that applies) \*

Graphics  
 Video  
 Content  
 Nothing  
 Other

What do you like about the BSE Training in BreHo, if any? (Check all that applies) \*

Graphics  
 Video  
 Content  
 Nothing  
 Other

Which app has better BSE Training feature, if any? \*


Pink Pakistan  
 BreHo  
 None

Why do you think the selected app is better in regards to BSE feature?

Any suggestions for improvement of this feature?

#### Symptom Recording feature

Symptom Recording feature about writing/drawing different symptoms found during BSE.



In which app is Symptom Recording feature available, every time you perform BSE? (Check all that applies) \*

Pink Pakistan  
 BreHo  
 None

What do you like about the Symptom Recording feature in the app(s) that you selected above?

Which app has better Symptom Recording feature, if any? \*

Pink Pakistan  
 BreHo  
 None

Why do you think this feature is better in app selected above?

Any suggestions for improvement of this feature?

#### Breast health app testing

Welcome! Thank you for participating in BHA study. You should by now have explored the two apps allocated to you. The time consuming part is done. Now, you just have to complete this short questionnaire. This questionnaire will help us understand which app you like better and why, what features are lacking and what is needed to make the related apps "complete".

Did you test the app - Pink Pakistan? \*


Yes  No

Did you test the app - BreHo? \*

Yes  No

#### Symptom Tracking feature

The Symptom tracking feature allows you to look back at past data via visuals or text.



Which app has Symptom Tracking feature? (Check all that applies) \*

Pink Pakistan  
 BreHo  
 None

What do you like about the Symptom Tracking feature in the app that you selected above?

Which app has better Symptom Tracking feature, if any? \*


Pink Pakistan  
 BreHo  
 None

Why do you think this feature is better in app selected above?

Any suggestions for improvement of this feature?

#### Reminder feature

Reminder feature - It shows alerting date and time for monthly breast self-examination verification.



Which app has "Reminder" function? (Check all that applies) \*

Pink Pakistan  
 BreHo  
 None

What do you like about the Reminder feature in the app that you selected above?

Which app has better Reminder feature, if any? \*

Pink Pakistan  
 BreHo  
 None

Why do you think this feature is better in app selected above?

Any suggestions for improvement of this feature?

### Section 2 - App UI

Onboarding (or Sign Up process) is easy in which of these apps? (Check all that applies) \*

Pink Pakistan  
 BreHo  
 None

Is any of these apps "intrusive" (i.e. made you feel unsafe)? (Check all that applies) \*

Pink Pakistan  
 BreHo  
 None

If so, what aspect made it intrusive?

What do you think is lacking in these apps? How can they be made better to meet women's breast needs?

Which app has better graphics? \*

Pink Pakistan  
 BreHo  
 None

Which app has better (easy to understand) content? \*

Pink Pakistan  
 BreHo  
 None

Which app has language options that you are comfortable with? \*

Pink Pakistan  
 BreHo  
 None

Would you like the apps to be in any other language (Any other language preference)?

How easy was it to navigate through the Pink Pakistan app? \*

1  2  3  4  5  
 Difficult Easy

How easy was it to navigate through the BreHo app? \*

1  2  3  4  5  
 Difficult Easy

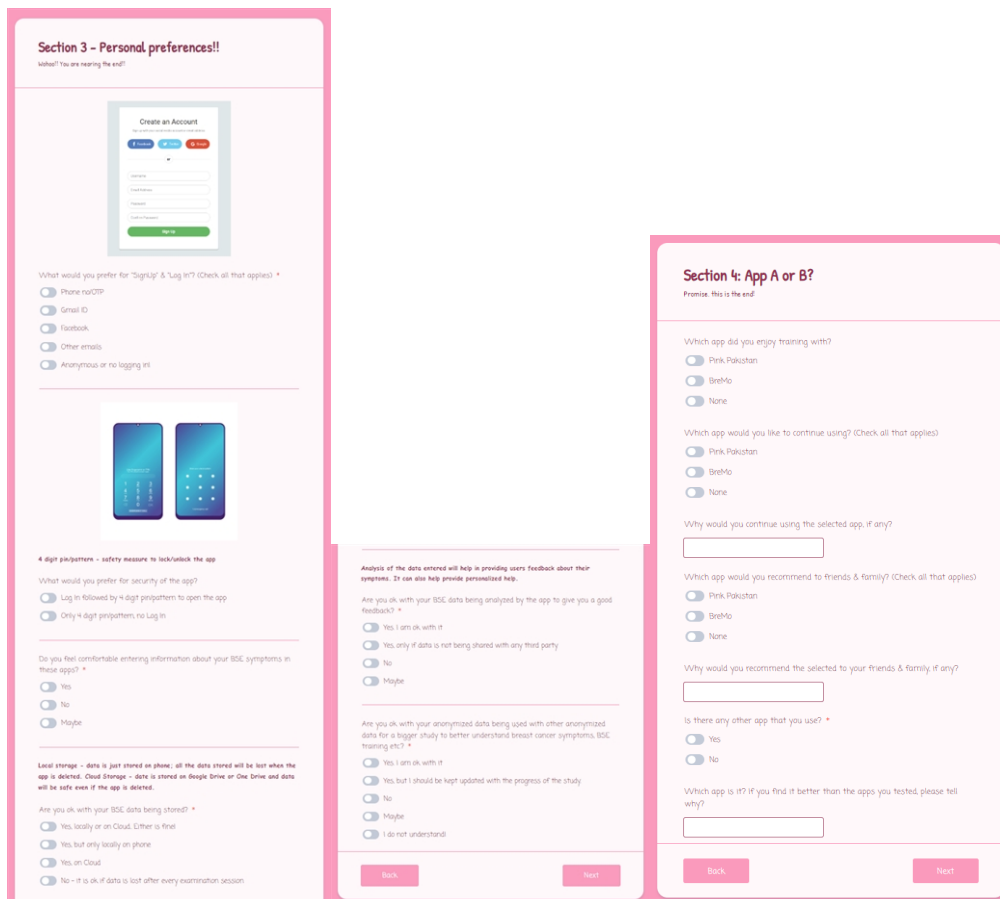


Figure C: Questionnaire template for BHA study, where only name of App 1 was changed

D. Additional features of BreMo V2

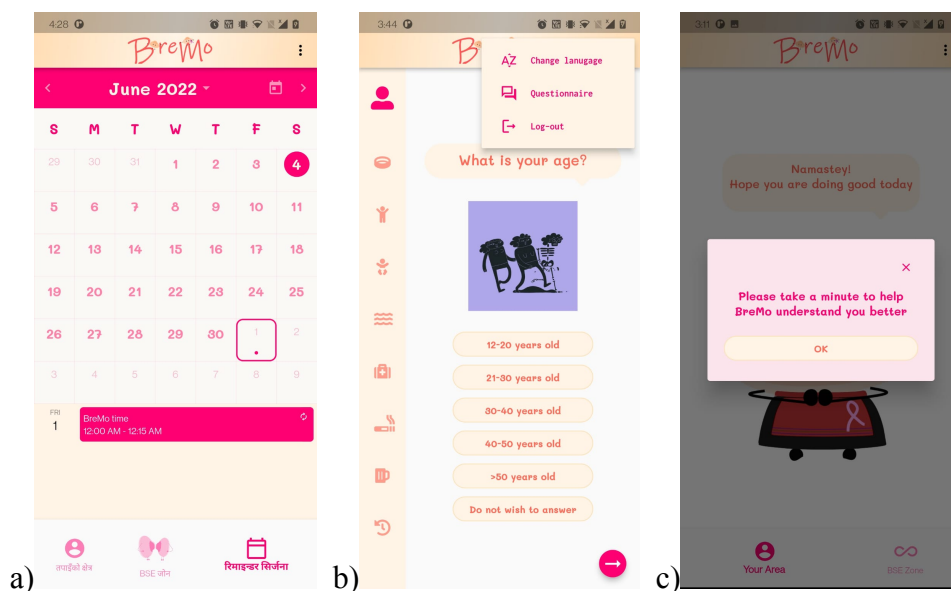


Figure D: Screenshots of BreMo V2: a) Calendar to select date for BSE, b) Side Menu - top right corner, c) Alert box intimating users to complete the questionnaire

# E: BreMo Version 3 prototype

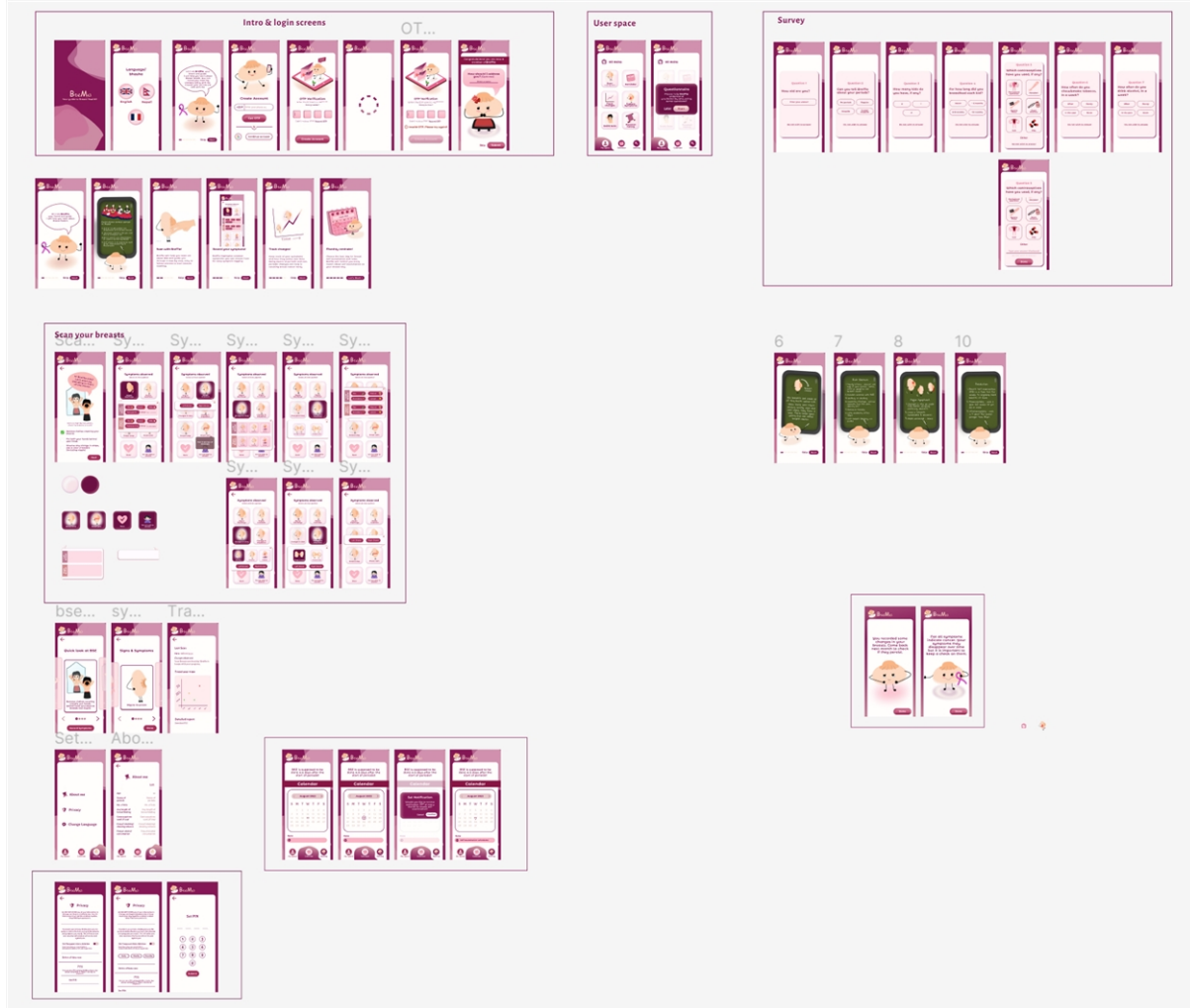


Figure E: BreMo Version 3 prototype - improved app

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