Bounce: Designing a Physical Activity Intervention for Breast Cancer Survivors

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ABSTRACT

The pervasive use of personal mobile devices provides an advantage for the delivery of a behavioral intervention anywhere and anytime. However, behavioral outcomes are dependent on adoption and sustained use of mobile-based interventions. Design approaches for engagement and feasibility of use in everyday life have been studied among the general population, especially to promote physical activity. In this paper, we discuss a design process that addresses additional barriers to adoption when the target population has symptoms, limitations, or needs resulting from a specific health condition. We designed a smartphone-based physical activity intervention for breast cancer survivors by combining behavior change theory with empirical evidence. In a preliminary evaluation, participants found the application engaging and useful, and continued to use the application briefly after the evaluation ended. We illustrate how our design process was used, and could be applied to other specific health conditions.

CCS CONCEPTS

• **Human-centered computing → User interface design**; *User-centered design*; • **Applied computing → Health care information systems**; Health informatics;

KEYWORDS

Behavioral intervention technology, breast cancer survivors, physical activity.

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1 INTRODUCTION

Behavioral intervention technologies (BITs) are behavioral and psychological interventions that use a broad range of technologies (*e.g.*, smartphones and web-based applications) to change behaviors related to physical health, mental health and wellness [21]. Traditional face-to-face interventions can be resource intensive, and therefore prohibit people from seeking help. By virtue of their ubiquity, BITs are a scalable means to help individuals adopt and sustain healthy behaviors [25].

BITs are designed and evaluated using behavior change theories such as social cognitive theory, the transtheoretical model, and the theory of planned behavior [13]. These theories help to illuminate factors, barriers, and determinants of behavior change that can inform the design of interventions. However, as Schueller *et al.* explain, *"behavior change theories and research within psychology provide little insight into how people interact with digital devices and technologies to promote integration into people's lives and sustained use"* [25]. Translating theory-based design strategies into systems features is non-trivial. More research is needed to describe how behavioral and design theories can be translated into BIT features [4].

Breast cancer survivors are a large and growing population with unique barriers and needs relevant to the design of BITs. Early detection and improved treatment options have raised the number of breast cancer survivors to over 3 million in the U.S. as of 2016 [27]. There is strong evidence for the efficacy of exercise to address a variety of cancer survivorship problems including disease-free lifestyle [8] and complaints such as fatigue and joint pain [2]. Yet, the number of cancer survivors who are physically active is low–one study of breast cancer survivors found that only 4.6% followed physical activity guidelines [26]. Breast cancer specific barriers to physical activity include issues such as lymphedema [24] and loss of appendicular skeletal muscle mass [3], which present actual or perceived risks of injury or discomfort during physical exertion.

In this paper, we describe the design process we used to understand the lived experiences of breast cancer survivors, and combine those findings with behavioral theory to develop a BIT for physical activity. Finally, we evaluated the use of the resulting BIT with four breast cancer survivors over three weeks. Our design process contrasts the universal behavior of physical activity with the unique needs of breast cancer survivors, whose past treatments present unique barriers to physical activity [3, 15].

2 RELATED WORK

There is a growing cross-disciplinary interest in BITs, but limitations remain in our understanding of how to design technologies for sustained use in everyday life, so they can serve as effective vehicles for delivering a behavioral intervention. Although high-level design recommendations abound, less is known about how to translate them into specific interventions, or how to apply them across intervention types for specific populations and needs.

Behavioral Intervention Technologies

The design of BITs is typically informed by theory-based strategies including goal-setting, rewards, self-monitoring, and conditioning [18]. For example, Consolvo, *et al.*, [4] propose eight theory-driven design strategies for BITs, including that they should: help users reflect on abstractions of their data that show progress towards a goal, be unobtrusive and interrupt daily life only when necessary, reward users with positive reinforcement of desired behaviors, and give users control over their data. However, translating such theory-based design strategies into system features is nontrivial, as is evaluating how and why a BIT may have worked [18].

Research that helps us understand the role of technology in delivering behavioral intervention tends to focus on evaluation, via usability testing and field trials of systems (*e.g.*, [5]). We complement this research by focusing on early design stages, and showing how BIT designers can take into consideration their target population's lived experiences with a specific health condition (*e. g.*, what type of positive reinforcement can BITs provide that is unique to the affordances of the technology?).

Physical Activity Interventions

Physical activity interventions that leverage mobile and wearable devices have largely focused on the general population. Systems tailored to more specific populations have included *iCanFit*, a mobile-enabled web application to promote physical activity among older cancer survivors [15]. *iCanFit* showed efficacy in a pilot study [15], and demonstrated user affinity toward a goal-setting feature [16].

Some physical activity interventions initially designed for the general population have then been tailored for cancer survivors, demonstrating feasibility–however neither the design approach nor the behavioral outcomes are clear or replicable [9]. To the best of our knowledge, physical activity interventions specifically for breast cancer survivors have not been designed for mobile devices. Lee and colleagues developed a web-based physical activity intervention for breast cancer survivors in South Korea [19]. Their system demonstrated usability and feasibility [19]. Further research is needed to understand the design of mobile BITs for physical activity of breast cancer survivors combining theory-based methods and empirical evidence.

3 DESIGN PROCESS

Our multidisciplinary design team consisted of human-computer interaction researchers with experience designing BITs, and clinical and behavioral researchers with experience designing interventions for breast cancer survivors. Our design process, illustrated in Figure 1, comprised of three activities: review of behavioral theory to identify key constructs, semi-structured interviews to understand the breast cancer survivorship experience, and co-design with clinical and behavioral researchers. Data from the three design activities were iteratively compared and combined using both inductive and deductive analysis [12]. For example, codes that emerged from the interview data were compared to existing knowledge of survivors' barriers from the literature (*e.g.*, pain and fatigue). The constant comparative method and affinity diagramming [14] were used to synthesize all the data into features of an intervention (see Table 1).

Review of Behavioral Theory

We conducted a review of literature on behavior change theories, BITs for sedentary behavior, behavioral interventions for breast cancer survivors, and survivor-specific barriers to physical activity. Our approach to reviewing behavioral theory was based on Hekler *et al.*'s [13] recommendation for balancing four levels of specificity: meta-models, conceptual frameworks, constructs, and empirical evidence.

Meta-models. Enabling generalizability, meta-models are useful for identifying high-level intervention approaches from which to generate an overall concept for a BIT [13].

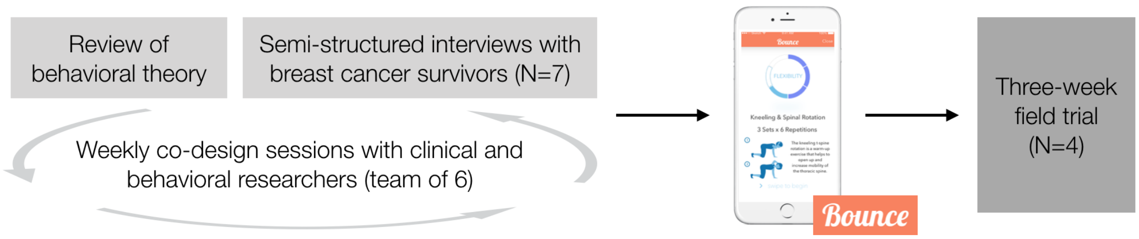

Figure 1: Design process consisting of three activities iteratively informing one another.

Meta-models are thus aligned with one of Norman’s fundamental principles of interaction, conceptual models [22]. Meta-models provide a broad perspective on factors affecting behavior including individual, interpersonal, cultural, and environmental determinants. We drew on the social ecological model [13] to consider various factors that could be addressed, in order to select which behavior change mechanism may be the most effective, feasible, and useful approach for promoting physical activity among breast cancer survivors. We considered, for example: will the BIT act as a personal coach, a social support network, a goal-setting tool, a game with an incentive and reward structure, or some combination of these?

Conceptual frameworks. Conceptual frameworks are used to predict and explain behavior by modeling an individual’s intention and decision-making toward changing a behavior. After reviewing a variety of frameworks, we found that the Transtheoretical Model (TTM) of behavior change [10] was most commonly applied to physical activity interventions as well as BITs (e.g., [9, 19]). However, we did not find that TTM provided specific enough guidance for the design of a digital intervention. In contrast, Social Cognitive Theory (SCT) [1] had more concrete concepts for influencing our design process. SCT has also been successfully applied to BITs targeting physical activity [23]. Ultimately, we used these frameworks in combination based on their similar constructs and common mechanisms for behavior change, as outlined in Table 1.

Constructs. Each conceptual framework explains behavior using constructs–highly interrelated factors affecting behavior [13]. Common constructs include self-efficacy and social influence [10]. Constructs provide guidance for design, but empirical evidence should be used to understand the experiences of end users, and give nuance to the relationships among constructs within a conceptual framework. We identified the constructs that are most applicable to physical activity of breast cancer survivors, and as we gathered empirical evidence to guide how we would apply these constructs, we referred back to the holistic framework that the constructs belong to.

Empirical evidence. Empirical evidence empowers the design process with specificity by grounding design decisions in the lived experiences of end users. We reviewed literature on the target behavior (physical activity) and the end user population (breast cancer survivors) to inform decisions throughout the design process. Extant literature identified known barriers and motivators to physical activity, including those specific to breast cancer survivors [29]. However, a nuanced understanding of the lived experiences of breast cancer survivors is required to design a BIT that would fit a user’s everyday life to effectively promote behavior change [13]. We therefore conducted semi-structured interviews with breast cancer survivors to inform design iterations.

Semi-structured Interviews with Breast Cancer Survivors

Semi-structured interviews enabled us to focus on human-centered aspects (e.g., motivations, fears, concerns) of a behavioral intervention that provide rich information for empathy-driven design of BITs [20]. We conducted semi-structured interviews with seven breast cancer survivors to learn about their experiences, preferences, and concerns. Each interview consisted of four sections: health history and current symptoms, general technology use, motivators and barriers to physical activity, and feedback on design mockups and concept ideas generated by our research team. Interviews were recorded and transcribed for analysis. The interviews were conducted individually with each participant by two members of the research design team. Findings from these interviews were a partial input for the co-design sessions.

Co-design with Clinical and Behavioral Researchers

Over four months, our research design team held weekly co-design sessions in which we (1) discussed literature on behavior change theories, BITs, and breast cancer survivorship, (2) shared interview highlights, and (3) iterated on mockups. Design sessions began with sharing new insights from our

Mechanism	Conceptual Framework	Construct	Empirical Findings	Intervention Feature
Cognitive	SCT	Goal Setting	Variation/ balance in an exercise program Freedom to plan the exercise routine	F1: Balanced exercise plan
Cognitive	SCT	Verbal Persuasion	Reassurance from a cancer specialist Exercises validated by experts	F2: FAQ tab and cautionary warnings
Cognitive	TTM	Consciousness raising	Fear of injury to surgical site	
Cognitive	SCT	Self-monitoring	Track progress, steps, time, and results	F3: Multiple representations of data
Cognitive	TTM	Self-reevaluation	Increase motivation for exercising Maintain the pre-diagnosis identity	
Social	TTM	Helping relationships	Connect with other survivors Motivate other survivors Join the social community	F4: Social interaction
Social	SCT	Social modeling	Visual demonstration of the exercises	F5: Virtual Exercise trainer
Behavioral	TTM	Reinforcements	Personal and meaningful reinforcements Personalized or customizable rewards	F3: Multiple representations of data / F6: Incremental levels and progress indicators
Behavioral	SCT	Mastery experience	Nudge breast cancer survivors along Maintain a "keep moving" attitude	
Behavioral	TTM	Group recognition	Exercise is more enjoyable with a friend	F4: Social interaction

Table 1: Our design process, which combined behavior change theory with empirical evidence on breast cancer survivors, resulted in six features that comprise the Bounce intervention.

literature review. Findings were then reported from recent interviews with survivors. As design sessions progressed, we entered into discussions about how those insights could inform our design strategy and BIT features. Throughout these discussions, we used iterative sketching and mockups [11] to communicate new ideas for features, while frequently circling back to the literature and interview data[1].

4 BOUNCE: A BIT FOR BREAST CANCER SURVIVORS

Our design process resulted in a design concept of Bounce, a smartphone-based physical activity intervention for breast cancer survivors. Table 1 shows how our design process combined behavioral theory and empirical evidence to elicit features of the intervention. From left to right, Table 1 shows the relationships between how we: considered cognitive, social and behavioral mechanisms of behavior change; applied two conceptual frameworks, social cognitive theory (SCT) [1] and the transtheorical model (TTM) of behavior change [10]; and used constructs of both conceptual frameworks, such as goal setting from SCT [1] and consciousness raising from TTM [10]. The rightmost column lists the six features of the Bounce intervention that resulted from this design process. Below, we describe each of the features and how they were derived.

Feature 1: Balanced Exercise Plan

Bounce delivers a physical activity intervention balanced across three exercise categories: aerobics, flexibility, and strength (Figure 2–1). Users are presented with a set of exercises to choose from, plus an option for one rest day per week. All exercises were defined by clinical and behavioral specialists in breast cancer survivors that were part of our research team.

This feature addresses two needs: variety in exercise type and intensity; and choice in exercise schedule. Survivors' needs for variety and choice relate to the SCT construct of ***goal setting*** (Table 1). According to the behavioral theory,

[1] Institutional Review Board (IRB) approval was obtained from the universities involved in the project. All participants consented to participate in our project.All participants consented to participate in our project (e.g., to be interviewed and co-design with our research team).

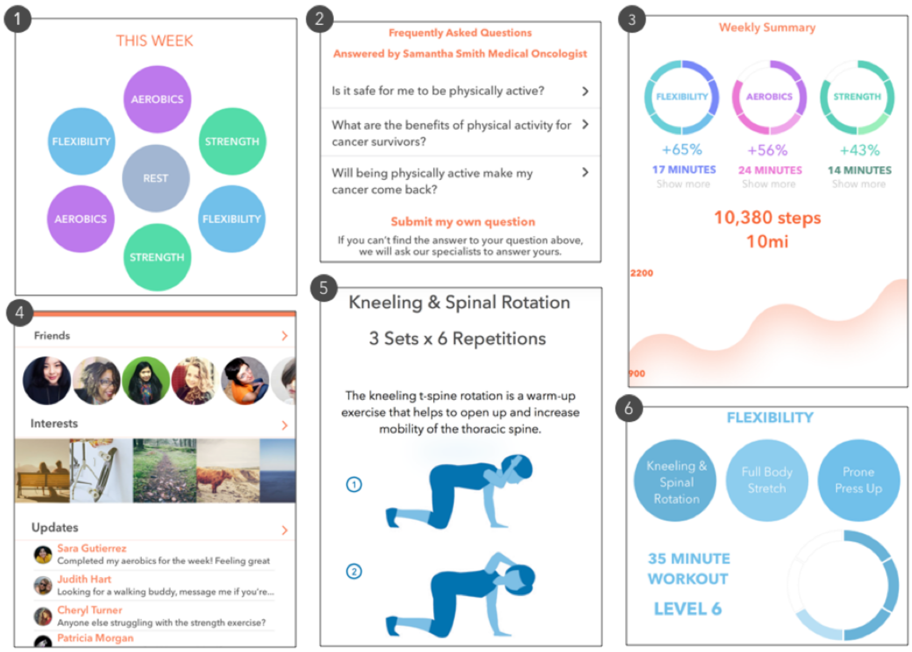

Figure 2: Bounce intervention features.

people can get closer to the changes they desire by formulating their intentions as both long-term and short-term goals. By having the power to make decisions about what and when they will change, they become more likely to engage in the healthy behavior. The balanced exercise plan is based on the ***goal setting*** construct within SCT–it incorporates participant preferences for variety and choice, and input from medical oncologists during co-design that helped us develop a bank of exercises appropriate for survivors.

Our empirical evidence shows that participants perceived that balanced exercise routines are beneficial to their health. Participants gave us positive feedback about the six days of varied exercises in Bounce:

> P7: *“[the design of Bounce] lines up so closely with what I’m currently trying to do that I felt that this was very reasonable for me... six days activity, one day of rest was spot on and mix up the types of activities... you can cover all the different areas...”*

According to the literature, lack of time and inconvenient exercise schedules are among survivors’ highest barriers to physical activity [29]. Participants recommended functionality that would give them choice in which exercises they would like to perform. The balanced exercise plan enables users to be in charge of scheduling their exercise.

Feature 2: FAQ Tab and Cautionary Warnings

Breast cancer survivors’ intentions to exercise can be thwarted by unique barriers. Our empirical data show that participants acknowledged the following as barriers to PA: fear of pain or injury, actual pain from attempting to exercise, fatigue, and limited access to specific advice for breast cancer survivors pertaining to exercise (Table 1). Similarly, in the literature, we found that survivors are negatively affected by cancer-related fatigue and joint pain [17].

> P4: *“I knew I had limitations, [but] if you have something that has been reviewed by a cancer exercise specialist, it’s like, ’it’s not going to hurt anything, We’re already in pain, and we don’t want to cause any further harm to ourselves...”*

Survivors want to access physical activity information that was tailored to them as breast cancer survivors. They want to know which exercises are appropriate based on their treatment history, but these exercises should come from a trustful source of information (*i.e.,* an oncologist or a cancer exercise specialist). To address these needs, we designed a Frequently Asked Questions (FAQ) tab and cautionary warnings (Figure 2–2). All content for FAQs and exercise descriptions was provided by medical oncologists from a local hospital.

The FAQ tab explains why exercises are safe or unsafe for survivors based on their treatment history. Survivors can view default Q+A’s, or submit their own question to a cancer exercise specialist. This feature was inspired by the TTM construct, ***consciousness raising*** (Table 1), which suggests that users would proceed with greater self-efficacy if they learn new facts, ideas, and tips that support the healthy behavior change [10].

Also, we designed treatment-specific cautionary warnings to be displayed above each exercise description, meaning that an exercise has been approved (or disapproved) by a clinical expert specializing in medical oncology. Each time the user opens a new exercise description, the app generates a motivational message if the exercise is safe (e.g. "Go ahead! You got this one!"), or a warning if their treatment history warrants caution (e.g. *"This one may be a little tough on your shoulder. Stop if you feel any pain."*). This feature was supported by the SCT construct, ***verbal persuasion*** (Table 1), which establishes that strong encouragement for the behavior change (e.g. telling someone they can do it) is a strong motivator [10]. ***Verbal persuasion*** is most effective when coming from a trusted authority, such as a medical oncology specialist.

Feature 3: Multiple Representations of Data

Survivors need straightforward representations of data that show them the real numbers associated with their activity, as opposed to an abstract representation of progress. For many survivors, walking is their main form of exercise, and they are motivated by visuals about their distance and time. Our empirical data suggests that survivors frequently check Health apps (*e.g.,* Google fit) to track their steps. Four out of seven participants expressed that walking is their main form of exercise.

> P6: *"You might have a lot of women who are not able to actually do a lot of exercise, like crunches but they can do a lot of walking. And for me, definitely walking is number one."*

To help survivors track their exercises' metrics, Bounce provides multiple representations of data (Figure 2–3) –rich data visualizations to help them monitor their progress and compare their performance to the prior week. In designing a feature to address the need for meaningful, simple data visualizations, we sought guidance from both SCT and TTM conceptual frameworks. According to these ones, a person is more likely to engage in behavior change when presented with *reinforcements* and opportunities for ***self-reevaluation*** and ***self-monitoring*** (Table 1). ***Self-reevaluation*** combines both cognitive and affective assessments of one's self-image with and without an unhealthy behavior, such as a sedentary versus an athletic person. ***Self-monitoring*** is the systematic observation of one's own behavior. This includes observing and recording the behavior [10]. To enable users' self-reevaluation, self-monitoring, and provide reinforcements to engage users in more physical activity, user's physical activity data is represented in multiple ways. Simple data visualization shows users their number of steps and time spent exercising. Additionally, we used gamification techniques [6] such as badges and trophies to reward users once they reach incremental accomplishments. Bounce also uses pop-up notifications to remind and encourage users to perform a physical activity if they have not already done so in the day, along with pop-up notifications to congratulate users on their levels of achievements in the form of positive reinforcement.

Finally, to design this feature, we initially explored data visualizations using motivational themes, such as representing total walking activity using distances between famous city landmarks, or earning sports or plant-themed trophies. Domain experts liked the idea of motivating themes during co-design, however participants had varying preferences for which them would be motivating, and overall preferred more straightforward representations of their numerical data. Our iteration on this feature therefore moved forward with circular, linear, and percentage-based representations of data without themes (Figure 2–3).

Feature 4: Social Interaction

Survivors need opportunities to connect with other survivors who have experienced similar treatments and surgeries, and who are relatively close in age or activity level. To meet this need, we designed a social interaction feature (Figure 2–4) that enables users to join or create groups based on special interests, treatment history, concerns, and location. This feature supports behavior change by encouraging users to build ***helping relationships*** and ***group recognition*** (Table 1). According to TTM, people who have ***helping relationships*** and ***group recognition*** are more confident in their ability to change, and develop a more favorable outlook on the behavior itself. ***Helping relationships*** combine caring, trust, openness, and acceptance, as well as support for healthy behavior change. They can be achieved through rapport building, therapeutic alliances, counselor calls, and buddy systems [10]. TTM also suggests that people would be more motivated to engage in behavior change if they feel like part of a team. Specifically, the construct of ***group recognition*** suggests that positive reinforcement from a group can increase the probability that healthier responses will be repeated [10]. Bounce's social interaction feature can be used to connect survivors with a friend that is on the same level as them. They can remotely follow the same plan and share their experiences and tips for exercising.

Findings from both our literature review and our empirical data indicate that survivors need more social support to overcome barriers to exercise. Specifically, having an exercise partner or team can increase survivors' motivation and confidence to exercise [15].

> P3: *"I think that's [the social interaction feature] great because I'm a social person... even when I walk, I have someone with me or you're encountering other people... it's always easier with a team than trying to go it alone."*

Survivors are most motivated to exercise when their exercise companion is also a survivor. However, our participants noted that it could be difficult to find a suitable exercise buddy. Every survivor has a unique experience as there are many different types of breast cancer and many courses of treatment. BITs must, therefore, be sensitive to survivors' unique physical activity levels, and help them connect with other survivors who are on the same level-playing field. The social interaction feature enables survivors to create and share a personal profile based on their interests, PA level and treatment history (Figure 2–4).

Feature 5: Virtual Exercise Trainer

According to our findings, survivors are more comfortable and confident in their ability to perform an exercise when they see someone else performing the exercise –particularly, someone like them. To address this need, we designed a virtual exercise trainer (Figure 2–5) that provides two types of instructions for survivors: (1) a written description and (2) a visual step-by-step demonstration. Each time the user clicks on an exercise, the exercise trainer appears beneath the written description. She shows the user the start position and end position for the exercise. This feature is based on the SCT construct of ***social modeling*** (Table 1), which states that interventions should include *"detailed demonstrations of the small steps taken in the attainment of a complex objective"* [10]. SCT suggests that people would be more likely to engage in behavior change if they see someone like themselves successfully engaging in the behavior. From our empirical data, participants indicated that they need someone to follow, as visual demonstrations are particularly helpful in learning a new exercise.

> P4: *"...having somebody tell you what it is and then demonstrate what it is, is really going to help people do it properly and have the proper form."*

The virtual exercise trainer enables users to view a figure representing them and learn how to correctly and safely execute the activity.

Feature 6: Incremental Levels and Progress Indicators

Our empirical data revealed that breast cancer survivors need a program that nudges them along slowly toward their long-term goals. To address this need, we developed incremental levels and progress indicators (Figure 2–6) inspired by the SCT construct, ***mastery experience*** (Table 1). Each level contains three progress indicators - 6-segment circles that show the progress of users based on the level of difficulty attempted. By attempting an easy, medium, or hard exercise, the user completes one, two, or three segments of the circle, respectively. The completion of the circle acts as an immediate, positive reinforcement for attempting the exercise, and a reminder of what is left to accomplish. The goal of this feature is to motivate users to perform attainable, yet progressively challenging exercises ***(mastery experience)*** [10] through the fundamental psychological driver, completion. People are wired to *"fill in the gaps"* –we seek closure on incomplete tasks because we must otherwise exert greater effort to retain that item in our mind [7]. Once we have checked that item off our list, behavioral theory suggests that we are more confident in our ability to accomplish the next task, even if it is slightly more difficult than the last [10]. Our empirical data suggests that breast cancer survivors have a *"keep moving"* attitude. However, to reach their long-term fitness goals, they need something to nudge them along a little at a time:

> P5: *"It's baby steps. I feel like if it was broken down into a smaller picture, it might be easier to get motivated to do it. But I just see this huge goal and I'm like, 'There's no way [I can complete that].'"*

During our co-design sessions, clinical specialists who work with breast cancer survivors explained that barriers to physical activity are extremely high for survivors. They strongly recommended that all survivor-specific interventions take a gentle, step-by-step approach to physical activity, to keep survivors motivated and willing to push forward. Bounce aims to help survivors progress gradually from one level to the next, moving them ever closer to their long-term fitness goals (Figure 2–6).

5 PRELIMINARY EVALUATION

Based on the design concept described in the previous section, the first functional prototype of Bounce was implemented as an iPhone application using the Swift programming language. This prototype represented most of the Bounce concept, except features 2 and 4. To evaluate validity and feasibility of the Bounce concept, we conducted a three-week field trial with four breast cancer survivors. The goal of the evaluation study was to understand the experiences of using the BIT in everyday life to inform further iteration.

Methods

Participants were recruited via a flyer placed in a clinic, inviting breast cancer survivors with *iPhones* to volunteer for the study. Interested individuals were directed to contact the principal investigator. Participants were selected if they: (1) had completed primary breast cancer treatment; (2) did not meet the Centers for Disease Control and Prevention physical activity guidelines for adults (*i.e.* were sedentary); (3) currently used a smartphone; (4) were able to read and speak English. Initially, seven survivors signed up for the study. Four participants met these criteria and, after screening, were enrolled in the field trial (average age = 35 years, average time since breast cancer treatment = 3 years). Participants were interviewed for 60-90 minutes during an initial meeting, in which we also installed the application onto their personal phones for a three-week field trial. The interview focused on their experiences with treatment, their barriers to physical activity, and their wellness goals. At the end of the three-week trial, participants were interviewed for 20-30 minutes to follow up on the usability and feasibility of the Bounce intervention, and to elicit opinions and feedback on its design. Interviews were recorded and transcribed for analysis. Interview transcripts were analyzed using qualitative techniques such as open and axial coding [28], and thematic analysis [12]. All participants gave written consent to participate in the study.

Results

Adoption and Use. All participants perceived Bounce as useful and motivating. Participants reported using Bounce frequently during the three weeks. On average, each participant interacted with Bounce 8 times a week (Figure 3). Surprisingly, participants continued using Bounce after the end of the three-week field trial[2]. All four participants used Bounce in week 4, three in week 5, two in week 6 and only one in week 7 (Figure 3). These results might indicate the degree of adoption by participants, showing that it has the potential to engage some survivors for more than three weeks. On average, participants completed 30 exercises available in Bounce along the three weeks, more than one exercise daily (P1 = 47 exercises, P2 = 28, P3 = 17, P4 = 27).

Participants discussed the usefulness and functionality of Bounce among their family and friends outside the breast cancer survivor community. All participants highly recommended the physical activity intervention to other breast cancer survivors.

> P2: *"I was telling my friends: 'This would be so awesome for that woman that's coming out, and doesn't know what to do... It could be a really positive thing for women that have breast cancer, and that had to have surgery or just women that have chemo and they're struggling with the side effects of that."*

[2]Participants consented to share their Bounce's data including the data collected after the end of the trial.

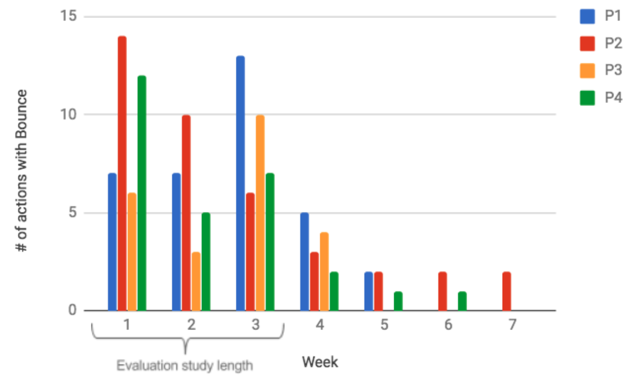

Figure 3: Number of times participants interacted with Bounce each week.

Fitness Level Adaptability. In general, all participants expressed a positive perception of the balanced exercise plan feature. They enjoyed how the variety of exercises was structured, clearly defining each exercise's purpose, focus, and intensity.

> P4: *"I enjoyed the structure of the variety saying that if you already did three cardios that week, then you should probably do more of the stretching..."*

We found that participants experienced a sense of motivation after they were able to successfully complete a level of exercise and move onto the next intensity level. However, all participants perceived that the exercises were too easy to perform overall. Once they had achieved the highest intensity available to perform an exercise, they were not fully satisfied with their physical activity. Participants wanted to feel more challenged, by engaging in longer physical activities with increased levels of intensity.

> P3: *"[I need exercises to be] both, longer and more difficult, I needed to be more challenged."*

Despite participants' satisfaction with the balanced exercise plan, our results indicate that Bounce needs an adaptability module that takes into account users' specific characteristics (*e.g.*, age, treatment types, and timeline) to generate and suggest an adaptive exercise plan. Adaptability would include a variety of exercises, and a wide range of intensity levels and length according to users' specific needs and progress. Although this characteristic seems to be obvious, we found that having variety and choice in an exercise plan was not enough to challenge participants. Thus, the adaptability module should also consider medical records and approval from clinical experts.

Adaptable and Customizable Progress Indicators. All participants expressed that viewing personal progress such as duration of physical activity, number of performed exercises, and number of steps was a useful feature that provided motivation and encouraged them to continue their efforts. Additionally, most of the participants expressed that pop-up notifications –which reminded them to engage with the intervention or rewarded their engagement with the intervention– were useful. However, two participants suggested that further adaptability would be more effective. For example, Bounce should learn from the users' routine to discern the time of day users usually exercise. The following day if a user does not get up and do a physical exercise by that time, Bounce would then send a pop-up notification to remind them, instead of choosing an arbitrary time for a reminder. On the other hand, two participants expressed the effectiveness of Bounce's gamification concept and admitted that attaining badges provided a major source of motivation.

> P2: *"I liked getting badges because it feels like you're doing something. And I liked watching the circle, like I'm doing it and then you get your little, 'Hooray!' "*

Visual Supports to Promote Correct Exercise Performance. All participants felt confident in performing the exercises included in Bounce's balanced exercise plan. The knowledge that these exercises had been validated by experts was comforting.

> P3: *"Some of the stretches in here are correlated to some of the stretches my physical therapist had given me... So was good to see that."*

One of the most important considerations in providing a physical activity intervention for breast cancer survivors is to ensure the correct execution of exercises to avoid possible pain, injury, or discomfort related to past treatment. Users should have enough information to guide them in performing the exercises correctly. Our results indicate that participants perceived the virtual exercise trainer feature as useful in this regard. However, participants requested a higher level of detail from the visual supports.

> P4: *"...videos of seeing the women doing the exercises would be great... –form is really important and I think a lot of people don't know if they're doing it correctly..."*

Videos would enhance users' ability to visualize the exercises in motion and thus have the potential to provide greater comfort and confidence in engaging in physical activity, as well as understanding and maintaining correct exercise form.

6 DISCUSSION AND CONCLUSION

While many BITs for physical activity focus on quantifying behavior change, our findings speak to the importance of quality in a physical activity intervention. One of the most successful features of the Bounce intervention was providing a balanced exercise program, and participants further recommended adaptable intensity, variety, and length of exercises to help meet individual users' needs and goals. Likewise, participants were also interested in detailed visual supports so they could ensure they were performing exercises correctly. Adaptability and customization may therefore increase the effectiveness of quantifying and visualizing a user's behavior change. Nonetheless, we think that the results from our preliminary evaluation showed that our BIT, designed using behavioral theory and empirical data, might have the potential to support physical activity for breast cancer survivors.

In this paper, we describe our design process of combining the use of behavior change theory and empirical data to design a BIT for breast cancer survivors. Instead of designing a BIT based entirely on theory and then evaluating it in field studies, our suggestion is to design BITs using all levels of specificity. Researchers should compare and contrast meta-models, conceptual frameworks, constructs, and empirical findings (e.g., observations about specific behavior and user characteristics), then decide which constructs to use as the foundation for BIT features and functions. Based on our results, the following recommendations emerged: conceptual frameworks are better applicable when the design process is starting, as they helped us to understand how each conceptual model defines behavior change interventions and what constructs of each conceptual model could apply to our problem. Selecting the constructs, we matched the theory with the empirical evidence, with domain experts helping us to prioritize the constructs. We hope our results would guide or motivate other researchers in combining different methods during the design process (e. g., theory and empirical evidence). Future BITs would benefit from a standardized methodology for designing behavioral intervention technologies.

7 LIMITATIONS AND FUTURE WORK

One limitation of our work is the number of participants during the evaluation study. Future work includes to explore the evaluation of Bounce with more breast cancer survivors, including a wider age range and different stages of cancer. Additionally, we plan to conduct another design iteration incorporating the results of our initial evaluation. As the social interaction feature was not available during the evaluation, we are interested in investigating if this feature can impact physical activity motivation, enabling users to create a social community for motivating other breast cancer survivors in physical activity.

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