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Supporting User Adherence to Weight Loss Behavior Change through Smartphone Applications

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Abstract

Almost half of global adults have attempted to lose weight in recent years. Many people make their own diet and exercise plans, and use websites and smartphone applications to track their progress. However, over 45% of weight loss application users quit these applications, and their weight loss goals due to lack of desired features, perceived lack of self-control, and due to the time-consuming and tedious nature of dietary tracking. The theory-based strategies of stimulus control, rewards and social support can address these challenges. In this dissertation, we investigate the effectiveness of these three strategies in supporting user adherence to dietary tracking and behavior change. We used a user-centered design approach to determine user requirements for the implementation of these strategies. We then implemented the strategies and evaluated user experiences and efficacy through field studies.

For the stimulus control strategy, an application to track causes of negative eating behaviors (cues) was developed. After identifying these cues, users were presented with recommendations for healthier behaviors to use. The stimulus control strategy led to a 3 times (3x) higher adherence to dietary tracking compared to a control group, and users achieved their calorie goals 52% of the time vs. 39% for the control group. User satisfaction with stimulus control was 65%. Social support was provided through a group fitness application that offered a structured eating and exercise plan to groups of less than 10 people, and the

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strategy resulted in a 2.3 times (2.3x) improvement in adherence to fitness goals from baseline, and scored 60.8% in user satisfaction. To assess the impact of rewards, a game with cash and virtual rewards was implemented. Users played the game irregularly and felt the strategy was unsuitable for consistent, long term tracking, leading to a user satisfaction score of 44%. These results reveal that supporting users to suppress triggers of negative behavior and recommending alternative healthy behaviors, as well as providing social support may be effective for supporting adherence to weight loss behavior change.

Keywords:

behavior change strategies, health and fitness, smartphone applications, user-centered design, human-computer interactions

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1. Introduction

1.1 Background

Global rates of overweight and obesity have more than doubled since the 1980s. In 2014, 39% of world adults were overweight and 13% were obese [56]. The increasing rates are a major public health concern. Both overweight and obesity increase the risk of developing chronic diseases such as cardiovascular disease, diabetes, cancers and musculoskeletal disorders [44], and chronic diseases account for more than half of all deaths worldwide [56].

The World Health Organization recommends behavior change (healthy eating and increased physical activity) for weight loss and long-term healthy weight maintenance [56]. Healthy eating involves eating calorie balanced meals (meals within a person's personal calorie goal, which is calculated based on weight, height and physical activity level) and increasing intake of fruits and vegetables as well as whole grains. The recommended activity level is 150 minutes of moderate intensity aerobic (cardio) exercises or 75 minutes of high-intensity cardio every week [44].

Behavior change theories (BCT) explain how human behavior arises and they outline several strategies that can be used in order to achieve behavior change. There are several theories, and altogether, around 20 strategies have been suggested. Table 1 (adopted from [25]) lists the strategies. Strategies in the "Behavior" category are actual habits that people undergoing behavior change need to use in a daily or regular manner. Strategies in the other groups are concerned with:

- Building knowledge - e.g. providing knowledge on calories and the required calorie balance for weight loss
- Building skills e.g. providing cooking lessons
- Identifying and addressing erroneous perceptions
- Helping people address the role of emotions such as depression and stress on negative eating and physical activity habits

Knowledge	Behavior	Cognitive	Emotion-focused	Therapy
General information	Realistic goal-setting	Perceived benefits	Stress management	Skill-building
	Self-monitoring	Perceived barriers	Negative feelings management	Increasing knowledge
	Rewards	Perceived risks		Motivation help
	Social support	Perceived norms		
	Time management	Self-confidence		
	Stimulus control	Self-talk		
	Role modeling/vicarious learning			
	Relapse prevention			

Table 1: List of behavior change strategies adapted from Doshi et al [25]

1.2 Weight Loss Products and Services

A global survey found 50% of world adults had attempted to lose weight in 2014 [17]. They used various strategies and products including structured and self-directed diet and exercise plans e.g. WeightWatchers, Jenny Craig and LoseIt!, meal delivery services e.g. NutriSystem, meal replacement products e.g. SlimFast (offers protein shakes, smoothies etc.), and diet products such as “Diet Cola and diet pills. Using a diet or exercise plan typically involves adhering to a daily or weekly personal goal e.g. adhering to a calorie goal or completing a number of minutes of exercise. Structured plans have specific daily goals, usually created by a professional nutritionist or physical trainer, while self-directed ones allow users to determine their own daily goals.

With the increasing growth of the Internet and smartphone usage, many structured diet and fitness plans have become available in health and fitness websites and smartphone applications. However, most people attempting weight loss use self-directed (own) diet and exercise plans that focus on calorie and weight monitoring, as well as increasing physical activity, often through walking more [68] [67]. Smartphone applications provide useful tools to aid those following self-directed plans, and over 75% of smartphone owners [51] have downloaded one or more health and fitness applications. The behavior change strategies emphasized in the applications are usually: setting a personal calorie intake goal, daily self-monitoring/tracking of food and exercise [7] [24], social support and rewards. Providing a physical activity goal was only included in 20% of the top 30 applications [58]. Some of the most popular dietary and fitness smartphone applications include: MyFitnessPal, LoseIt, MyNetDiary, FitBit, LiveStrong, All-in-Fitness and NutritionMenu [58].

A review of 25 of the most popular free and commercial products [34] found only Jenny Craig and WeightWatchers showed evidence for long-term effectiveness, possibly because like the clinical programs, the programs guided users on how to use the various theory-based behavior change strategies (Table 1) in their lives through counseling and peer support groups. Both plans are more heavily focused on healthy eating than on physical activity. The plans have a high cost barrier however, with WeightWatchers costing $43 a month, while Jenny Craig has an average cost of $570 a month, and are therefore unlikely to have a high impact on public health. Another study by the NWCR [47] found that people who used their self-directed diet and fitness plans for weight loss as opposed to structured plans, had an easier time maintaining weight loss in the long term because experimentation during the weight loss phase enabled them to understand which eating and activity habits had most effect on their weight, and the techniques they used to change these negative behaviors had become habitual. Those who used organized programs on the other hand had to learn how to change their regular eating and activity habits once they completed their weight loss programs. Dietary tracking and healthy eating were the main strategies used during weight loss whereas physical activity was mainly used during weight maintenance.

Clinical weight loss programs such as the Diabetes Prevention Program [33] have also proven overwhelmingly effective at assisting initial weight loss and at ensuring long-term weight loss maintenance. The programs also use a structured plan to help participants apply several of the behavior change strategies to their lives.

Overall, research suggests guiding people through the use of theory-based behavior change strategies e.g. through diet and exercise plans, may be more effective in the long-term compared to using diet products, meal replacement and meal delivery services. Supporting dietary tracking and healthy eating may also be more important for people attempting weight loss.

1.3 Problem Statement

Although smartphone applications provide useful tools to aid users following self-directed weight loss plans, and over 75% of smartphone owners have downloaded a health and fitness application [51], research shows around 45% of weight loss application users quit the applications before achieving their goals [51]. The reasons include abandoning the weight loss goals, lack of desired features in the applications, perceived lack of self-control of eating and exercise behavior, and the time-consuming and tedious nature of dietary tracking [41] [51] [49].

The stimulus control strategy can help suppress lack of self-control, as it deals with removing triggers of negative behavior, but it has not been included in many existing smartphone applications [7]. On the other hand, rewards and social support, which are known to support motivation and adherence to tasks, are widely included but their implementation in existing applications has been shown to be ineffective [50] [28].

Current research has aimed to identify design shortcomings in the implementation of these behavior change strategies in smartphone applications, and to propose potential solutions. However, these solutions are largely conceived by researchers, with little input from users on their needs and preferences. Since "lack of desired features" is a major reason for quitting weight loss applications, identifying users' requirements is necessary to create more effective applications. Likewise, including additional behavior change strategies to address barriers like "lack of self-control" is also needed.

1.4 Research Objectives and Scope

The aim of this work was to use a User-centered design (UCD) approach to implement and evaluate the effectiveness of stimulus control, rewards and social support strategies, in supporting user adherence to weight loss behaviors, particularly dietary tracking and healthy eating.

In UCD, end-users influence the final design of a product by being involved in various stages of the design process such as requirements gathering and prototype testing. We used focus groups, surveys, interviews, along with field studies in an iterative process to:

- Identify users' requirements for the implementation of the identified behavior change strategies, and for additional features and interactions to include in the applications for further support.
- Evaluate the effectiveness of these strategies at supporting adherence.
- Evaluate user experiences and determine how these experiences contributed to the observed effectiveness.
- Identify how to improve the design of the proposed strategies and features.

We focused on normal weight users because many people attempting to lose weight do have a healthy BMI [17], and because forming a tracking habit is the precursor to eating behavior change, which may prevent overweight and obesity in future.

We limited our work to healthy eating behavior change, because research shows healthy eating may be more important to people during the weight loss stage [47], whereas physical activity becomes more important during the maintenance stage. In addition, numerous works have already successfully explored and recommended how to design applications to support physical activity behavior change (e.g. [18] and [50]), but very few have focused on applications for healthy eating behavior change.

1.5 Dissertation Outline

This dissertation is organized as follows. In chapter 2, we present related works on strategies that have been used to support dietary and physical activity behavior change. In chapter 3, we present the design and evaluation of the *WeightBoss* application, which implements the stimulus control strategy, and in chapter 4 we present the design, implementation and evaluation of *HappyInu*, a game with cash and virtual rewards. Chapter 5 presents a participatory design study, where users of both *WeightBoss* and *HappyInu*, along with other participants drew on their experiences with weight loss applications to design the concept for a dietary tracking application that would address the challenges they faced. In chapter 6, we present the user requirements study on how to provide social support in fitness applications. We then present the design of *MyFitnessTeam*, a group fitness application that we developed, and the results from a 6-week field study on user experiences with the application and its effectiveness on healthy eating and physical activity behavior change. Chapter 7 concludes this dissertation with a discussion on the various strategies evaluated and recommendations for future research.

2. Related Works

In this chapter, we present related works on supporting user adherence to dietary and physical activity behavior change through both mobile phones and computer applications. The works we review can be grouped into three (3) main categories: Simplifying self-monitoring, providing health coaching and supporting user motivation. Strategies used to support user motivation include: persuasive applications, games, rewards and social support.

2.1 Simplifying Self-monitoring

Manual self-monitoring (tracking) is a time-consuming, tedious and error prone process [41], and researchers have aimed to reduce user burden through several ways. Early works focused on automatic detection of walking, running and cycling activities through the use of mobile phone and wearable sensors ([4], [20]). Newer research has expanded to detecting and counting repetitions of other physical activities such as yoga poses, push ups etc. through integrating sensors into exercise equipment such as exercise mats ([37], [78], [70]) and weight lifting equipment [35].

To support food tracking, Andrew et al [5] developed POND, a streamlined food diary, where users track the number of portions eaten of the various food groups e.g. proteins, carbohydrates and vegetables. While easy and fast to use, some users felt more detailed tracking (calories, nutrients) was necessary in order to meet their goals. Other researchers have used photo-based food diaries. In [21], both a mobile application (DECAF) and website were provided. The DECAF application only allowed users to upload their photos, while the website could be used to provide additional details such as the meal components, social context (with whom the meal was eaten), location and feelings after eating the meal. The study found providing photo-journaling reduced the number of users who chose not to journal due to difficulty from 60% to 23%. Photos also enabled recall of context and triggers of behavior and users felt photos provided an easier way of determining whether a meal was healthy or unhealthy (compared to food labels, calories etc.) because they had an image of what healthy and unhealthy meals looked like, but could not relate this image to nutritional values, and it was easier to understand the size of a meal and how processed it was from photos. DietCam [39], an iPhone application, automatically recognized the types of foods and their volumes, from 3 photos or a short video. The information was used to obtain a calorie estimate of a meal. The overall accuracy of the system was 92%.

In addition to simplified journaling, reminders/notifications have been used to trigger the journaling process. Bentley et al [9] found that including reminders in their application improved the average food logging rates of users from 12% to 63%.

2.2 Health Coaching

Health coaching has included supporting user's knowledge on healthy eating, as well as providing personalized feedback on how to improve current behavior.

Supporting user knowledge on healthy eating has mostly been achieved through casual games. One such game is LunchTime [57], where users in a team were provided 3 meal options and asked to choose the best one for their health goal. Goals could be weight loss, manage diabetes etc. A new challenge was posted daily with users having 12 hours to respond, allowing them to research the food options in the game and therefore reflect on the choices. An initial study found the game supported reflection on individual eating behavior resulting in a shift in perceptions. A long-term study is however needed to determine how much this attitude shift results in actual eating behavior change. In a similar game, OrderUP! [32], users acted as waiters who had to recommend healthier foods as alternatives to the ones virtual customers ordered. Users enjoyed the game and reflected on their eating behavior but wanted the system to include information on why a certain choice was the best.

Applications that provided personalized behaviour feedback to users include HealthMashups [9] and MyBehavior [64]. In HealthMashups, an Android application displayed statistically significant observations (based on Pearson's correlation) between various context data and user's behaviour such as eating, sleeping and walking. Natural language was used to convey the observations and the strength of the correlation e.g. "You walk significantly more on Fridays", and observations were updated daily. Data sources for the application include automatically-sensed data (city, weather, user's free/busy hours from the calendar), third-party sensor data (weight, step count and sleep from Withings Scale and FitBit), and manually logged user data (food, exercise, mood and pain). After a 90-day field study, the authors found that the system improved users' self-knowledge on how various contexts affect their wellbeing, and they initiated life changes to address these. As a result of these changes, participants managed to lose weight (2.3 Kg average over 90 days) and had a significant improvement in their mood. In the MyBehavior application [64], users manually logged food intake and physical activity. Automatic sensing was also used to collect walking, running, stationary and driving activities. Logged data was tagged with GPS location. Unsupervised clustering and optimization were then used to learn user behaviors at various locations, and provide food/activity recommendations that the user could easily implement in their current lifestyle. Use of MyBehavior resulted in significant improvements in walking minutes and calories burned through non-walking activities, even when barriers such as low mood and bad weather existed. Users also followed significantly more personalized suggestions than non-personalized suggestions (control condition).

2.3 Supporting User Motivation

Persuasive Applications

A well-known persuasive systems for behavior change is UbiFit [20]. In UbiFit, the wallpaper on users' phones was used to depict user's physical activities during the week, with every 10 minute session of activity depicted as a flower, and every completed weekly goal depicted as a butterfly. Different types of activities were depicted by different flowers to persuade users to engage in a variety of activities. To avoid the effect of negative feedback, physical inactivity during the week was depicted as an empty garden. The system improved users physical activity levels (minutes of exercise per week), and the authors found users who had the glanceable display (wallpaper) had significantly higher activity levels compared to users who had the system without the display.

Games

Games for behaviour change have mostly been aimed at promoting physical activity, but dietary self-monitoring and behaviour change has also been studied. Fujiki et al developed NEAT-o-Race and NEAT-o-Sudoku mobile phone games [31] to promote physical activity. Both games used aerobic activity, measured by a wearable sensor as input. In NEAT-o-Race, movement in real life resulted in real-time movement of the players virtual avatar in a race against other players. Each race lasted for short periods e.g. 24 hours, and coach avatars and notifications were used to motivate more physical activity whenever a player lagged behind. In NEAT-o-Sudoku, the measured aerobic activity corresponded to game points which the player could use to get a hint on how to complete a Sudoku puzzle. Both games. Evaluation found more consistent players of the game had more physical activity minutes, and the real-time nature of the games fueled competition. Ahtinen et al [3] developed "Into", a mobile application which automatically sensed users step counts and visualized the distance covered on a map. Players could set goals e.g. "Walk from Helsinki to Tampere" and they could collaborate with friends to complete the goal. The interface displayed a different animal based on the speed of progress towards the goal e.g. snail for slow progress and horse for fast progress. Users enjoyed the game and found a virtual trip to be an easily understandable and interesting way to understand their physical activity levels.

To support healthy eating, Time to Eat [62] users chose a virtual pet and uploaded their breakfast photos every day to "feed" their pets. The healthiness of the breakfast was scored and an email sent to the user from their pet, with feedback such as a healthier meal recommendation or appreciation for a healthy breakfast. The game was aimed at adolescents and evaluation found players were twice more likely to eat breakfast than those who did not play the game.

Rewards

Behavior change applications usually offer virtual rewards such as points, ribbons and trophies that are earned at pre-specified milestones set by the application. Some also offer cash rewards when the user accumulates a specified number of points. A study by Munson et al [50] found that users find virtual rewards unmotivating. In particular, the use of points alone was deemed confusing since users did not have a way of knowing the significance of earning a certain number of points was. This is in contrast to games where more points lead to more powers or in studies such as [6] and [75], where points are related to social status. Studies on the effect of cash rewards on health behavior meanwhile have found people lost more weight if there was a money reward [15], and the effect increased if a large sum ($500) was to be split amongst successful members in an anonymous group [40]. Both [15] and [40] studied overweight and obese patients.

Social Support

Applications have aimed to provide users with social support through: sharing fitness activity data with friends, incorporating fitness interventions into existing social media platforms and providing group interventions in group fitness applications.

Sharing of Fitness Activity Data

Sharing fitness updates is widely included in both commercial (e.g. *MyFitnessPal, FitBit*) and research applications (e.g. [50] [23] [18] [18]). In most applications, a message is automatically generated and posted on the user's SNS account. The method has several challenges however, such as user concerns over privacy, overburdening friends' with updates and appearing boastful or narcissist ([28] [61]), and many users find their posts are often ignored ([50] [28]) or receive 'likes' without additional feedback [61]. A framework for making auto-generated and user-generated updates more likely to receive the desired feedback was developed by Epstein et al [28]. Other applications ([4] [18], Nike+, Endomondo) share updates to a small group of friends within the application. The friends are usually drawn from the user's existing social network e.g. real life friends and co-workers. This approach was shown to inspire social comparison and competition in [4].

Some people opt to broadcast their fitness journeys independently on social network sites (SNS) such as Twitter, Instagram and Facebook. Twitter posts are mostly on physical activity (goals and activities done) [72], while Instagram has been used to share both food and physical activity posts [13]. Users on both platforms usually share to the general public. Facebook users tend to share health updates with friends, and they have a preference on which friends should receive certain updates [53].

Integrating Interventions into Existing Social Media Platforms

Social media applications have high user retention rates (95% retention on Android), and researchers have attempted to improve adherence to behavior change interventions by offering them within social media platforms. Merchant et al [48] created a private Facebook group to deliver weight loss information by a health coach. Over 72% of the posts received at least one interaction (e.g. like) from users, with polls and photos being most popular, but user engagement visibly declined with time. Maher et al [45] used a Facebook application to provide existing Facebook friends with a physical activity intervention, and results showed access to the application significantly improved weekly moderate to vigorous intensity exercise minutes, with the effect being larger for participants who logged in more frequently and those who were insufficiently active at baseline. Likewise, Foster et al [30] used a Facebook application to post user's daily step counts (from a pedometer) to their newsfeed. They found that posting step counts resulted in a significantly higher number of steps. On Twitter meanwhile, a study [74] found that Twitter use predicted weight loss, but there was a significant decline in both active engagement (posting) and passive engagement (reading posts only) after 3 months.

Group Fitness Applications

In several applications, users are grouped together and share updates towards a common goal. Features to support group collaboration or facilitate competition are usually included. In [16], [27] and [26], users posted updates on how they completed an application-given daily goal. The studies found social conditions improved performance, with [26] finding groups with more non-challenge based interactions had higher levels of performance.

Other works have included both competition and collaboration elements, and evaluated the efficacy of the elements against each other. In Pass the ball [65], users took turns tracking their physical activity using their smartphone accelerometers for 1-hour intervals and competed against other teams, while in

HealthyTogether [12] people were paired up and required to track their FitBit steps in order to earn badges. Badges were either earned independently and users competed against their paired partner, or both users' performances contributed to the score either equally or with the user's personal score contributing slightly more. The competitive element was less effective than the collaborative elements. Nishiyama et al [54] studied 5 forms of collaboration and competition and found teams where members could see their team's progress towards a common goal and other teams' progress performed best. When team members could see progress towards the common goal and individual contributions of each member, overall performance lowered but individual performance had a lower variance. Likewise, when team members could collaborate towards a goal, but not compete against other teams, performance lowered.

2.4 Chapter Summary

Applications for dietary and physical activity behavior change have focused on simplifying user effort through automated tracking and machine learning of causes of behavior, and on supporting user motivation through persuasion, enjoyment (games), rewards and social influence. Automated tracking, persuasive systems, games, and providing social influence through group interventions proved popular with users and had significant effect on behavior change. Providing social influence through sharing and providing rewards however had several challenges, which affected efficacy.

3. Implementation and Evaluation of Stimulus Control Strategy

3.1 Introduction

Many human behaviors are a result of physical, mental, emotional or environmental cues. For instance, people eat in response to hunger cues, and drink in response to a thirst cue. There are several other cues for eating and drinking including stress, feeling overwhelmed, being at a specific location e.g. a food court and a specific time e.g. every 12:30 PM [73]. A cue is known as a *stimulus* if its removal leads to a change in response (behavior) [69]. The stimulus control strategy for healthy eating is concerned with identifying cues for negative eating patterns and suppressing or removing them. Cues for positive behaviors can also be added to increase the probability of engaging in healthier eating behaviors [63]. By suppressing or removing stimuli, the automatic negative response to the stimuli is also suppressed, and this can help address the feeling of lack of self-control many people face when attempting dietary behavior change [49] [63].

The goal of this study was to apply user-centered design to implement stimulus control for dietary behavior change aimed at weight loss, in a smartphone application. In this chapter, we present the user requirements study, implementation and evaluation on the effectiveness of the strategy, and user experiences with our implemented application. Although our work is limited to dietary behavior change, the strategy can also be used for encouraging participation in both opportunistic and scheduled physical activity. We discuss how this can be achieved in section 3.6.

3.2 Study Method

We recruited sixteen people (3 male, 13 female, average age: 24.9 years) to participate in the study. The participants were recruited via a Facebook post looking for: *"People interested in helping to design a calorie tracking application and to participate in a field study and interview afterwards"*. Thirteen (13) participants were full time University students and 3 were employed full time in desk jobs. Eight participants were Asian and 8 African. Ten of the participants had used calorie counting applications for a period of 2 weeks to 2 months.

Eight of the recruited participants took part in a user requirements study. All 8 participants had used calorie counting applications before. The study was aimed at identifying: (i) desired input methods, (ii) how stimulus control feedback should be presented e.g. natural language short messages such as in [9], via graphs or other methods, and (iii) what additional features and interactions to provide. We conducted one-on-one interviews over Skype (n=6) and in person (n=2). Each interview was started with an explanation of the stimulus control strategy, and participants were then asked the following questions:

- What type of stimuli should be collected e.g. mood, GPS location etc.?
- How do you want to input food and context information? Search through a database, list of common foods, likert scale etc.
- What would be the best way to present feedback?
- What other features do you require in the application?

Following the requirements study, two applications, *WeightBoss* (with stimulus control features) and *HealthyLife* (control application with no stimulus control features), were developed based on the user requirements.

We then conducted a 25 day field study with all 16 participants to compare how effective the 2 applications were at: (i) supporting user retention (usage of the applications) after initial novelty has worn off, and (ii) helping users to achieve their calorie goals. We hypothesized that removing negative cues due to stimulus control would enable users of *WeightBoss* to achieve their calorie goal more often than users of *HealthyLife*, and that the confidence gained through this success would mean *WeightBoss* would also be more effective at supporting use retention. The experiences with both applications were also collected in exit interviews interview, in order to determine further requirements for providing stimulus control in weight loss applications.

The participants were randomly divided into 2 groups of 8 participants each. One group used the *WeightBoss* application and the other group used the *HealthyLife* application. The study period was divided into a baseline (7 days) and intervention phase (21 days). During baseline, participants in both groups were provided daily calorie tracking features. During intervention, *WeightBoss* users got access to stimulus control features in addition to the calorie tracking features, while *HealthyLife* users continued to use only daily calorie tracking.

3.3 User Requirements for Inclusion of Stimulus Control in Weight Loss Applications

Relevant stimuli

Participants were interested in the effect of: time (n=1), semantic location (n=2), hunger (n=3), emotion (n=5), social context i.e. party, lunch with friends etc. (n=5), cravings (n=8) and habit (n=8).

Input method

To input food information, all participants were against the idea of using the extensive calorie databases that are used by existing applications e.g. FitBit and FatSecret, and that are made publically available through APIs. The reasons given were: (i) too many options in the search results to choose from, making the process time-consuming and confusing, (ii) many of the foods and brands were irrelevant for people outside the USA and (iii) missing food items (Asian and African cuisine). Instead, users requested a custom database of foods and drinks that they consumed most often to be created. Five participants suggested displaying the database entries as a searchable list of foods. The foods should be grouped e.g. Grilled dishes (Yakimono) and Rice dishes, and each list item should contain the food name and serving size. Users could then click on buttons next to the food item, to increment/decrement the number of servings they ate. For context information, participants (n=6) suggested displaying a radio list (one selection only) of the different stimuli. Figure 1 shows mock-up interfaces created during the user requirements phase, for the meal (food) and context information input pages.

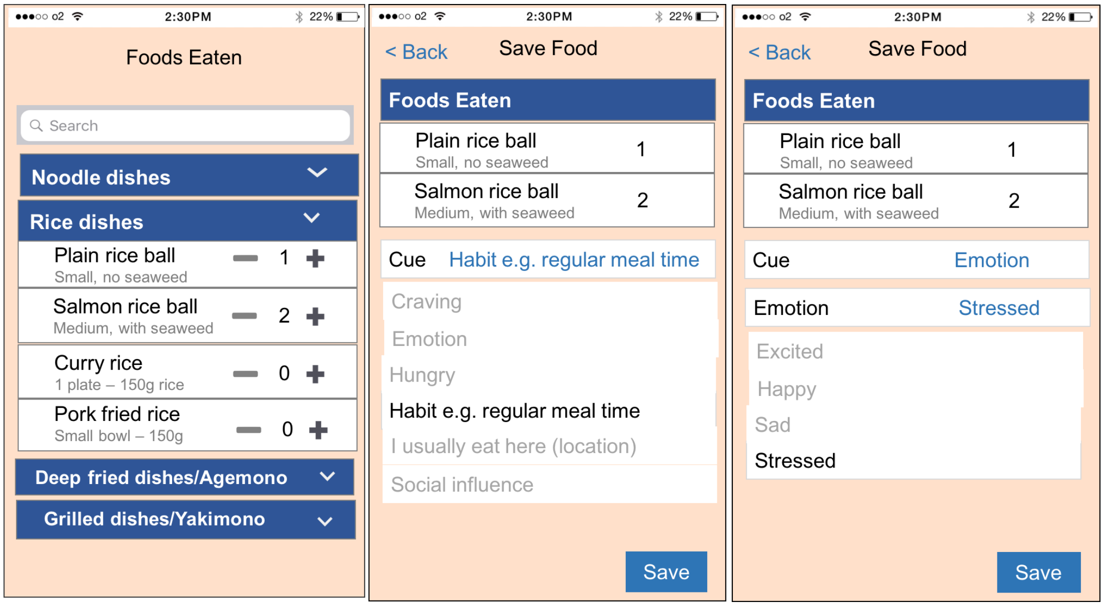


Figure 1: The figure shows sketches for the proposed interfaces for food input (left) and context information input (center and right).

Feedback Presentation

Numerical values (calories eaten, calories used, calories remaining) and weight trend graphs are the main way feedback is presented in existing calorie tracking applications. All participants suggested the use of numerical values and graphs would therefore be more intuitive for them to understand.

3.4 WeightBoss and HealthyLife Applications

We developed *WeightBoss* and *HealthyLife* based on the identified requirements. Our custom database contained 200 foods and drinks. Data for the foods to include in database was collected from the participants through Google Sheets, and calorie values were collected from existing calorie databases such as FatSecret (www.fatsecret.com) and Eat Smart (www.eatsmart.jp).

In *WeightBoss*, users were given a personalized calorie goal and they were required to enter foods eaten, amount, main reason for eating (cues) and the semantic location or emotion for each meal. Users could choose from 6 different cues (hunger, craving, emotion, habit, location and social influence) and 11 semantic locations grouped into: home, work and eating out. Habit refers to eating behaviors such as eating at specific times even when not hungry e.g. during coffee breaks on the way to work, constant snacking at work and always clearing the plate even when full.

Two kinds of feedback were then offered:

1. Calorie intake for the day (eaten, remaining)
2. Graphs depicting:
   (a) The user's calorie intake, calorie goal and weight trend over 7 days (*calorie trends graph*). The weight trend and calorie goal were plotted as line graphs and the calorie intake was plotted as bar graphs. (Fig. 2)
   (b) Calorie intake vs. Eating cues over 7 days (*Eating cues graph*: Fig. 3 (left))
   (c) Calorie intake vs. Semantic Locations over 7 days (*Semantic locations graph*: Fig. 3 (right))

To help the user see the trigger foods (foods that contributed most to calorie intake), calorie intake in the eating cues and location graphs was plotted as a stacked column, with each stack showing the amount of calories consumed from a type of food e.g. fried side dish, breakfast dish etc. A calorie intake vs. emotions graph (similar to the calorie intake vs. locations graph) was not implemented due to time restrictions, but its inclusion could also help participants determine the effect of different emotions on eating behavior.

Along with the feedback graphs, users were guided on how to: (i) identify an important negative eating cue, (ii) adopt a theory-based action/behavior (behavior goal) to suppress or remove the cues. To identify important negative eating cues, users referred to the *eating cues graph*. The cue which had the highest calorie intake associated with it was the most important one. In Fig. 3 (left) for instance, the graph shows that most calories the user consumed were due to "Hunger", and the main food they ate was "Rice dishes". The most important cue is therefore "Hunger" and the application would recommend evidence-based behaviors that deal with overeating due to hunger such as to drink 2 glasses of

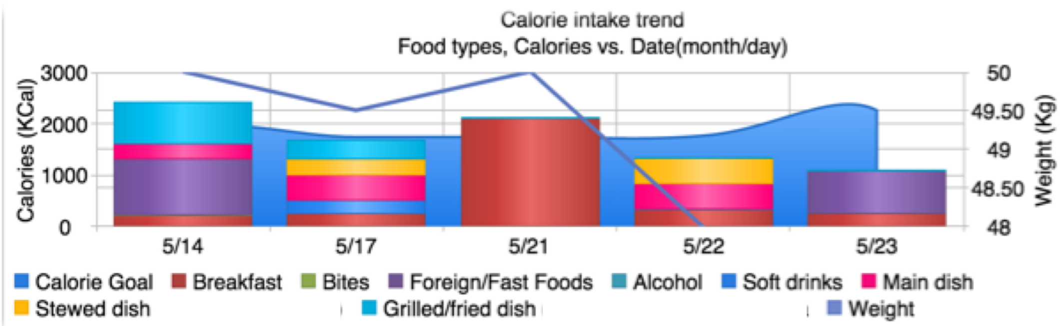


Figure 2: The 7-day calorie intake and weight trend graph from WeightBoss

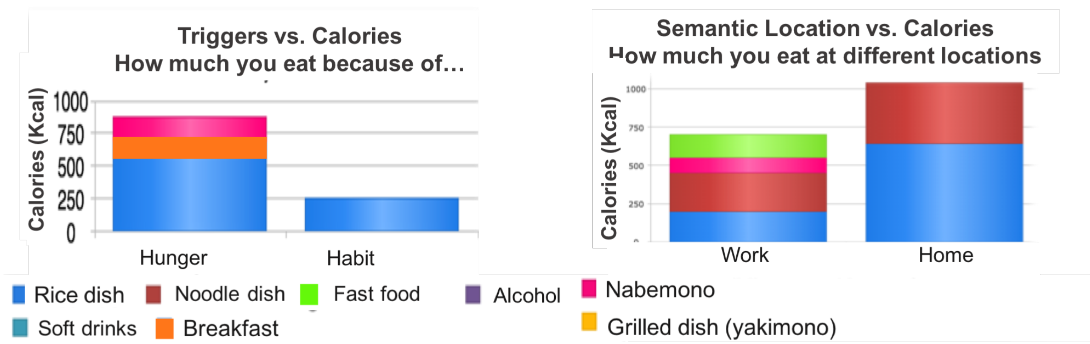


Figure 3: The calories eaten due to different cues (left) and the calories vs. semantic locations graph (right) from WeightBoss

water before a meal, to eat a meal or snack every 3-4 hours to avoid excessive hunger, practice mindful eating (chewing thoroughly and eating without distractions) or eating lower-calorie Rice dishes [63].

WeightBoss provided at least 5 behavior goals (recommendations) on how to address each cue, and users then chose one goal to use on a daily basis. We gave users a number of choices so that they could choose a behavior that was consistent with their physical and social environment as well as preferences. Table 2 shows some of the behavior goals recommended to users by the *WeightBoss* application.

Whenever a behavior goal had been used consistently during the day, it could be marked as completed. If the user had consistently used the behavior goal but no weight change or less than desired weight change was observed in the following week, they were prompted to review their *eating cues graph* to verify that they were addressing the most important eating cue, and if this was correct, to select a different behavior goal.

After a user had identified a behavior goal that led to the desired weight loss each week, they could stop regular calorie tracking and instead only log their weight and whether or not they had used their behavior goal each day. Since this is much faster and easier than meal tracking, it could also motivate users to continue with the application over the long-term.

Fig. 4 shows the WeightBoss home page and behavior goal selection screens.

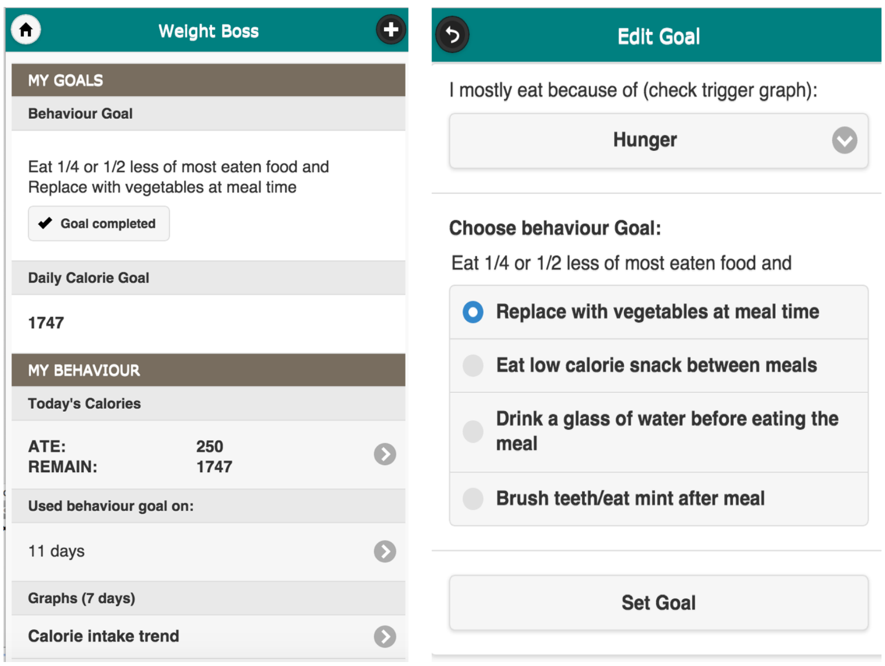


Figure 4: The WeightBoss home screen (left) and the behavior goal selection screen (right).

In the HealthyLife application (control application), users could also set a calorie goal and log their daily meals (type and amount) but context information was not collected. Users got daily calorie intake summaries and a weight trend graph as feedback, which is similar to the feedback in existing weight loss applications. General tips on how to lower calorie intake e.g. reduce portion size and manage cravings by distracting yourself were also provided in a website.

Cue	Example of negative behavior	Recommended behavior goals
Social influence (party)	Drinking many glasses of beer	Drink a big glass of a low-calorie, non-alcoholic drink e.g. water with lime after each beer.
		Drink one or more glasses of water before you start drinking for the evening.
		Order small size, ultra-light bottles instead of the usual.
	Drinking wine	Dilute your drink with sparkling water (1:1 ratio).
Hunger	Eating large portions	Eat and snack at regular times (every 2-3 hours between a meal and snack, and a snack and next meal).
Habit	Mindless snacking	Do not buy any high-calorie snacks. Buy or prepare single serving of nuts, fruit or raw vegetables instead.
	Eating until plate is clear	Put less food on the plate or remove 20% of food on the plate before eating.

Table 2: Some of the behavior goals *WeightBoss* recommended to address negative eating cues

3.5 Evaluation Results

During the baseline phase, participants in both groups were asked to track their daily calorie intake. After the baseline phase, *WeightBoss* users were then given the stimulus control feedback graphs and prompted to select a behavior goal. During the intervention phase, they were asked to log whether or not they had used their chosen behavior goal every day, and to log calorie intake at the end of the day at least 3 times a week in order to gather ground truth on effect of behavior goal on calorie intake and enable them to change the behavior goal if needed. *HealthyLife* users were asked to continue with daily calorie tracking.

Adherence to Dietary/Calorie Tracking

In the baseline phase, all participants in both groups managed to log their daily calorie intake everyday i.e. 100% adherence rate. Adherence levels for both groups declined during the intervention period. By the fourth week, *HealthyLife* users (control) group had an average adherence rate of 1 day a week while *WeightBoss* (experiment) users had an average adherence rate of 3 days a week. This difference in adherence was not significant (t=-1.37, p=0.19).

Changes in Calorie Intake Trend

During the baseline week, the experiment and control groups both had relatively low levels of success in achieving their calorie goals. On average, the *WeightBoss* (experiment) group achieved the calorie goal on 1.75 days (25%) vs. 2 days (28.6%) for the *HealthyLife* (control) group. The difference between these two groups was insignificant (t=0.23, p=0.82), showing both groups were relatively equally matched in their ability at the beginning of the study.

By the end of the intervention phase, the *WeightBoss* group achieved the calorie goal an average of 52.1% of the time vs. 31.9% for the *HealthyLife* group. The change in the calorie goal achievement rate from baseline was significant for the *WeightBoss* users (t=-2.96, p=0.02), but not for *HealthyLife* users (t=0.12, p=0.9).

Strategies Used to Reduce Calorie Intake

The *HealthyLife* (control) users only got daily calorie feedback and a weekly weight trend as feedback. To reduce their calorie intake during the intervention phase, five reduced the portion size of the foods they regularly ate, and three quit snacking and ate during mealtimes only. The five users who chose to cut down on portion sizes reported using various means to decide the correct portion sizing. Two used the resources provided on the website to determine protein, carbohydrate and vegetable servings while three arbitrarily decided how much less to eat.

Four of the *WeightBoss* users found that their main cue for eating was *habit*. They chose to use distraction techniques (n=1), eating healthier snacks (n=2) and avoiding trigger locations to address this (n=1). Three users found they regularly overate when hungry, so they chose to cut down 20-50% (based on how much the graphs showed they overate) of the foods that contributed most to their calorie intake, and one user decided to reduce the portion sizes of all foods he regularly ate.

User Experiences

Opinions on ***WeightBoss*** Feedback graphs

All 8 users of *WeightBoss* found it useful to have a graphical depiction of eating cues and how different food types contributed to their daily calorie intake. Six users were surprised to find they routinely ate high calorie foods such as crisps and pizza due to cues like boredom and habit, while the remaining 2 knew they were emotional eaters but did not know the high amount of calories they consumed over due to this habit.

> "I didn't realize how much calories I eat from snacking. When I used (calorie counter application), I didn't notice because in the list, the meal entries had more calories than individual snacks. But when you add up the calories for each group, the snacks and meals are almost equal calories over a week." - P2

> "I have been struggling to cut out junk food and I was wondering why I just can't seem to stop myself from buying it. I didn't realize

> I'm eating because of boredom so from now I'm making an effort to occupy myself more especially on Saturday evenings (when the behavior regularly occurred)." - P8

The *calorie trends graph*, which showed the combined weight and calorie trend over the past 7 days, was also popular. Participants felt that having an overview of calorie intake over the week helped them cope with disappointment if they did not achieve their daily calories goals ("*(The graph) helped me remember that I still have opportunity to achieve my goals so I didn't get so discouraged if I exceeded my calorie goal."* - P3). The aim of this calorie trend graph was to enable users to compare different days and see what they did on days when they met their calorie goal against what they did on days they exceeded the goal, and therefore enable them to modify eating behavior appropriately. The interview confirmed that the users did frequently compare the performance on different days and try to come up with theories on why they met/did not meet the calorie goal. For some participants (n=3), looking back on past achievements motivated them to remain vigilant about calorie intake for the rest of the week (*"I started week 2 really well and just seeing the graph made me motivated to keep my eating in check so the calorie bars for the whole week would stay below the calorie goal line"*- P2). However, the other participants (n=5) reported feeling they could "reward" themselves whenever the calorie trend graph showed them meeting the calorie goal consistently for 3 or more days. This reveals the importance of incorporating a reward strategy that will not lead to lapses.

Opinions on *WeightBoss* Behavior Goals

The participants remarked that having behavior goals made them more confident in their ability to succeed in achieving their calorie goal (*"I found WeightBoss less stressful than calorie counting because I had a plan, and it's a plan based on fact not guessing."* - P6). All participants also reported that on busy days, it was easier to commit to a behavior goal than to tracking calories since it was less taxing. This may be confirmed by the higher adherence level of the WeightBoss users.

Rating of ***WeightBoss*** and ***HealthyLife***

We asked participants in both groups to rate the application and their experiences between 1 (very unsatisfied) and 5 (very satisfied). WeightBoss scored an average of 3.25 out of 5 (65%) while HealthyLife scored an average of 2.45 out of 5 (49%).

User Recommendations for Improving WeightBoss and HealthyLife

The *HealthyLife* users faced several challenges including: discouragement over not achieving their calorie goals and lowered motivation with time. Although the calorie feedback provided could be used to determine which meals to avoid in future, they felt that analyzing the daily food logs was too time-consuming and boring, and although they would learn what foods to avoid, they would not learn what foods to eat instead. They remarked that having a meal planning tool and personalized recommendations would help them achieve their goals.

> *"My frustration with calorie tracking is that you get feedback after you have already eaten. It would be better if I had a meal planner tool where I could enter what I want to eat today, and see if the calories are ok (within calorie goal) or not. If they are not ok, then the application can recommend similar meals that would change my calorie balance."* - P10.
>
> *"I would like information on how to achieve my calorie goal. So maybe summarize what things I'm eating that are bad for my calorie goal, and give me a healthier suggestion. Something like 'Instead of drinking Starbucks 5 times a week, drink it 2 times a week only because it makes up 20% of your calorie intake."* - P13.

WeightBoss users also faced lowered motivation with time, particularly on days when they had low moods and on days when they were busy. The lowered motivation was also a result of the "boring" nature of calorie/behavior goal tracking. Five of the 8 participants recommended having an application where their calorie intake was reflected in a virtual character, to make dietary and behavior goal tracking more interesting. The remaining 3 participants felt adding social features such as sharing with friends would make the application more interesting.

> *"It gets boring just inputting calories or yes/no (using the behavior goal), so maybe a game where my calorie intake has an impact on a virtual avatar would make it more interesting."* - P4.
>
> *"Maybe adding some sharing features like posting what I ate, sharing recipes and chatting with other people losing weight would be fun."* - P3

In addition to low motivation, *WeightBoss* users (n=5) also felt more guidance on how to meet certain behavior goals e.g. "eat lower calorie foods" was needed. They felt personalized food recommendations from the application could help them achieve this.

Two *WeightBoss* users found that despite using the behavior goal accurately and consistently, they were not achieving their calorie goal. They therefore required additional support on how to modify the goal or food choices.

3.6 Extending the WeightBoss Application to Support Increased Physical Activity

Increasing physical activity is also an important part of weight loss and maintenance. Our work was limited to dietary behavior change, but the WeightBoss application could be extended to provide cues that help people engage in more exercise. Studies show that the two most important cues to engaging in physical activity are time and the people around [60, 71].

One simple feature WeightBoss could support therefore, is providing an exercise alarm to prompt users to take regular exercise breaks and to remind them to prepare exercise gear. For instance, the alarm could prompt workers to take short (5-10 minutes) walking breaks at regular intervals during the workday or use GPS location and push notifications to interrupt just-in-time and suggest use of stairs instead of an elevator at work, or persuade the user to use a slightly longer walking route or go on a short walk before getting into the house. Over time, the duration of these exercise breaks could be lengthened until the user is meeting recommended guidelines such as walking continuously for 30 minutes. To support users in choosing to do the exercise when the alarm rings, the application could show how the day's net calorie intake and the weekly weight and calorie intake trends (Fig. 2 - left) would change if the user consistently engaged in all recommended physical activity. Additional rewards such as those used in gamification (points, levels etc.) could also be added.

Another way to support exercise would be to provide a feature that pairs up users in nearby locations to act as each other's exercise partners. At a pre-agreed scheduled time, the application would remind the users to meet up at the agreed location for their joint exercise session.

In addition to these *people* and *time* cues, the application could also provide guidance on how to use environmental cues to support engaging in opportunistic exercises. For example, the application could suggest placing a post-it note on the bathroom mirror to remind the user to do 10 jumping jacks after brushing their teeth.

3.7 Limitations of the WeightBoss Application and Future Work

The main limitation in *WeightBoss* was the lack of rewards in both applications. Rewards are an evidence-based strategy to build new habits [66]. In this study, we felt that achieving the daily calorie goals and seeing a declining weight trend in each week would be sufficient intrinsic (internal feeling) rewards to support motivation. However, our evaluation showed that participants preferred that more explicit rewards such as rewards in a game should be offered. In the next chapter, we implement and evaluate the effectiveness of various rewards.

Another limitation was the high focus on weekly calorie intake and weight trends on *WeightBoss*, instead of equal focus on both daily and weekly trends. We chose this longer-term focus for two reasons. First, weight tends to fluctuate during the day and from one day to the next. We therefore felt that showing users that they were experiencing weight loss by the end of the week, despite mid-week fluctuations,j would lead to less discouragement. Second, we wanted to show users which regular eating habits are most responsible for calorie intake. Although evaluation shows both objectives were achieved, the limited focus on daily calorie intake meant some users overindulged on certain days (usually Mondays or mid-week), as they felt they could "make up for it" on another day. Overall, this behavior meant all participants had very low levels of weight loss over the 25 days (average: 0.34 Kg lost instead of a 1.5 Kg loss if calorie goals had been consistently met). Future works should therefore also provide detailed feedback and behavior-goal recommendations for both daily and weekly calorie intake.

Finally, the scope of our study (dietary behavior change only) meant we did not recommend physical activity as a means of reducing net caloric intake, which may have contributed to the fairly average success rates observed (participants achieved calorie goals 52.1% of the time). If physical activity recommendations had been included, most users would have been able to exceed their calorie goals by 350-364 KCal more each day without effect on weight, as this amount can be burned off by 1 hour of walking or cycling, or 30 minutes of circuit training [63]. Indeed, research shows the people most successful at long-term weight loss engage in at least an hour of exercise every day [77], and populations such as the Maasai in East Africa manage to maintain a healthy weight despite a high-fat diet, partly due to very high levels of physical activity [59]. Integrating physical activity stimulus control and behavior-goals should therefore also be included in future works.

3.8 Chapter Summary

In this chapter, we presented the design and evaluation of the WeightBoss application, which provided users with stimulus control support to help lower the burden of daily dietary tracking, and to support eating behavior change. We compared the user experiences and behaviors of *WeightBoss* users against a control group who used a calorie tracking application (*HealthyLife*) based on standard, existing calorie trackers.

We hypothesized that the stimulus control feedback and behavior goal-setting on the *WeightBoss* application would enable users to remove negative cues for eating, and hence enable them to meet their calorie goals more frequently. We also felt this increased success would lead to higher confidence, and make them use the application more often at the end of the study.

We found that user retention on both *WeightBoss* and *HealthyLife* declined during the study. Both groups faced lower motivation with time, and required more features such as personalized food recommendations or gamification and social support features to make application usage more likely over the long-term. However, *WeightBoss* users had a slightly higher level of application usage than *HealthyLife users*, and interviews revealed this was partly due to the ease of logging adherence to behavior goals compared to calorie tracking. This suggests that implementing features that reduce the burden of daily dietary tracking as time goes on can be a means of reducing the currently high attrition rates associated with weight loss applications.

We further found that users of *WeightBoss* were more satisfied with their experiences with the application (65% vs. 49%), were more confident about their ability to achieve their calorie goals, and did indeed achieve their goals significantly more than at baseline. This shows that providing detailed graphs that help users cues that are most responsible for calorie intake and then guiding them on how to suppress or remove these cues can be an effective way of providing stimulus control in weight loss applications.

4. Implementing and Evaluating Intrinsic and Extrinsic Rewards in Games for Behavior Change

4.1 Introduction

We identified in chapter 3 that many users felt that gamification and rewards would make calorie tracking more enjoyable and help them conquer the challenge of lowered motivation for dietary tracking over the long term. Games have been used successfully to promote both knowledge of healthy eating [57, 32], and to support physical activity [31]. Their influence on dietary behavior change however has only been studied for adolescents [62]. Rewards are an evidence-based strategy for supporting the formation of new habits [66]. They can be intrinsic (internal feelings that provide satisfaction), or extrinsic (external rewards). Intrinsic rewards are more motivating over the long-term but extrinsic rewards can push people to engage in a new behavior. Current implementations of rewards in calorie tracking applications (virtual rewards e.g. badges and trophies) have been unmotivating ([50]), but cash rewards have proven effective at motivating overweight and obese patients ([40], [15]). In this study, we wanted to investigate:

- How to promote the intrinsic rewards for dietary tracking and healthy eating behavior change through games
- How effective intrinsic and extrinsic rewards are in supporting consistent dietary-tracking behavior, and dietary behavior change

4.2 Study Method

We first conducted informal brainstorming sessions with 8 participants (average age: 26.5 years), to determine what types of games and rewards are interesting to users of smartphone, weight loss applications. Five of the participants were from the WeightBoss study (chapter 3) and had suggested using games as a motivational strategy. The other 3 participants were recruited from the University laboratory, and were interested in joining future studies on dietary behavior change.

We asked the participants to describe:

- What game scenarios are appropriate for a dietary tracking/behavior change game
- what types of user tasks should be included
- Which user actions should be rewarded and punished
- What rewards and punishments should be given.

We then developed the *HappyInu* game for meal tracking after the requirements study, and conducted a 21-day (3 weeks) field study with 10 participants (8 male, ages 23 - 49) to determine the effectiveness of the game. Participants were recruited through a news bulletin and a Facebook post targeted towards staff and students of a graduate university in Japan who were interested in food tracking. The bulletin described the application's purpose and rewards available. Participants were required to use their own Android devices. Due to the low number of participants, we did not split them into a control and experiment group.

In a pre-game survey, we collected baseline data including how often participants played smartphone games, the types of games they played and their motivations for playing, and how often they tracked their calorie intake.

After the field study, participants completed an exit survey where they rated *HappyInu* in terms of how enjoyable they found it and its suitability for dietary tracking. They also provided open-ended responses about their experiences with *HappyInu* including: favorite features, challenges encountered and suggested improvements. A group interview was used to provide further insight on survey responses.

4.3 User Requirements

Game scenario and User tasks

Participants were interested in a game where their eating habits were reflected in the growth of a virtual character. Healthy eating would be reflected as healthy growth, overeating as obesity and under-eating as malnourishment. It was felt that having such a visualization would prompt the game players to engage in more healthy eating.

The preferred characters were either human characters or pet characters. Since the focus of the game would be on an avatar, participants felt game tasks should focus on performing everyday activities with the character such as in the *Sims* game, and performing healthy tasks such as walking and running.

> *"In exercise games, you win based on how active you are. I think you could do the same thing for a healthy eating game, where the healthier you eat the better off your character is, and the more things they can do. So if you overeat, your character gets fat and maybe can't compete in a race."* - P5
>
> *"I think I need a reminder of why junk food is bad, so show my character getting fat in a game. For fun, you can have interactions with the character like feeding, going to work, like in Sims."* - P1

Rewards and Punishments

All participants were uninterested in virtual rewards such as ribbons and trophies. They suggested avatar-initiated interactions such as a pet character bringing a gift (n=2), or being provided with points that could be used to unlock game levels and features (n=4) as more appropriate rewards. Three participants also felt that cash rewards should be earned through a long-term competition e.g. at the end of 30 days, with the healthiest person obtaining the rewards. To support motivation to win the competition, they suggested that a leaderboard be provided.

Regarding which user actions should be rewarded, participants felt: (i) consistently logging meals, (ii) selecting healthy meals more often than unhealthy ones in a specific period of time and (iii) engaging in more physical activity than normal should be rewarded. To ensure all players, whether beginners or experienced in weight loss had a fair chance at winning the competition, participants (n=2) suggested progressive difficulty in user tasks e.g. *"For example, level 1 tasks can be to log all 3 meals for 3 days, and in level 2, log all 3 meals for 5 days and gain bonus points for each healthy meal."*-P3.

Participants suggested that to motivate players to keep their avatars healthy, punishments should focus on making game interactions such as the ability to interact with other players unavailable, when the avatar's health declined.

"Surprises could be a nice reward. Like a pet dog (avatar) bringing you a bone he dug up." - P5

"I think you should provide a table of all player scores (leaderboard) to make it more competitive." - P8

4.4 The HappyInu Application

HappyInu is a 3-level Android game that we developed, where players adopted and cared for a pet puppy over 30 days. At the end of the 30 days a dog competition took place and the two healthiest puppies (based on the health score computed in the game) won cash rewards. In addition, the game included small cash rewards for completing various tasks.

Depending on the players internal motivation, their objective in *HappyInu* could be: (i) to have a healthy pet, (ii) to win the big cash prizes in the competition (and gain recognition from other players) or (iii) to win as much money as possible by completing many of the tasks with smaller cash rewards. All three objectives required daily care of the puppy, which in turn required the user/player to do dietary tracking and healthy eating, and therefore all 3 motivators would lead to the desired behavior change. We describe the user tasks in *HappyInu* in more detail in section 4.4.

We chose the pet care approach for two reasons. First, the care-giving approach has been successful in prior work and second, our target users were young to middle age adults, who were likely to have played pet care games such as Tamagotchi [2] and we hoped the nostalgia would make the games interesting.

Application Screens

HappyInu consists of seven main screens: welcome, upload, uploads history, main game, store, recommended foods and reminders. In the welcome screen, users could see their puppy's hunger level, the amount of points (virtual money) and cash rewards (wallet) that they had earned. Buttons to navigate to other screens were also provided.

The upload screen allowed users to take a photo of their meal or choose a photo from the gallery, and a form for additional information such as hunger level and mood. Fig. 5 shows several screens from the application.

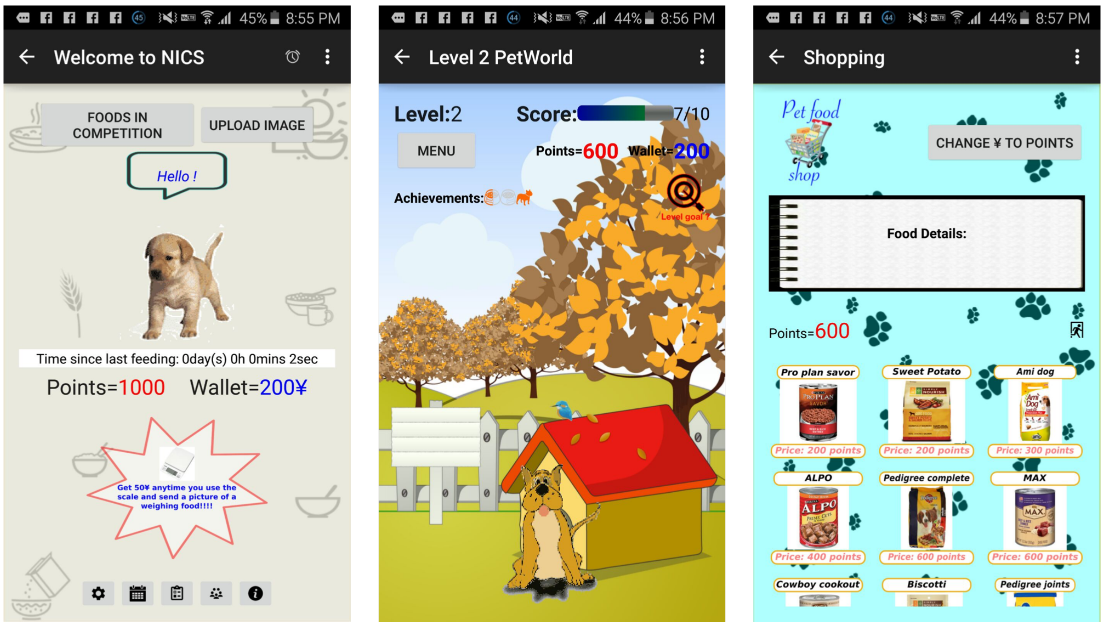


Figure 5: HappyInu application (left to right): Welcome, Main game and Virtual shop screens

Gameplay, Rewards and Punishments

At the beginning of the game, players chose their puppy from a virtual store and named it. Different breeds of dogs with varying personalities were available. We provided this pet selection and naming to foster an initial bond between the player and the puppy.

Players had to provide daily care for the pet, in order to support its health and growth. The puppy grew every time its health score exceeded a specific value, and the 2 puppies with the top health scores at the end of 30 days won \$125 and \$60 respectively in cash. These two amounts correspond to 10% and 5% of the average monthly stipend the students receive and we felt it was a fair amount to motivate playing.

In order to care for the pet, players had to feed, walk and play with the puppy. Puppies could be fed a maximum of three times a day to reinforce to players that part of healthy eating is to eat three main meals. *HappyInu* issued

3 daily notifications to remind the players to provide meals to their pets. Players could set the times for the notifications.

In level 1 of *HappyInu*, players could only feed the puppy, in level 2 they could feed and walk the puppy and in level 3 they could perform all three care functions. The gradual increase in difficulty enabled players to slowly get used to the game's demands and also stopped the game from being repetitive. In addition, progression through levels can give players a sense of progress and accomplishment, which may increase their feelings of competence and therefore raise intrinsic motivation to continue playing the game [66].

All pet care items e.g. food, toys, and walking leash, could be bought or rented from a shop in the game using virtual currency (points). Prices ranged from 200 1,000 points per item, with healthier pet foods and more durable/cute accessories costing more. Providing the pet with healthier food would make their health score increase faster, and thus increase the player's chance of winning the biggest cash prize, while providing cuter accessories could be a means of gaining recognition from other players.

Players were given 1,000 points at the beginning of the game, and afterwards they earned points by uploading photos of their meals (food tracking photos). Each uploaded photo, regardless of the healthiness of the meal, earned 100 points. This was done to ensure users could continue playing even if they chose unhealthy meals. After photo upload, the photos were manually reviewed. If the meal was found to be in the "Recommended foods" page of the application, the players earned bonus points. These recommended foods were healthy meals i.e. meals that contained an average number of calories (550KCal or less). We hoped more players would choose healthy meals in order to gain more points, and in turn, be able to afford healthier foods for their pet. If the player ate a recommended meal and showed they had used a food scale to weigh their food (accurate portion size estimation), they earned \$1.5 in addition to the bonus points.

EXIF data was used to verify uploaded photos had not been previously uploaded, and to get time and location information for implementation of stimulus control feedback in a future version with more levels. We used photo-based food tracking because it is simple and fast, had been used effectively in prior studies [9], and could provide the additional context details like location automatically.

This initial version of *HappyInu* was aimed at promoting a consistent tracking habit and not on assessing eating behavior change, and therefore we did not provide calorie feedback in this initial implementation, but planned to include it in the next version (with stimulus control feedback).

Overall, *HappyInu* was designed to offer both intrinsic and extrinsic rewards. The intrinsic rewards were: public recognition (through winning a prize in the dog competition), pleasure (through playing the game), progress and accomplishment (through completing challenges and going through the levels) and contribute to something meaningful (research). Extrinsic rewards were the virtual currency (points), puppy's health score and real cash.

We chose to link players' meal choices to virtual points and small cash rewards instead of directly visualizing the effect of their meals or weight trend on the avatar (as stated in user requirements) for two reasons. First, Lin et al [42] found that directly modeling a player's actions on a virtual avatar could lead to disengagement when the avatar's health declined. This was due to players feeling guilt or wishing to avoid seeing the consequences of their actions. Secondly, we felt having to care for and interact with the pet would be more interesting than simply viewing the effects of eating behavior.

To avoid the guilt feelings observed in [42], and to adhere with the users' requirements for punishment, if a user failed to feed the puppy, only the health score lowered. The puppy's visible health did not deteriorate. Likewise, the puppy did not die even if the player continued to fail to feed the puppy. Instead, the player was temporarily demoted to a lower level, which meant they lost some of the interactions they could have with the pet e.g. taking the puppy for a walk.

4.5 Evaluation Results

All 10 participants in the field study were moderately active game players, with five participants playing games up to three times a week, two playing at least once a week and one playing everyday. Two participants played games less than once a month. The main motivation for playing was "just for fun" (pleasure) but some also played out of boredom. The most popular game types were: puzzle, action/adventure, strategy and word games.

None of the participants were actively tracking their calorie intake at the time of the study. However, five participants were intending to start within the next 6 months (contemplators) or had just started tracking (action stage), and the rest had no immediate intentions for change (pre-contemplators) but were interested in the game-based approach to tracking.

Adherence to Dietary Tracking

Participants used *HappyInu* as frequently they played other games i.e. five participants played up to three times a week, one played everyday and four played about once a week (average adherence: 2.7 days a week). These rates remained consistent throughout the study. Although participants did not play everyday, EXIF data indicates that four users (all in action stage) often uploaded food photos taken on previous days, meaning they continued food tracking even without playing the game. Pre-contemplators and contemplators mostly uploaded only on the days they played. However, no participant tracked on a daily or predictable (e.g. every Tuesday) basis.

The survey revealed that the action stage users were the only ones who liked the reminders but the reminder times did not always coincide with meal times, leading them to sometimes forget to track. The other users did not like or want reminders, and they ignored them. In the interview all participants remarked that they felt playing the game everyday would be *"too time consuming"* and *"a bit too much"*. They wanted to play on a casual basis and therefore felt the game should be designed *"to reward tracking, especially consistent tracking"* but *"to not make (force) people play everyday"* i.e. to stop lowering the puppy's health score due to underfeeding. On the days participants did use the application, they played consistently throughout the day, uploading multiple photos and feeding the puppy multiple times.

Application Reception and Rating

Participants were generally happy with *HappyInu* with several expressing interest in continuing to use the application and asking for the game to be made more elaborate and challenging in future versions, and for an iPhone version.

An average rating of 3 out of 5 stars ("Good") was given for the question: *"How enjoyable do you find the HappyInu game?"* Favorite features for the pre-contemplators were: (i) the inclusion of a beneficial behavior (food tracking) into the game and (ii) both the small cash rewards for eating the games recommended meals and the big cash rewards from the dog competition. Contemplators and action participants liked the: (i) photo-based tracking, (ii) the "fun" (game-based) approach and (iii) the small cash rewards. All participants liked the game storyline, animations and in-game tasks. The application was not rated higher because participants wanted more in-game tasks particularly strategic tasks such as completing a timed maze or solving a puzzle with the puppy to make the game more challenging and engaging.

A rating of 2.2 out of 5 stars ("Poor") was given for: *"How suitable is HappyInu for food tracking?"* The low score was because users could only see a history of uploaded meals without any calorie information or personalized recommendation. The feedback had not been included since this initial study was only aimed at evaluating different rewards for enabling consistent tracking behavior and not the use of feedback for behavior change. Feedback was important to all participants, including those not intending on behavior change.

Participants' Perceptions of Rewards

Participants appreciated the idea of rewards and suggested rewarding more behaviors such as for uploading an image at the time of eating and for recommending the application to a friend. However, instead of cash, most preferred vouchers that they could use in an application store or on a shopping trip, since these are common rewards from other systems they used. In the interview, we found that users preferred virtual rewards (points and surprises from the pet) for doing recommended actions, as cash rewards would *"make me associate the action with money so if I don't want the money, I will stop doing the action" - P7.* Participants also suggested that players should receive game points after specific time intervals e.g. every day so they can continue playing even if they do not have any new food photos.

Motivators for Application Usage

Participants rated (from 0 - not true at all to 3 - very true) how much various factors motivated them to use *HappyInu.* All participants were primarily motivated to track eating behavior at the beginning of the study. Fig. 6 shows the results at the end of the study. *"Contribute to research"* was the main motivator (average = 2.88) followed by pleasure (*"I enjoy the game"*) and *"to tracking eating behavior"* (average = 2.0).

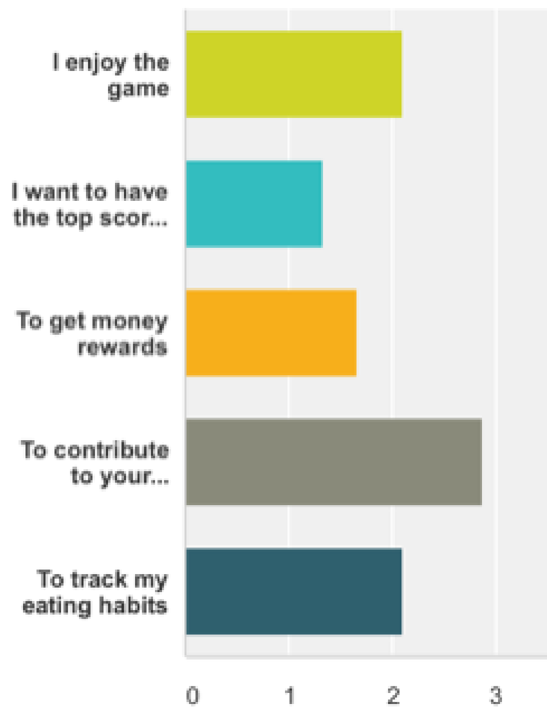


Figure 6: Motivators for playing HappyInu

Challenges Faced and Suggested Application Improvements

Despite using reminders and rewards to promote habit formation, no participant formed the tracking habit. Some participants felt the reminders were burdensome and they generally ignored them, while others ignored them because the reminder came when they were not eating and they forgot to track later on. Participants suggested a subtle, persistent reminder to take photos e.g. via an ambient display and to issue a quiet update like *"a message from the pet on what has been happening in its world"* to motivate them to play. Participants also suggested having the input page as the main page *"like in SnapChat (social media application)"* so they could quickly take and upload the image, even if they were not planning to play the game.

4.6 Discussion

With *HappyInu*, we aimed to promote a daily food tracking behavior by using intrinsic rewards and extrinsic rewards. We conducted an initial study to determine users' experiences with the rewards and the effect of these rewards. Here, we discuss the effects of the various rewards and suggest how to design games that support habit formation.

Effect of HappyInu on Motivating a Daily Diet Tracking Habit

To form a new habit, a cue to trigger the desired behavior, and a reward to reinforce the benefit of the behavior are needed. In *HappyInu*, we used notifications (3 a day, 1 for each meal) as cues and points (virtual money), health score and cash as rewards (Fig. 7).

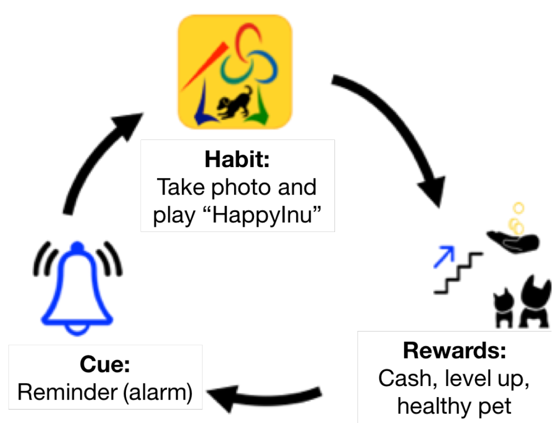


Figure 7: The cue-habit-reward cycle that HappyInu aimed to create

In the study, users only played *HappyInu* when bored or due to free time, which were the same cues for playing other smartphone games, and they did not want to play *HappyInu* or any health game daily. Action stage users viewed notifications as a cue for taking meal photos (not for playing) while other users ignored the notifications. Fig. 8 shows the observed cue-habit-reward cycle.

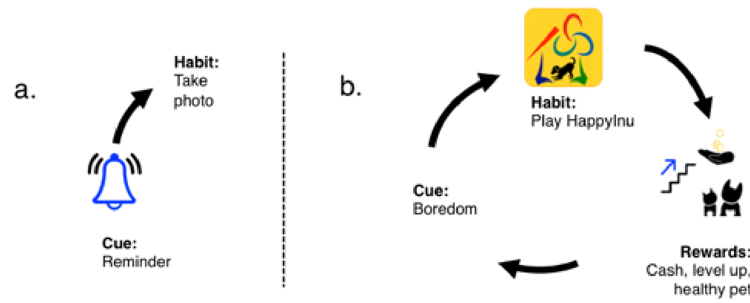


Figure 8: The cue-habit-reward cycle HappyInu players exhibited

The different response to notifications in action and pre-action users is consistent with behavior change theory [76] which states that action stage users are already committed to change and will use behavior change strategies such as self-monitoring while those not ready for change need to believe in the benefits of changing and their ability to change before they fully engage with strategies for change.

However, the fact that action stage users continued to rely on old triggers for playing *HappyInu* and their reluctance to play daily reveals that they gave *HappyInu*, and behavior change games in general, the same role as other games - to pass the time. Therefore gameplay alone may not be effective to enforce strategies that need to be used daily. It can however be paired with an ambient display such as in [20], which would serve as persistent cue to solve the timing problem. The display should show both the actions needed along with the current progress and the rewards to be gained, to motivate users. For instance, the display can show an image for each meal that the user needs to track, and the points, cash or other rewards to be gained when all meals have been tracked.

Effect of Rewards

Effect of Intrinsic Rewards

In the study, we found that the biggest motivators for all users were intrinsic rewards, particularly contribution to something meaningful (research), and pleasure (fun). The desire to contribute enabled users to continue playing *HappyInu* at a constant rate despite technical challenges such as being unable to disable the notifications and the lack of calorie feedback, and despite being busy over the holidays in the study period. The motivators are similar to what motivates people to contribute to user-generated content sites such as Wikipedia [55]. This shows that having rewards such as the application donating money to a charity of the user's choice once a milestone is reached may motivate users more than providing personal rewards.

Effect of Extrinsic Rewards

In the beginning of the study, participants were most interested in cash rewards but by the end of the study the main motivators were all intrinsic. The cash rewards were only slightly motivating to users ready for change, but were still important (although not main motivator) for those not ready to engage in behavior change.

Theories such as the self-determination theory [66] suggest that when people are no longer motivated by extrinsic rewards, their motivation for a task may reduce and if intrinsically-motivated tasks are provided external rewards, then the intrinsic motivation level may decrease upon removal of the rewards. During the interview, we found that action-stage users deliberately ignored the cash rewards so they would not form an attachment and thus lower their internal motivators. This strategy ensured that if the reward had been removed at later stages, they would still have enough motivation to continue working towards their health goals. Users in the other stages had low self-efficacy on their ability to win the competitions due to their inability to play regularly, and they therefore gave up trying to have the healthiest pets. In both cases, the "removal" of the extrinsic reward did not lead to decreased engagement (users continued playing at the same rate) because the intrinsic rewards of contributing to research and meeting health goals were more important. However, the removal of extrinsic rewards may have stopped the motivation level of non- action-stage users from improving in times when they could play more regularly, and therefore means of boosting users' competitiveness in a competition e.g. offering bonus points, may be needed.

Participants' ambivalence towards cash rewards is different from studies such as ([40],[15]). In these studies, participants were overweight and therefore losing weight was important for their health and they needed to do it. Cash rewards gave them added incentive. In our work, all participants were of a healthy weight and while they were all interested in weight loss, since no negative health effects would result if they failed, they took a more relaxed approach to behavior change and focused more on intrinsic instead of extrinsic rewards. They were however motivated to earn points, unlike in]citemunson2012exploring, because this would allow them to continue using the application.

Recommendations for Rewards in Weight Loss Applications

Contribution to something meaningful and pleasure were the biggest motivators for continued application usage. Applications could exploit these factors by offering rewards such as: monetary contributions to a charity of the user's choosing when they complete a specific milestone and asking users to support people training for a marathon by sharing their daily healthy meal photos to motivate the trainees.

Gamification elements such as competitions and the virtual pet by themselves were popular with users. A persuasive application such as UbiFit, which does not require user interactions beyond data input, but which visualizes the effect of the behavior may be more effective than a full game. Furthermore, providing resources for living a healthy lifestyle such as recipes, exercise videos and social interaction features could also provide pleasure.

Limitations

The study had three main limitations. First, the number of participants was small, and therefore we could not confirm whether the results were significant. Second, we limited the pets in the game to puppies/dogs but some participants preferred other pets like cats and snakes and could not fully engage with the puppy. The Time to Eat study [62], which had a wide range of pets, had a more positive user-engagement level.

Finally, the study was conducted during the university Christmas break when many participants were traveling. The disruption in routine caused by travel and the fact that holidays are known to lead to relaxed, sedentary behaviors may have affected users' engagement.

4.7 Chapter Summary

In this study, we described the *HappyInu* application, which was aimed at promoting the intrinsic rewards of dietary tracking, and to assess the effect of intrinsic and extrinsic (cash) rewards on normal weight users. We found that games were a popular way to make tracking enjoyable but users did not want to play daily. Apart from the desire to track health, both pleasure and the desire to contribute to something meaningful were major motivators. Extrinsic (cash) rewards were less motivating than intrinsic rewards but still important for those not ready for behavior change. Our study reveals the need to include more intrinsic rewards in behavior change applications, and the need for some extrinsic rewards to motivate those reluctant to change. We also see the potential of pet-care games for adult behavior change and the need for pairing games with ambient displays to promote daily healthy behavior.

5. Conceptual Design of the Ideal Dietary Tracking Application

5.1 Introduction

Following the field studies on *WeightBoss* and *HappyInu*, we aimed to identify users' final ideas on how to support self-directed weight loss attempts via smartphones. We present the study and results in this chapter.

5.2 Study Method

We randomly selected some of the participants from the *WeightBoss* (n=4) and *HappyInu* (n=5) studies, and recruited other people who had used weight loss applications at least twice, and whose weight loss attempts had lasted between 1 and 3 months for participation. We included these extra participants to get a more thorough understanding of the challenges that remain with existing dietary tracking applications, and to facilitate a richer discussion on the merits and disadvantages of different user ideas.

Twenty-six participants (14 males, average age: 26.85 years), took part in the study. Twenty were full-time graduate students and six were full-time employees. The study was done in Japan. Recruitment was done via email and Facebook posts.

Three one-hour group sessions were conducted in total. In the beginning of each session, participants completed a paper survey with their demographic data and a summary of their previous weight loss experience (Qn: "List all weight loss attempts in the last 2 years. For each, indicate: when it was, applications used, how long the attempt lasted (approximate) and approximate weight loss achieved"). An unstructured discussion was then conducted around two points:

- what challenges did you encounter with food tracking?
- How can we design better tracking experiences (features, interface and interactions?)

When discussing the second questions, we wrote the suggested ideas and drew mock interfaces and use cases on a whiteboard. We provided each participant with a sheet of paper on which they could write alternative ideas and draw alternative interfaces. We also asked participants to vote "yes/no" for each of the suggested ideas on this paper. In addition to ideas suggested by participants, we also solicited opinions on the merits and drawbacks of different kinds of applications e.g. behavior change games (virtual pet care such as in *HappyInu*, adventure/puzzle games etc.), stimulus control feedback with personalized food and activity recommendations as well as group fitness applications.

5.3 Results

Desired Input Methods

Participants felt an ideal dietary tracking application would provide a variety of input methods. Specifically, they identified: photo-based, tracking adherence to healthy/unhealthy behaviors and database search (with streamlined results). The preferred input method at a given time would depend on context, and participants desired the appropriate input method to be provided automatically. Table 3 describes the desired input methods and when each method would be appropriate.

Table 3: Preferred input methods and when to offer them

Input Method	When Preferable & Why	Implementation Comments
Photo-based	**For daily tracking and for beginners to dietary tracking**. This method is less time-consuming and less difficult to learn than manual input methods, and it would therefore make it easier to adhere to. *"Using photos for input is best for beginners because they don't have to worry about whether they selected the right choice from the database. They can just focus on feedback and changing their diet." - P2*	**Photo input:** On application start-up, display the camera immediately for faster input. Allow users to tag images with descriptions e.g. names of salad dressings for accurate calorie analysis. In addition, mine social media accounts for user's food images using hashtag e.g. #appnamelunch. *"I post my lunch photos on Facebook, so if applications can get that information, it would be simpler for me. You can search images by hashtag to get them."* **Calorie estimation method:** To estimate the calories in the meal, participants suggested either using crowdsourcing, with professional nutritionists, or automated image analysis. Automated image calorie estimation algorithms have only been tested on a variety of foods and in controlled settings, and therefore their accuracy in the real world requires to be further studied. Despite this, participants preferred the automated calorie estimation since it would enable them to get immediate calorie feedback.

Continuation of Table 3		
Input Method	When Preferable	Implementation Comments
Adherence to healthy behavior Fig. 9	**For weight maintenance and for busy periods.** Calorie tracking requires a lot of effort for both tracking and analyzing feedback. Focusing on weight trends, and ensuring a majority of the meals are healthy and of the right portions is more sustainable.	Recommend behaviors to track e.g. *"Fill $\frac{1}{2}$ of your plate with vegetables and fruit".*, but also allow users to define their own behaviors and goals. Provide radio buttons or a Likert scale so users can enter subjective estimates on the healthiness of the meal, and of the amount. Furthermore, notify users when their calorie intake trend is negative e.g. they fail to adhere to the goal for 3 or more days.
Location-aware database search	**For social situations.** It may be awkward and seem rude to take photos.	Display results from the menus of restaurants, shops etc. located around the user's current GPS position. Use user's past search history to order and/or filter the results. e.g. *"When I'm on (university) campus, present the menu items from the cafeteria and shop, with the meals I have eaten before appearing at the top." - P9.*

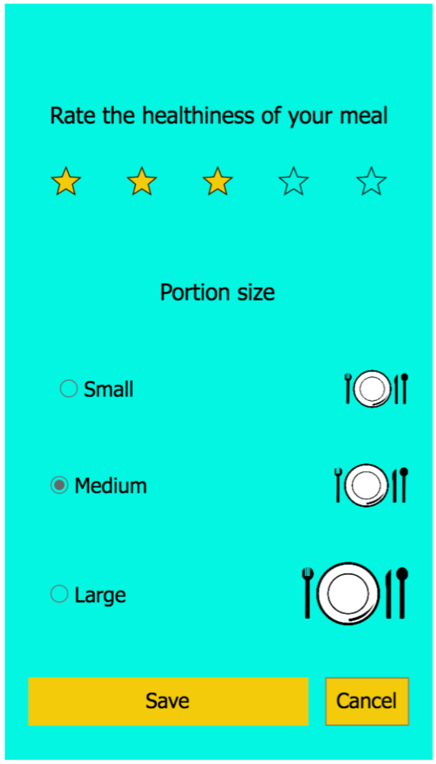


Figure 9: Participants' sketch for an interface to track adherence to healthy/unhealthy behaviors in the ideal dietary tracking application.

Desired Feedback

Participants indicated they rarely reviewed calorie summaries and graph data in detail due to time constraints and not knowing how to analyze the data. Instead, they used frequent glances (<30s) to check progress towards the daily goal and make decisions on the next meal. In sketches for the ideal feedback interfaces (e.g. Fig. 10), they indicated preference for 3 kinds of feedback: (a) summary of progress towards daily and overall goals (b) automatically-generated summary of which behaviors to correct (tips) and (c) personalized recommendations on how to correct the negative behaviors (suggestions/advice). Examples of desired tips and advice are shown in Table 4. Healthy eating articles such as [1] outline common negative eating behaviors. Multi-label classification could be used to tag all negative behaviors a meal entry corresponds to using the calorie, nutrient and portion size details. The most frequent behavior, and its contexts e.g. usual times, location of behavior can then be presented to the user (tip). Advice should be actionable for the user i.e. within their skill level, preferences and available resources (location, budget etc.). This can be assessed during application registration and users past choices. In addition to immediate actions, the application can also use past and future context to anticipate challenges and forewarn users. For instance, people who stress eat could be given coping strategies whenever their calendar fills up.

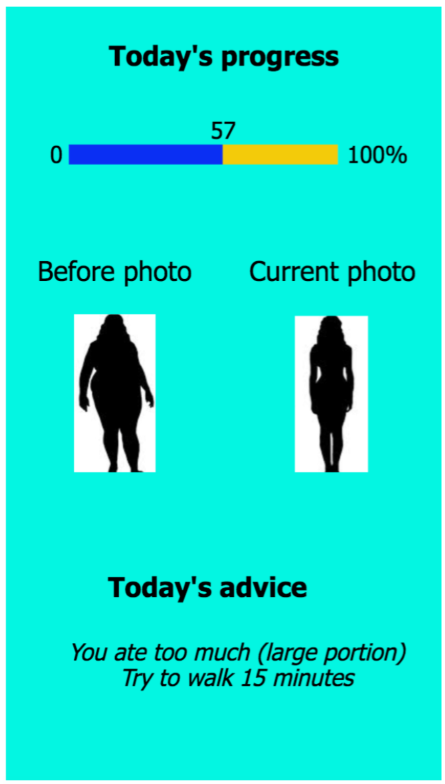


Figure 10: Participants' sketch for the feedback page in the ideal dietary tracking application.

Desired Interactions

Currently, applications present the same page as the main page (usually review page) and use notifications with a general message as reminders. However, participants desire a dynamic application - where the application opens directly to

Tips	Advice Focus
Over-eating	How to reduce portion size without going hungry
Mindless snacking	How to identify and replace snacking cues
Unhealthy meals e.g. high fat, unhealthy diet	Meal substitutions and cooking instructions

Table 4: Examples of negative eating behaviors, and advice to address them

the input page during food-tracking times, and to the review page during other times, and where the content on the feedback page is alternated to make the experience "exciting". Likewise, while reminders are useful, participants felt they could be more effective if: (a) interruption occurs near meal times and free times, and more importantly, (b) the message in the notification varies and focuses on the next action the user should take and the rewards to be gained e.g. "If you input your next meal, we can suggest similar, less caloric choices for you tomorrow". This would create interest in reading new notifications and performing the recommended actions.

5.4 Chapter Summary

We presented users' ideas on the design (features, interfaces and interactions) of the ideal dietary tracking application. These ideas were derived from their experiences with existing dietary tracking applications, as well the applications presented in chapters 3 (WeightBoss) and 4 (HappyInu).

6. Implementing and Evaluating Effectiveness of Group Fitness Applications for Social Support

6.1 Introduction

In addition to stimulus support and rewards, this work aimed to implement and evaluate the effectiveness of social support in weight loss behavior change adherence. In this chapter, we present the user requirements study, implementation and evaluation of *MyFitnessTeam*, a group fitness application.

Existing weight loss applications have aimed to provide social support to users through sharing features, and through offering behavior change interventions to groups. Of the 2 approaches, group interventions have been shown to be both popular with users and effective for motivating change e.g. in [27] [26]. However, the interventions included and methods for providing social support (e.g. competition, collaboration, etc.) vary widely among applications, and current research has mostly focused on quantitative analysis of their effectiveness. It is unknown which approaches best meet users' expectations, and how user experiences affect the observed efficacy. In this study, we had three objectives:

1. Identify user requirements for group fitness application (social support sought and desired application features and interactions)

2. Implement a smartphone application (*MyFitnessTeam*) based on the identified requirements, and evaluate its effectiveness on supporting adherence to fitness goals

3. Assess user experiences with the application, and determine how these may have affected efficacy

6.2 Study Method

User Requirements Gathering

We first created a list of the social support features in 2 existing applications: *MyFitnessPal* (in-application social feed and share to Facebook/Twitter), and

Nike+ (social feed and competition). We presented these, along with a description of the 4 types of social support, i.e. emotional support is offering empathy, praise, and acceptance, informational support is providing useful information, instrumental support is the provision of tangible assistance, and appraisal support is providing information for self-evaluation, to explain the meaning of social support, and how using of social features in applications may lead to obtaining such support. The explanation was to aid the non-native English participants.

We then conducted 4 one-hour focus group sessions with 42 participants in total (n=14, n=6, n=8 and n=14), where 23 were male and the average age was 26.75 years. Each session had 2 facilitators. Participants had used dietary, physical activity and weight loss smartphone applications in the previous year for more than a month, and were interested in using group fitness applications to support adherence to their fitness goals. The number of participants was not predetermined. Successive focus groups were conducted until data saturation was reached. Participants were recruited from a university mailing list and Facebook groups and the study was conducted in Japan. Thirty-six (36) participants were full time graduate students and six (6) were full time employees. Participants came from Japan (5), South-east Asia (16), the middle east (3), Africa (6), Europe (9), North America and South America (3). Sixteen participants (38.5%) had previously achieved their fitness goals through the use of fitness applications.

The focus group started with a paper survey collecting demographic data and previous experiences with fitness applications (Name of application, participant's goal, duration of use, goal achievement i.e. succeeded, failed, on-going and reason for quitting). We then gave a brief presentation on social support theory and how it is currently implemented in fitness applications, followed by an unstructured discussion around the following questions:

A semi-structured discussion around the following points was then conducted:

- What type of fitness application did you use most in the previous year?
- What challenges did you face, and what type of social support would help you overcome them?
- Imagine a group fitness application through which you can gain the desired social support.

– How should the application be designed - application flow, inputs, group member interactions etc.?
– Who would you like to have in your support network - strangers, only, current acquaintances, both, people with a similar goal etc.?

When discussing the questions, probes e.g. *"Can you tell me more about that?"* and *"Can you draw what you mean?"* were used to gain further insight. Participants called out their answers, which were then written on a whiteboard and discussed. The whiteboard was also used to draw proposed use cases and interfaces, and count votes for the various ideas. Each participant also had paper on which they could write down further remarks or draw alternative ideas to those on the white board. The focus groups were video recorded and notes were taken during the sessions.

Following the focus groups, coding was performed. To identify desired social support, a priori codes (information, emotion, appraisal, instrument) were used to categorize which type of social support each response corresponded to, while open coding was used for responses on application design. The user requirements specification outlining: required social support, list of interfaces and their designs, required inputs, outputs, user-user and user-application interactions for each of the interfaces was then typed out.

Application Development and Validation

We used extreme prototyping and web-based tools (HTML, CSS, Javascript) to develop the application prototype. The dynamic prototype was presented to 2 participants from the focus groups in order to verify that the interfaces and application flow met the requirements specification. The final prototype was tested in-situ by 10 participants from the focus group. Participants reported bugs and gave feedback on the interface design and interactions during a 1 hour group interview. All comments were noted on a whiteboard and photographed. We then developed the final application, *MyFitnessTeam* (Fig. 12).

Field Evaluation of MyFitnessTeam

We then conducted a 6-week field study with 23 participants (16 males, 7 females, average age: 26.80 years) to evaluate *MyFitnessTeam*. Participants were recruited in the same manner used during the requirements gathering study.

The field study consisted of 1 week of baseline, 4 weeks of intervention and 1 week of post-intervention. During baseline and post-intervention, participants had access to exercise plans and calorie data but not social features or daily challenges.

The primary measure was frequency of adherence to fitness behaviors i.e. number of days in a week on which participants did at least 30 minutes of physical activity and ate at least 1 healthy meal (during baseline and post-intervention) and number of days on which users completed the daily challenges (during intervention). At the end of the second week of the intervention phase, we released an updated version of *MyFitnessTeam*, which added a "public sharing" feature. By default, photos uploaded on *MyFitnessTeam* were only shared with the user's group mates. In "public sharing" mode however, the photos could be viewed by all *MyFitnessTeam* users. This feature was added at the request of participants as a means of gathering more social support.

We investigated the following research questions:

RQ1: Is MyFitnessTeam effective at supporting behavior change?

We hypothesized using *MyFitnessTeam* would lead to higher adherence compared to both baseline and post-intervention, due to the motivational aspect of seeing others' fitness posts, and from social support extended by group members. We also hypothesized that the "public sharing" feature would lead to increased adherence, due to users having a wider audience responding on their posts.

We used a Friedman test to compare the participants' adherence levels during the baseline, intervention (weekly average during the 4 intervention weeks) and post-intervention periods, and the Nemenyi test for posthoc analysis. Although comparing to the 4-week average may reveal high differences in adherence partly due to novelty, Klasnja et al argued [38] that demonstrating the use of a technology leads to a pattern consistent with how the intervention works (providing social support increases adherence in this case) is sufficient to demonstrate the efficacy of the technology with reasonable confidence. We used the Friedman test due to the nonparametric nature of our data.

A Wilcoxon signed rank test was used to compare the participants' adherence levels in the first 2 weeks of the intervention phase (before the public sharing feature) to the final 2 weeks (after the public sharing feature).

RQ2: Is MyFitnessTeam more effective for certain users e.g. those active at baseline?

We had two conflicting hypothesis. We felt people with higher baseline fitness levels would likely have overcome barriers to behavior change and therefore be more likely to successfully adhere to fitness goals. However we also felt the social comparison opportunities in *MyFitnessTeam* would motivate less active users to perform to a similar level as the baseline active ones. We first grouped participants into 4 baseline fitness groups: *low* (0 days of adherence), *light* (1-3 days of adherence), *medium* (4-5 days of adherence) and *active* (6-7 days of adherence). We then calculated the average number of challenges completed in each week of the intervention phase by the 4 groups, and applied a Kruskal-Wallis test.

Men are also generally more physically active than women [46] but social support has been shown to double womens' participation in exercise [29]. We wondered whether *MyFitnessTeam* would lead to similar performance from male and female participants, and we used a Mann-Whitney U test to compare the adherence of male and female participants.

RQ3: Does MyFitnessTeam support adequate exchange of social support, and what factors/features are responsible?

The purpose of group-based interventions is to provide social support opportunities to users, and an inadequate level of social support could limit the efficacy over the long-term.

We assessed: (i) how much social support was extended by users of *MyFitnessTeam*, (ii) whether users felt the level of social support was adequate or inadequate, and (iii) what factors influenced users in offering support.

To evaluate extended support, 2 individuals open coded the comments participants posted on each other's photos. Each identified theme was then assigned to one of the 4 types of social support. The total number of comments for each type of social support exchanged by each group was counted. Participants in each group then reported via survey, whether the social support extended to them, met, did not meet or exceeded their expectations, and what influenced their decision to extend support to others.

We hypothesized that participants who posted more actively on social media would be most active at extending support on *MyFitnessTeam*. We used self-reported social media posting levels to group participants into: *low* (Infrequent use or never post), *light* (post 1-3 times a week), *medium* (post 4-6 times a week) and *active* (post daily) social media use level. We then used a Kruskal-Wallis test to compare the number of comments posted by these 4 types of participants.

We also felt the public sharing feature would lead to more extended support due to the wider audience for posts, and we used a Wilcoxon signed rank test to compare the number of comments posted before and after the addition of the public sharing feature.

RQ4: How have the user requirements changed after in-situ use?

Studies have shown that day-to-day use of a technology can reveal implications that were not thought of or intended during design [19], and therefore, we asked participants to complete a 10-question online survey consisting of open-ended and multiple-choice questions after the field study. Open-ended questions focused on user experience, specifically, perceived social support, frequently used features in the application, and how the application design could be improved. Multiple choice questions assessed factors that affected motivation and preferences for the application design. The order of options in multiple-choice questions were randomized to prevent bias. Follow-up interviews were conducted with individual participants (n=9) to gain further insight into their open-ended survey responses. Notes were taken during the interviews. Both open-ended responses and interview notes were independently, openly coded by two people using word processing software. The coded data were then compared and discussed to decide the final categories.

6.3 Results

User Requirements for Group Fitness Applications

Table 5 summarizes the challenges faced with existing applications, proposed solutions, and the number of participants who voted for each solution. The challenges faced were similar to those identified in [22], [14], and [43]. All the proposed solutions (Table 5, "Proposed Solutions") involved gaining knowledge (informational support) from fitness experts or people pursuing a similar fitness goal. In addition to informational support, 22 participants (52%) felt getting emotional support from others would motivate them. The types of emotional support most desired were: encouragement, respect and empathy.

Table 5: Challenges faced with existing fitness applications & proposed solutions

Application type	No. of participants	Main challenges faced	Proposed solutions
Calorie counter	8	1. Lack of knowledge on meals to eat to achieve calorie goal (n=8, 100% of participants) 2. Lack of time to search for calorie or nutrition information of foods (n=6, 75% of participants)	1. Provide information on foods and exercises which are suitable for goal (n=8) *"Recommend healthy foods to help me meet my goal, and the right serving size. But the app should consider my location so it doesn't recommend foods I can't make in Japan."* - P34 2. Help users gain knowledge and skills from others (n=5) *"I struggled with healthy eating because I can't cook. I want an app that also allows things like recipes and cooking instructions or advice from other people."* - P23 3. Provide tips for handling barriers such as cravings and low motivation (n=3). *"I want information like 'Drink water before eating to feel fuller'"*- P17

Continuation of Table 5			
Application type	No. of participants	Main challenges faced	Proposed solutions
Walking, running tracker	11	1. Lack of motivation/time to achieve set goal (n=7) 2. Lack of knowledge on what goals to set after achieving the recommended goals e.g. 10,000 steps per day (n=4)	1. Provide progressively difficult goals (n=9) *"Make it like a game where you start with easy goals and progress. "* - P18 2. Provide information on alternative fitness goals that are similar to the achieved goal (n=3) *"It would be great to have a search function to see goals other people are doing or find a fitness plan" - P31*
Diet and exercise plans	23	1. Plans do not consider users' preferences, diet restrictions, access to resources or cooking skills (n = 22). 2. Plans focus on short term diets not long term behavior change (n=1)	1. Provide generic instructions on what a meal should contain and what exercise should be done (n=23) *"Instead of saying 'Eat this food' then say 'Make sure your meal is less than this calories and has this much protein'" - P40* 2. Assist the user to meet recommended guidelines e.g. calorie control, portions of fruits, 150 min. of exercise (n=23) *"It's important to focus on overall health not just short-term things like low-calorie diet for weight loss." - P15*

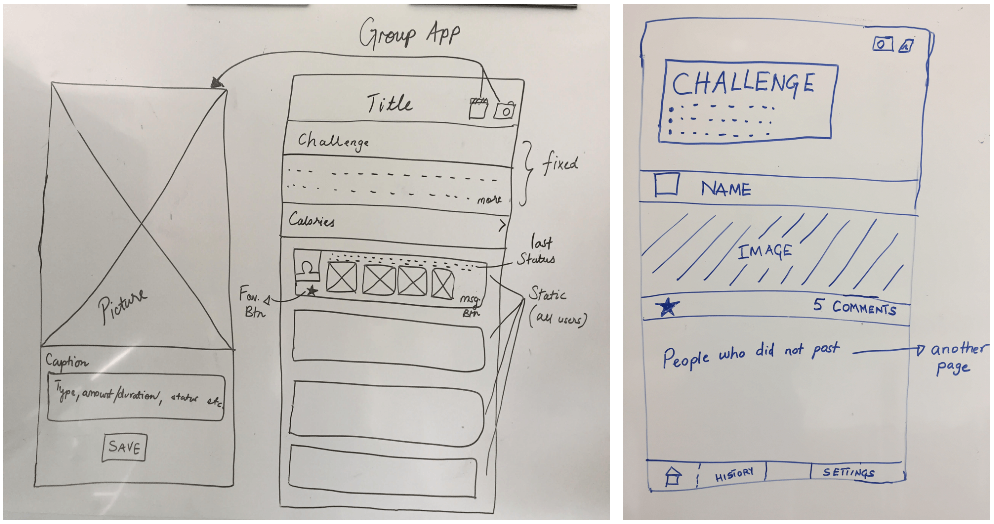


Figure 11: The left and center sketches show the proposed photo upload page and the home pages from the user requirements focus group. The sketch on the right shows the redesigned home page proposed at the validation group interview.

Desired Application Design

Twenty-nine participants (69%) wanted an application that provided daily exercise and healthy eating challenges created by a fitness expert to groups (*"I want something like a game with a daily mission that says all the tasks you need to do for that day."* - P28). Group members would then post updates on how they completed the challenges. They remarked that completing the same goal with others would enable them to learn from each other through observation (*"I'd like to see how other people stay focused and reach their goal."* - P15), create a common experience which they could use to offer informational and emotional support (*"It will be easier to get proper advice and help from people who are going through the same thing."* - P18), and keep them motivated (*"It's more fun to do something with others than to do it alone so I think it will help with motivation"* - P5). The other designs suggested were to pair up users in order to keep each other accountable (n=3, 7%), and to pair users with a coach who provides daily goals and feedback (appraisal & emotional support) (n=10, 24%). However, participants were concerned the latter approach could be costly and coaches may not provide adequate emotional support.

Participants proposed interfaces for the home page and input page (Fig. 11). The home page interface contained a description of the daily challenge, a link to the calorie content of various foods, followed by a list of all group members. Under each member's name, a grid of photos they uploaded for the daily challenge would be displayed along with a message button, "favorite post" button and the caption/status of the last uploaded image. It was felt that showing a summary of every member's uploads would allow them to see inactive members so that encouraging messages could be sent.

In the validation stage however, participants felt this interface had several challenges. First, new photos did not appear at the top of the page. Instead, users had to scroll down to the name of the person who uploaded the photo and select the new photo from the grid in order to view it in full-size. Second, if group members had not uploaded any photos, a list of names with no images was displayed, which was reported to be unmotivating and confusing. Participants proposed a new home page design where all uploaded photos appear in reverse chronological order with the uploader's name and caption on top of the photo (Fig. 11). Information on inactive participants could instead be obtained by going through an additional history page.

In-group & inter-group interactions

Participants wanted to be able to comment i.e. write short text messages on group members' updates and to select their favorite post (photo). Commenting would enable them to ask questions and to exchange tips and emotional support, while the favorite post feature would encourage competition and provide further emotional support through recognition. Some participants were also interested (n=12, 28.6%) in inter-group competitions as a way of motivating them to adhere to challenges.

Input method

Most participants (n=36, 83%) preferred group members' posts to be limited to photo or video only, because they were deemed more interesting and more believable than text updates (*"It would make me believe people are really doing these challenges with me."* - P8). Moreover, they felt that sharing photos or videos would encourage them to choose healthier meals (*"If I know I am going to be sharing evidence of my meals I'll eat better."* - P18) and provide a better opportunity to learn about portion sizing and the correct way to execute certain exercises from others.

Support Network and Privacy

Participants preferred to form a group with people who shared a similar goal even if they were strangers rather than with friends or acquaintances due to the high interest in informational support (Table 5, "Proposed solutions"). They felt the advice and tips from people pursuing a similar goal would be most relevant. To ensure privacy, they suggested limiting group sizes to less than 10 members. There were concerns that a group of strangers or acquaintances might not exchange comments frequently and participants were interested in features to prompt interactions.

Outcome expectations

Participants wanted *adherence* to daily challenges as the primary outcome, with weight loss, improved walking distances etc. being the secondary outcomes. Many (n=34, 81%) felt that focusing on the effort (adherence) rather than progress towards a goal would protect them from discouragement if they failed to achieve these goals. They also felt focusing on the discipline of adhering to a plan would enable them to better meet their health and fitness goals in the future.

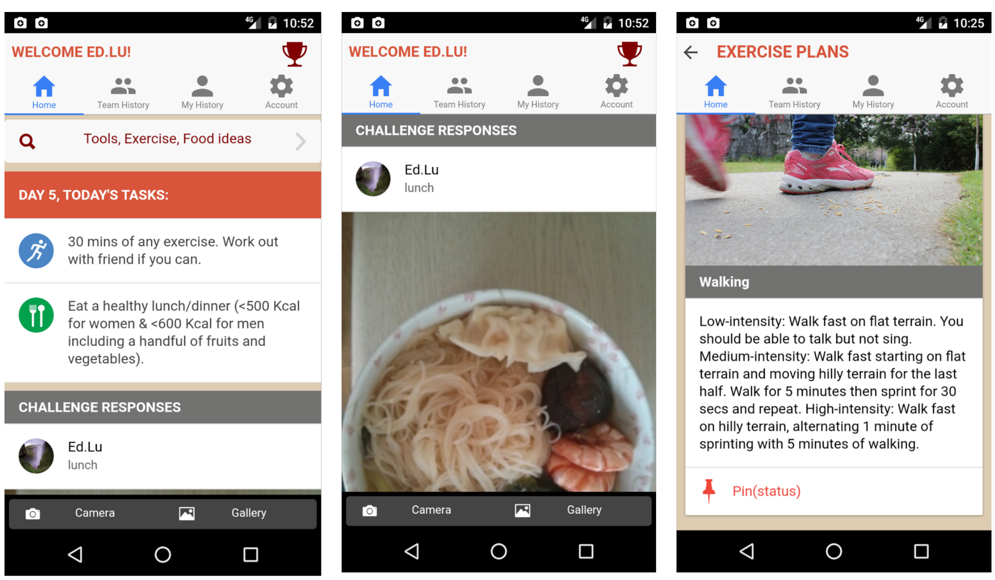
Table 6 summarizes the identified user requirements.

MyFitnessTeam Application

We developed *MyFitnessTeam* (Fig. 12) based on the requirements and validated its design through a field deployment with 10 users from the focus group. *MyFitnessTeam* is an Android and iOS application that offers daily fitness challenges to groups. The application consists of four tabs: home, team history, personal history and account. On application startup, the home page (under home tab) is shown with instructions on how to register and create a new group or join an existing group. Once the user belongs to a group, the home page shows a list

Table 6: User requirements specification for group fitness applications

Application goal	Provide daily challenges (exercise & healthy eating) to groups of users. Group members share updates on how they completed the challenge. Also provide advice on how to achieve the challenges.
Group membership	Allow users to create or join an existing group where members are pursuing a similar fitness goal/plan.
Input	Limit user challenge updates to photos or videos only
Group member interactions	Provide commenting feature & a "favorite" button
Inter group interactions	Support inter-group competitions



(a) (b) (c)

Figure 12: MyFitnessTeam application: (a) and (b) show the daily challenge and timeline respectively. (c) shows the exercise plans page.

of all the tasks in the daily challenge (Fig. 12(a)). Group members post photos showing how they completed the challenges and these appear below the challenge ((Fig. 12(b)). Users can see all the posts made by group members on previous days under the "team history" tab, or view their personal posting history under the "personal history" tab. The account tab contains register and login/logout functions as well as group membership functions (create a group, join a group, quit a group).

In this study, *MyFitnessTeam* offered one fitness plan consisting of 28 days of daily challenges developed by a nutritionist and physical trainer. Table 7 shows the weekly goals of the plan. During recruitment, participants were informed that the fitness plan consisted of daily exercise and healthy eating tasks, and completion of all challenges could lead to slight weight loss. This was partly due to ethics requirements, and partly to ensure only participants who could safely lose weight and whose fitness goals aligned with weight loss (and not weight gain or muscle toning for example) would participate.

Each daily challenge consisted of a physical activity and healthy eating task. For exercise tasks, users had to complete a specific number of minutes of exercise e.g. *"Do 30 minutes of moderate-intensity cardio exercises"*. Every week, users had 3 days of cardio exercises, 2 days for strength training and flexibility exercises, 1 day to do any exercise they wanted and 1 rest day. The healthy eating tasks required eating meals within a specified calorie range, eating a portion of fruits and vegetables, and replacing sugary snacks. Three times a week, an optional team bonding task to prompt social interactions, and hence address users' concerns over low social interactions amongst strangers, was also included. Team bonding tasks were of three types: (i) sharing bits of personal information, e.g. *"post a photo of your favorite healthy snacks"*, to help users learn more about each other and therefore feel more comfortable interacting, (ii) sharing information and emotional support messages e.g. *"share a fitness tip", "post an encouraging comment on your group mates' photos"*, and (iii) group activities e.g. arranging to eat/work out with groupmates.

To help users complete the challenges, *MyFitnessTeam* included a list of meals and exercise plans grouped by type e.g. Rice dish, soft drinks, cardio exercises. Each food item had a calorie amount, numerical serving size and a photo to

Week	Weekly Goal
1	90 minutes of exercise (60 min. low-intensity cardio, 15 min. strength training, 15 min. flexibility exercises), Eat 5 healthy meals
2	135 minutes of exercise (90 min. low-intensity cardio, 30 min. strength training, 15 min. flexibility exercises), Eat 10 healthy meals
3	145 minutes of exercise (90 min. mid-intensity cardio, 40 min. strength training, 15 min. flexibility exercises), Eat 14 healthy meals
4	200 minutes of exercise (Recommended: 90 min. mid-intensity cardio, 40 min. strength training, 15 min. flexibility exercises, but users could choose to distribute exercise minutes differently), Eat 19 healthy meals

Table 7: Weekly goals of the daily challenges

help users visually see the serving size and ingredients, and each exercise had a description of how to complete the exercise as a low-intensity, moderate-intensity and high-intensity workout. Tips on how to maintain motivation and substitute exercise equipment were also provided. Fig. 12(c) shows a cardio exercise plans from *MyFitnessTeam*.

Field Study Results

All 23 participants completed the study. They completed an average of 17.65 (63.04%) challenges, and participants gave *MyFitnessTeam* an average score of 3.04 out of 5 (60.8%). The most popular features were photo sharing and the food calories list and exercise plans. Participants were motivated by both social comparison and inter-group competition.

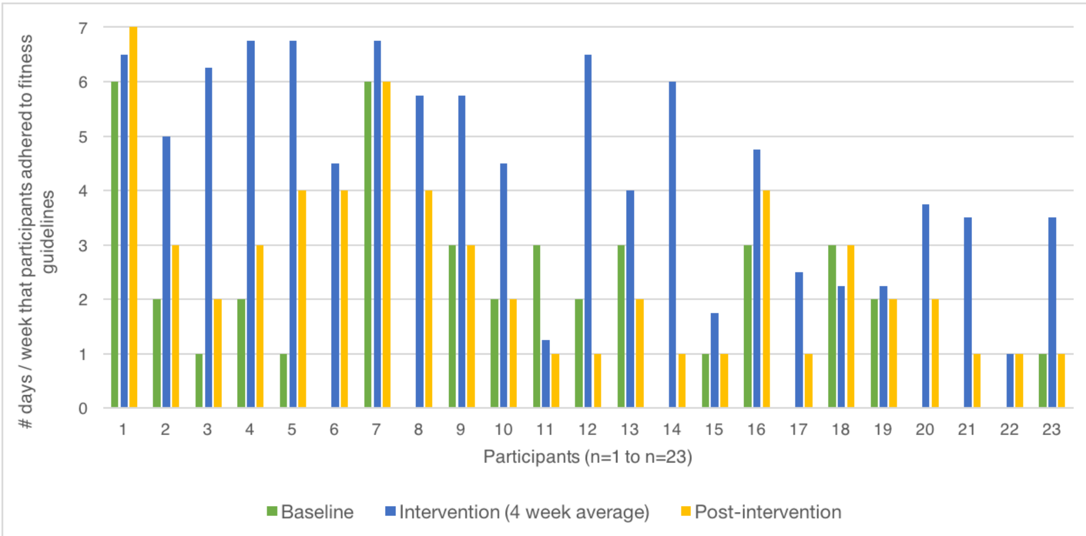


Figure 13: Baseline, intervention and post-intervention adherence to physical activity and healthy eating for the 23 participants

6.4 Composition of Participant Groups

Participants self-divided into 5 groups. The main criteria used to decide on a group was their friendship level either with the administrator (creator) of the group, or with other group members. Those without friends participating in the study joined groups where the group's goal (selected by the administrator at group creation) matched their own.

Group 1 had 5 members (4 male) who considered themselves *"very close"* friends. Group 2 had 3 male members who were strangers, while group 3 had 6 members (5 male) who considered themselves casual acquaintances. Group 4 had 5 members (3 male) who were *"relatively close"* friends and group 5 had 4 members (1 male) who were strangers.

Effect of MyFitnessTeam on Adherence to Fitness Behavior

Fig.13 shows the baseline, intervention and post-intervention adherence of each of the 23 participants. There was a significant difference in the median adherence during the three phases of the study ($\chi^2 = 27.07$, p=0.00001). Posthoc testing showed a significant difference between baseline and intervention (p=0.000003)

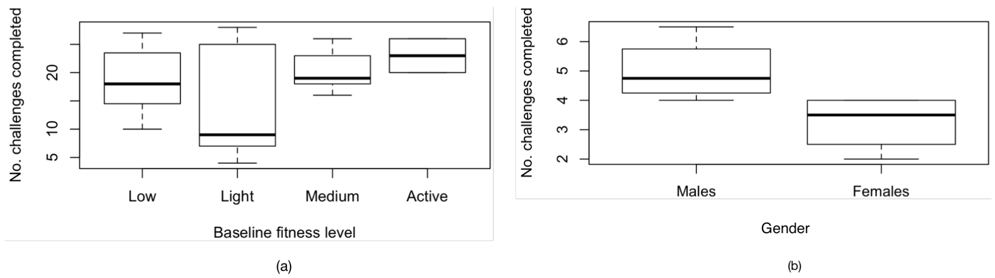


Figure 14: Box-plots of the adherence levels of participants based on: (a) their baseline fitness adherence levels, (b) their gender

and between intervention and post-intervention (p=0.0026), but no significant difference between baseline and post-intervention (p=0.27). The median adherence of the participants before and after inclusion of the public sharing feature (median=10 days and median=9 days respectively) was not statistically significant (p=0.06).

Fig.14(a) shows the intervention phase adherence levels for participants with different levels of baseline adherence (low, light, medium and active). The difference in adherence during the 4 weeks of intervention across the groups was insignificant ($\chi^2 = 1.91$, p = 0.59). Male and female participants (Fig. 14(b)) on the other hand had significant differences in median adherence levels (20 days for men, 13 days for women, p=0.04).

The difference in adherence between male and female participants was due to different primary motivation and location of exercise. Male participants were primarily motivated to determine their limits for physical activity in each week (*"I don't usually go to the gym but I thought it would be a great time to work harder."* - P15) or to compete against others (*"Whenever I had time, I did a challenge and I encouraged everyone in my team to do the same so we could be the best team."* - P10), while female participants had a fixed idea of how much physical activity they wanted to achieve in a week and only strived to reach this personal goal (*"I usually exercise on Sundays but I wanted to exercise 3 times a week so I only did 2 more challenges each week."* - P21, female). In addition, 6 of the 7 female participants did not participate in strength training challenges due to misconceptions on the effect of these exercises on physique. Additionally, male participants primarily exercised in the gym, sports facilities or outdoors, and they encouraged their group mates to join them, making the experience more fun (*"This (study) was fun for me because I usually exercise alone but now I was able to encourage my friends to join me in the gym."* - P14), while female participants chose to exercise alone at home despite having free, daily access to both sports facilities and the gym.

Extended and Perceived Social Support

Participants posted 7 types of comments on each others' posts: encouragement, chatting, negative remarks, advice, accountability e.g. reminders of the group's goal, and an explanation of the uploaded post (photo and caption) by the uploader. Comments in the chatting category were mostly questions and answers on portion sizes, exercise facilities and strategies used to achieve the challenges.

Comments in the encouragement category were an extension of emotional support while advice, accountability and chatting categories were an extension of informational support. Fig. 15 shows the number of comments (messages) for each of the 4 types of social support shared by the groups. Only group 1 participants (n=5, 21.7%) perceived an adequate level of social support. All other participants reported ' *"low"* levels of perceived support.

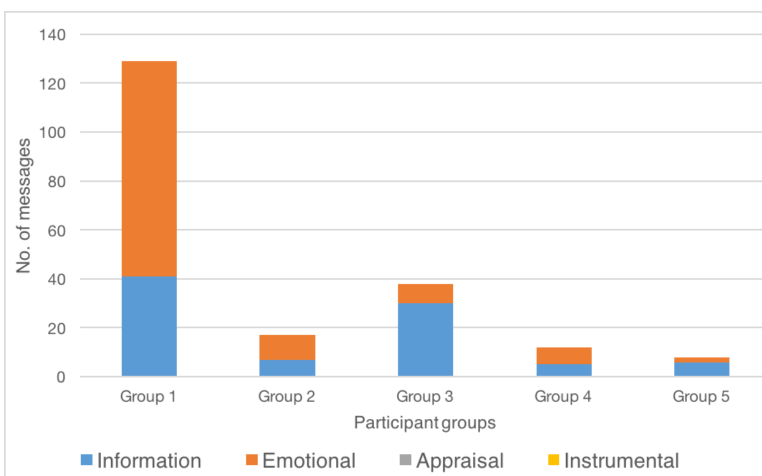


Figure 15: The number of messages exchanged by the 5 groups for each of the 4 types of social support messages

The median number of messages exchanged in the groups before and after including the public sharing feature (Median=7 messages and median=10 messages respectively) did not vary significantly (p=0.875). Participants confirmed that the feature did not lead to increased levels of perceived support because they felt self-conscious about posting their food and activity updates to a wider audience. They instead shared general information such as the healthy food options in different restaurants.

Factors affecting extension of emotional support

More than half of the emotional support messages posted by participants in groups 2 to 5 was on days when the team bonding task in the challenge provided a prompt of what to post e.g. *"Write a 'well done' comment on your favorite post"*. Members of these groups reported feeling *"awkward"* and *"unsure"* of what type of emotional support to offer, apart from praise, and when to offer the support. They were also wary of offering praise frequently because it would seem insincere. Group 1 participants (P1 to P5) however extended emotional support consistently throughout the study because they had agreed at the beginning of the study to comment on each uploaded photo, in hopes constant feedback would support their motivation.

Factors affecting extension of informational support

Participants in groups 1, 3 and 4, who were friends in real life, often exchanged information support outside the application, especially on meal choices and exercises to do in order to meet personal fitness goals. Group 1 and 5 members were strangers and they feared offending their group members by extending unsolicited advice and information. They did ask questions about others' meal and exercise choices, but were careful to *"not be too intrusive"* (P23).

Level of extended social support based on social media posting behavior

Fig. 16 shows the number of social support messages posted by participants based on their social media posting behaviors. Participants in the "Medium" category, and the 2 outliers in the "Light" category all belonged to group 1, which had a pre-agreed strategy to post comments on each others' photos. Discounting these

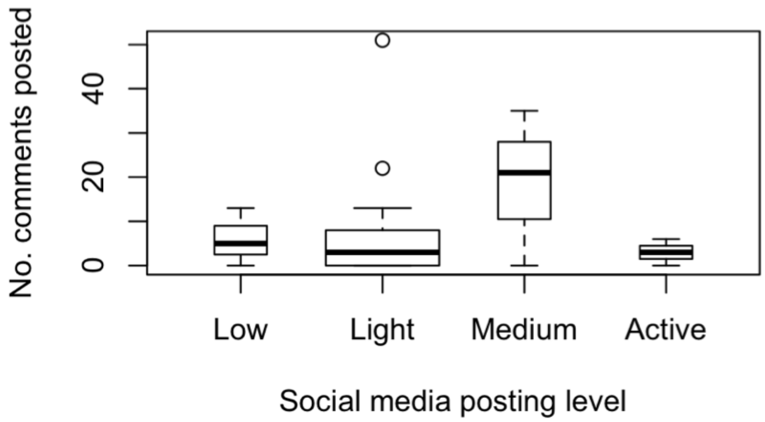


Figure 16: The number of social support messages exchanged by participants of low, light, medium and active social media use behaviors

participants, the level of social support extended by the remaining participants did not vary with social media use behavior. This was confirmed by a Kruskal-Wallis test ($\chi^2 = 0.74$, p = 0.86). Interviews revealed that even participants who posted on social media actively felt unsure on how to best support others through comments.

Challenges Faced and Changes in User Requirements

Several participants (n=13, 56.5%) reported that increasing knowledge and confidence with healthy eating and exercising over the course of the study made the daily challenges feel *restrictive* (*"I think some of the calorie restrictions became inappropriate for my goal - muscle toning and weight maintenance. I would prefer to choose my own challenges."*-P12, *"I enjoyed cardio more and I would prefer to focus more on that than."*-P23). They suggested overcoming this challenge by giving users the ability to personalize the fitness plans. One way to achieve this would be to specify the duration of physical activity a user should aim for, and let them decide which type of exercises to do, and to let users specify their own healthy eating goals.

Another challenge faced was the low level of social support exchanged despite the team bonding tasks (*"I didn't get enough support from my group."*-P8). Some participants (n=10, 43.5%) felt pairing up with friends and acquaintances instead of strangers, even if they had different fitness goals, would address this. A more popular suggestion (n=20, 87%) was to encourage increased use of the public sharing feature to solicit support, especially when users had achieved a goal or were struggling with the challenges (*"My group isn't very active. I have lost quite a bit of weight but there were no comments on my post. I want to share it with more people, maybe I can get more responses."*-P9).

Although team bonding tasks were effective in prompting supportive interactions, they were unpopular with most participants (n=18, 78.3%). They felt social sharing was something to be on SNS with friends, and group fitness applications should focus on sharing challenge-related information only.

Finally, participants revealed that inter-group competitions were initially motivating, but as the performance gap between groups increased, they quickly became demotivating (*"No, I don't like inter-group competitions. It's just demotivating when you realize you can't win."*-P12). Participants felt more frequent, short-term competitions e.g. daily or weekly would be more appropriate, as low-performing groups would have a chance to start over.

Characteristics of Most Successful and Least Successful Participants

The top five participants all belonged to the same group (group 1), and they shared the following characteristics:

- They all believed their individual success depended on how active their group was.
- They therefore interacted often with their groupmates to offer praise and encouragement as motivational support.
- They felt their current physical activity and healthy eating behaviors required significant improvements, and they believed in their ability to improve with the support of the fitness plan and their group mates
- They firmly believed that the daily challenges met existing guidelines on physical activity and nutrition and would help them achieve their fitness goals.

The bottom three participants shared the following characteristics:

- They belonged in groups where individual members were not concerned with the performance of their fellow group mates. These groups therefore rarely commented on each other's photos, and did not attempt more challenges than required for meeting their personal goals.

- They felt their current physical activity and healthy eating behaviors were inadequate but did not believe in the necessity of significant improvements or in their ability to achieve the required changes even within the support structure in the application (i.e. low self-efficacy).

Table 8: Overview of the results from MyFitnessTeam field study

Measure	Findings
Efficacy (Supporting adherence to fitness behaviors)	1. Significantly improved adherence levels compared to both baseline and post-intervention. 2. Participants across different levels of baseline fitness had similar adherence levels i.e. people who were baseline inactive achieved similar adherence to baseline active individuals 3. Male participants significantly outperformed females.
Extended social support in groups	Group members mostly offered encouragement or exchanged information about their food and exercise choices. Groups comprised of friends were more likely to ask for/offer information. Participants who actively post on social media did not extend more support than inactive participants.
Perceived social support in groups	18 of 23 participants (78%) perceived low levels of both emotional and informational support. They wanted the application to engineer emotionally-supportive interactions.

Continuation of Table 8	
Measure	Findings
Preferences for application design	1. Offer daily challenges developed by a fitness expert to groups of users 2. Allow groups to either follow the same fitness plan or different fitness plan 3. Provide a public-sharing space for members of different groups to exchange information and gain more support.

Discussion

Our work aimed to determine users' design preferences for group fitness applications and to evaluate the effectiveness of the proposed design. Tables 6 and 8 summarize our findings.

We found that users look to group fitness applications to gain information and emotional support in the form of guidance from experts and advice and tips from peers for the former, and through exchanging empathy, respect and encouragement for the latter. They envisioned an application that provides daily, common goals (challenges) to a small group of users, who then post photo or video updates on their progress and comment on others' posts, would best provide the needed support. Our field study showed that the design proposed is effective at supporting increased adherence to fitness, with baseline inactive users managing to achieve similar levels of adherence to baseline-fit users due to social comparison. However social support exchanges through comments were low, with most exchanges occurring when the application prompted users on what to say, which may lower the efficacy of the application with time. Engineering social interactions is therefore important. Socio-cultural factors also prevented the application from being as effective for females as for male participants.

Informational and emotional support are the main forms of social support found in online support groups [10] [36] and studies have found that people usually seek/gain informational support first, through lurking on online communities and following health and fitness social media accounts [72] [10]. Those who require emotional support usually start posting after gaining the required information [72] [10] [61]. The higher preference for informational support compared to emotional support during the focus group could be explained by this need to address gaps in knowledge. Due to the short length of the field study, we were unable to assess whether users' preferences for support would change with time. However, we did see indications that emotional support became more important over the course of the study. Firstly, some participants expressed a desire to change their social networks (fellow group members) from anyone who had a similar goal and plan to real-life friends (even those pursuing different goals) in order to gain more emotional support. Secondly, participants frequently commented on the need for group applications to engineer emotionally-supportive interactions among group members due to the low levels of support extended in the groups.

The small groups, common goal and daily challenges format proposed by the focus group participants has been implemented in several group fitness applications in literature [27][16][45][26]. Similar to MyFitnessTeam, these applications led to a significant improvement in outcome measures, thus demonstrating the potential benefits of this approach. In MyFitnessTeam and [27], users were required to post photos to challenges, but the challenges in [27] were not from a structured fitness plan. In [26], [16] and [45], users could show they completed a challenge through a text update and/or clicking a 'Done' button. It is unclear whether one approach has advantages over the other, and thus follow-up studies may need to assess this.

How Well Existing Applications Adhere to the Identified Requirements

Several free and commercial group fitness applications implement one or two of the 3 (small groups, common goal and daily challenges) elements. *Teemo* for instance employs both small groups and a common goal. Up to 9 Facebook friends can form a group and collaborate towards completing a goal such as "Climb Mt. Everest" through their individual workouts. *Yog*, *Running Club* and *FitRockr* provide a common goal. The first 2 allow users to schedule a virtual run (start time, duration) and provide real-time updates of the progress of every user taking part in the run, while *FitRockr* converts any physical activity into points, thereby allowing users doing different activities to have a common comparison metric either for competition or for striving towards a common goal e.g. achieving a specific number of points. *Fit Friendzy* and *Fitocracy* provide both a common fitness goal/plan and regular challenges. However, the challenges are usually user-defined, and group sizes are often very large (up to thousands of users per group). Fitocracy does offer fitness plans with daily or weekly challenges created by professional coaches that users can enroll to, but the bulk of social interactions and thus support is between a coach and each individual user, not within peers. The user satisfaction with, and relative efficacy of these different applications has not been studied, and it is therefore unclear whether it is necessary to have all 3 elements, or whether a subset of the 3 is adequate.

The Challenge of Low Social Support Interactions

The low levels of social support observed in *MyFitnessTeam* have also been observed by Cavallo et al [11], and [27] found participants desired more social interactions.

We found that providing prompts to offer praise or encouragement via team-bonding tasks resulted in more messages of support, which shows the need for applications to be more proactive at engineering social interactions.

Most existing applications provide social features such as a discussion wall, 'comment' buttons on posts and 'like' buttons, but many do not prompt use of these features or provide guidance on what to say, and therefore small groups may still face experience the low-usage challenge. Fortunately, an increasing number of applications now try to engineer interactions. Some like *RunKeeper Live* notify users when their friends start an activity, and they can view their friends' progress and statistics in real-time so they can send appropriate support. Others like *Nike+* provide features to "nudge" inactive friends. We propose other methods applications can use to promote social interactions in section 6.4.

Group Formation Strategy to Promote User Adherence

The top performing participants, in addition to being ready for behavior change, also realized the importance of receiving emotional support from fellow groupmates in order to boost their motivation and performance. They also understood that the best way to receive emotional support was to extend similar support to others. The worst performing participants on the other hand were neither ready for a lot of change nor ready to interact with others.

To promote the chances of individual success, we thus recommend that a mini-survey be administered at the time of registration, to assess users' baseline behavior, their attitudes towards behavior change and basic personality. Groups should comprise of people of similar personality, with either equal numbers of users who are ready for change and those who are not, or with slightly more users who are ready for change. Ideally, users who are not ready for change would then be motivated both by observing the fitness activities of the others, and through the emotional support they would receive.

Design Recommendations for Group Fitness Applications

We propose 5 methods applications can use promote more social support in group fitness applications, based on participants' experiences and comments in the field study.

Assist Users to Form a Social Interactions Strategy

The top performing group in our study had members who realized the positive impact of encouragement, praise, and pairing up for challenges, which resulted in their pre-agreed social support strategy. Applications should inform users on the importance of collaborating both in-application and face-to-face (if possible). This could be achieved through statistics on the impact of social interactions on adherence to goals or applications could propose ways members can collaborate (pairing up, assigning roles such as "motivator" and "exercise scheduler" to members).

Provide Prompts to Interact with Other Members

Applications typically issue notifications updating a social circle of a friends' recent progress and achievements. Suggestions of messages and actions that friends can take to show their support could be appended to these updates e.g. *"X completed the challenge today. Send a congratulatory message"* or *"Comment on your favorite photo with 'I like ...'"*. Alternatively, buttons such as 'like', and 'favorite', can be extended such that when a user clicks on the button, instead of just incrementing the number of clicks, a comment box also appears with a prompt for the user to specify their feelings e.g. *"I like ...."* or *"Well done on...."*. Participants who are struggling to adhere to the challenges or to complete the challenges should also be aided in requesting support for instance by prompting them to share their struggles, or by guiding them to relevant information resources.

Provide an In-application Public Sharing Space for Tips, Conversations and Emotional Support
Informational support was highlighted as an important form of social support in the focus group. Providing an in-application public sharing space where users from different groups can exchange tips, information on location of resources e.g. exercise facilities, recipes and exercise plans etc. can allow easier access to valuable information. Many fitness applications provide web-based forums, but in-application forum features are still not as widely supported. Information seeking effectiveness can lead to higher levels of perceived empathy [52], and therefore this strategy may also help address the challenge of low levels of emotional support within groups. Allowing individuals and groups to share their challenge photos to such a public space can further address this challenge, as individuals can gain both informational and emotional feedback from non-group members.

Provide Opportunities for Vicarious Learning from the Best Performing Groups and Individuals
Vicarious/observational learning [8] can promote behavior change and participants in our study showed interest in its inclusion in group fitness applications. Top performing groups and individuals can support others by either sharing their photos to the public domain for a day, sharing short stories on their fitness journeys (motivations, challenges faced and strategies used to overcome them), answering a subset of user questions, live-streaming their meal choices and exercise sessions or mentoring/coaching an individual. Rewards such as badges and small gifts donated by users and intrinsic rewards of contributing to something meaningful can be utilized to encourage participation.

Allow Individual Competition and Awards to Recognize Individual Achievements

Many participants felt competitions motivated them to perform more challenges. To support competitive users who may be in non-competitive groups i.e. a group where the majority of members are motivated by their internal goals and not competition, a leaderboard of individual performance could be provided in addition to a group leaderboard. Furthermore, users could be allowed to personally reach out to users in other groups to challenge each other to mini-competitions.

Limitations and Future Work

One limitation of the study was the low number of participants in the various subgroups during the field study, which meant we could not determine whether observations were statistically significant. We also relied on participants self-reporting their activity levels which may have resulted in over-reporting.

Further work on the effect of group applications over an extended period of time is needed. Determining correlates and determinants of individual and group performance levels is also needed to provide more design recommendations.

6.5 Chapter Summary

In this chapter, we presented results from a focus group on the social support users desire from group fitness applications. We also presented their requirements for features and interactions in these applications. These included providing daily physical activity and healthy eating tasks that users in a group attempt. We developed MyFitnessTeam based on these requirements and evaluated its effectiveness through a 4-week field study (n=23). We found that adherence to physical activity and healthy eating increased significantly. Men had significantly higher levels of adherence to females, and participants had significantly higher levels of challenge adherence and social interactions when the challenges were more specific, requiring all group members to engage in the same type of physical activity and eat the same type of meal, than when they allowed group members to choose different activities and meals. There were no differences in adherence and in social interactions based on baseline physical fitness level and social media posting behavior respectively. Groups consisting of real-life friends exchanged more informational support, but both groups of friends and groups of strangers had low levels of emotional support due to lack of knowledge on when and how to extend such support. We presented 5 design recommendations on how to engineer in=group collaboration and interactions, and how to ensure users are aware of strategies they can use to promote their success.

7. Conclusion and Future Work

7.1 Summary

The aim of this research was to use a user-centered design (UCD) approach to first identify users' requirements for the implementation of three theory-based behavior change strategies: stimulus control, rewards and social support, in smartphone weight loss applications, and to then evaluate the effectiveness of these strategies in promoting dietary behavior change. Requirements gathering was conducted via one-on-one interviews, surveys, and focus groups, and evaluation was done through field deployments of prototype applications that were developed based on the user requirements specification. The scope of the evaluation was limited to efficacy of the strategies for dietary behavior change for two reasons. First, dietary tracking and behavior change are the main strategies used by people looking to lose weight [], and second, because much research on health and fitness behavior change support has already identified users' requirements for applications to promote physical activity but relatively few studies have been conducted for dietary behavior change.

The stimulus control strategy received the highest user satisfaction score (65%), and had the highest effect on adherence levels (3x higher adherence than control group). Use of the strategy also enabled participants to significantly improve the number of days on which they achieved their calorie goals. Stimulus control involves identifying triggers (cues) of behavior, and either removing them or suppressing them, thus lowering the probability of the behavior re-occurring. The importance of providing feedback that helps users identify troublesome behaviors and recommending behaviors to address them was further confirmed in the focus group study on designing the concept for an ideal dietary tracking application (chapter 5).

Providing group interventions (through *MyFitnessTeam*) was also effective, with 21 of the 23 participants in the field study significantly improving their adherence to healthy eating and physical activity behaviors compared to baseline. Male participants, and those who were inactive at baseline, had the most improvement in adherence. User satisfaction with the strategy was 60.8%. However, despite grouping users and providing a shared experience through challenges, exchange of information and emotional support messages was low, since users were unsure when and how to offer such support. Providing in-application prompts to post supportive messages, along with directions on what users could write, led to more supportive messages being exchanged, which demonstrates the need for group applications to be proactive at initiating inter-user interactions.

Finally, users felt that although dietary behavior change games sounded fun in theory, they were too time-consuming to use on a daily basis. This was reflected in the low user satisfaction score (44%) and adherence rate (2.6 out of 7 days a week) observed in our deployment of the *HappyInu* application. Participants also felt having real rewards such as cash and gifts would undermine their motivation and ability to change in the long-term, since they would associate behavior change with gifts, and removal of the gifts would make them less likely to keep up the behavior.

Overall, our study has contributed the following knowledge. First, we show that the stimulus control strategy, which is largely unimplemented in existing weight loss applications, can build user's confidence in eating behavior change. This translates into increased motivation and adherence to the weight loss goals. Once the most important cues have been identified, the strategy can also be used in place of calorie tracking, and therefore further improve long-term adherence due to the lower user effort required. Secondly, we show that group fitness applications that offer structured plans are effective ways of promoting adherence across different kinds of users (baseline-active, baseline inactive, men and women). However, user motivation for using the applications is mostly to gain informational and emotional support, but user interactions to offer each other with support need to be prompted. We provide recommendations on various ways applications can intervene and engineer these interactions. Finally, we show that games for healthy eating behavior change support may not be effective over the long-term, but gamification elements such as competitions and rewards, particularly those that provide users with the feeling that they are contributing to a worthwhile cause, can be leveraged to support behavior change.

7.2 Limitations

All our studies suffered from two main limitations. First, both the user requirements studies and field studies had relatively low number of participants, which affects the ability of the results to be generalized to the wider population.

Second, the field studies conducted were of a short duration (21 to 42 days). Research shows that only around 20% of people who have lost weight manage to maintain their weight loss for a year or more [77]. They do so by eating breakfast and low-calorie meals everyday, as well as exercising for around an hour each day (usually walking). Although our studies did show positive behavior change, it is difficult to determine whether participants would continue using the behaviors they adopted once they quit the applications. Because stimulus control does deal with removing cues, users of this strategy may have a high potential of adhering to new behaviors in the long term. Similarly, users who can manage to obtain social support from a group of peers (people with similar goals) may achieve long-term success. However, it is unclear how the proposed applications in this work would support users on permanently removing negative cues, and on maintaining contact with their peer groups. Further long-term studies are therefore needed.

7.3 Future Work

There are a number of research questions that were unanswered by this work. These include:

- What is the short-term and long-term effectiveness of the "ideal" diet tracking application proposed in chapter 5?
- What are the long-term effectiveness of stimulus control, rewards and social support strategies on weight loss behavior change, and how can the application designs be improved for higher efficacy?
- How effective would an application that combines several strategies e.g. stimulus control and social support be in the short and long term?

Combining Stimulus Control and Social Support in Weight Loss Applications

From the study on social support requirements (chapter 6), we identified that users want social applications to provide a *common experience* e.g. through a common goal.

One way of providing this common experience is to have users form small groups (2-8 people) at registration, and then ask them to decide on a group physical activity goal e.g. *300 minutes of exercise this month.* The application should then guide the users to schedule a regular physical activity session with at least 1 other member from the group as a means of working towards the goal, and provide timely reminders to the users on *when*, *where* and *with whom* they need to meet up for exercise. The application should also prompt these users to share photos or videos of their exercise sessions, and prompt the other users to give positive feedback. As mentioned in section 3.6, providing such time-based and people-based cues have been shown to be strongly correlated with increased physical activity.

In addition to regular scheduled exercise, the application can also provide just-in-time recommendations for opportunistic exercise to individual users e.g. *climb the stairs instead of taking the elevator*. If the user follows the recommendation, the application can then share this with the rest of the users' groupmates, and prompt them to provide encouragement or praise.

The *individual intervention and public sharing* approach used for opportunistic exercises can also be used for healthy eating stimulus control. Users would privately log their weight and calorie intake information, and privately view the visualized feedback. However their chosen behavior goal (from the application's recommendations) should be shared with the rest of their groupmates and each day, the application should prompt them to share photos or videos of how they completed/used their chosen behavior goal (e.g. photo of portion size of meal if behavior goal is to reduce portion size). If the user does not upload any photos over the course of the day, they can be prompted to share the challenges they faced in keeping their goal on that day. In both cases, the application should prompt other members of the group to provide the appropriate feedback e.g. empathy, encouragement, advice, praise etc.

To further motivate users to adhere to their goals and to share their progress, competitions could be used. The application can provide a visualization of the teams' overall progress towards their goal e.g. 300 minutes of scheduled exercise this month, as well as the progress of other teams. Individual contributions of each group member towards the goal should also be provided. Although Nishiyama et al found that doing so was less effective than not providing details of individual contribution [54], we believe that the lower variance that would result among individual members' performance is a worthy benefit.

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References

[1] Preventing weight gain, 2015.

[2] Tamagotchi in japan, 2015.

[3] Aino Ahtinen, Pertti Huuskonen, and Jonna Häkkilä. Let's all get up and walk to the north pole: design and evaluation of a mobile wellness application. In *Proceedings of the 6th Nordic conference on human-computer interaction: Extending boundaries*, pages 3–12. ACM, 2010.

[4] Ian Anderson, Julie Maitland, Scott Sherwood, Louise Barkhuus, Matthew Chalmers, Malcolm Hall, Barry Brown, and Henk Muller. Shakra: tracking and sharing daily activity levels with unaugmented mobile phones. *Mobile networks and applications*, 12(2-3):185–199, 2007.

[5] Adrienne H Andrew, Gaetano Borriello, and James Fogarty. Simplifying mobile phone food diaries: design and evaluation of a food index-based nutrition diary. In *Proceedings of the 7th international conference on pervasive computing technologies for healthcare*, pages 260–263. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), 2013.

[6] Yutaka Arakawa and Yuki Matsuda. Gamification mechanism for enhancing a participatory urban sensing: Survey and practical results. *Journal of Information Processing*, 24(1):31–38, 2016.

[7] Kristen MJ Azar, Lenard I Lesser, Brian Y Laing, Janna Stephens, Magi S Aurora, Lora E Burke, and Latha P Palaniappan. Mobile applications for weight management: theory-based content analysis. *American journal of preventive medicine*, 45(5):583–589, 2013.

[8] Albert Bandura and Richard H Walters. *Social learning theory.* Prentice-Hall Englewood Cliffs, NJ, 1977.

[9] Frank Bentley, Konrad Tollmar, Peter Stephenson, Laura Levy, Brian Jones, Scott Robertson, Ed Price, Richard Catrambone, and Jeff Wilson. Health mashups: Presenting statistical patterns between wellbeing data and context

in natural language to promote behavior change. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 20(5):30, 2013.

[10] Heather Buchanan and Neil S Coulson. Accessing dental anxiety online support groups: An exploratory qualitative study of motives and experiences. *Patient Education and Counseling*, 66(3):263–269, 2007.

[11] David N Cavallo, Deborah F Tate, Amy V Ries, Jane D Brown, Robert F DeVellis, and Alice S Ammerman. A social media–based physical activity intervention: a randomized controlled trial. *American journal of preventive medicine*, 43(5):527–532, 2012.

[12] Yu Chen and Pearl Pu. Healthytogether: exploring social incentives for mobile fitness applications. In *Proceedings of the Second International Symposium of Chinese CHI*, pages 25–34. ACM, 2014.

[13] Chia-Fang Chung, Elena Agapie, Jessica Schroeder, Sonali Mishra, James Fogarty, and Sean A Munson. When personal tracking becomes social: Examining the use of instagram for healthy eating. In *Proceedings of the CHI Conference on Human Factors in Computing Systems*, pages 1674–1687. ACM, 2017.

[14] James Clawson, Jessica A Pater, Andrew D Miller, Elizabeth D Mynatt, and Lena Mamykina. No longer wearing: investigating the abandonment of personal health-tracking technologies on craigslist. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing*, pages 647–658. ACM, 2015.

[15] Mayo Clinic. Money talks when it comes to losing weight., 2013.

[16] Nathan K Cobb and Josée Poirier. Effectiveness of a multimodal online well-being intervention: a randomized controlled trial. *American journal of preventive medicine*, 46(1):41–48, 2014.

[17] The Nielsen Company. We are what we eat. January 2015.

[18] Sunny Consolvo, Katherine Everitt, Ian Smith, and James A Landay. Design requirements for technologies that encourage physical activity. In *Proceedings*

of the SIGCHI conference on Human Factors in computing systems, pages 457–466. ACM, 2006.

[19] Sunny Consolvo, Beverly Harrison, Ian Smith, Mike Y Chen, Katherine Everitt, Jon Froehlich, and James A Landay. Conducting in situ evaluations for and with ubiquitous computing technologies. *International Journal of Human-Computer Interaction*, 22(1-2):103–118, 2007.

[20] Sunny Consolvo, Predrag Klasnja, David W McDonald, Daniel Avrahami, Jon Froehlich, Louis LeGrand, Ryan Libby, Keith Mosher, and James A Landay. Flowers or a robot army?: encouraging awareness & activity with personal, mobile displays. In *Proceedings of the 10th international conference on Ubiquitous computing*, pages 54–63. ACM, 2008.

[21] Felicia Cordeiro, Elizabeth Bales, Erin Cherry, and James Fogarty. Rethinking the mobile food journal: Exploring opportunities for lightweight photo-based capture. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, pages 3207–3216. ACM, 2015.

[22] Felicia Cordeiro, Daniel A Epstein, Edison Thomaz, Elizabeth Bales, Arvind K Jagannathan, Gregory D Abowd, and James Fogarty. Barriers and negative nudges: Exploring challenges in food journaling. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, pages 1159–1162. ACM, 2015.

[23] Franco Curmi, Maria Angela Ferrario, Jen Southern, and Jon Whittle. Heartlink: open broadcast of live biometric data to social networks. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 1749–1758. ACM, 2013.

[24] Artur Direito, Leila Pfaeffli Dale, Emma Shields, Rosie Dobson, Robyn Whittaker, and Ralph Maddison. Do physical activity and dietary smartphone applications incorporate evidence-based behaviour change techniques? *BMC public health*, 14(1):646, 2014.

[25] Amol Doshi, Kevin Patrick, James F Sallis, and Karen Calfas. Evaluation

of physical activity web sites for use of behavior change theories. *Annals of Behavioral Medicine*, 25(2):105–111, 2003.

[26] Honglu Du, G Michael Youngblood, and Peter Pirolli. Efficacy of a smartphone system to support groups in behavior change programs. In *Proceedings of the Wireless Health 2014 on National Institutes of Health*, pages 1–8. ACM, 2014.

[27] Daniel A Epstein, Felicia Cordeiro, James Fogarty, Gary Hsieh, and Sean A Munson. Crumbs: Lightweight daily food challenges to promote engagement and mindfulness. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, pages 5632–5644. ACM, 2016.

[28] Daniel A Epstein, Bradley H Jacobson, Elizabeth Bales, David W McDonald, and Sean A Munson. From nobody cares to way to go!: A design framework for social sharing in personal informatics. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing*, pages 1622–1636. ACM, 2015.

[29] Amy A Eyler, Ross C Brownson, Rebecca J Donatelle, Abby C King, David Brown, and James F Sallis. Physical activity social support and middle- and older-aged minority women: results from a us survey. *Social science & medicine*, 49(6):781–789, 1999.

[30] Derek Foster, Conor Linehan, Ben Kirman, Shaun Lawson, and Gary James. Motivating physical activity at work: using persuasive social media for competitive step counting. In *Proceedings of the 14th International Academic MindTrek Conference: Envisioning Future Media Environments*, pages 111–116. ACM, 2010.

[31] Yuichi Fujiki, Konstantinos Kazakos, Colin Puri, Pradeep Buddharaju, Ioannis Pavlidis, and James Levine. Neat-o-games: blending physical activity and fun in the daily routine. *Computers in Entertainment (CIE)*, 6(2):21, 2008.

[32] Andrea Grimes, Vasudhara Kantroo, and Rebecca E Grinter. Let's play!: mobile health games for adults. In *Proceedings of the 12th ACM international conference on Ubiquitous computing*, pages 241–250. ACM, 2010.

[33] Diabetes Prevention Program (DPP) Research Group et al. The diabetes prevention program (dpp). *Diabetes care*, 25(12):2165–2171, 2002.

[34] Kimberly A Gudzune, Ruchi S Doshi, Ambereen K Mehta, Zoobia W Chaudhry, David K Jacobs, Rachit M Vakil, Clare J Lee, Sara N Bleich, and Jeanne M Clark. Efficacy of commercial weight-loss programsan updated systematic reviewefficacy of commercial weight-loss programs. *Annals of internal medicine*, 162(7):501–512, 2015.

[35] Peter Hausberger, Andreas Fernbach, and Wolfgang Kastner. Imu-based smart fitness devices for weight training. In *Industrial Electronics Society, IECON 2016-42nd Annual Conference of the IEEE*, pages 5182–5189. IEEE, 2016.

[36] Kevin O Hwang, Allison J Ottenbacher, Angela P Green, M Roseann Cannon-Diehl, Oneka Richardson, Elmer V Bernstam, and Eric J Thomas. Social support in an internet weight loss community. *International journal of medical informatics*, 79(1):5–13, 2010.

[37] Kuk Jin Jang, Jungmin Ryoo, Orkan Telhan, and Rahul Mangharam. Cloud mat: Context-aware personalization of fitness content. In *Services Computing (SCC), 2015 IEEE International Conference on*, pages 301–308. IEEE, 2015.

[38] Predrag Klasnja, Sunny Consolvo, and Wanda Pratt. How to evaluate technologies for health behavior change in hci research. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 3063–3072. ACM, 2011.

[39] Fanyu Kong and Jindong Tan. Dietcam: Automatic dietary assessment with mobile camera phones. *Pervasive and Mobile Computing*, 8(1):147–163, 2012.

[40] Jeffrey T Kullgren, Andrea B Troxel, George Loewenstein, David A Asch, Laurie A Norton, Lisa Wesby, Yuanyuan Tao, Jingsan Zhu, and Kevin G Volpp. Individual-versus group-based financial incentives for weight loss: a randomized, controlled trial. *Annals of internal medicine*, 158(7):505–514, 2013.

[41] Brian Yoshio Laing, Carol M Mangione, Chi-Hong Tseng, Mei Leng, Ekaterina Vaisberg, Megha Mahida, Michelle Bholat, Eve Glazier, Donald E Morisky, and Douglas S Bell. Effectiveness of a smartphone application for weight loss compared with usual care in overweight primary care patientsa randomized, controlled trialsmartphone application for weight loss in overweight primary care patients. *Annals of internal medicine*, 161(10_Supplement):S5–S12, 2014.

[42] James J Lin, Lena Mamykina, Silvia Lindtner, Gregory Delajoux, and Henry B Strub. Fishnsteps: Encouraging physical activity with an interactive computer game. In *International Conference on Ubiquitous Computing*, pages 261–278. Springer, 2006.

[43] Edith Talina Luhanga, Akpa Akpro Elder Hippocrate, Hirohiko Suwa, Yutaka Arakawa, and Keiichi Yasumoto. Towards proactive food diaries: a participatory design study. In *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct*, pages 1263–1266. ACM, 2016.

[44] Carol A Macera et al. Promoting healthy eating and physical activity for a healthier nation. *Center for Disease Control and Preventiion. Viewed at http://www. cdc. gov/healthyyouth/publications/pdf/pp-ch7. pdf*, 2003.

[45] Carol Maher, Monika Ferguson, Corneel Vandelanotte, Ron Plotnikoff, Ilse De Bourdeaudhuij, Samantha Thomas, Karen Nelson-Field, and Tim Olds. A web-based, social networking physical activity intervention for insufficiently active adults delivered via facebook app: randomized controlled trial. *Journal of medical Internet research*, 17(7), 2015.

[46] Marrifran Mattson and Jennifer Gibb Hall. *Linking Health Communication with Social Support*. Kendall Hunt Publishing Company, 2011.

[47] Maureen T Mcguire, RR Wing, ML Klem, HM Seagle, and JO Hill. Long-term maintenance of weight loss: do people who lose weight through various weight loss methods use different behaviors to maintain their weight? *International Journal of Obesity & Related Metabolic Disorders*, 22(6), 1998.

[48] Gina Merchant, Nadir Weibel, Kevin Patrick, James H Fowler, Greg J Norman, Anjali Gupta, Christina Servetas, Karen Calfas, Ketaki Raste, Laura Pina, et al. Click like to change your behavior: a mixed methods study of college students exposure to and engagement with facebook content designed for weight loss. *Journal of medical Internet research*, 16(6):e158, 2014.

[49] CJ Metzgar, AG Preston, DL Miller, and SM Nickols-Richardson. Facilitators and barriers to weight loss and weight loss maintenance: a qualitative exploration. *Journal of human nutrition and dietetics*, 28(6):593–603, 2015.

[50] Sean A Munson and Sunny Consolvo. Exploring goal-setting, rewards, self-monitoring, and sharing to motivate physical activity. In *Pervasive computing technologies for healthcare (PervasiveHealth), 2012 6th international conference on*, pages 25–32. IEEE, 2012.

[51] Elizabeth L Murnane, David Huffaker, and Gueorgi Kossinets. Mobile health apps: adoption, adherence, and abandonment. In *Adjunct Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2015 ACM International Symposium on Wearable Computers*, pages 261–264. ACM, 2015.

[52] Priya Nambisan. Information seeking and social support in online health communities: impact on patients' perceived empathy. *Journal of the American Medical Informatics Association*, 18(3):298–304, 2011.

[53] Mark W Newman, Debra Lauterbach, Sean A Munson, Paul Resnick, and Margaret E Morris. It's not that i don't have problems, i'm just not putting them on facebook: challenges and opportunities in using online social networks for health. In *Proceedings of the ACM 2011 conference on Computer supported cooperative work*, pages 341–350. ACM, 2011.

[54] Yuuki Nishiyama, Tadashi Okoshi, Takuro Yonezawa, Jin Nakazawa, Kazunori Takashio, and Hideyuki Tokuda. Towards health exercise behavior change for teams using life-logging. In *e-Health Networking, Applications and Services (Healthcom), 2014 IEEE 16th International Conference on*, pages 397–403. IEEE, 2014.

[55] Oded Nov. What motivates wikipedians? *Communications of the ACM*, 50(11):60–64, 2007.

[56] World Health Organization. The top 10 causes of death, January 2017.

[57] Rita Orji, Julita Vassileva, and Regan L Mandryk. Lunchtime: a slow-casual game for long-term dietary behavior change. *Personal and Ubiquitous Computing*, 17(6):1211–1221, 2013.

[58] Sherry Pagoto, Kristin Schneider, Mirjana Jojic, Michele DeBiasse, and Devin Mann. Evidence-based strategies in weight-loss mobile apps. *American journal of preventive medicine*, 45(5):576–582, 2013.

[59] Irene Berg Petersen. The maasai keep healthy despite a high-fat diet, 2012.

[60] Rosemary Pimm, Corneel Vandelanotte, Ryan E Rhodes, Camille Short, Mitch J Duncan, and Amanda L Rebar. Cue consistency associated with physical activity automaticity and behavior. *Behavioral Medicine*, 42(4):248–253, 2016.

[61] Sean Pinkerton, Jessi L Tobin, Sydney C Querfurth, Iowayna M Pena, and Kathleen S Wilson. those sweet, sweet likes: Sharing physical activity over social network sites. *Computers in Human Behavior*, 69:128–135, 2017.

[62] John Pollak, Geri Gay, Sahara Byrne, Emily Wagner, Daniela Retelny, and Lee Humphreys. It's time to eat! using mobile games to promote healthy eating. *IEEE Pervasive Computing*, 9(3):21–27, 2010.

[63] National Diabetes Prevention Program. Participant notebook for months 1 to 6, 1996.

[64] Mashfiqui Rabbi, Min Hane Aung, Mi Zhang, and Tanzeem Choudhury. Mybehavior: automatic personalized health feedback from user behaviors and preferences using smartphones. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing*, pages 707–718. ACM, 2015.

[65] John Rooksby, Mattias Rost, Alistair Morrison, and Matthew Chalmers. Pass the ball: enforced turn-taking in activity tracking. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, pages 2417–2426. ACM, 2015.

[66] Richard M Ryan and Edward L Deci. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American psychologist*, 55(1):68, 2000.

[67] Mary K Serdula, Ali H Mokdad, David F Williamson, Deborah A Galuska, James M Mendlein, and Gregory W Heath. Prevalence of attempting weight loss and strategies for controlling weight. *Jama*, 282(14):1353–1358, 1999.

[68] Mary K Serdula, David F Williamson, Robert F Anda, Alan Levy, Alan Heaton, and Tim Byers. Weight control practices in adults: results of a multistate telephone survey. *American Journal of Public Health*, 84(11):1821–1824, 1994.

[69] Murray Sidman. Reflections on stimulus control. *The Behavior Analyst*, 31(2):127–135, 2008.

[70] Mathias Sundholm, Jingyuan Cheng, Bo Zhou, Akash Sethi, and Paul Lukowicz. Smart-mat: Recognizing and counting gym exercises with low-cost resistive pressure sensing matrix. In *Proceedings of the 2014 ACM international joint conference on pervasive and ubiquitous computing*, pages 373–382. ACM, 2014.

[71] Karyn A Tappe and Karen Glanz. Measurement of exercise habits and prediction of leisure-time activity in established exercise. *Psychology, health & medicine*, 18(5):601–611, 2013.

[72] Rannie Teodoro and Mor Naaman. Fitter with twitter: Understanding personal health and fitness activity in social media. In *ICWSM*, 2013.

[73] A Janet Tomiyama, Traci Mann, and Lisa Comer. Triggers of eating in everyday life. *Appetite*, 52(1):72–82, 2009.

[74] Gabrielle M Turner-McGrievy and Deborah F Tate. Weight loss social support in 140 characters or less: use of an online social network in a remotely delivered weight loss intervention. *Translational behavioral medicine*, 3(3):287–294, 2013.

[75] Yoshitaka Ueyama, Morihiko Tamai, Yutaka Arakawa, and Keiichi Yasumoto. Gamification-based incentive mechanism for participatory sensing. In *Pervasive Computing and Communications Workshops (PERCOM Workshops), 2014 IEEE International Conference on*, pages 98–103. IEEE, 2014.

[76] W Velicer, J Prochaska, J Fava, G Norman, and C Redding. Transtheoretical model: detailed overview of the transtheoretical model. *Cancer Prevention Research Center.[online] Available: http://www. uri. edu/research/cprc/TTM/detailedoverview. htm*, 1998.

[77] Rena R Wing and Suzanne Phelan. Long-term weight loss maintenance–. *The American journal of clinical nutrition*, 82(1):222S–225S, 2005.

[78] Bo Zhou, Mathias Sundholm, Jingyuan Cheng, Heber Cruz, and Paul Lukowicz. Measuring muscle activities during gym exercises with textile pressure mapping sensors. *Pervasive and Mobile Computing*, 2016.

Publication List

Main Publications

Luhanga, Edith Talina. 'Evaluating the effectiveness of stimulus control, time management and self-reward for weight loss behavior change', Doctoral School at International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp Doctoral School 2015). ACM, 2015.

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Luhanga, Edith Talina Luhanga; Hippocrate, Akpa Akpro Elder; Suwa, Hirohiko; Arakwa, Yutaka; and Yasumoto, Keiichi. 'HappyInu: Exploring how to use games and extrinsic rewards for consistent food tracking behavior', Mobile Computing and Ubiquitous Networking (ICMU 2016), 2016 Ninth International Conference on. IEEE, 2016.

Factors that Affect Success in Group Behavior Change Applications, Edith Talina Luhanga, Akpa Akpro Elder Hippocrate, Yutaka Arakawa, Keiichi Yasumoto, 2017, Behavioral Change and Social System, Vol. 2, (vol.2).

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Other Publications

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