The Influence of Message Framing on Engagement with a Mobile Application for Motivating Exercise

by

Anh Dang-Viet Nguyen

Submitted to the Department of Electrical Engineering and Computer Science

in Partial Fulfillment of the Requirements for the Degree of

Master of Engineering in Electrical Engineering and Computer Science

at the

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September, 2011

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I do not believe that listing here the names of people who helped me carry on through this project is anywhere close to enough. Throughout almost two years working on this project, I have learned more than I ever did before. I have met people that changed my life forever. Please accept my deepest gratitude to you.

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ABSTRACT

Mobile phone personal health monitoring software is designed to help people monitor and change their behavior. Exercise applications may measure heart rate, temperature, distance traveled, and movement. Although some of these programs incorporate behavioral theories to motivate engagement and behavior change, it is not yet clear that the devices can maintain engagement long term for individuals who are not strongly inclined to exercise already. If people do not use health apps for long periods of time – weeks, months or years instead of days – there are unlikely to be long-term health benefits. This paper describes a new mobile health application designed to motivate exercise via brisk walking: MyWalk. MyWalk delivers timely, tailored feedback messages intended to persuade additional brisk walking. An experiment was conducted to explore how message framing impacts application usage using participants who downloaded the application from an online app store.

Author Keywords

Engagement, Health, Mobile, Phone, Pervasive Technology, Reinforcement, Personal Health Informatics, Design, Human-Computer Interaction

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Behavior changes in diet, physical activity, and medication adherence are necessary to improve many health conditions, but achieving them is difficult. Making and maintaining behavior change requires health awareness, clinic consulting, and determination.

Mobile phone technology creates new opportunities to help people stay healthy. Unlike people, mobile phones are unable to listen to a person and provide tailored advice. Mobile phones do, however, have some potential advantages that might help improve healthcare delivery at low cost if they can be exploited. Specifically, software running on phones can be extremely patient and persistent, offer greater anonymity, manage huge volumes of data and use it for tailoring feedback, use many modalities to influence, and scale to population scale at low cost.

Recent examples of preventive, health-related mobile phone apps include informational and mobile-optimized health-tracking websites, exercise games, personal fitness monitoring devices, mobile phone personal health tracking, and behavior change aid applications. See Appendix X.1 for examples.

The Problem: Maintaining Engagement

Mobile heath applications (apps) could potentially be deployed to hundreds of thousands of people at minimal cost, but little is known about how to maintain user engagement. Despite an explosion of commercial apps available for personal health tracking on phone app stores, the only public data available on usage for most apps is number of downloads. This number does not capture whether people are downloading apps and trying them for five minutes or using them daily for many months. Companies often have a financial incentive to withhold release of more meaningful engagement data. Although usage data on most such devices are not publicly available, it is likely that following a brief period of initial enthusiasm, interest in using many of these products drops quickly.

There are many ways one might make a mobile phone application for health tracking more engaging. For instance, the app might use game design theory to make the app more fun to use. Or, the app might be designed to be extremely easy to use, which will increase adoption. Or the app might be designed to exploit behavioral strategies such as encouraging social support or reporting social norms, which also make the applications more effective at aiding health-related behavior changes over extended periods of time.

For a persuasive technology to succeed in its goals, applications need to maintain high levels of engagement so that the health messages, regardless of what they are, can be persistently delivered. Success of the application depends on its ability to engage the users beyond the initial period of enthusiasm. Engagement is a precondition for success.

Contributions

The MyWalk mobile phone app is an example of a persuasive technology that uses tailored reinforcement to motivate behavior change. In this work, we explore the impact of the message framing, particularly positive message framing, on engagement, where we define engagement as how long we can keep users running and checking an app.

All mobile health apps deliver messages to the user at one time or another. In this work we consider the impact that the framing of those messages may have on the engagement (independent of the rest of the application) using a controlled experiment. The study uses MyWalk as the main data source. We investigate whether positive *reinforcement* by the means of *message framing* can be more effective than negative reinforcement at creating engagement. Not surprisingly, we find that *any* reinforcement, regardless of framing, improved significantly participants' usage compared to no reinforcement. To date with data sample size of 439, our experiments are inconclusive whether one particular type of message framing leads to the most improvement. We also report qualitative results on MyWalk users' phone habits and patterns that may provide insight to designers of other types of personal health tracking applications intended to motivate health behavior changes for long periods of time.

RELATED WORK

MyWalk is an example of a persuasive technology that uses tailored reinforcement to motivate behavior change. We explore the impact of the message framing, particularly positive message framing, on engagement.

Persuasive Technology

As a fast-growing area of research and development, persuasive technology focuses on using computing systems such as websites, computer games, public displays, or mobile devices to motivate and influence people. Fogg identified and proposed seven types of pervasive technology tools as interactive products designed to change attitudes or behaviors: 1) persuading through simplifying, 2) guided persuasion, 3) persuasion through customization, 4) intervening at the right time, 5) taking the tedium out of tracking, 6) persuasion through observation, and 7) reinforcing target behaviors. He shared many real life experiences demonstrating that persuasive technology tools can successfully be used to motivate people to exercise, buy more products, donate to charity, and stay in touch with family members, among other things [1].

Several recent studies have successfully applied these theories to promote healthy behavior changes (e.g. UbiFit [2], ChickClique [3], and Fish'n'Steps [4]). Based on cognitive dissonance, goal-setting and positive reinforcement theories, UbiFit uses on-body sensing, real-time activity inference and a glanceable mobile display to encourage people to incorporate regular and varied physical activity into everyday life [13]. Using presentation of self and communication/persuasion models, ChickClique helps motivate teenage girls to exercise by exploiting their social desire to stay connected with their peers [3]. The Fish'n'Steps study applies the transtheoretical model to design a social computer game that links a player's daily foot step count to the growth and activity of an animated virtual character, a fish in a fish tank [4].

In UbiFit and ClickClique projects, participants signed up for monetary incentives and agreed to use the project's applications for 28 days and 6 days, respectively. The authors of these studies assume that people will use the application long enough to accrue health benefits without the same compensation as the research subjects. The compensation in UbiFit project was up to $250. In fact, face-to-face interaction with the researchers may increase sense of responsibility to continue using the technology. More studies are needed evaluating engagement when participants receive no financial compensation and in conditions that will lead to less bias to stay in the study to please the investigators.

Maintaining engagement is essential for applying behavior change theories. Engagement in using an app does not ensure the app will be successful in helping someone achieve health habit changes, but the health habit changes will certainly fail if the user does have regular engagement, or interaction, with the app. An application ignored by the user will not lead to sustainable behavior change.

Message Framing

Most health-relevant messages can be framed in terms of the gains or costs losses associated with a particular behavior, and the framing of such persuasive messages influences health decision making [5]. In particular, positive messages focus on achieving desirable gains or avoiding undesirable outcomes. On the other hand, negative messages emphasize lost and undesirable outcomes. Aldridge's study [6] demonstrates how the same piece of information can be framed differently:

- Positive: If you eat at least 2 cups of fruit and vegetables per day, your risk of colon cancer is reduced by X%.
- Negative: If you do not eat a minimum of 2 cups of fruits and vegetable per day, your risk of colon cancer is increased by X%.
- Neutral: You should eat at least 2 cups of fruits and vegetables per day.

Which framing type, *positive*, *negative*, or *neutral* is best may change based on the particular domain. In fact, Rothman and Salovey's [5] paper concluded that the context in which health-related decisions are made can highly affect the effectiveness of framed health messages. However, when in doubt, when creating a persuasive technology, is one method more likely to impact engagement? When a computer is presenting information, people may be less enthusiastic about receiving negative messages from a computer and so therefore it is worth seeing if positive may lead to more engagement.

Reinforcement

A reinforcer is anything occurring in conjunction with an act that tends to increase the probability that the act will occur again. Positive reinforcement occurs when a rewarding stimulus is added immediately following a response [7]. One benefit of using mobile phones is that positive reinforcement can be delivered in a timely and continuous way - "just in time" [14].

For increasing engagement in an exercise tracking application, we can apply positive reinforcement by detecting and rewarding people with virtual rewards during or right after physical activities in order to encourage more activities in the future. Appropriate scheduling of reinforcement may also motivate people to continue using the app long-term. In this study, every message an app conveys has some pre-determined framing, and our goal is to explore the impact of positive framing versus negative, neutral, and mixed framing on engagement in a study where participants are not given any type of financial incentive or met with face-to-face.

APPLICATION MYWALK

MyWalk is a Windows Phone 7 (WP7) application designed to motivate casual users to increase their quantity of brisk walking. MyWalk offers a game-like experience whereby users track their walking daily using the phone's location-based sensing and internal accelerometer.

Main Features

The design of MyWalk evolved from 4 other projects. Appendix X.2 contains lessons that we have learned and applied to the design and implementation of MyWalk. During the design process of MyWalk, we employed User-Centric Design guidelines [12] that emphasize involving potential users as early and as often as possible. We iteratively moved from design concepts to high fidelity prototypes. The features in the app, described below, are those that pilot users identified as most compelling and interesting.

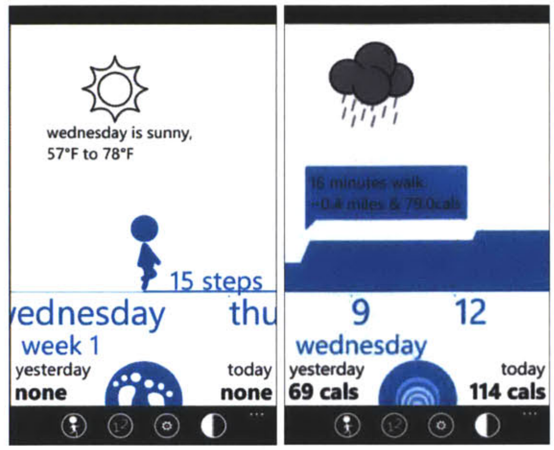

Figure 1. Main screen of MyWalk showing a time-based interface that users can swipe left and right to see their daily progress.

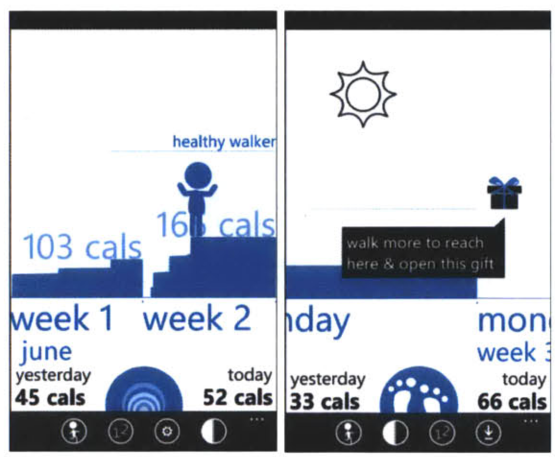

Figure 2. Week view of progress; animated character provides immediate feedback; weather forecast as background decoration; surprise gift for active users.

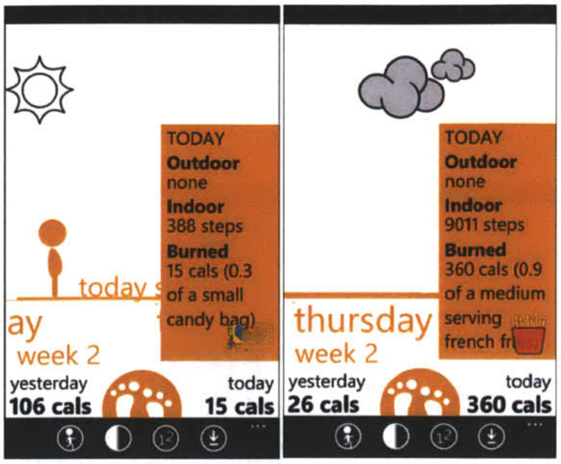

Figure 3. Daily walking efforts were converted to caloric expenditure, which was displayed with a reference food to aid with visualization of impact of behavior.

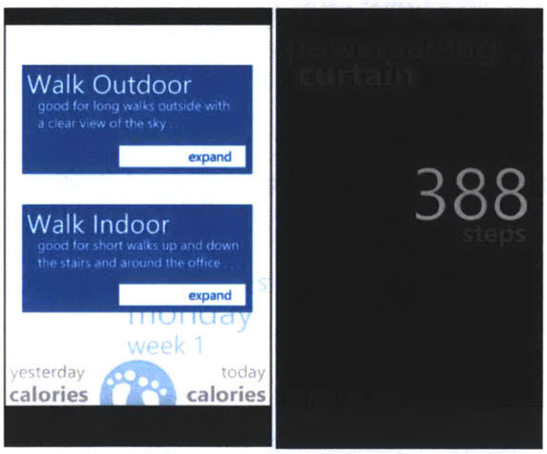

Figure 4. Two different choices for tracking and special mode to save power and prevent mis-hitting buttons.

Demo video clips of how the app user interface provides encouragement can also be found at www.mywalkapp.com

Tracking Algorithms

MyWalk uses the both the phone's motion sensor (i.e., accelerometer) and location sensor (i.e. global position system (GPS) and wireless towers) - to let users track walking (distances and speed) under various environment conditions. The accelerometer sensor requires the phone's display to be on in order to work, which drains the phone battery quickly. GPS is more battery efficient but relies on satellite signals that are only available when the user is outside with clear sky.

Limitations

We include both sensors because each of them has their own limitations. In the current version of Windows Phone, app cannot run and collect data unless it is opened and on the foreground. Motion sensor API is even stricter in the fact that the phone screen has to be on otherwise no accelerometer data will be available. These make it extremely difficult to maintain tracking. By switching out the apt to check emails and write text messages without relaunching the app, tracking session is pretty much ended. While turning in the screen on in order to use motion sensor, users can easily mis-click on phone buttons and the screen, leading to accidentally quit the app.

We tried to overcome these problems by these methods. Users switch out of the app, a pop-up message saying "Tracking stopped, tap to launch) will be scheduled to appear in 1 minute. So after users are done check email, they will see the pop-up message and be able to tap on it to relaunch the app. In order to improve the tracking, we first tried to running GPS and motion sensor simultaneously to collect as much data as possible. Our initial test phase reported that most people are confused about what works and what not, so we made an important decision in the app. Now every time users start the app, they will be presented with two pieces options of Walk Indoor (uses motion sensor and steps algorithm) and Walk Outdoor (uses location sensor and GPS algorithm) showed in figure 4. By this, not only we can educate our users about strength and weakness of the technology we use, but also take in human input to let system does the best given that.

Step Algorithm

The app uses the accelerometer which is built in any Windows Phone to detect steps. The accelerometer is a motion sensor that outputs the g-force or weight per unit of mass for each coordinate in 3D space: x, y, and z. During walking, the body moves up and down, hence causing the phone to bounce accordingly. We process accelerometer data at 40Hz and compute the derivative of the acceleration vector magnitude differences. The derivative is then smoothened by moving windows (7) and calculating means to remove noises. On the filtered derivative, a peak-finding algorithm identifies local minimums and maximums. A step is defined to be one local max peak and one local min peak consecutively within 500ms. Based on empirical testing with the investigative team, we established thresholds for peaks and frequency (maximum 3 steps per seconds for a normal human walking) that would let the algorithm recognizes most normal human steps and rejected what seems to be too slow, too light, or too fast.

Here is the essential pseudo-code of the step algorithm:

```
IF (looking-for-max-peak)

BEGIN
  IF (previous-previous-magnitude <
  previous-magnitude && previous-
  -magnitude > current-magnitude &&
  current-magnitude >
  PEAK_HUMAN_THRESHOLD)

  BEGIN
    1. SET looking-for-min-peak
  END

END

ELSEIF (looking-for-min-peak)

BEGIN
  IF (previous-previous-magnitude >
  previous-magnitude &&
  previous-magnitude < current-magnitude
  && current-magnitude <
  -PEAK_HUMAN_THRESHOLD)

  BEGIN
    IF (is-valid-human-frequency)

    BEGIN
      1. Count step
      2. SET looking-for-max-peak
    END

  END

END
```

Figure 6. Pseudo-code of step counter algorithm

Given the right thresholds, our step counter code above could go as high as 96% averagely in 5 sessions of 100 normal-stride steps each. The code is also meant to be simple and fast enough for real time processing. It is possible to extend the app so that the step counter can be recorded from an external pedometer.

GPS Algorithm

The Windows Phone 7 OS also provides location tracking APIs which poll locations periodically. The acquired location data can have accuracy ranging from 3 meters to 2.5 kilometers around the actual position depending on GPS and wireless tower availability. We have developed an algorithm to recognize the user's movement and translate location into walking distance, speed and estimated calories burned. The algorithm ignores movement caused by flickering GPS signals. This often happens when weather is bad, making signals become noisy or when a user stays indoors and still turns on tracking using GPS. Although the user does not move from his desk but the phone API produces invalid locations with inaccurate accuracy (even though the accuracy tag of the recorded location said "precise in a radius of 3 meters", the recorded location could be 300 meters away). The signals were probably distorted through walls and windows. MyWalk takes clues from signals accuracy changes and previous signals data to minimize these false walks caused by signal fluctuation.

First, we reject logged location data that have accuracy radius overlapping each other. This will remove cases when signals are suddenly lost, causing the location data center coordinate to move around with much larger accuracy radius that probably contains the current real coordinate. Hence, only if this is a totally new location with accuracy circle non-overlapping with existing ones then we add this location to our valid list. We then run this list through an averaging window size of 5 to further eliminating noise. Figure 7 shows the final result.

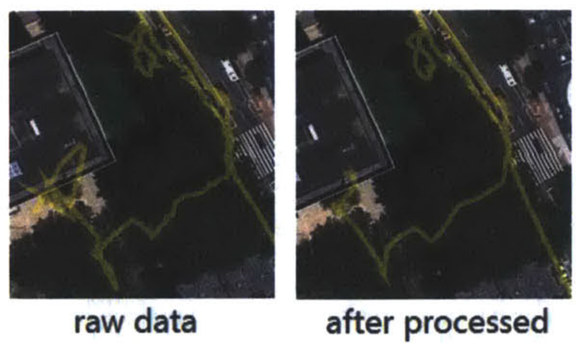

Figure 7. Results of GPS algorithm.

Messages Scheduling

One feature of the app is to send reminders to exercise to users if they do not use the app often. MyWalk adaptively schedules pop-up reminders (called "toasts" in WP7) based on how often a user has accessed the app. Figure 8 illustrates how the system works.

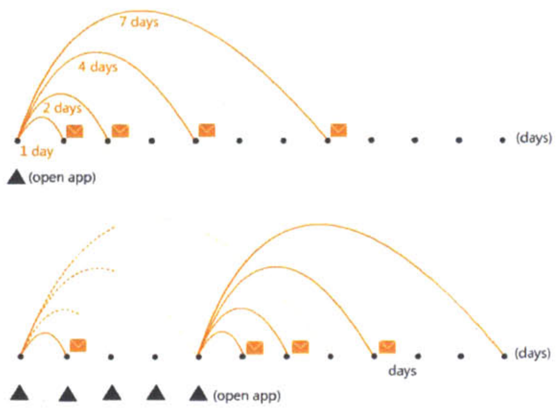

Figure 8. Show how reminding messages are scheduled and delivered.

Figure explanation: The upper diagram is an inactive user; the lower diagram is an active user. On the horizontal day line, whichever day has a grey triangle underneath means the user opens the app on that day. The curve lines show how reminders get scheduled for later days. The dotted curve lines mean some reminders were scheduled but then canceled.

We would like to have a system that delivers fewer pop-up messages to active users and more to inactive users. The key of the system is to always make the assumption that "after a user opens the app, the user will forget to open the app again". If reminders feature is enabled, every time a user opens the app, the app will automatically schedule future reminders (with framed messages). If the user opens the app before then, reminders will be erased so s/he will not get unnecessary reminders. If the user actually does forget, then reminders will go as planned and remind the user once in a while.

To reduce annoyance to users, messages will be delivered at random time from 8am to 8pm. The dates chosen to deliver messages also gradually space out to be: 1 day after, 2 days after, 4 days after, and 7 days after the last time the user opens MyWalk. After 7 days of sending framed messages without the user running the app, no more reminders are sent.

Notice that if the user actually opens the app before that, all undelivered schedule pop-up messages are erased, and a new set of tailored messages for the next 7 days is scheduled so reminders will also be up to date.

The whole process is power efficient because it does not require frequent monitoring or background processing from the phone client. To schedule future messages, the app submits schedules to an online server. This central online server checks every minute to see if any phone client needs to be sent a scheduled message. If so, the message is sent. Phones only need to be connected to a phone network to receive the schedule message and automatically display the scheduled pop-up message.

There is chance that a participant temporarily does not have network connectivity, for example when riding a subway. In that case, the reminder will be received when phone is back to coverage again. The server keeps a log of which messages were delivered successfully so we do not analyze data for users that lost many messages due to connectivity problem (about 59% participants got at least one message undelivered).

The goal of message scheduling is to evaluate the impact of message framing.

METHODOLOGY

Study Design

The MyWalk app, was published on the Windows Phone Marketplace on July 23, 2011. As new users download the MyWalk app from the app store, they provide informed consent and then are randomly assigned by the software into one of five study conditions: only positive feedback (POSITIVE), only negative feedback (NEGATIVE), only neutral tone feedback (NEUTRAL), a mix of the three types of feedback (MIXED), or no feedback at all (NONE). Upon installation, since device unique is ID is inaccessible, a unique identification number (ID) will be generated for each participant. In our analysis, we will use these unique IDs to analyze data while keeping the users' identity anonymous. This ID will persist throughout all the times the participant opens the app unless the app is uninstalled. If the participant reinstalls the app, it is likely s/he will be assigned to a different group. We have not found way to prevent this on WP7 platform but it is possible to we can separate out such participants by comparing internet protocol (I.P.) address.

Our application tracks usage of the application (described in previous section) using the remote software monitoring tool, Application Analytics Preemptive (Appendix X.3), and loggings from our message scheduling server on AppEngine (Appendix X.3). Details on the functionality of both monitoring applications are explained in the appendix. Usage data (as defined by use of various app features) are then compared between conditions to measure long-term engagement. The software will communicate to the server using the phone's data network.

Upon a person agrees to participant in the study on the first screen of the app and starts using, usage data will be collected through the formerly mentioned software monitoring tools. The study duration in this paper is the two weeks following app installation for each participant. After two weeks, usage statistics are still sent to the software monitoring tool until s/he uninstalls or stops using the app. Participants can opt to quit the study and have all their related data excluded from the study whenever they want from the app main settings screen.

Message Framing

All messages displayed by MyWalk are framed based on the participant's assigned condition: POSITIVE, NEGATIVE, NEUTRAL, MIX, or NONE.

To develop the messages and confirm the framing, we informally asked 6 native English speakers in our lab to evaluate 69 sample framed messages and cluster them by framing type. We removed 18 messages that were not consistently classified as the same framing type, and we also adjusted some messages based on the feedback so they were unambiguously classified. A message is mostly information on the user's progress or a general health fact followed by some encouraging text. The encouraging text could be positive, negative, or nothing (in case of NEUTRAL). One such example is these three messages:

- *You have walked 500 feet. (*NEUTRAL*)*
- *You have walked 500 feet. Fantastic job! (*POSITIVE*)*
- *You have only walked 500 feet. You should try harder. (*NEGATIVE*)*

We have 17 message groups of different facts. It means that participants in framed-message condition POSITIVE, NEGATIVE, and NEUTRAL will get exposed to up to 17 different messages. The MIXED condition can see up to 51 messages and NONE condition will not see any of these messages.

All 51 messages can be found in Appendix X.4.

Influence Channels

It is ideal if we can continuously monitor the user's walking to provide timely reinforcement. Background processing, also known as computational multi-tasking, is the ability of a phone application to keep running a program and performing computations even if that particular program is not "open" or in the foreground on the phone's screen. The iPhone and Windows Phone 7 operating systems do not afford this functionality to third-party apps, and provide only limited permission to suspend and quickly restore the app. Therefore, the app will need some other method of user intervention to remind users to keep running the app after they use a different app. Otherwise, the app cannot track distances traveled. MyWalk uses tailored prompts to do this. The level of effort required for people to use the app is higher than we would like, but given that we are studying engagement based on message framing. This "worst case" scenario is actually a benefit. If the study result is favorable then it can be readily replicated to other health apps currently on market, including those that do not have the limitation on background processing.

MyWalk can display messages in three different channels afforded to us by the Windows Mobile 7 operating system. The three channels are HOMESCREEN, IN-APP, and TOAST, with examples showed in figure 9.

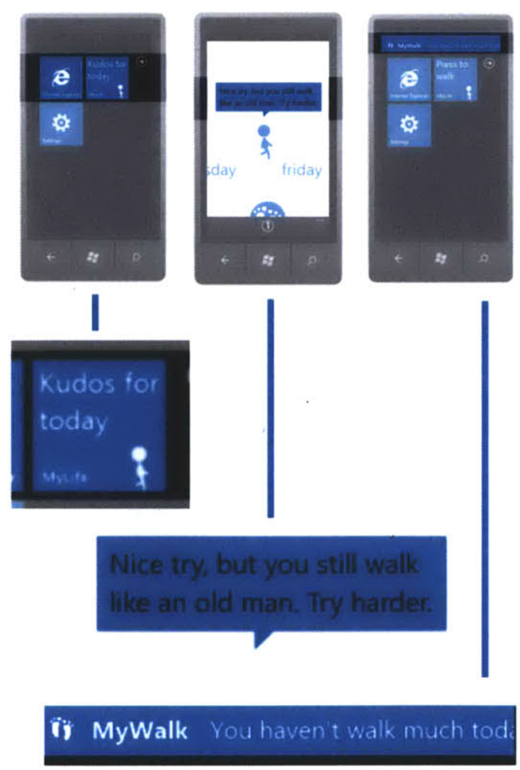

Figure 9. Three channels to display framed messages. Left to right: HOMESCREEN, IN-APP, and TOAST.

- HOMESCREEN: When users are not actively viewing the app with the phone's screen on, the home screen's app launcher can display encouragement to influence users [2]. Home screen are scheduled to change every 1, 2 and 3 days. (similar to TOAST)
- IN-APP: Users are shown framed dialogs every time they start the app or when they unlock screen after at least five minutes walking with the app.
- TOAST: Pop-up messages are scheduled to notify users at any time, so-called "toasts" in Windows Phone 7 graphics user interface (GUI) guideline. How TOAST messages are scheduled is described in chapter VI.

Among 51 framed messages mentioned in previous section, 30 of them (10 m.g.d.f.) are for IN-APP channel and the 21 messages (7 m.g.d.f.) are used in both HOMESCREEN and TOAST channels.

A typical scenario goes as follows: *A new user downloads and installs the app and is randomly assigned into the POSITIVE condition. Through the app tutorial, the user learns how to use the app to track his walking and uses it for few minutes. He decides that the app is interesting and he saves the app shortcut to phone's home screen to use later. On the next day, when he opens the phone home screen to scroll through email and weather notifications, he notices the app's HOMESCREEN shortcut image changed into a message congratulating him on his first walking efforts yesterday (this message has been scheduled since last time he opened in the app). Later during the day, since he has not opened the app for the whole day, the MyWalk message scheduler sends him an encouraging message via a TOAST. The phone plays a sound and/or vibrates as if a text message comes. He then checks on the phone, sees the message and remembers that he wants to do some exercise.*

This scenario shows how a person can get starting into the habit of using the app occasionally. The person may not or ever turn the app on every time they walk around, do errands. Nevertheless, for a study on engagement, we ultimately are interested in finding which way we can make people think about the app more often, and as the result, think about improving health more often.

Monitoring Variables

Users who download MyWalk are informed of the information the app collects and required to sign a consent form on anonymous submission of usage data to the study. Following are how we evaluate the *engagement level* of people in each condition: NONE, NEUTRAL, POSITIVE, NEGATIVE, and MIXED.

Assume each condition consists of n participants, the participant i^{th} will be $user_i$ ($1 \leq i \leq n$). To normalize all participant data with different start dates, we translate all participants usage dates to the *day_index* of 1, 2, 3, etc. Each $user_i$ can open the app numerous times, each time is one session with these properties:

- $session_i.t\_open$: timestamp of when $session_i$ starts.
- $session_i.t\_close$: timestamp of when $session_i$ ends.
- $session_i.t\_duration$: equals $t\_close - t\_open$.
- $session_i.day\_index$: numder of days since first download day
  with $1 \leq i \leq n$: n number of users in the group

Throughout the course of the study, depending on the participant's condition and how often he uses the app, participant i will receive framed messages through the 3 channels. Each message, k ($1 \leq k \leq m$: m = number of messages participant i received), will have these properties:

- $message_k.m\_type$: neutral, positive, or negative.
- $message_k.m\_time$: timestamp of when $message_k$ is sent from server to participant i.
- $message_k.m\_channel$: IN-APP, HOMESCREEN, or TOAST.
- $message_k.m\_delivered$: *true* if participant sees the message and launch the app. This applies to pop-up messages only.

We calculate these values for each group:

a. Longest day of usage (*v_longest*)

For $user_i$, the longest day he still uses the app is:

- $user_i.\ v\_longest = max(user_i.session_k.day\_index)$
  with $1 \leq k \leq s$, s = number of app sessions $user_i$ opened the app.

The *v_longest* value of a whole group will be average longest value of all its users:

- $Group.v\_longest = \frac{\sum user_i.v\_longest}{n}$
  with $1 \leq i \leq n$: n number of users in the Group

b. Percentages of times that users open app due to pop-up framed messages (*v_reminded*)

A framed message via TOAST channel is considered successfully invoked a user to launch the app is time when the user does open the app within 3 minutes of receiving the message:

- invoked($message_k$) = 1 (1 = successful, 0 = failed) iff exists j :
  $message_k.m\_time \leq user_i.session_j.t\_open \leq message_k.m\_time + THESHOLD\_OPEN$

  with $THESHOLD\_OPEN$ = 3 minutes
  with $1 \leq k \leq m$: m = number of messages $user_i$ received.
  with $1 \leq j \leq s$: s = number of app sessions $user_i$ opened the app.

For each $user_i$:

- $user_i.\ v\_reminded = \frac{\sum \text{invoked}(\text{message}_k)}{m}$
  with $1 \leq k \leq m$: m = number of messages $user_i$ received.

The *v_reminded* value of a whole group will be average of the percentage of reminders that triggered usage fo each of its users:

- $Group.v\_reminded = \frac{\sum user_i.v\_reminded}{n}$
  with $1 \leq i \leq n$: n number of users in the Group

c. Feature Variables

Besides measuring three values above, we also monitor frequently-used features of the app, such as the number of times and what time a participant uses what features each session.

DATA COLLECTION

MyWalk was approved on the Windows Phone app store on June 30, 2011 with the latest version released on July 23, 2011. Upon downloading and running the app, participants must provide informed consent to participate in the study (see Appendix X.5).

Participant Recruiting

Any Windows Phone users can find MyWalk on the Windows Phone app store - Marketplace. The store allows for one short paragraph to describe the software along with screenshots. Figure 10 shows how the app appears on the app store.

Figure 10. The MyWalk application is available on Windows Phone Marketplace and advertised as shown.

The following steps were taken to promote the app:

- The investigators submitted to Windows Marketplace and made the app available in 35 different countries over the world for no charge in order to make the app as accessible as we can.

- A landing website was developed and available for anyone to access without going to the app store, http://mywalkapp.com .

- The investigators forwarded the app information and the website link to their personal networks.

- Two promotional videos are created and shared on YouTube and the landing website.

Participant Qualifications

We selected qualified participants from the pool of users who downloaded the program. Participants met these requirements:

1. U.S. users as determined by the software analytics tools. Of 1,625 users, 339 were excluded because of this criterion.

2. App version: 1.3
   We only consider data collected from the participants who downloaded and used our latest version 1.3 of MyWalk to ensure all participants experience the same set of features. We also eliminated people involved in the project who installed the app manually or use the test version. Of 1,286 users from (1), 215 were excluded because of these criteria.

3. Use more than one time:
   number of app sessions > 1.
   We filter out all users who only open the app once and then never open the app again. These one-time users are likely people who downloaded the app out of curiosity only or who already decided the app features set do not fit them. Of 1071 users from (2), 249 were excluded because of this criterion.

4. Two week study duration:
   $user_i.session_1.dayindex + 14 \leq date\ of\ analysis$
   No matter if a participant uses the app two times or uses the app every sing day, the participant should have the app installed on his phone for at least two weeks. Of 822 users from (2), 386 were excluded because of this criterion.

All qualified samples set size is N=436.

Users Adoption

After being released for a month, MyWalk has been enjoying a steady stream of new users every day. Appendix X.3 shows the daily growth in users. As of August 26, 2011 after 34 days on the app store, MyWalk had 1,625 downloads in total, adding about 70 new downloads/day.

Participant Demographics

As of August 24th after 5 weeks on the app store, out of 1,625 consented app users, 1,286 were from North America (as reported by Microsoft Marketplace online). Appendix X.3 shows the location of users worldwide.

This study measures effects of message framing using examples from the English language, and so we restrict the analysis of results only to participants that are reportedly North America that were deduced from our software monitoring tool.

We do not require our users to enter their weight and height in order to use our application. However, users can voluntarily fill in a survey form to anonymously submit such information for research purposes. In N=77 users who submitted information, 42% are male, 58% are female.

The male participant's average weight is 199.80 lbs (σ=47.2, min=120, max=340) and average height is 5'10" (σ=0.34 min=5', max=6'7"), making the Body Mass Index (BMI) to be 28.4 which lies in the Overweight range (25-29.9) [9].

Similarly, the female average weight is 189.88 lbs (σ=44.3 min=110, max=275) and average height is 5'5" (σ=0.2 min=4'11", max=5'10"), resulting in the overweight BMI of 27. This reaffirms that our participant population are indeed our target users who can benefit from exercise and weight loss.

We have collected sufficient qualified participants for most our participant groups except one group. There was a software error that assigned all participants who should have been in the NEGATIVE condition into NEUTRAL. Here we still report our pilot results with the goal of collecting additional data in all five conditions in future work.

ANALYSIS

In order to measure the engagement impact in each condition, we observe daily the ratio of participants who still use the app since first day of app installation. Although it is common to have usage drops sharply right after the first day, we expect that our message framing system will improve the usage over time. We also expect that usage improvement varies between groups different tailored messages of neutral, positive, negative, or mixed.

Engagement Levels

We processed all data collected on the qualified users and calculated their average longest days of usage (*v_longest*) scores. Figure 11 shows the *v_longest* scores of four groups NONE, NEUTRAL, POSITIVE, and MIXED, and table 1 shows the detailed statistical information of each group.

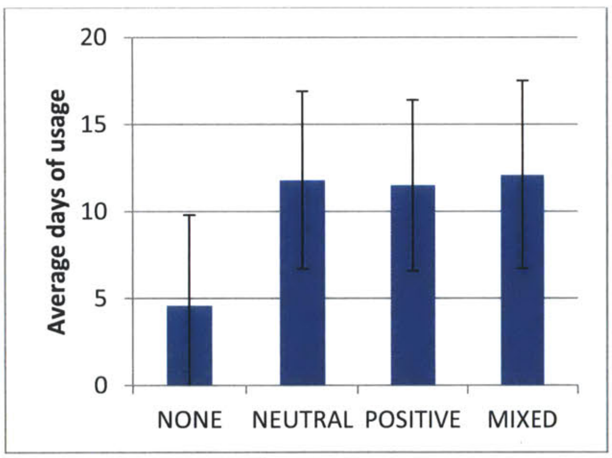

Figure 11. The average longest days of usage for each study group. The error bars are their standard deviation.

	NONE	NEU	POS	MIX
Participants (N)	82	176	85	96
Average longest days of Use (*v-longest*)	**4.6**	**11.8**	**11.6**	**12.2**
Standard Deviation(σ)	5.2	5.1	5	5.4
Standard Error	0.57	0.38	0.54	0.55
Min total days	1	1	1	1
Max total days (2-week study period)	14	14	14	14
Actual max total days (beyond 2-week study period)	17	20	20	19

Table 1. Table captions should be placed below the table.

A t-test between NONE and POSITIVE *v_longest* was computed to test if a group with messages reinforcement can influence people to use apps significantly longer compared to the group without any reinforcement. The results are included in figure 12 below.

	NONE	*POSITIVE*
Mean	**4.6**	**11.8**
Variance	27.04	25
Observations	82	85
Hypothesized Mean Difference	0	
df	114	
t Stat	-8.988	
P(T<=t) one-tail	<.001	
t Critical one-tail	1.658	
P(T<=t) two-tail	<.001	
t Critical two-tail	1.981	

Figure 12. t-test between *v_longest* of NONE and POSITIVE group samples.

We can say any reminder message appears to significantly increase engagement by prompting for increased app usage further from the install date.

2. Impact of Message Framing

We want to know if our differently tailored message can change user behaviors differently. Table 1 above did not show much difference between NEUTRAL, POSITIVE and MIXED *v_longest*.
From here, we have to look more in details of how participants change day by day in each group. Figure 10 shows the percentages of users opening the daily after they download the app for the 4 participant groups: NONE, NEUTRAL, POSITIVE, and MIXED.

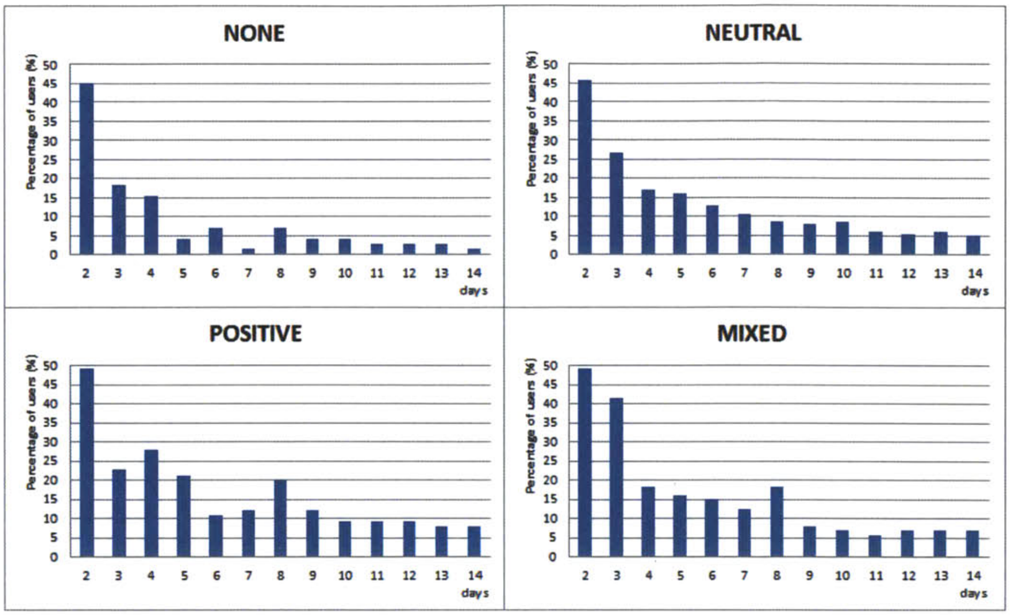

Figure 13. Show how the percentage of users changes day by day across different groups.

Figure 13 reaffirmed our former observations. Overall, the NONE condition showed a lower app commitment than other cases. NEUTRAL, POSTIVE and MIXED showed more resilient usage over time, likely thanks to the message scheduler system. Among the three groups, NEUTRAL appears steadily declining in terms of the ratio of users who still uses the app. POSITIVE and MIXED however have more sporadic rises of percentages improvement which is possibly because of how differently messages were framed.

As formulated in the Methodology section, we will compare the success rate *v_reminded* of framed messages delivered via the TOAST channel between the groups.

Groups	NEUTRAL	POSITIVE	MIXED
Count (n)	56	51	39
Sum	8.113	9.316	5.106
Average	**0.145**	**0.183**	**0.131**
Variance	0.016	0.033	0.008
ANOVA			
Source of Variation	Between Groups	Within Groups	Total
SS	0.067	2.862	2.929
Df	2	143	145
MS	0.034	0.02	
F	1.682		
P-value	0.19		
F crit	3.059		

Figure 14. ANOVA test against v_reminded of three framed-message groups.

We have made assumption in this ANOVA test that the variances of all errors are equal to each other, they are independent and they are normally distributed.

The chances that users will open the app after they see our tailored messages displayed via TOAST channel for NEUTRAL, POSITIVE, and MIXED are 14.5%, 18.3%, and 13.1% respectively. However, the test does not show a statistically significant difference between groups. However, we did learn that reminder messages via TOAST do have about 13%-18% chance of making users relaunch the app.

Note that we do not use all samples from each group. Since our TOAST messages deliver system depend on an external server and push notification service of the WP7, there are cases where messages got lost at time of schedule. To make sure all samples of users get exposed to the expected number of framed messages, we excluded all samples that have at least one message that is unsuccessfully delivered, as reported from our server's logs.

DISCUSSION

Impact of Message Framing via Reinforcement on Engagement

Is MyWalk a useful app? A market report from the analytics firm Pinch Media [10] shows that most apps on the iPhone market, excluding news apps, are no longer used after just a 2 or 3 days. There are indeed many MyWalk participants who quit using the app after the first day 561 out of 1,625 downloads) but there are also participants who used the app almost every day up to 20 days after installation (24 out of 1,625 downloads). The average days before quitting among NEUTRAL, POSITIVE, and MIXED are also as high as 11 days after installation. Our message scheduler system has created more extended usage in framed-message groups compared to the no-framed-message group. More users need to be recruited to determine the impact, if any, of message framing.

Users Feedback

Our final app design was achieved through 15 interviews with potential users during designs process in order to get the right design abstraction and right set of features. After releasing the app, we have followed app reviews from the Windows Marketplace and accepted feedback through email. Although the user base is small, we have received mostly positive feedback so far. Some specific comments are listed below:

- *"I really enjoy seeing my progress and the fact that it sends me a message when I haven't walked that day!!! =)"*
- *"I absolutely love it... so easy to understand...n love how I saves ur progress..,*
- *"It's very useful."*
- *"Inspiring!"*

Other feature requests include:

- Social features.
- Implementation of coming the Windows Phone 7.5's new APIs.

Other Usage Patterns

Table 2 shows summary from the software monitor Preemptive.

Feature	Times
Application Runs	6540
Unique Users	1597
Avg. Time in Application	0:07:38
Choose Walk Outdoor	2,225
Choose Walk Indoor	1,735
Use Pacing	1,768
Power saving mode	1,583
Click Day Summary	1,321
Walk 1000 steps per week	627
Walk 5000 steps per week	450
Walk 10000 steps per week	237
Walk 14000 steps per week	340
Walk 30000 steps per week	146

Table 2. Usage summary across all users

Between two modes Walk Outdoor (with GPS) and Walk Indoor (with accelerometer), 56% of time users chose to walk outdoor. Users spend more than 7 minutes playing or walking with MyWalk on average. This shows our users most use the app for quick and short walks whenever convenient, this is just what we expected. During the first 5 weeks period, our users reached 1000 steps mark 627 times. A part of them (146) went on to reach 30,000 steps per week. This is not nearly as high as we expected since 1,000 steps (roughly 0.5 miles) is quite easy to achieve. We have implemented a small gift feature (the second screenshot of Figure 2) to reward users. We plan to refine our tracking experience and create more desirable rewards to improve this number.

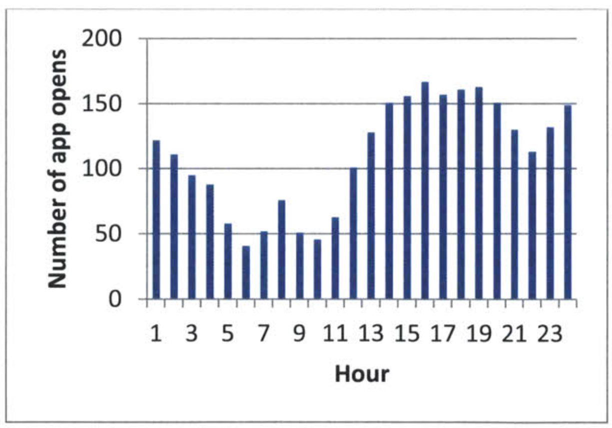

Figure 15. Distribution of times users open app on hours.

People used the app the most during the afternoon from 2pm to 7pm.

Personalization, rewards, pacing, gifts, food convert, etc. are all small features throughout the app to make using it more enjoyable. Although they are potential factors that more or less influence users' engagement, they do not interfere with our main study because all participant groups used the same platform.

CONCLUSION AND FUTURE WORK

Contributions

We have successfully released MyWalk to the market and had a five-week period gathering engagement data on which of several message framing strategies maximizes engagement.

We believe study results can contribute new insights beyond lab environment and be readily applied to current applications on mobile health. We have proved that message framing via reinforcement can help people engage in the app more. From our analysis, we also learned somewhat about phone habits of people who are interested in using health app.

We also came up with a good method to overcome the background processing limitation of current popular mobile systems. With adaptive message scheduler and push notification, we can still deliver intervene users behavior even if users do not current open the app.

Limitations

There are many features that we wish we could implement that Window Phone 7 (as well as iPhone) system prohibit. Besides background processing, the phone system only allows processing accelerometer data when the phone's screen is on. This not only drains battery quickly but also contributes to users hitting buttons unintentionally, quitting the app when they put into pants pocket. We tried to overcome these limitations by using the message scheduler and a power saving mode. If users turn on the power saving mode, an overlaying interface (screenshot in Figure 4) will overlay the screen to display essential information, minimize animation refresh, and prevent accidental button clicking.

Future Work

To increase our number of users (now that the software properly assigns people to all five conditions), we plan to promote on different news channels and technology blogs.

Besides addressing the limitations above, we also plan to implement several new features to make the app experience more complete. With the new Windows Phone 7.5 software update released in a few months, we will be able to set limited scheduled background processes to improve tracking. Another new API will also let us present pop-up messages and change home screen shortcuts without an external server, ensuring consistent delivery and more personal.

We hope this work will provide design guidance and useful lessons for developers of future persuasive mobile health apps. MyWalk employs several game elements like use of virtual characters and acquisition of virtual rewards. More ideas and designs can be found in our prototypes in appendix X.6. Our vision is that MyWalk can eventually serve as a platform to study effects of dominant health behavior theories such as cognitive dissonance, goal-setting, and presentation of self [11] in a popular mobile health app.

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APPENDIX

1. Current Health Applications on Market

Website	Games	Personal device	Phone applications
FitDay's FreeDiet & Weight Loss Journal, Gyminee, WalkMe, Heart360, Route Tracker, TrainingPeaks, LiveStrong.com, WeightWatchers.com	WiiFit, WiiSport, Dance Dance Revolution, My Weight Loss Coach, Jinsei Game of Life	Polar F11 Heart Rate Monitor, Nike + iPod Sport Kit, Garmin Forerunner 405, Tekuteku Angel Pocket Pedometer, Philips DirectLife	UbiFit, UbiGreen, SportsDo, A Fast Food Diet, Health n Family, Weigh Tracker, Health Cubby, Tap and Track Calories, iHeartRate Monitor, iFitness

Table A1. List of health-related applications

2. Our Previous Apps and Lessons

a. Plogger

In 2008, I worked with Professor Stephen Intille on a mobile phone named Plogger. Plogger stands for "Personal Life Logger". Plogger's goal is to help users rapidly and easily construct and review a diary of their daily activities by exploiting the sensing capabilities of Google Android. The application makes it easy to label life events along dimensions of interest, such as productivity, stress, or fun. Plogger then provides summaries that may help users learn how to allocate more time to those things that provide the most value in their life. This figure shows the main screen of the Android application.

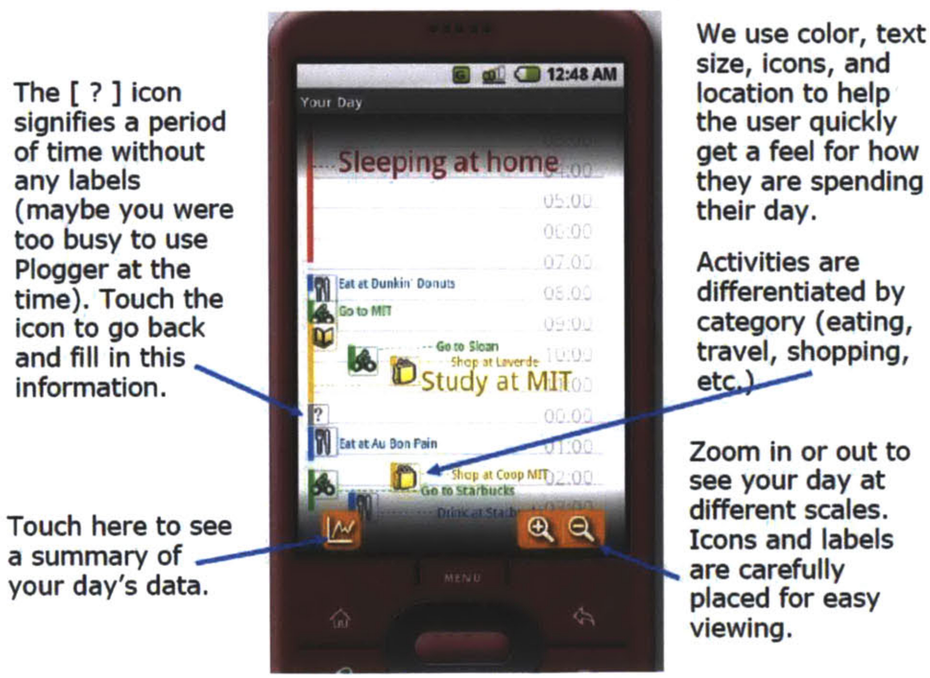

Figure A1. Screenshot of Plogger

Lessons: Plogger provided first experiences on using sensors and on visualization techniques to display multiple activities of a person's day.

b. StepLively

StepLively was another project done at MIT House_n, Architecture Department with Prof. Stephen Intille and PhD student Yi Han. This is an activity tracking mobile app which encourages more walking by using an on-the-spot positive reinforcement system with built-in sensors, phone alerts, and self-competition. The app runs on Windows Mobile 6.5 platform which allows apps to run silent on the background throughout the day without disturbing users and can actively alert phone users.

This figure shows how StepLively translates phone users motion throughout the day into points and presents to users his progress against himself day by day.

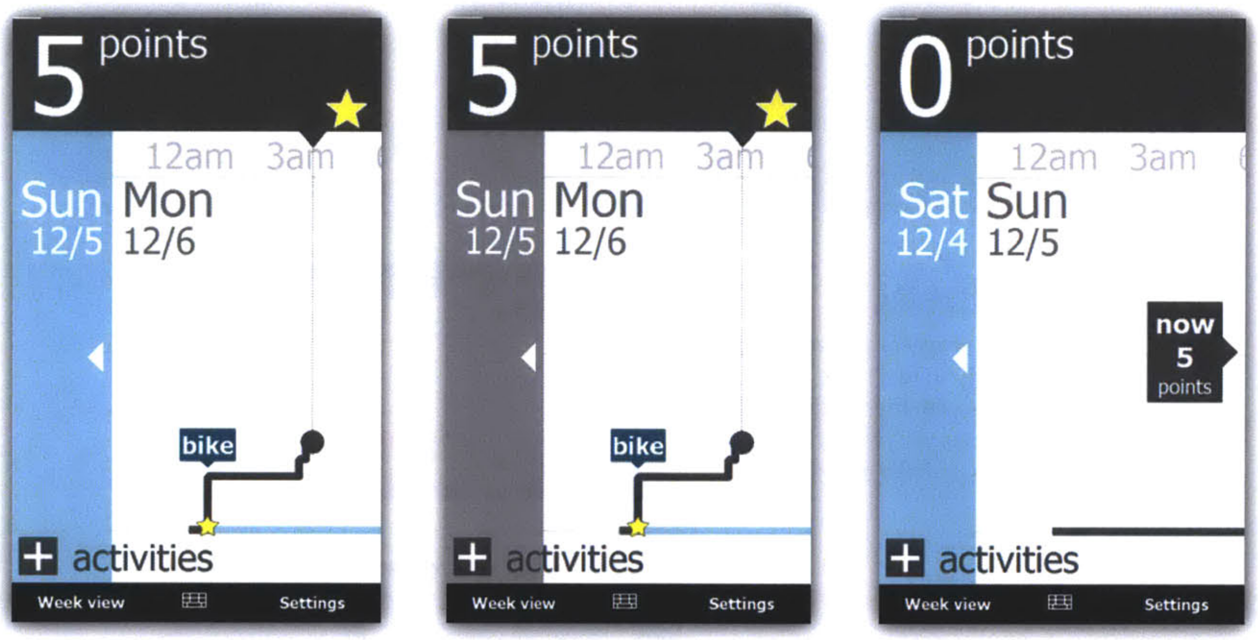

Figure A2. Screenshots of StepLively

Lessons: This is a highly abstract design where users can just glance at the interface and know if he is currently better or worse than he performed in previous week. This study also explored the effectiveness of on-time reinforcement and simple competition against oneself.

c. MyLife

MyLife was developed in summer of 2009 and in summer of 2010 at Microsoft Research Asia (MSRA) under supervision of Dr. Eric Chang. Similar to StepLively, MyLife also uses the Windows Mobile 6.5 to take advantage of the ability to record activity throughout the day. On the other hand, MyLife offers a much richer tracking and visual representation. Tracking covers steps counting, popular sport activities, and diet entry. MyLife recreated a visual diary to fully display what users did every day from walking to exercising to eating. Based on these partly automatically collected partly manually input data, users can then choose to do more in-depth analysis on number of calories they burn or consume, to set goal to lose weights, or to compete with friends and family. Screenshots of main features are showed in this figure.

Figure A3. Screenshots of MyLife

Lessons: MyLife provided opportunities to test out many motivating ideas, far beyond those in Plogger and StepLively. However, the projects also encountered usability problems. One big problem is battery consumption for constantly tracking, hindering normal phone activities. Another drawback of the projects is lack of user inputs. We included too many features that may or may not influence user behaviors in attitude.

We take lessons learned from previous projects to create application MyWalk with the right design abstraction levels for users, right sets of features that users want to use, and a technology can readily be used to measure impacts.

3. Monitoring Tools

Preemptive:

This is a professional third-party tool to monitor user statistics and bug reports of Windows Phone platform.

- Provide app sessions: every time the participant opens and closes the app.
- Provide user demographics.
- Provide information about when a participant uses certain feature (by adding tracking code to specific functions)
- Doesn't require users to be online all the time.

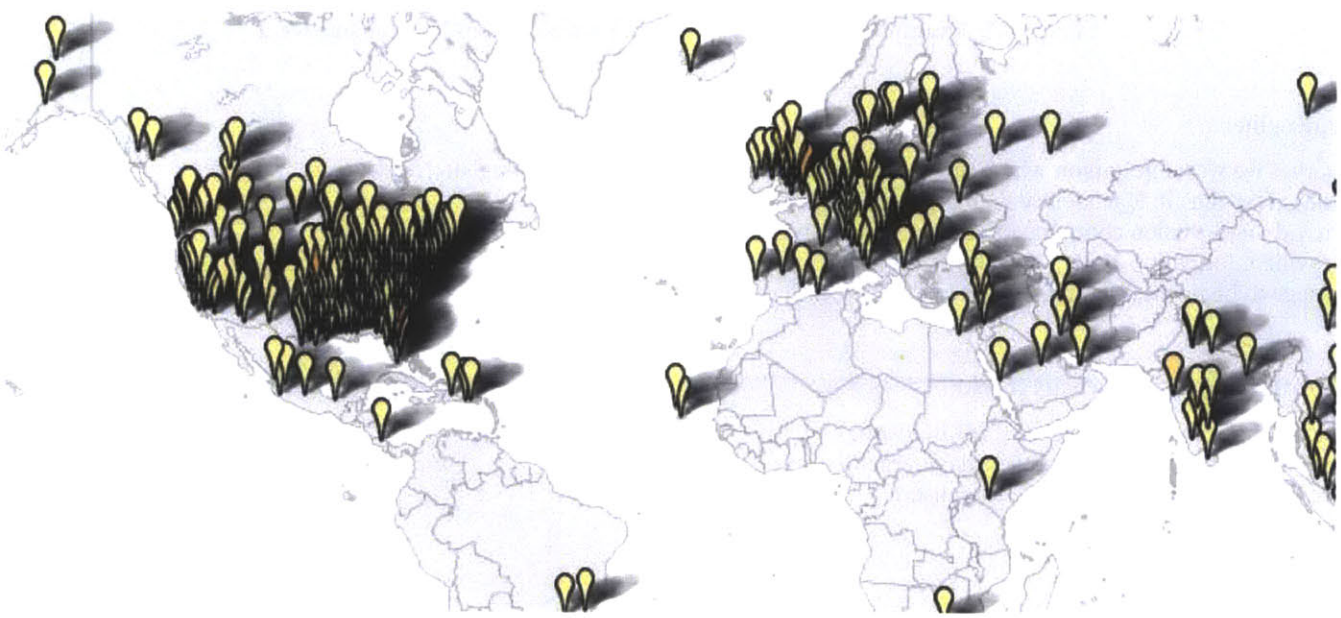

Figure A4. Map statistics provided by app store presents our participants estimated locations.

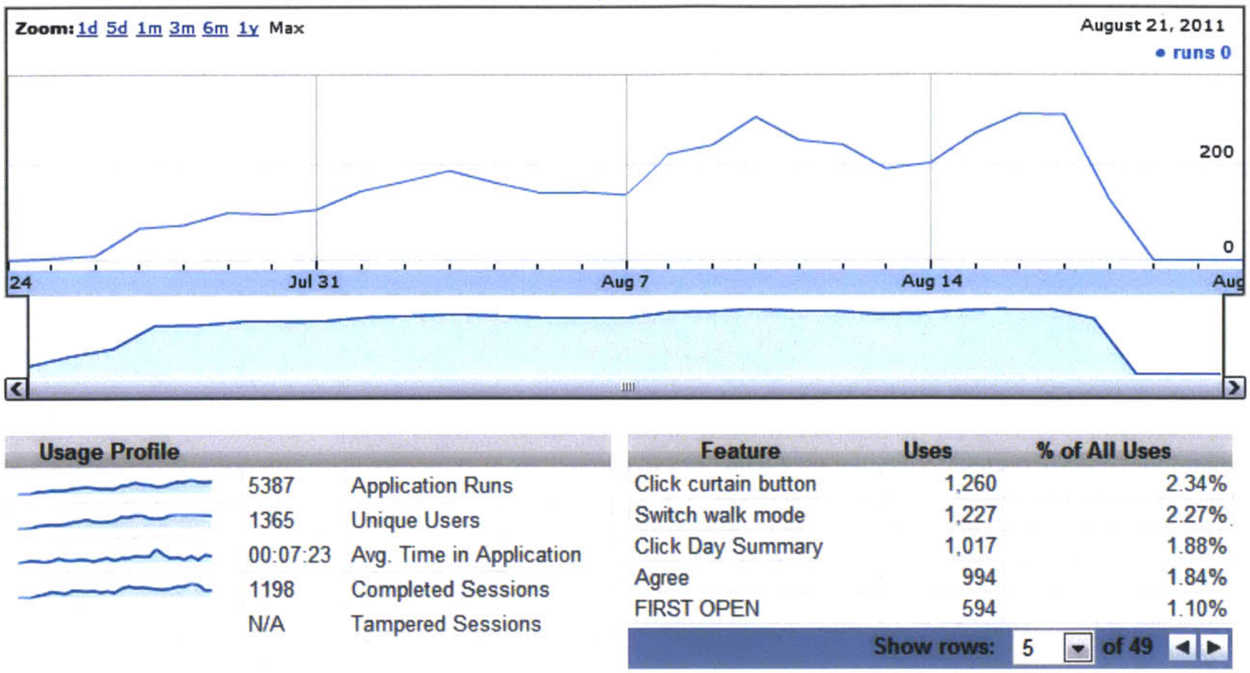

Figure A5. Example of report on features used provided by PreEmptive.

AppEngine:

A server we wrote in Python which schedules and send reinforcement event to registrered devices.
- The server runs independently with the phone app.
- Provide information about the number of devices registered with servers and when.
- Provide information about which reinforcement message is sent to which user and whether if users successfully receive the message to be displayed on his phone.

Microsoft download, website track:

Official app management website of Microsoft.
- Provide number of users and their demographics info.
- Provide reviews and feedbacks from users.

Figure A6. Growth of user base provided by Microsoft Marketplace.

Website track:

- Provide how the public awareness about the app grows overtime through words of mouth.

4. Framed Messages

	Neutral	Positive	Negative
IN-APP	You have walked 500 feet.	You have walked 500 feet. Fantastic job!	You have only walked 500 feet. You should try harder.
	Let's walk for 15 minutes.	Let's walk for 15 minutes. At this pace, you can do a marathon in no time!	Let's walk for 15 minutes. Don't be like an old man.
	MyWalk really misses you.	MyWalk really misses you. Please keep up your efforts!	MyWalk really misses you. You haven't tried to exercise much recently.
	You walked 300-350 ft yesterday with MyWalk, how much can you walk today?	You walked 300-350 ft yesterday. Walk a few more steps and you'll become a pro walker.	You walked 300-350 ft yesterday with MyWalk. That's only impressive if you're a toddler.
	It's been 12 hours since the last time we walked.	It's been 12 hours since the last time we walked, let's keep up with your great efforts!	It's been 12 hours since the last time we walked, I'm disappointed.
	You walked 3 times this week. Let's do more.	You walked 3 times this week. I admire your determination.	3 times this week, my tortoise walked more than you did.
	You walked about the same as an average person does in America.	You walked more than an average person. Let's aim even higher!	You walked less than most people in America. Please try harder.
	Hello. This is your 3rd time walking with MyWalk.	This is your 3rd time walking with MyWalk. You're doing great! Let's walk more together!	This is your 3rd time walking with MyWalk. Don't lose out to your laziness please.
	Walking can improve your health.	Uber! Walking more can help you decease heart disease by 10%.	You will get chubby if you don't start taking walking seriously!
	A walk will do you good.	Another walk will make you look and feel even better.	You've done less walking than a turtle turned upside-down today.
HOMESCREEN and TOAST	Walk now	Great job today	Lazy couch potato
	Press to walk	You totally aced	Only that many steps?
	Don't forget to walk	Michael Jordan of walking	Get up and walk
	Walked today	Hi five!!!!	You lazy bum, move!
	Walk more?	Kudos for today!	Cobweb on your shoes?
	Let's walk	Rock star walker!	Stand up and walk!
	Free time? Let's walk	Do more walking!	Don't be lazy

Table A2. List of all framed messages.

5. Participants Consent Form

This consent form is presented to user when they first open the app. The user will have to agree to participate in the study in order to start using the app.

CONSENT TO PARTICIPATE IN

NON-BIOMEDICAL RESEARCH

Measuring and Motivating Walking via Mobile Phones

You are asked to participate in a research study conducted by Kent Larson, Research Scientist, Stephen Intille, Research Scientist, and Anh D. Nguyen, Research Assistant from the Department of Architecture at the Massachusetts Institute of Technology (M.I.T.) You were selected as a possible participant in this study because you are at least 18 years of age and do not work directly with members of the research team. You should read the information below, and ask questions about anything you do not understand, before deciding whether or not to participate.

* PARTICIPATION AND WITHDRAWAL

Your participation in this study is completely voluntary and you are free to choose whether to be in it or not. If you choose to be in this study, you may subsequently withdraw from it at any time without penalty or consequences of any kind. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

* PURPOSE OF THE STUDY

In this study, we are investigating the different features to engage people to use an exercise phone app more. Besides the basic feature to track walking steps, we want to see if interactive graphics and exercise reminders can increase the number of times people use the app.

* PROCEDURES

If you volunteer to participate in this study, we would ask you to do the following things:

You will be asked to install the app on your phone. After that, you can turn on the app before walking to track your steps.

You will be introduced to different features of the app including viewing process and setting goals.

You will be notified by the app if you haven't turned on the app to track your walking for a more than a day.

You can use all other features and applications in your phone as usual.

Sometime when using the app, your will be asked to fill out a survey about your walking habits and your experience in the study.

You may choose to share your steps online or compare with those of friends who also use the App.

The duration of the study is six months. You can opt out the study any time via the Settings menu. After you opt out or study ends, you can continue to use the app without any relation to the study.

* POTENTIAL RISKS AND DISCOMFORTS

You may at times find the reminder to excise annoying. You can set the frequency of reminder or turn off the setting any time you want.

* POTENTIAL BENEFITS

By participating in this study, you will have the opportunity to learn about how phone technology can be applied to your exercise habits. The result of this study can help design better and easier to use future phone application to keep track and encourage exercises.

* PAYMENT FOR PARTICIPATION

We appreciate your participation in our study. The phone application will be available free for you to download from the application store. You can use the software for as long as you want even after the study ends.

* CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law.

Your sensor data, survey responses, and other study data and results will be referenced by an ID number in order to protect your identity.

When the results of the research are published or discussed in conferences, no information will be included that would reveal your identity. Your name will not in any way be associated your data, including video recordings. Once your data are anonymized, they may be shared with other researchers for future studies.

* IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact

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857-928-1947, lugia@mit.edu

* EMERGENCY CARE AND COMPENSATION FOR INJURY

"In the unlikely event of physical injury resulting from participation in this research you may receive medical treatment from the M.I.T. Medical Department, including emergency treatment and follow-up care as needed. Your insurance carrier may be billed for the cost of such treatment. M.I.T. does not provide any other form of compensation for injury. Moreover, in either providing or making such medical care available it does not imply the injury is the fault of the investigator. Further information may be obtained by calling the MIT Insurance and Legal Affairs Office at 1-617-253 2822."

* RIGHTS OF RESEARCH SUBJECTS

You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you feel you have been treated unfairly, or you have questions regarding your rights as a research subject, you may contact the Chairman of the Committee on the Use of Humans as Experimental Subjects, M.I.T., Room E32-335, 77 Massachusetts Ave, Cambridge, MA 02139, phone 1-617-253 6787.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

____

Name of Subject

____

Name of Legal Representative (if applicable)

____________________________________ ______________

Signature of Subject or Legal Representative Date

SIGNATURE OF INVESTIGATOR

In my judgment the subject is voluntarily and knowingly giving informed consent and possesses the legal capacity to give informed consent to participate in this research study.

____________________________________ ______________

Signature of Investigator Date

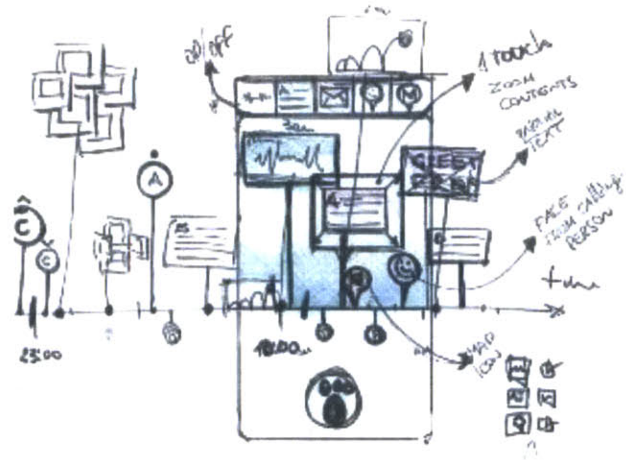
Table A3. MyWalk's consent form.

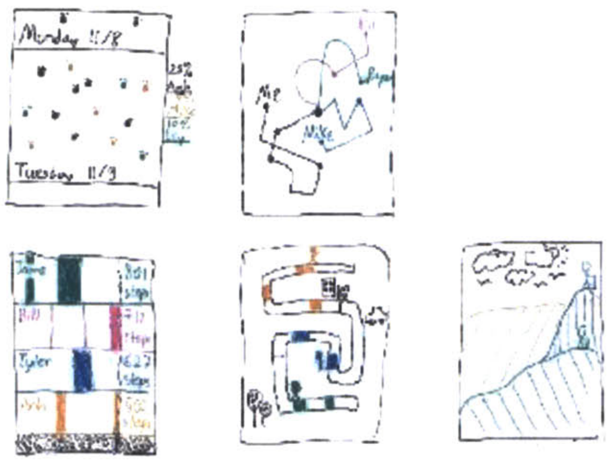
6. More Designs and Ideas

This section shows how we from concepts to designs to all the ideas that we believe can help other people improve health.

Figure A7. Design concepts

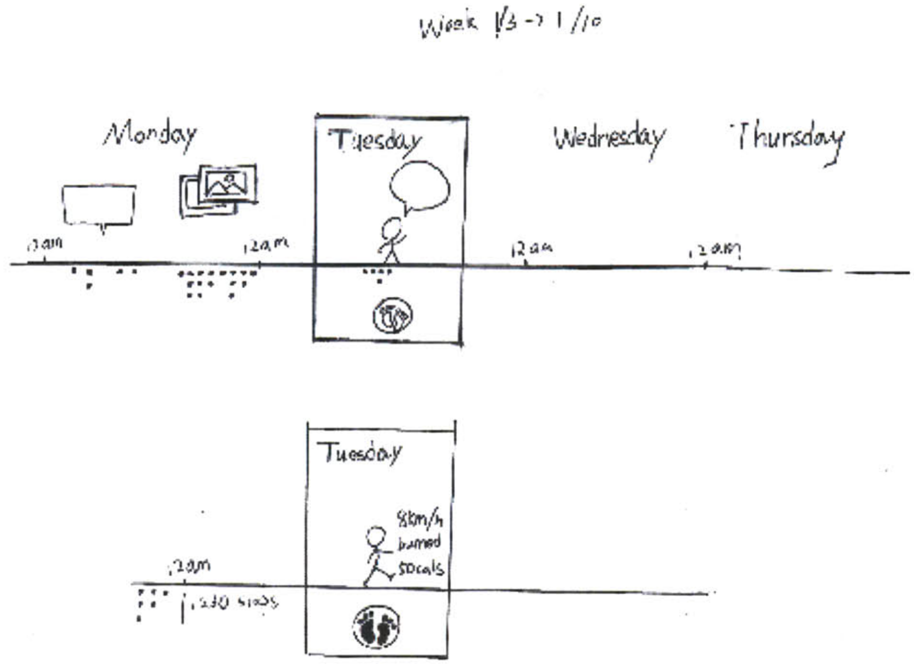
We want an interface that can reflect different aspects of the user's life. It should be a visual diary telling when the user tried hard and when he had fun.





We want a rich interface. We want a world where the more people exercise, the more people meet each other, and the more engaging the world becomes.

Figure A8. Design concepts (continue)



We want an interface that lets us travel back and forth in time smoothly. It has to be scalable and offer different perspectives at different levels.

Figure A9. Design concepts (continue)

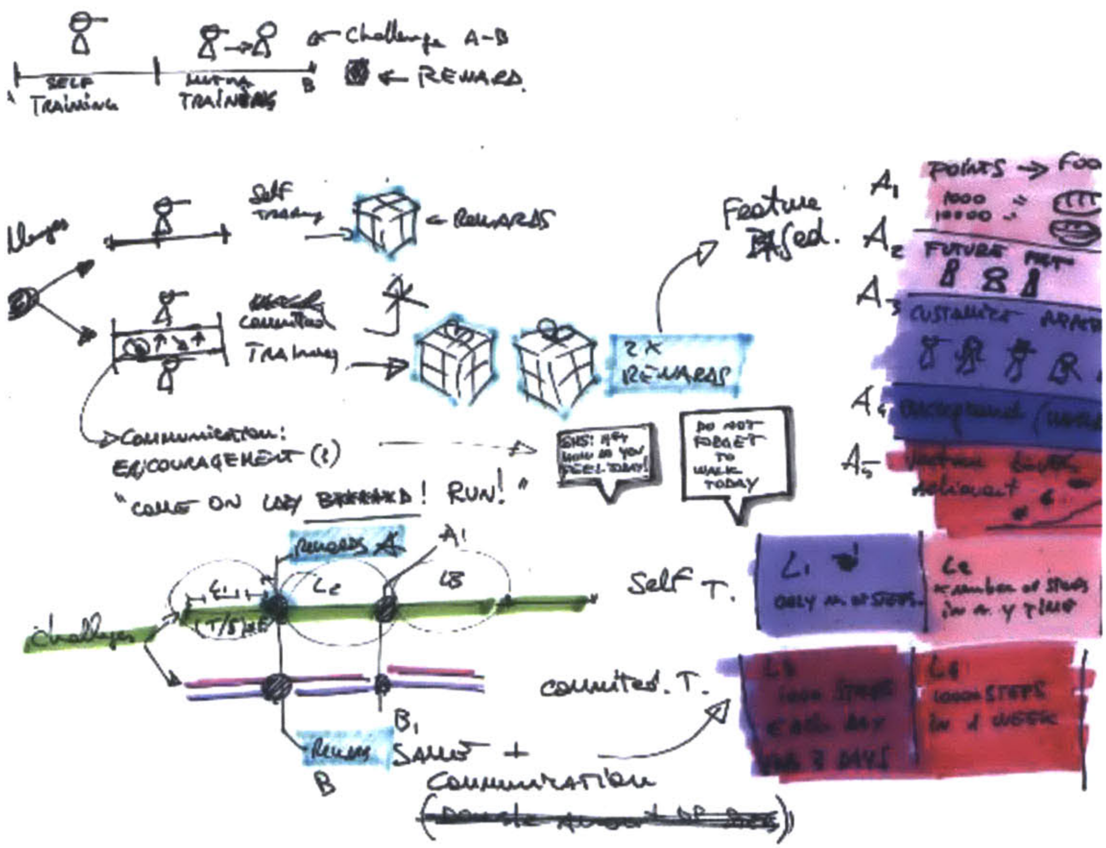


Figure A10. Design concepts (continue)

To engage people in the app, we want to make people think of traveling. The experience should be rewarding and full of surprises.

Figure A11. Design concepts (continue)

Figure A12. Design concepts (continue)

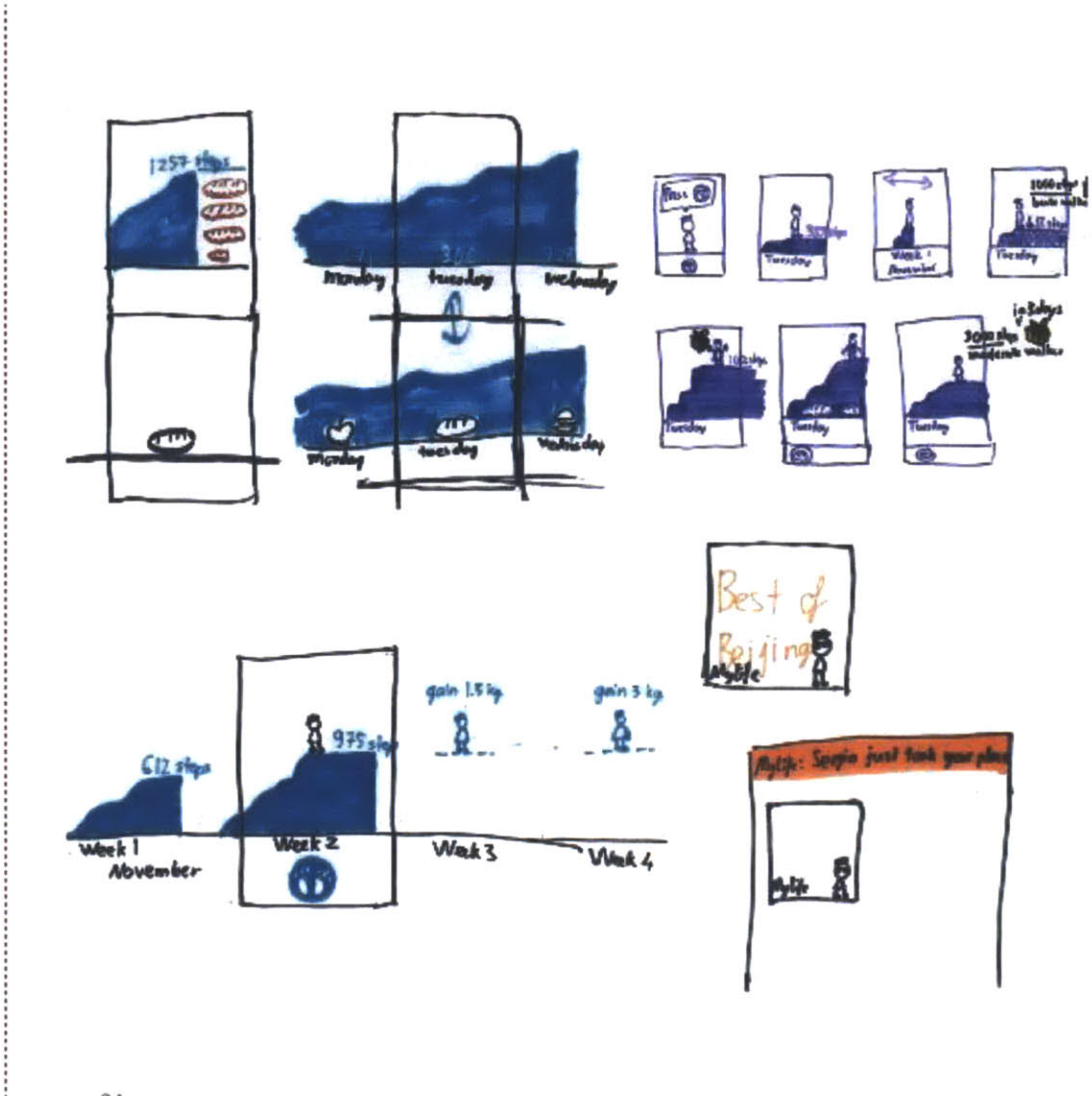


Figure A13. Design concepts (continue)

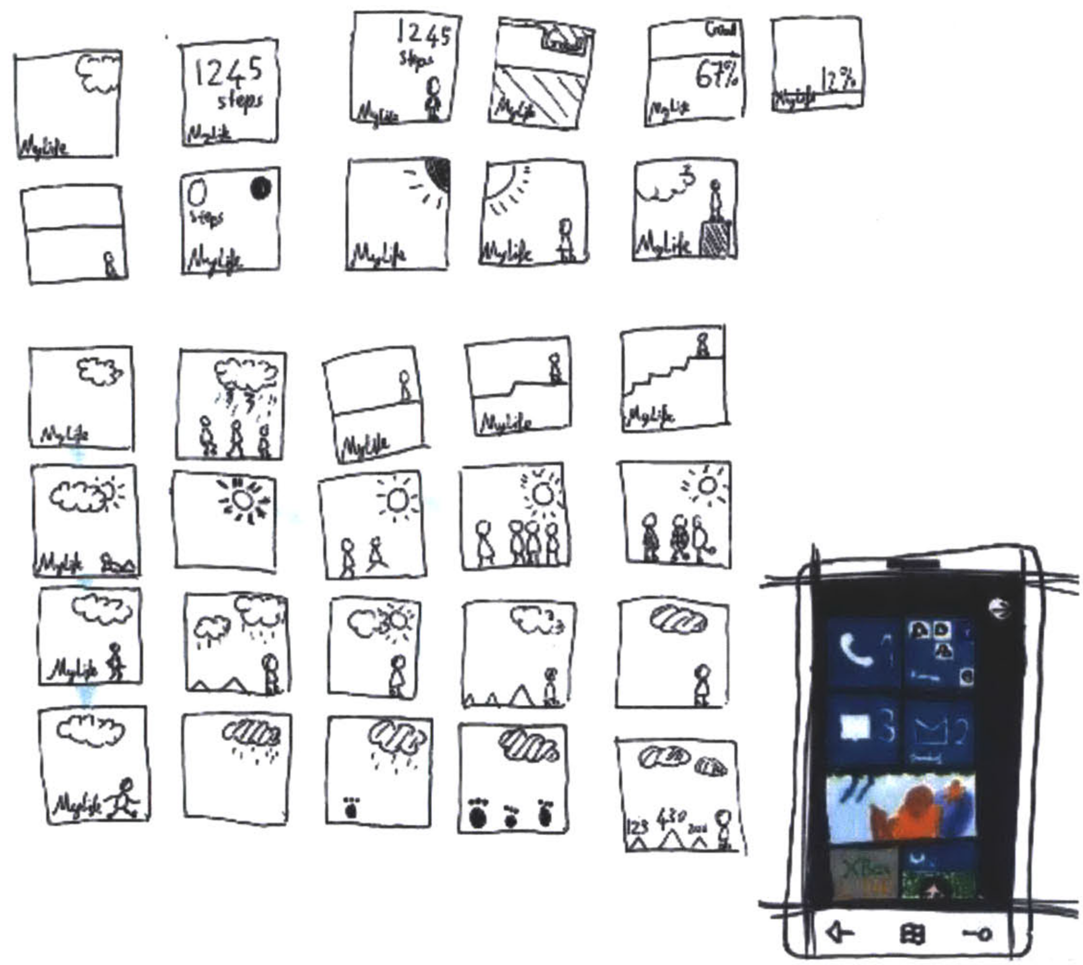


Figure A14. Design concepts (continue)

More on the our design philosophy and user-centric design process can be found at this online book: http://www.blurb.com/books/1945880 .

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