

Smartwatch Centered System for Facilitating Group Processes of
Small Teams in a Statewide Health Promotion Program

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Dissertation submitted to the Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

in

Computer Science

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June 18, 2018

Blacksburg, Virginia

Keywords: Smartwatches, glanceable interfaces, group dynamics, physical activity

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ABSTRACT

Physical inactivity is a major cause of disease in the United States and globally. Effective physical activity interventions often use community based approaches due to the demonstrated effectiveness of combining individual and group based behavioral strategies towards encouraging physical activity behaviors and influencing social norms. Such interventions can increase their impact by adopting technology based solutions to facilitate the underlying behavioral strategies. Current technologies for persuading physical activity primarily focus on facilitating the individual level behavioral strategies and de-emphasize the interpersonal aspects. This dissertation focuses on the development and evaluation of technology that is aimed at facilitating group dynamics-based strategies for promoting physical activity within small socially connected teams. This dissertation introduces a multi-component smartwatch-centered system (FitAware) that uses sensors to automatically track physical activity and leverages the advantages of the watch form factor to facilitate both group and individual level behavioral strategies via non-interruptive, glanceable, and frequent feedback updates. This manuscript describes the design and evaluation of FitAware in the context of an 8 week statewide physical activity community-based intervention, culminating in guidelines for system development that have been tested in educational settings.

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GENERAL AUDIENCE ABSTRACT

Physical inactivity is a major cause of disease around the world. A good way to tackle this challenge is to conduct community-based physical activity interventions because of their effectiveness in the use of both individual and social approaches for influencing behaviors. An important challenge with such interventions is increasing their impact on the communities. Mobile technology can be used as a platform that can help reach more people. Mainstream devices for promoting physical activity focus on facilitating individual level behavioral strategies (e.g., how many steps one walked) and de-emphasize the interpersonal aspects (e.g., how ones steps compare to friend's steps) which makes them less than optimal for facilitating the social approaches within community interventions. This dissertation focuses on the design, development and evaluation of a system that prioritizes both individual and interpersonal behavioral strategies for promoting physical activity. This work introduces a multi-component smartwatch-centered system (FitAware) that uses sensors to automatically track physical activity and leverages the convenience of the wristwatch information accessibility to facilitate both group and individual level behavioral strategies via non-interruptive, glanceable, and frequent feedback updates. This dissertation describes the design and evaluation of FitAware as part of an 8 week statewide physical activity community-based intervention, culminating in guidelines for system development that have been tested in educational settings.

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Chapter 1

Introduction

Individuals that adhere to regular physical activity tend to experience lower risks for diabetes, heart disease, various types of cancer, and many other diseases [116, 2, 152]. Centers for Disease Control and Prevention recommended no less than 150 minutes of weekly moderate-intensity aerobic physical activity to maintain a healthy lifestyle [56, 124]. Only one in five adults in the United States meet these requirements [160, 57]. The Task Force on Community Preventive Services recommends *community interventions* due to their demonstrated effectiveness at improving physical activity behaviors [85] and, in the case of small group focused interventions, better participant engagement due to the inter-personal factors that occur in small and cohesive groups [151]. These interventions typically combine both the individual (goal-setting, self-monitoring and feedback) and interpersonal (e.g. social support and social comparisons) behavioral strategies as mechanisms for improving physical activity behaviors [154, 18, 115, 86, 153, 69].

Community interventions are considered to be effective in in-person settings, with the health specialists facilitating the behavioral strategies [35, 81, 159]. However, approaches that seek lower cost and higher scalability via the use of interactive technology based mediums of delivery tend to be less effective [4]. In particular, web based solutions suffer from high dropout rates and low user engagement levels [51]. Smartphone based solutions are demonstrably better due to the use of sensors for automatic physical activity tracking and the convenience of the mobility [89]. However, as with web based solutions, the smartphone wellness apps still suffer from high dropouts and low user engagement [135, 136].

Wearable fitness trackers, on the other hand, retain the convenience of the automatic tracking offered by smartphones and also offer the simplicity of the glanceable wrist worn wearable form factor [119, 66]. Wearable fitness trackers have been recognized to be promising with regards to increasing physical activity [26]. In the public health contexts, they are also recognized for their costs effectiveness [4]. However, fitness trackers are not immune from high dropout rates and declining user engagement [92]. One of the core shortcomings of wearable fitness trackers is the restricted feedback via the glanceable display as it only conveys information focused individual level behavioral strategies (self-monitoring, goal setting and feedback) [133, 139, 4]. The feedback associated with the interpersonal level strategies (such as rankings in the social group) is only available through less accessible means such as smartphone or web interface [5]. This is problematic as the wellness tracker users predominantly just briefly glance at the wellness related feedback [66] – something that is supported well by the watch-like form factor [67] but not on smartphone [6, 5, 103].

These observations led to the following general question:

How can designers create wrist worn glanceable interfaces that help improve user engagement in group based community fitness interventions by facilitating both group and individual fitness awareness?

Motivated by the general question above, as well as the emergence of mainstream smartwatches, the following is the research statement of this dissertation:

Good smartwatch centered design, with a focus on timely and sustained information access, can facilitate group processes among small teams in the context of behavior change programs—resulting in design considerations that are demonstrably useful for the development of smartwatch centered systems.

In order to address this thesis, two research questions and their corresponding hypotheses need to be addressed. The first research question and the associated hypotheses are as follows:

- RQ1: How does a smartwatch centered system, with a design focused on conveying individual and group physical activity via passive updates, facilitate participant engagement in a group dynamics-based community intervention?
 - H1: Smartwatches presented to users as part of a group dynamics health intervention program will be regularly worn and used under certain conditions

- H2: Participants, as they regularly look at the watch display to check the time, date, and notifications, also notice the glanceable, physical activity and ranking updates on the watchface
- H3: Regular observations of the group process related information presented on the watchface influence health behaviors, engagement with the companion smartphone app, and awareness of the personal and group information.

To address this question, this dissertation presents a novel multi-component smartwatch centered system (FitAware) that uses a Pebble smartwatch, a companion Android app and a web server to facilitate individual and group dynamics-based behavioral strategies in the context of a physical activity community intervention. The design of FitAware leverages mainstream smartwatches that expand on the capabilities offered by fitness trackers via larger and programmable displays that can be conveniently used to present customized glanceable feedback [67, 138]. FitAware design is focused on providing users with high comprehension and reaction via non-interruptive feedback updates tailored around facilitating the underlying behavioral theories embedded in the intervention. The FitAware design accomplishes this by presenting non-interruptive smartwatch watchface updates in a glanceable fashion. The design approach is supported by the inherent information accessibility advantages of smartwatches [103, 138, 67], the self-interruptive behaviors of users, as well as the common usage habits of wellness trackers smartwatches. The smartwatch component (see Fig 1.1) conveys individual level behavioral strategies via personal step count indicator on the top

left, and the group dynamics-based interpersonal level behavioral strategies via the personal rank, team steps and team rank indicators. The top left corner shows user daily step-count information to enable reflection on personal goals. The top right corner displays rank within the team, encouraging competition. The bottom left displays total team steps informing users about the collective group progress. And finally, the bottom right corner displays team rank among all teams for the day, promoting competition between teams and cooperation and mutual encouragement within the users team members to improve rank. Every 15 minutes, the smartwatch exchanges information via Bluetooth with the companion Android app which, in turn, exchanges information with the web server.

The FitAware system was designed following a set of design objectives informed by the body of knowledge from the related work. The system was deployed and evaluated in the context of a statewide community physical activity intervention where small teams with pre-existing social connectedness used FitAware for 8 weeks. Nine teams of coworkers tracked progress with FitAware on a daily basis and engaged with the glanceable feedback aimed at facilitating the group and individual behavioral strategies underpinning the intervention via the indicators that conveyed group as well as individual progress and social comparisons enabling competition and cooperation.

Based on the initial design objectives that guided the design and development of FitAware as well as the evaluation results, a set of design considerations was produced to address the following research question and the corresponding hypotheses:

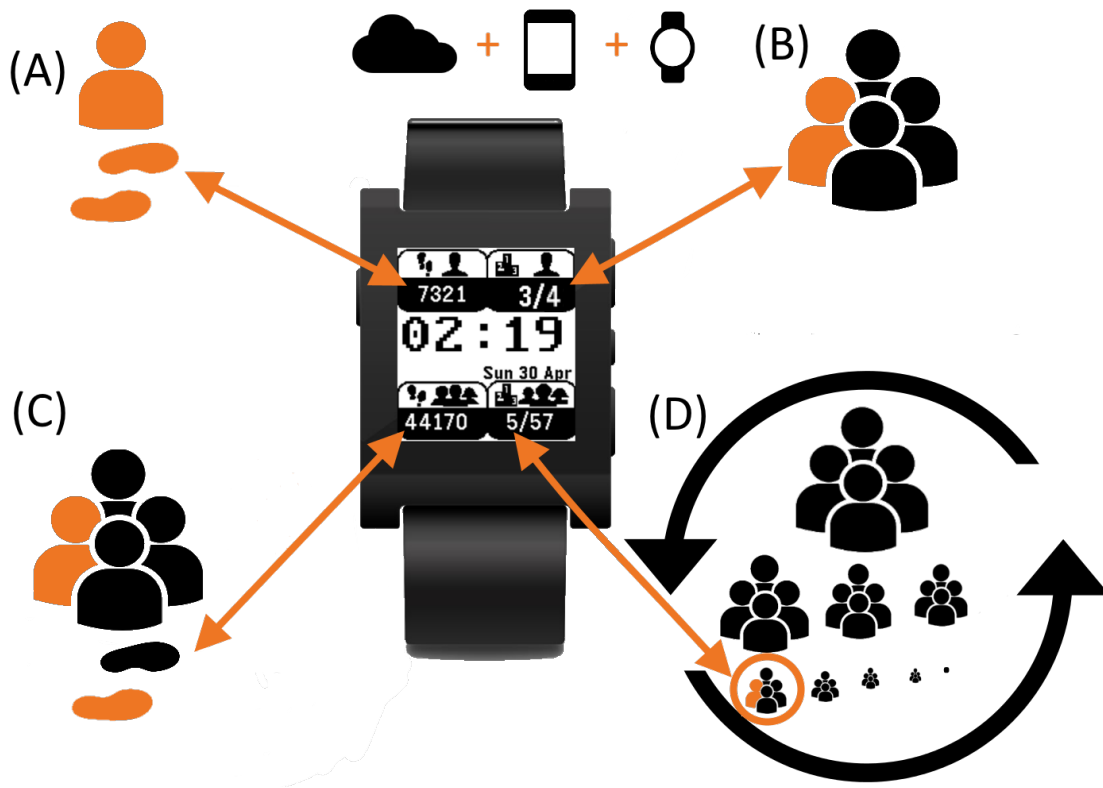


Figure 1.1: FitAware smartwatch component: a)personal steps b)personal rank c)team steps d)team rank.

- RQ2: How do the novice designers interpret and apply the design considerations to design group process based smartwatch systems that promote physical activity behaviors?
 - H4:Design considerations can be exemplified, during an in-class project assignment design and development.
 - H5: Students will show evidence of good understanding of the design considerations.

The design considerations were derived from the set of initial design objectives with an outlook on the FitAware evaluation results as well as the evolution of the mainstream smartwatches with regards to the capabilities related to presenting feedback. The research questions and the corresponding hypotheses were addressed via an in class assessment based on the usage of the design considerations as part of a homework assignment. Thirty-four students completed individual assignments that required them to design a FitAware-like smartwatch-centered system that would tackle the nationwide epidemic of physical inactivity by channeling individual and group dynamics-based behavioral strategies. Student submissions in the form of detailed wireframes of their designs and scenarios were assessed using a set of basic rubrics established by three HCI experts with experience teaching the course.

Chapter 2 of the dissertation describes prior and related work that provide the body of knowledge helpful for understanding and leveraging the unique capabilities of smartwatches towards facilitating group and individual behavioral strategies for promoting physical activity. Chapter 3 introduces a set five design objectives informed by the relevant research discussed in preceding chapter, then it describes the design process of initial version of FitAware and concludes by presenting a set of findings from an in-situ field evaluation. Chapter 4 describes the revisions to the system informed by the findings from the in-situ field evaluation, then it presents results of an 8 week statewide deployment and concludes by discussing the findings in the light of the research question as well as the design objectives that were followed during the design and implementation of FitAware. Chapter 5 proposes

a set of design considerations based on the initial design objectives as well as the results of the statewide deployment and provides results of an in-class assessment in the context of an upper level mobile software development class towards addressing RQ2 and the associated hypotheses. Chapter 5 concludes by discussing how the design considerations were assessed and how the results led to a path towards a revision of the considerations. Chapter 6 summarizes the dissertation and discusses it in terms of its contributions and potential future directions.

Chapter 2

Prior and Related Work

This chapter describes the prior inspirational efforts that demonstrated the potential for smartwatches in monitoring important information and highlighted the need for further research. The chapter outlines related work in core areas of relevance to this dissertation, including importance of physical activity, community interventions, group dynamics, and technology and group fitness. This chapter also discusses different technological mediums in the context of group focused physical activity promotion studies.

2.1 Prior Work

In the spring and summer semesters of 2014, smartwatches were initially explored as part of a teaching experience in an undergraduate junior/senior level mobile software development computer science course. The unique aspects of the smartwatch form-factor were explored

from both, the software development and the HCI perspectives. Motivation stemmed from the fact that in 2014 smartwatches were innovative and upper level classroom was a great platform to investigate smartwatches from the perspective of hardware, software development and user experience. The results were interesting and led to projects that leveraged sensors, multi-device communication and the information accessibility advantages of the smartwatch display. The details of this work appear in the Proceedings of ACM SIGCSE Conference [43].

The class followed a modular format described in proceedings of IEEE FIE [40] that prescribes modularized integration of core mobile topics. The course was divided into two-week modules, where every module covered fundamental aspects of mobile development with Android OS. One module focused primarily on smartwatches. The class was project driven and required students to undertake a semester project. We allowed to do semester long projects and three students elected to use Pebble.

Three students elected to incorporate Pebble as part of their projects. The applications produced as a result of this project leveraged various unique capabilities of the Pebble smartwatch. For instance one student created an app that tracked like and comments count of her organization's Facebook page and updated the smartwatch screen. Another student created a system that tracked temperature and humidity of a server room and then periodically updated Pebble display with the readings thus allowing the user to monitor the climate in a server room via glancing at the display (See 2.1).

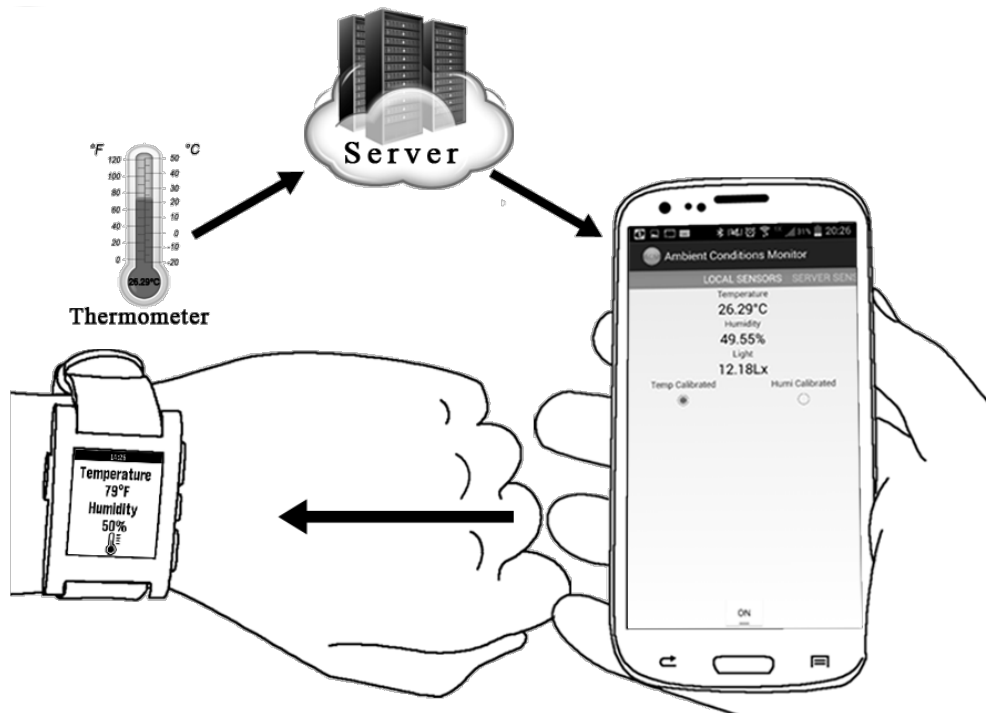


Figure 2.1: Server room temperature monitor: an example of how smartwatch display can be used to provide frequent glanceable updates.

We learned that smartwatches represent a unique combination of compactness and accessibility of a regular watch with the power of a smartphone with regards to capturing, exchanging and representing information. This initial experience with the smartwatches led to the next step which was to investigate how smartwatches can be used to help in the domain of physical activity promotion where information capture and representation play an important role.

2.2 Importance of Physical Activity

Individuals that adhere to regular physical activity tend to experience lower risks for having diabetes, heart diseases, various types of cancer and many others [116, 2, 152]. Centers for Disease Control and Prevention recommend at least 150 minutes of moderate-intensity aerobic physical activity each week to maintain a healthy lifestyle [56, 124]. Only one in five adults in the US meet these requirements [160, 57]. Furthermore, low socioeconomic status and older age have shown to negatively affect physical activity levels [55, 146]. The health complications caused by inadequate physical activity levels are associated with millions of deaths [93] worldwide and a multi-billion-dollar burden on economy due to adverse effects on population productivity as well as the increased health-care costs [33]. As a response to the widespread physical inactivity epidemic, the Task Force on Community Preventive Services recommends *community interventions* due to their demonstrated effectiveness of improving participant physical activity behavior change [85] and, in the case of small group focused interventions, better participant engagement due to the inter-personal factors that occur in small and cohesive groups. [151].

2.3 Community Interventions

2.3.1 Overview

Community-based interventions view the community as a set of geographically collocated social groups that can be reached in their natural environments [85]. Evidence has been produced to show that this approach to targeting of intervention participants can lead to stronger population level impacts [128], enable a variety of mechanisms that can be used to leverage interpersonal factors to influence behaviors and, when compared to interventions target individuals, achieve higher cost effectiveness [22]. Community-based interventions base their strategies on the fact that individual behavior is influenced as a result of interaction with various types of social environments (e.g., organizational, interpersonal, socioeconomic, and cultural)[114, 118]. These interventions can be broadly grouped into three categories: interventions employing individual focused strategies for behavior change that use the community aspect for the recruitment purposes, community focused interventions using multiple levels of influence (individual and interpersonal) to change participants behavior, and interventions that change environmental factors (i.e., incentivizing behaviors through recreational facilities, healthy food and policy) with the intention to influence community member behaviors [15]. This dissertation primarily focuses on the interventions that seek to combine both the individual and interpersonal levels of influence in order to positively change physical activity behaviors. Systematic reviews of such interventions confirm that that effective interventions typically use strategies for the both levels of influence [154, 18, 115, 86, 153, 69].

2.3.2 Group dynamics

A number of interventions have successfully used the interpersonal level of influence to improve physical activity behaviors by leveraging the social factors occurring in small groups [48]. The interpersonal strategies employed by such interventions are based on group dynamics principles. The study of group dynamics dates back to the early 20th century and reveals that cohesive groups have a strong influence on the group members [97]. Later in the century, a conceptual model, focused on building teams in the exercise setting and motivated by the phenomenon of individuals being influenced upon joining a group [23, 96], compartmentalized group dynamics-based principles affecting *group cohesiveness* into the categories of *group environment*, *group structure* and *group process* [21]. This conceptual model (referred to as 'team building conceptual model') prescribes that groups with a given initial structure and environment can develop cohesiveness through ongoing interpersonal interactions (*group process*) such social interactions and social comparisons [54] in the form of competition and cooperation (see Figure 2.2).

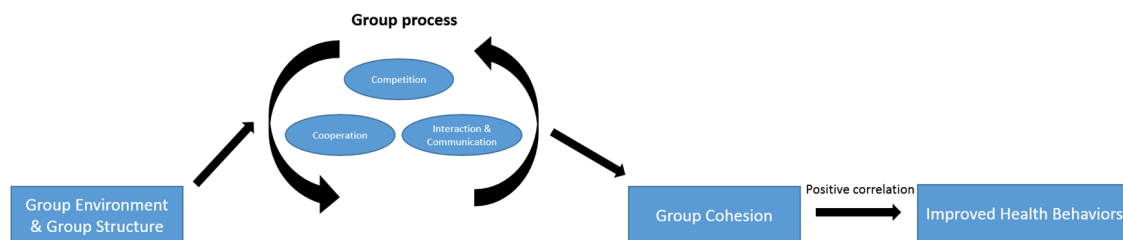


Figure 2.2: The team building conceptual model (Carron & Spink, 1993) in the context of PA behavior change interventions.

Evidence shows that group cohesion is a positive factor for the community intervention

outcomes [19, 151] and thus it should be facilitated by employing tailored group dynamics-based strategies [131] and assessed [46]. Many of interventions successfully utilized the group dynamics-based principles to promote group cohesion and ultimately improve physical activity behaviors [48, 72, 16, 142] via an in person medium delivery, however, others have struggled when switching to a technology based medium. The next section discusses these interventions in more detail and reveals the barriers inherent to the technology based interventions.

2.3.3 Group Dynamics-Based Community Interventions

Systematic reviews of [48, 72] physical activity behavior change interventions utilizing one or more group dynamics principles, evaluates the strengths and weaknesses of such interventions and an understanding on how the group dynamics principles are applied in practice. The review considered interventions that used elements of group dynamics or at least one of the strategies prescribed by the team building conceptual model [21]. Of the identified 52 group dynamics-based studies, 48 demonstrated positive results in terms of the intervention outcome variables and physical activity levels. In terms of the strategies used, the review determined that there was no standard collection of strategies shared between the interventions. The most common strategies included: goal setting, interaction and communication, social support and self-monitoring, developing a sense of group distinctiveness, collective and individual problem solving, leadership, group norms, competition and cooperation. Social cognitive theory, goal setting, and group dynamics were the most common theories and

conceptual models underpinning these studies.

Studies explicitly documenting the use of group dynamics-based principles are of particular interest for this dissertation, as they provide details with regards to the factors influencing group processes and ultimately the physical activity behaviors.

2.3.3.1 Offline Interventions

Many group dynamics-based studies can be categorized as "offline" for not using the Internet or connected devices for any of the intervention aspects. One such study [45] successfully applied group dynamics principles to facilitate physical activity behavior change of 33 older adults divided into 3 groups for the duration of six weeks. The groups met every two weeks for collective strength, cardiovascular and aerobic exercises. Some of the group cohesion facilitating efforts included instructor-led communication, collective group-goal setting and collaborative work towards achieving the team goal via in class group physical activities. In another "offline" study [47] low income older adults were targeted at congregate-meal sites for 12 weeks. Active for Life [70] successfully applied group dynamics theory in an intervention that targeted 1167 middle aged, mostly female, healthy but insufficiently active participants working at the same company. Teams of five to eight coworkers had their group cohesion facilitated via in person activities that developed group roles, norms, fostered interaction and competition. In yet another "offline" study [137], group dynamics principles were used to successfully increase cardiovascular fitness of middle aged inactive females from rural

areas. The participants were divided up in groups and attended weekly meetings at a local track where they walked for thirty minutes and engaged in various group cohesion focused activities.

In 2008, investigators of Walk Kansas [44, 87] successfully utilized group dynamics principles in a large scale physical activity community intervention with Carron and Spinks team-building model [21] at its foundation to improve physical activity behaviors of the participating individuals. The program participants were in close-knit groups of around 6 people, often with opportunities for frequent or regular interaction. These groups defined their team name, set their collective physical activity goals, and proceeded to track their daily physical activity levels for the duration (8 weeks) of the program. The groups reported their progress (on paper) and received feedback from the program managers on a weekly basis. As part of the weekly feedback the groups were able to compare their performance to others and thus engage in a friendly competition. Leading to significant increases in physical activity levels, the study applied group dynamics principles by establishing group roles, norms and goals, and facilitating communication. Based on similar constructs of Walk Kansas, Move More [49] successfully increased physical activity levels and demonstrated behavior change among 115 older adults that periodically met in a classroom to exercise and engage in group cohesion activities such as establishing group norms, tracking collective physical activity, communication and others. Taken together, group dynamics-based interventions have worked with a variety of populations and settings, and with a wide range of

group dynamics principles employed.

2.3.3.2 Online interventions

The 'offline' (in-person) program delivery format while effective is difficult to scale up due to the inherent constraints such as cost, space, reliance on staff and scheduling [35, 81, 159]. As a way to mitigate these challenges, recent studies propose using the Internet as the communication channel of delivery for group dynamics-based physical activity interventions.

Irwin et al. [81] conducted a study in a laboratory setting with college aged participants to test the efficacy of an 'online' group dynamics-based physical activity promotion system. The system enabled groups of two to engage in group cohesion activities via a synchronous web interface. Some of the activities included communication and discussions, establishing team distinctiveness via name and icon, team based collaborative puzzle game, setting group norms and virtually collocated exercising via webcam video stream. The study results were generally positive—demonstrating high perceptions of cohesion and significant impact on physical activity levels. As for the long term interventions, Ehlers et al.[35] adapted an 'offline' evidence based book-club physical activity intervention [79] into an 'online' one, by allowing the participants to attend and interact via tablet devices on a weekly basis. The tablet interface allowed a group of twelve women to engage with motivating materials (eBooks and interactive workbooks about physical activity) and participate in interactive videoconferencing sessions involving discussions and collective problem solving. The results

were mixed, as some participants reported feeling less connected to the group, while others had positive impressions and claimed that they could only participate because they were given the ability to do so remotely.

The same book club based intervention was adapted by another study [104] that used web discussion boards as the platform for group engagement. During the multi-week intervention, small groups of four to five middle-aged women were encouraged to perform group cohesion related tasks such as creating group goals, collaborating towards the group goal, answer discussion questions and reflecting on motivational materials. The results revealed increased physical activity levels and self-worth. However, only 60% of the participants completed the study. The authors concluded that using group dynamics-based strategies did not succeed at alleviating the common issue of rapid user engagement decline with web based interventions [48, 157, 161].

While the evidence shows that physical activity behavior change interventions targeting small social groups and utilizing group dynamics principles are promising and effective, the transition into the technology mediated formats is in the early stages and suffering from the participation and engagement decline. Reduced engagement and participation imposed by the technology based mediums is a major limiting factor for conveying the underlying behavioral strategies, ultimately undermining the effectiveness of the interventions translated from 'offline' to 'online'. For example, reduced engagement with the medium of delivery implies reduction in received feedback necessary for conveying the group process related

strategies (competition, cooperation and others). This issue is shared across different types of Internet-based mediums with the primary culprit being the perceived burden from interaction with the systems [51]. The following section reviews a spectrum of technology-based mediums of delivery and the associated opportunities as well as the challenges in the context of interventions that include the interpersonal level of influence on health behaviors.

2.4 Technology and Group Fitness

The work in this dissertation builds on prior efforts that seek to understand how technology can have a role in supporting group fitness efforts. This section examines some of the most relevant related work in web, smartphone, and wearable fitness tracking technology.

2.4.1 Web

The use of web based mediums for health and wellness programs is motivated by the opportunity to increase reach (at the moment of writing this dissertation the percentage of US adults using the Internet has exceeded 89% and 97% for adults under the age of 50 [134]) and decrease the costs associated with implementing such interventions [13]. Past decade has seen a rise of physical activity interventions that use web based systems as a medium of delivery for the behavioral strategies. A recent comprehensive review of Internet based

physical activity interventions [84] identified 72 studies published since 2001. According to the review, the interventions used social cognitive theory and transtheoretical model as the underlying behavioral basis, and targeted populations such as worksite employees, obese adults, college students, sedentary adults, individuals with diabetes and others. With regards to the interpersonal levels of influence, twelve interventions allowed the participants to communicate and interact over the Internet. The types of interactions included web based message boards for exchange of ideas and mutual support [65, 98, 111], supervised university Blackboard discussions [68], periodic support emails [76, 90], scheduled web based chat sessions [34, 75, 76]. As a way to facilitate social interaction several interventions allowed participants to send and receive messages via SMS [122, 60, 59, 143]. In one study SMS messages were sent to a web server which then aggregated, audited and forwarded them to other participants [60, 59] and in another study users could send messages from the web interface to other participants' cell phones [122]. While the web based studies have shown positive results, the high attrition rates upwards of 50% were so common that they became a 'fundamental characteristic' of web-based interventions [51, 13].

2.4.2 Smartphone

The share of US adult population using smartphones has more than double between 2012 and 2018 and reached 77% [135] and for one in five US adults, smartphones are the only means of accessing the Internet [136]. Smartphones are of interest for physical activity promotion efforts for of reasons that go beyond the high reach into Internet connected users:

(i) smartphones offer sufficient capabilities to capture, store, retrieve, communicate, and present user physical activity progress related data [91, 130], (ii) users feel attached to smartphones and keep them close most of the time [150, 158]. Numerous studies leverage the capabilities offered by smartphones to promote physical activity behaviors on both individual and interpersonal levels and commonly follow the four design requirements by Consolvo et al. [27]. A recent systematic review of 20 smartphone centered systems reveals that 12 used strategies for influencing on the interpersonal level from which 8 offered feedback on social comparisons (competition and cooperation) [106]. Overall, Literature shows evidence that, in the context of the interpersonal levels of influence on physical activity, smartphones can encourage communication [27], progress sharing [3], and social comparison (competition and/or cooperation) [1, 24, 99, 73, 156, 88, 7, 31] to increase physical activity. Smartphones have been shown to be valuable tools for supporting social interactions among members of a community [78] and for providing awareness of the activities of friends [61, 71].

One of the earliest examples of a smartphone based system for physical activity promotion was presented by Gasser et al.[62]. The authors leveraged the programmable capabilities of one of the early iterations of Symbian platform to build a custom wellness tracking application for a smartphone with a low screen resolution of just 176x208 pixels and hardware key based inputs (no touchscreen) and no sensors for capturing physical activity. The application was designed to support self-monitoring, goal-setting and social translucence [36]. Users were allowed to manually log their physical activity and consumption of fruits/vegetables while

also monitoring progress of their individual and group progress. The study also included a web based interface that mimicked the smartphone application with regards to the aesthetics and functionality. The result of a 28 day field study with 40 participants revealed that the smartphone application, while perceived to be difficult to use due to the hardware buttons, was used more frequently and consistently than the website.

Another early study relied on Windows Mobile devices to automatically track and share activities among friends [3]. The authors explored the usage and perceptions of the system through a user study with nine participants recruited from shared social circles (coworkers, friends and etc.) and divided into three groups. For the duration of ten days the subjects had their low, moderate and vigorous intensity activities tracked and shared in their groups via the application user interface. The functionality of the system allowed users to compare progress with their group members and monitor their physical activity status in real-time. While the focus of the study was on the technical aspects of the system and the accuracy of tracking physical activity via the proposed method (GSM triangulation using the cell towers), the qualitative results from interviews and diaries showed that participants found the system to be fun, informative and motivating.

Ahtinen et al.[1], designed a smartphone (Symbian OS based) app that enabled groups of individuals to collaboratively walk to various prominent locations around Finland, such as the North Pole, by summing up their physical activities and visualizing it as a trip to the destination on a map. The social elements of the app included collaboration and competition.

The study recruited 37 participants and grouped them into teams of around 4 for the duration of one week. The participants were recruited from existing social groups with the purpose of having teams. Survey and interview based findings revealed that participants liked the virtual trips with the most favorite aspects being cooperation and competition between the team members.

Motivated by the vast capabilities of modern smartphones for physical activity promotion, King et al. [88] describe the design and evaluation of three smartphone-based systems (named as follows: "social", "affective" and "analytical") aimed at exploring different behavioral approaches for motivating physical activity. The authors informed the design of the "analytical" variant by drawing from the social cognitive theory and self-regulatory principles of behavior change [8, 155], social influence theory [141] guided the design for the "social" and for the "affective" one they followed operant conditioning principles [148, 149]. Following a "design thinking" approach [74] the authors produced the three variants of Android apps utilizing the sensory capabilities of Android OS. The three apps were evaluated via an 8-week study with 68 adults from which 23 were assigned to the "social" app. To facilitate social influence, anonymous teams of four were formed by with randomly selected participants. It is notable that, all teams had two "confederate" users (virtual team members simulating physical activity). The "social" allowed the users to monitor physical activity progress of their own and two other (randomly selected) teams. The results of the evaluation revealed that the "social" and "analytic" apps were more successful as the "affective" variant failed to

convey physical activity progress feedback in a transparent way (e.g. numerically or graphically). In terms of the experience with the smartphones, 29% of the participants reported that the device was inconvenient to carry around and 23% found it difficult to use.

Chen et al.[24] explored the effectiveness of using cooperation, competition and social engagement in the context of socially connected groups of two. The study recruited 18 participants for the duration of two weeks and grouped them in pairs that shared social circles. The authors developed an Android app, HealthyTogether, which allowed groups to perform physical activities together, monitor each other, communicate, compete, cooperate and earn badges while automatically tracking physical activity. Results of the two-week long study were positive – cooperation and communication appeared to have influenced participants physical activity behaviors.

The use of smartphones as the mediums for facilitating behavior change strategies shows positive results in the context of short studies. However, in the real world context there are several challenges preventing wellness oriented apps from being used on a regular basis. Smartphone users tend to uninstall apps after just one use in 25% of the cases [123] and in the context of health and wellness apps 75% of them are uninstalled after the 10th use [112]. General reasons for uninstalling apps are security concerns, notification overload and ads [53] and in the case of wellness oriented apps a common reason is goal abandonment [120]. Challenges also arise from the hardware ergonomics perspective – smartphone form factor imposes certain barriers on the user experience [6] (for example users might choose

not to access the wellness app because of the anticipated burden stemming from the task of finding the smartphone, unlocking the screen and finding the app). It has been shown that smartphones often reduce the number of cases of user interactions due to the anticipated cognitive load associated with the steps (i.e., extracting the handset from a pocket followed by screen power-on/unlock sequence) required to getting to the screen [6]. Such reduction limits users exposure to valuable information aimed at promoting health behavior change. Additionally, smartphone apps often rely on notifications to gain user attention which comes at a cost of interruption [29, 30, 95, 132, 144] and users do not like interruption from unimportant [20, 109, 110] notifications (users consider non-social notifications as unimportant [144]).

One solution to these challenges is to present feedback in a non-interruptive and yet highly accessible way. In fact, a study on wellness tracking behavior [14], explored a non-interruptive approach by using passive notifications (simple icon/visualization that users discover while looking at the screen without the added interruption from vibration/sound) as the means of reminding users to track wellness data. The study revealed that passive notifications did not interrupt the users and succeeded in increasing user fitness data logging frequency. This can be explained by the findings from a study on mobile notifications that surveyed a large number of users and determined that they regularly check their smartphones without any tangible cues (vibration, light or sound) [11, 10, 127], thus performing self-interruptions. In the domain of communications theory, such behavior is referred to as "automaticity" [11].

Such "automated" self-interruptions are known to be rooted in the individual's social sense of connectedness which in turn drives the self-interruption behaviors through a mechanism of various triggers/cues [11] (visual/auditory and other reminders: visible people looking at their phones, long duration since last communication and individuals mood). Overall, self-interruptions provide opportune moments of brief and uninterrupted user attention available for information of lesser importance such as health and wellness related updates. Such self-interruptions are particularly valuable in the context of presenting wellness related feedback as it has been shown that users typically just glance at it [66].

2.4.3 Wearable Fitness Tracking Devices

Wearable fitness trackers such as Fitbit are equipped with glanceable displays (or indicators in some cases), sensors that continuously and automatically collect data and provide self-monitoring capabilities for measures such as step count, distance traveled, flights of stairs taken, sleep quality, heart rate and sedentary time [50]. A report from the US Department of Health and Human Services (based on literature review) claims that wearable fitness trackers can increase physical activity [26]. According to a 2015 market research report, over a half of US adults were aware of the popular fitness tracker brands and over 30% of them claimed that they considered purchasing one. From the perspective of community based interventions, fitness trackers are recognized to be advantageous from the reach and cost related points of view [133, 139, 4] but not as effective as the in-person ('offline') interventions in terms of the behavioral outcomes [4].

In a systematic review of behavioral practices used in fitness tracking devices revealed that the well-established individual level behavioral strategies (goal-setting, self-monitoring and feedback) were included in all of the systems whereas the interpersonal level strategies (competition, cooperation, communication and social support) were present in eight out of thirteen systems [102]. A study focused on analyzing the use of behavior change techniques in popular commercially available fitness trackers (Fitbit, Jawbone, Nike etc.) confirmed the presence of goal-setting, self-monitoring and feedback strategies across the board and also pointed out that all of the systems offered interpersonal level strategies (social support and social comparison) via the feedback on the companion smartphone and web interfaces [113].

In terms of the adherence to use and engagement, reports indicate that over 30% of the trackers are not used following a six to twelve month interval from the day of purchase [92]. According to a study focused on adherence challenges for wearable fitness tracking devices, over half of the users stop wearing them after two weeks [147]. The same study revealed that in the case of young adults the adherence challenges included reasons such as forgetting to wear, not forming a habit, poor aesthetic quality and lack of social comparison across similar demographic. Another study focused on older demographic reveal that the reasons for not wearing fitness trackers included issues such as tracking reliability and accuracy and lack of motivation [52].

Gouveia et al. [66] studied engagement habits of 256 Fitbit users via surveys and data logs capturing engagement with a custom smartphone app provided users with and expanded

feedback aimed at conveying reflection and persuasion. The results of the study revealed that in over half of the cases viewing the expanded feedback, users spent less than 5 seconds which then led to a conclusion that brief and frequent (glancing) interactions may be the primary means of how users prefer to access feedback.

In summary, fitness trackers do facilitate both individual and interpersonal behavioral strategies. However, the interpersonal level feedback is only accessible via smartphone/web interfaces thus preventing users from accessing such feedback in a glanceable fashion. In fact, a study in the domain smart apparel for running groups has pointed out that there no wearable systems that provide quickly accessible real-time group progress feedback [108]. Smartwatches can potentially address this issue by leveraging larger glanceable screens that can accommodate both individual and interpersonal levels of feedback [66, 63, 138] while still maintain the wellness tracking capabilities offered by fitness trackers.

A recent market report shows that the sales of smartwatches are on the rise and already exceeding the market capitalization of fitness trackers [80]. In terms of leveraging larger display for providing interpersonal level feedback smartwatches are promising: motivated by an observation that users typically just glance at the physical activity feedback [66], Gouveia et al. considered the design space of smartwatch glanceable interfaces [67]. As part of this exploration the authors assessed four different types of smartwatch interfaces among twelve young male participants that already owned a specific smartwatch. One of the smartwatch interfaces that participants had to use, provided step-count comparison information of an

average user (normalized based on a large database of tracked steps) with the same goal as the user. Thus, users were able to compare themselves to someone else with the same goal by simply glancing at the watchface (a simplified form of interpersonal feedback). The study found that participants often noticed and reacted to small step-count differences (500 or under) by walking within five minutes of discovering the information. The authors conclude that participants were more motivated to walk when they knew that it would not take much time to overtake the opponent or stay ahead. It should be noted that these observations are in line with the fact that individuals are best motivated by attainable goals [100].

These early findings suggest that smartwatches can effectively convey simple physical activity related information that users notice and react upon. Yet lacking is a deep understanding of how smartwatches can be a core component in group-centered fitness programs. Specifically, this research investigates how group process tailored frequent updates on the watchface can facilitate group processes [21, 44] such as competition, cooperation, interaction and communication.

Chapter 3

Design and Development of FitAware

The previous chapter covered the prior and related work to that helped outline unique aspects of smartwatches and how they can tackle the challenge of conducting promoting community physical activity interventions via technological mediums. This chapter starts by discussing the design and implementation of FitAware with an objective of supporting group dynamics-based behavioral strategies for a statewide physical activity community intervention. Details are provided on how the design draws from the established approaches to behavior change technology as well as prior studies that focused on exploring the unique capabilities of smartwatches. This chapter concludes by presenting the results of a small in-situ deployment and how it led to the formation of research questions and the corresponding hypotheses. Some content of this work appears in my paper in the Proceedings of ACM SIGCHI [39] and my Master's thesis in the Human Nutrition, Foods, and Exercise (HNFE) Department at Virginia Tech [38].

3.1 Design and Development

This section discusses the design and implementation of FitAware and how it draws from the current literature on behavior change technology and smartwatches in order to design and develop a system that leverages the unique capabilities of smartwatches to facilitate group dynamic-based strategies in the context of a statewide intervention. The section outlines the design objectives and describes how they were applied in the development.

3.1.1 Design Objectives

Prior to the design and implementation of FitAware, a set of design objectives was formulated drawing from the literature discussed in Chapter 2. Overall, the design objectives are informed by the observations that the current wearable fitness trackers, borrowing from the historically recognized ergonomic advantages of wrist watches [105], succeed at matching the common practice of users to just briefly glance at the wellness related feedback [67, 66] and ultimately help facilitate glanceable awareness – an approach that is considered to be advantageous for the persuasive technologies aimed at behavior change [28, 82, 58]. Furthermore, wearable fitness trackers have been recognized to be effective at increasing physical activity levels [26] and being cost effective from the public health perspective [133, 139, 4]. However, the information that is accessible via the glanceable indicators on wearable fitness trackers only convey individual level behavioral strategies [119, 66] and while only providing the interpersonal level behavioral strategy related feedback on the companion smartphone

and web interfaces [113, 67], thus making it not glanceable because of the required interactions inherent to web [51] and smartphone interfaces [10, 5, 6] ultimately not matching users preferred approach for accessing wellness related information. Below are the detailed descriptions of the five design objectives:

1. *Display daily information with frequent glanceable updates.* This strategy requires that the information presented to the users is in the form of frequent, glanceable and non-interruptive watchface updates with the goal of (as per McCrickard's IRC framework [110] for classifying notification systems) facilitating comprehension and reaction without the interruption. The justification for this design strategy is based on the following observations: mobile device users react negatively to interruptions from non-critical notifications [144] both in general and in wellness tracking contexts [119], a typical user interaction with wellness feedback is via brief glances under 5 seconds [66] which has been shown to be true in smartwatches as well [67] and frequently updated feedback leads to user interest in the presented information [129] and ultimately encourages checking habits [67, 10, 11]
2. *Time and date should be visible elements.* According to this design objective time and date need to be placed on the watchface and made easily readable. The justification for this requirement is based on the research suggesting that users glance at the watchface multiple times per hour [138, 117, 32] and that a major reason for glancing is to check time (much like the original wrist watches from the late 19th century) [67, 138]. Furthermore, in the case of watchfaces that present wellness related information, early

research findings suggest that the users initially motivated to check time then also checked the wellness feedback on the watchface [67].

3. *Continue watchface updates when offline.* This requires that the feedback on the watchface continues to update including the instances when the external data is unavailable (some examples of this include disconnected companion smartphone app or poor Internet connectivity preventing cloud sourced based updates). As it was pointed out for the first design objective, frequent updates are known to engage users and even contribute to checking habits [129] hence it is important to maintain frequent updates even when the source of the updated information is temporarily unavailable. Another evidence from research that motivates this design objective is the fact that in the case of automatic wellness tracking technology users react negatively to the perceived issues with accuracy/credibility of the feedback [92, 147, 119], hence it is also important to update feedback in order to "shield" users from perceiving accuracy/credibility issues with the feedback.
4. *Extend the feedback presented on the watchface.* This design objective requires that the glanceable information presented on the watchface should accommodate potential user needs for more in-depth feedback. This objective is in part motivated by a Consolvo's design requirement (of the widely used four design requirements [27]) for behavior change technologies stating that users should be able to, for example, review past physical activity progress. It is also motivated by the recommendation from Gouveia et al. [67] stating that glanceable smartwatch feedback should act as a trigger for further,

deeper engagement with the presented feedback.

5. *Optimize information presentation on the watchface around the underlying behavioral strategies and the display format.* The final design objective requires that the constraints imposed by the smartwatch display characteristics (size, resolution, color reproduction etc.) inform how the feedback is displayed, whereas the feedback itself is determined by the behavioral strategies that the system is aimed to help mediate. FitAware watchface design seeks to incorporate effective behavioral strategies on both individual and interpersonal levels and combines them together (as it is the case with effective interventions [154, 18, 115, 86, 153, 69]). The individual level feedback is intended to convey self-monitoring, goal setting and feedback behavioral strategies as it is the case with popular fitness trackers [102, 113, 67]. The interpersonal level feedback is informed by the group dynamics-based principles used in effective group dynamics-based intervention [21, 48] and seeks to convey group feedback necessary to convey strategies such as competition and cooperation (also commonly used in effective technology based interventions [106, 113]). In terms of the effective strategies for accommodating the feedback on the smartwatch display the design follows the design practices for small displays [107], adopts effective information visualization strategies for low resolution, small monochrome displays [140] and resorts to the "analytical" visualization theme which prescribes the use of simple to understand indicators [88] and finally, uses competitor analysis [74] to inform the aesthetic aspects of the design.

3.1.2 Applying the Design Objectives

This section describes how the five design objectives were implemented into a system composed of smartwatch, smartphone and web informed by the behavioral strategies underpinning a statewide group dynamics-based physical activity intervention.

3.1.2.1 Context

FitAware was developed to work in the context of FitEx, a group dynamics-based, statewide physical activity intervention administered by Virginia Cooperative Extension public health practitioners (also referred to as "agents"). The participant recruitment in this intervention happens in a hierarchical way: agents recruit team captains who in turn, invite members from their social circles (coworker, friends, family etc.) to form group of around six people. After the recruitment, led by a team captain, the groups select a name, and set individual goals (group goal becomes a sum of individual goals) and then track their physical activity for the duration of eight weeks. The intervention employs combines individual level strategies (self-monitoring, goal setting and feedback) with the successful interpersonal level strategies for community interventions [48] with a focus on facilitating the group process [21] which include: communication (team members are recruited from existing social circles in order to provide opportunities for interaction and communication), cooperation (team members receive feedback on overall group progress, individual contributions to the group progress and comparisons with other groups) and competition (via individual rankings within the

group). The groups also receive weekly updates which include overall rankings amongst all of the participating groups.

3.1.2.2 Implementation

FitAware was built to accommodate the underlying behavioral strategies of FitEx and included smartwatch, smartphone, and web components. The web component included interfaces that provided feedback and an option for manual progress tracking for the participants not using the smartwatch component. The smartphone component enabled the information to be exchanged between the smartwatch and the web server.

FitAware was developed following an iterative design approach that entailed multiple cycles of prototype design, implementation, evaluation and analysis [74] as such approaches are often used during the design and development of novel technologies for behavior change [88].

Smartwatch. The smartwatch used as part of the FitAware system was Pebble Classic – an inexpensive smartwatch known for a good balance between battery life and features. Pebble Classic features a monochrome display with a resolution of 144x168 pixel, fully programmable (in C and JavaScript) watchface and sensors for tracking physical activity (steps) and exchanging information with the companion smartphone (via Bluetooth). The first design objective (*Display daily information with frequent glanceable updates*) was implemented



Figure 3.1: FitAware smartwatch watchface and the companion app interfaces explored. The elements on the watchface (a) directly map to the four squares on the Android apps home screen where tapping the top left square opens up a screen with the user progress chart ("my info") for the day (b). Tapping the top right square opens a visualization and table displaying each team members contribution ("my rank") to the team steps (c). The bottom left opens up a progress chart ("team info") for all team members (d) and the bottom right square leads to a table with intervention statistics ("team rank") for the day and the whole period of the competition.

by placing the visual indicators for the feedback directly on the always-on watchface and updating them every 5 minutes. To satisfy the second design objective (*Time and date should be visible elements*) the time indicator was placed in the middle of the watchface and sized appropriately to ensure good readability [107]. The indicators surrounding the time indicator convey both individual and interpersonal levels of feedback. As per fifth design



Figure 3.2: The layout of watchface:top left show personal steps, bottom right shows team steps, top right shows user rank in the team, bottom right shows rank of the team among all teams.

objective (*Optimize Information presentation on the watchface around the underlying behavioral strategies and the display format*) the indicators reflected the underlying behavioral strategies of FitEx (See Figure 3.2): daily personal step-count supported individual level strategies (self-monitoring, goal setting and feedback). the other three indicators supported interpersonal level strategies such competition and cooperation by displaying daily values for personal rank in the team, collective steps for the day (team steps) and daily rank of the team among other teams (see Table 3.1 as it shows how these indicators support the group process via competition and cooperation). The third design objective (*Continue watchface updates when offline*) was supported via caching of the group member step count values

and then re-computing (every 5 minutes) the values for personal rank and team steps based on the updated personal step count values. The fourth design objective (*Extend the feedback presented on the watchface*) was addressed via an Android app discussed in the next paragraph.

Table 3.1: How 'personal steps', 'team steps', 'personal rank' and 'team rank' can facilitate competition and cooperation.

Group process	Knowledge	Example mechanism
Competition	Personal steps interpreted via rankings	User looks at the personal steps, personal rank and then opens My Rank/Team Info User looks at the personal steps, personal rank and the evaluates
	Personal steps interpreted via comparison with total team steps	User estimates the difference between team steps and personal steps and then opens My Rank/Team Info User estimates the difference between team steps and personal steps
Cooperation	Personal contribution interpreted via comparison to the team steps	User estimates the ratio between team steps and personal steps User estimates the ratio between team steps and personal steps and opens My Rank/Team Info
	Team steps interpreted via rankings	User looks at the team steps, team rank and then opens Team Rank User looks at the team steps, team rank and then evaluates

Smartphone. The companion smartphone app offers detailed information expanding on what is offered on the watchface. For instance, the personal step counter (Figure 3.1, b) is augmented with a chart that shows how the user arrived at the current step count throughout the day. For the team step counter (Figure 3.1, d) the smartphone app offers a similar chart, but for all team members. For the personal rank (Figure 3.1, c), the app provides exact step count for all of the team members. And finally, for the team rank (Figure 3.1, e), the app provides a list of teams, their steps and rankings.

Web. FitAware relies on a web data repository for syncing, storing, interpreting, and exchanging progress and ranking data between the smartphones and smartwatches. The website is required for text-heavy actions, like user account creation, goal setting, manual update of entries, and the user baseline physical activity assessment survey.

3.2 Pilot Evaluation

3.2.1 Overview

The purpose of this study was to pilot test FitAware in a setting resembling group dynamic-based community interventions. In order to gain an initial insight into the patterns of use and user experiences, both quantitative and qualitative data were gathered for a mixed-methods explanatory analysis. The qualitative data were collected via participant interview and the analysis followed grounded theory methodologies to explore the user experience with the system. The questionnaires and system usage logs contributed the quantitative data. The quantitative analysis yields descriptive information that is used to enrich the findings from the qualitative analysis. Overall, the objective of this in-situ deployment was two-fold: (i) obtain real world usage feedback so that it can help refine FitAware towards a large scale statewide deployment; (ii) explore the preliminary user experience of using FitAware.

3.2.2 Methods

3.2.2.1 Eligibility

Community members reflective of the FitEx program participants were sought to pilot test the smartwatch interface. Participants were 18 years of age or older, capable of moderate-intensity physical activity, with an Android smartphone, and willing to wear a Pebble smartwatch for the duration of 8 weeks. Additionally, the participants needed to have one or more eligible, socially connected (friends, coworkers, family etc.) individual(s) with whom to form a team.

3.2.2.2 Recruitment, Setting and Procedures

In an effort to best mimic the protocol of FitEx, study participants were recruited from the local community by a Virginia Cooperative Extension (VCE) agent who had participated in the past iterations of FitEx. The VCE agent invited the groups to gather in the local extension office for the study procedures (consent form, system set-up procedures, question and answer session). The procedures included system account creation, smartwatch and the app installation onto participants own Android devices, and a brief tutorial on how to use the system. Two teams were formed. The Virginia Tech Institutional Review Board approved this study (IRB 16-264).

One team was comprised of three members (P1, P2, P7) while the second team had four members (P3, P4, P5, P6). P1 and P2 from the first team are coworkers that had worked together for over 5 years, while P7 was invited by P2 via a public Facebook page for the members of the local community. The members from the second team represent two married couples (P3&P4 and P5&P6). Within the first week of the study, P7 asked to be removed from the study due to inability to wear the smartwatch in her work environment. In addition, P6 stopped tracking physical activity with the watch within the first week and declined to participate in the post study interview. P5 unpaired the Pebble smartwatch from her Android device, which prevented the tracked physical activity data to be received on the Android device. The participant was contacted, instructed, and periodically reminded regarding the syncing issue. The system data logs revealed that P5 did not re-pair Pebble with her Android device, thus producing no quantitative data of substance. Therefore, the quantitative results are limited to P1, P2, P3 and P4.

3.2.2.3 Quantitative Measures

Sociodemographics. At baseline, and as a part of the user account creation, every participant was asked to complete an online questionnaire to answer a series of questions about their demographics (age, weight, gender, race, employment and education), exercise habits (frequency and duration of mild, moderate and vigorous physical activity) and nutrition (daily consumption of fruits and vegetables per day). Additionally, the registration included an interactive interface for setting their weekly physical activity goals. The questions regard-

ing participants physical activity are based on the widely used and accepted International Physical Activity Questionnaire [7].

Physical Activity. The system captured participants steps via the integrated 3-axis accelerometer of the Pebble smartwatch. Steps were uploaded to the server and stored in the database for further analysis.

System Usage and Engagement. The smartphone app recorded user interactions with all of the apps user interface elements as well as the app related events such as information exchange with the smartwatch and saved them as log entries. Each log contains information about the system username of the participant, the corresponding timestamp (exact time of occurrence of the log), the description of the event (i.e., “Apps main screen loaded”, “User opened ‘my steps’ screen”, “User initiated step count synchronization from the smartwatch”, “Smartwatch received new ranking information” etc.) and the associated values (e.g., personal step count, team member step count and rankings). User engagement with the smartwatch was measured as the number of instances of manual syncing of the smartwatch steps with the smartphone app. In order perform this action, users sequentially pressed two buttons on the sides of the wearable. The engagement with android app was measured by counting the number of user initiated app launches as well as interactions with the four main screens of the app.

Qualitative measures. All of the participants were asked to participate in semi-structured interviews aimed at exploring their experience with the system (e.g., usability of the smartwatch, reactions to information updates, patterns of use) as well as the group dynamics

aspects of participating in teams. The group dynamics-related questions were primarily focused on the four dimensions of group cohesion [45]: individual's attraction to the group as a social unit (ATG-S), individual's perception that the group was integrated around the task (GI-T), and individual's perception that the group was integrated around the task (GI-S). Audio-recorded interviews were conducted by a trained research assistant, over the phone, or via Skype for the participants' convenience.

3.2.2.4 Qualitative Analysis

The interviews were transcribed verbatim by a group of trained research assistants. Upon completion of the transcriptions, the interviews were qualitatively analyzed following the abbreviated variant of the grounded theory approach [162]. In an effort to maximize the accuracy and depth of the analysis and address the issue of reflexivity, four coders performed the grounded theory approach. Upon completing the individual open coding tasks, the discrepancies and differences were resolved via Google Spreadsheets and the final set of codes was established. All of the audit-trail information was saved on Google Spreadsheets on backup sheets and as comments. For the axial coding an identical procedure was undertaken. The identified meaning units were aggregated into categories, sub-themes, and major emergent themes.

3.2.3 Results

Participants synced their smartwatch steps with the smartphone on average 2.6 times per day throughout the study (Figure 3.3), suggesting participants stayed engaged with the fitness task. Also, the smartphone app averaged 1.5 uses per day, also throughout the study (Figure 3.5). Participants did not seem to favor any of types of information when using on the smartphone, opening the “my info”, “my rank”, “team info” and “team rank” views 287, 212, 248, and 244 times, respectively. The participants noted all information had value, noting “[the four pieces of information] were all fairly important” (P2) and “the visual graphs I think are very beneficial” (P3).

Participants seemed to be attracted to both task and social aspects of the activity monitoring. P3 claimed he was able to reflect on his physical activity levels by regularly monitoring the smartwatch, noting “at the end of the day [it] made me really realize how much I was moving around”. The married couple P3 and P4 communicated about how P4s job limited her activity, with P3 noting that “we were noticing her job and more of an office setting... didnt really get her walking much”. P4 realized her husband is competitive and active, noting she wanted to be more active too.

While some participants seemed to care only about their team, others were aware of and motivated by other teams. P2 regularly checked his smartwatch to compare steps with his coworker P1, plus his team’s standing. He kept his team and himself in the lead, performing

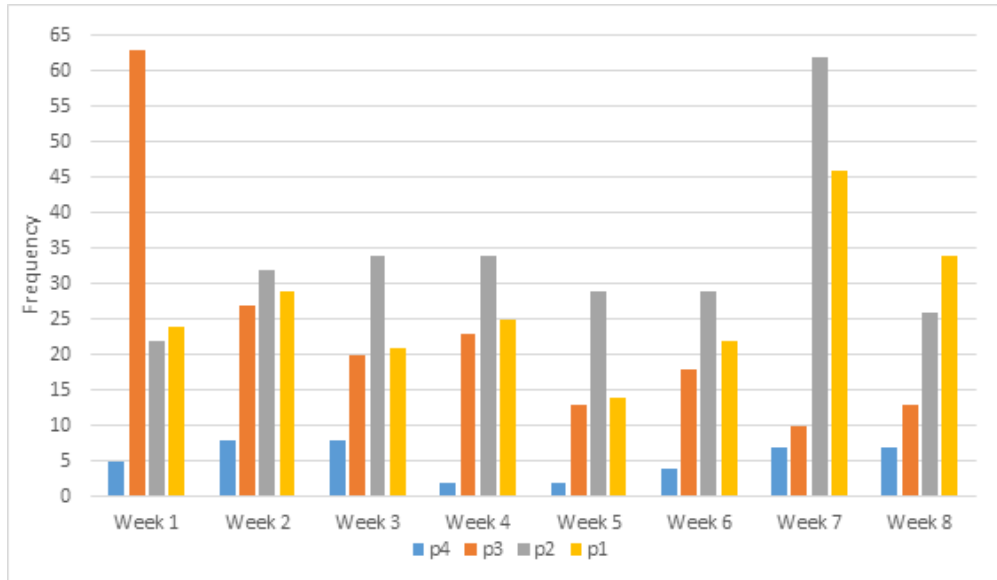


Figure 3.3: Syncing Smartwatch Steps.

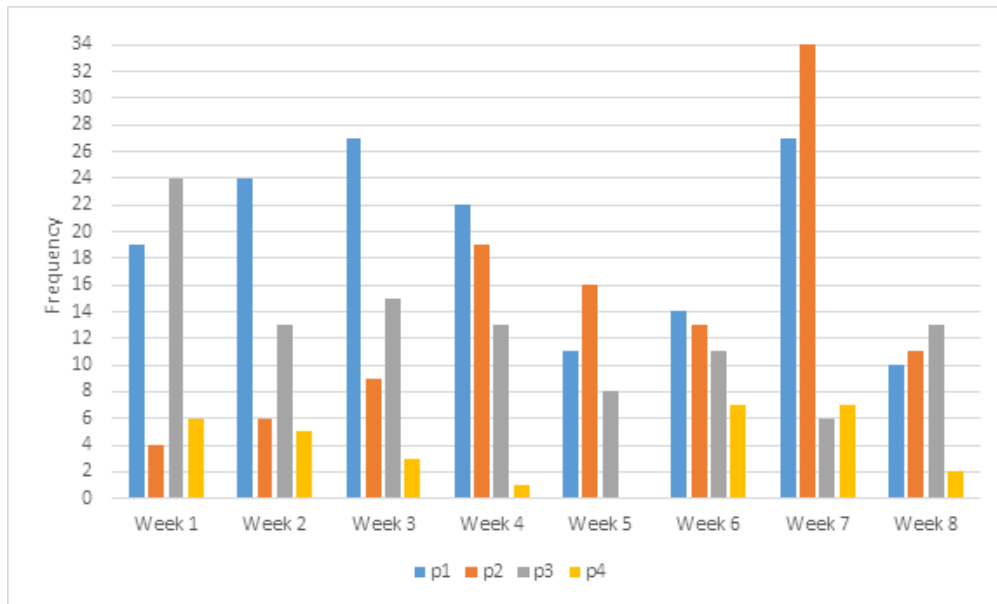


Figure 3.4: Android App Usage Count Per Week.

additional physical activities as needed, stating “I’d watch [P1s] numbers go up and go up... I had it on my watch, right there... I could keep track of where I was at and if I needed to...

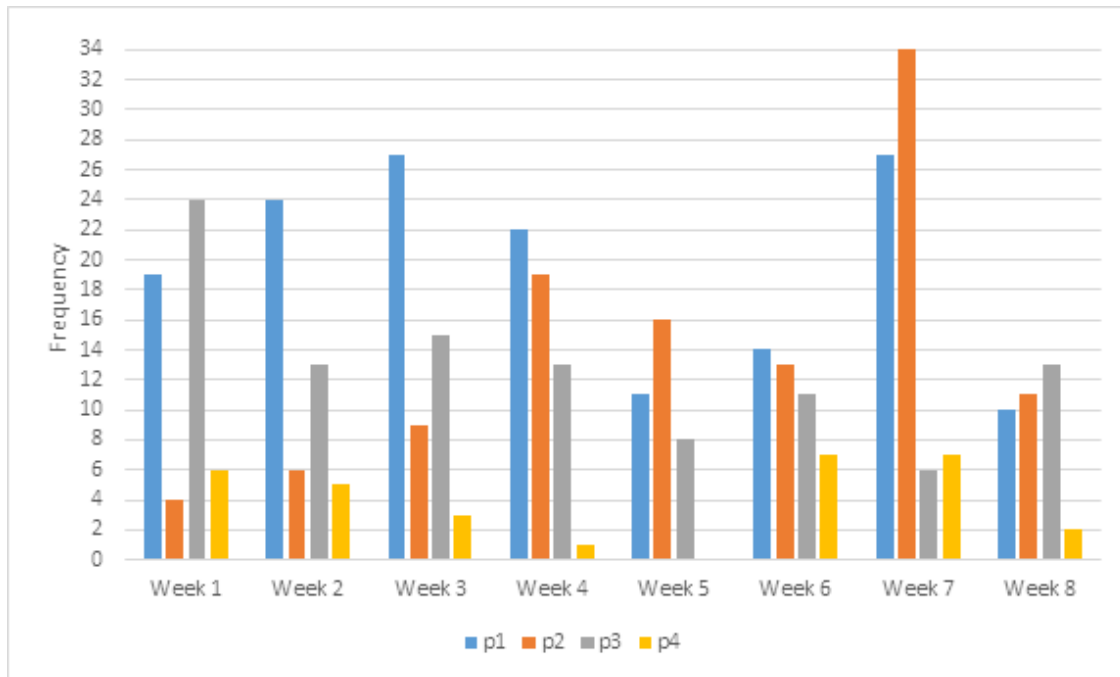


Figure 3.5: Android App Usage Count Per Week

walk some more”. P1 also checked the smartwatch numbers, using it as motivation: “It is awfully easy... to spend a lot of time on the computer... sometimes I just need a little bit extra intensity to get me going. So seeing the numbers made me do it”. P2 and P1 claimed they would joke with each other about the competition, reflected by frequent swaps in step count leads (see 3.5).

In terms of the system usability issues, users complained about how the system captured their progress. When participants force-synced (a way to push the steps from the watch to the companion app and then the website) manually, the tracked progress from the smartwatch recorded the time of the sync instead of the actual moment of when the steps were captured. This created situations where users observed “peaks” in their progress time chart (P2: “... it

looked like I did 12,000 steps at 11 o'clock at night ...", P3: "It would be great if those[steps] were more in real time now instead of just being in whenever someone syncs their phone then it updates that information...").

3.2.4 Discussion

FitAware showed preliminary support for participant competition and interaction (even in teams as small as the ones described in this study) thus leading to stronger perceptions of group cohesion. These findings were encouraging, especially when considering the fact that group dynamics-based community interventions delivered via remote mediums such as web (as opposed to supervised in-person practices) are known to suffer from low participant engagement and high attrition rates [51], thus failing to increase group cohesion. Strengthening of the sense of group cohesion is key in group dynamics-based intervention as it facilitates behavior change. The use of smartwatches with custom watchfaces to display group dynamics related information, provided positive preliminary results with regards to invoking participant behaviors suggestive of group cohesion, thus potentially leading to the positive behavior changes. Overall, these preliminary findings helped refine the hypotheses associated with RQ1 outlined in Chapter 1.

In terms of the usability issues, the representations of past physical activity progress on the companion smartphone app were not always accurate because the watchface only saved and synced the maximum step count for any given moment. This behavior led to situations

where smartphone app progress charts had unrealistic spikes due to the watch skipping one or more syncing cycles (Reasons: Bluetooth out of range etc.). Additionally, numerous user complaints received during the study due to the progress visualizations not loading, or loading inconsistently. These issues were attributed to the fact that the visualizations in the smartphone app were rendered as embedded webpages from the program website. And finally, the use of HTTP protocols for the data exchange between the smartphone app and the website sometimes led to session timeouts and appeared to be suboptimal for battery performance as the smartphone performed periodic 'pull' requests in order to receive updates. These issues were resolved for the statewide deployment described in the next chapter.

Chapter 4

FitAware Experience

This chapter focuses on the statewide deployment of FitAware and its evaluation with a focus on awareness from the glanceable feedback and its influence on group processes as well as individual behaviors manifested in physical activity behaviors, group interactions and engagement with the system. Section 4.1 describes the updates to FitAware in response to the usability issues identified in Chapter 3. Section 4.2 describes the statewide recruitment process and the results of the recruitment effort. Sections 4.3 and 4.4 cover the pre and post study procedures. Section 4.5 describes the methods for data capture and analysis used in this study, and Section 4.6 presents the results of the study. Section 4.7 revisits the hypotheses from Chapter 1 and the design objectives from Chapter 3 in the context of the results and concludes by presenting a series of implications. The results covered in Section 4 have also appear in published/accepted papers. Parts of subsections 4.6.1 and 4.6.3-4.6.7 will appear in PervasiveHealth 2018 [41], and some parts of subsections 4.6.1 and 4.6.3-4.6.5

appeared in the proceedings of ACM GROUP 2018 [42].

4.1 System Redesign

In recognition of the results from the initial small scale deployment discussed in Chapter 3 the entire system was revised.

Web. The mechanism of the information exchange between the smartphone app and the website was moved from pull based HTTP protocol to a push based Socket.IO implementation. This change allows the Android app to reduce power consumption and the push capabilities of Socket.IO allow the website to deliver updated information (ex. team steps, rankings) to entire teams at once.

Smartphone. The smartphone app offers a revised user interface for all four views. In the current implementation, all of the views are rendered natively as opposed to embedding webpages from the website. The progress charts for individual and team progress adopted MPAndroidChart [83] library to display daily time series for the total step count.

Smartwatch. The smartwatch watchface, while looking identical to the previous version, was updated to buffer data logs in local memory and transfer it to the phone every 15 minutes. The API for this features does not allow for explicit control of when and how the data is transferred to the smartphone. Repeated testing with Motorola X 2014, Google

Pixel, LG G Flex 2, LG G2/3/4, Samsung Galaxy Note 4/5, Samsung Galaxy S4/S5/S6/S7 confirmed that the data logs successfully transfer every 15 minutes. The watchface data log captures user steps every 5 minutes and also preserves the snapshots of the information displayed on the watchface. Furthermore, the with the updated approach the watchface can buffer up to 24 hours of data, thus preserving the progress that users captured irrespective of whether their smartphone was connected or not.

4.2 Statewide Deployment Procedures

4.2.1 Recruitment Process

FitAware was advertised during the recruiting stage of a statewide community outreach organization for a web-mediated group dynamics based physical activity intervention program. Interested participants (representing a small subset of the total program participant pool) completed a short survey allowing us to determine their eligibility based on their type of phone, willingness to wear a Pebble smartwatch, and the availability of friends, family, and coworkers who also met eligibility requirements. Eligible participants were contacted and individually assisted with the system installation and setup. This work asked participants to complete the program registration, which included demographics survey and physical activity goals. Participation in the study was voluntary with no compensation for completion.

4.2.2 Recruited Teams and Participants

The community outreach organization recruited 275 individuals in total, of which 27 were interested and eligible to use FitAware. These 27 contributed to 9 groups in our study. Per our eligibility criteria, groups were composed of individuals older than 18 that shared an existing social circle, with some or all of members equipped with an Android smartphone. Of the 9 groups (see Table 4.1 for the detailed breakdown), 4 groups had 4 FitAware users, 2 groups had 3, 2 groups had 2 and one group had only one FitAware user (one of the eligible members opted out from signing up for the study leaving the only other one alone). Groups g1, g9 and g6 were composed of strictly FitAware users while the other groups had two or more web users in each (web users had to manually enter their progress via the interventions web interface). All 27 participants were full-time coworkers and often worked in the same department or office (with the exception of g3, where all three members worked in different offices) and shared the same cubicle space (g1), floor (g9, g3, g5) or building (g2, g4, g6, g7 and g8). The occupations of the participants differed and included front desk receptionists, government clerks and university lab technicians. The participants varied in terms of age (23 to 61), gender (20 female/7 male), and race (20 Caucasian/5 African-American/1 Native-American/1 Asian), BMI (21 to 46) and education level (12 post college/9 college/5 some college/1 high school).

4.3 Pre-study Procedures

During the initial in-person meeting the participants registered on the website to create their account, choose a role (regular participant or captain), form teams (a captain can invite members into team), set goals and to provide demographic information such as age, sex, weight, height, education level, race and health status. Upon signing the consent form, the participants were asked also to complete the Social Support for Exercise Survey (SSES) [33] which is used to capture an individuals perceived levels of social support for exercise during the past three months, via Likert scale responses to questions that inquire about occurrences of collective exercises, encouragement to exercise, instances of adjusting schedules to exercise together and others. This survey allowed us to determine the interpersonal factors of the members in the groups.

4.4 Post-study Procedures

At the end of the study, the FitAware participants were offered the chance to complete a post-study survey and half hour interview for a \$20 compensation. The survey asked about user experiences with the smartwatch via questions inquiring about the reasons for looking at the watchface, priority of the indicators on the watchface, likelihood of noticing changes in the indicators and the perceived degree of awareness of the indicators (see Appendix E). The survey also included questions to determine the levels of group cohesion of the teams via an adapted version of the Physical Activity Group Environment-Questionnaire (PAGE-Q)

[46] which is used to assess the levels of perceived group cohesion in the group via questions inquiring about competition, cooperation, interaction, and competition.

4.5 Methods

It is important to learn how the experience with the glanceable feedback from fitness smartwatches can influence user engagement and physical activity behaviors in a group setting. As stated in the introduction, this work seeks to determine how FitAware can channel underlying behavioral strategies via glanceable feedback about personal steps, personal rank, team steps, and team rank. This study explores FitAware impacts on physical activity behaviors, group behaviors, and system engagement.

4.5.1 Data Collection, Analysis and Survey Design

To better understand the variables inherent to field studies, a three-pronged approach was used that included surveys (to help quantify user perceptions about the experience with the system and their groups), system usage data (to explore participant physical activity levels and engagement with the system) and interviews (transcribed verbatim and thematically coded by five coders following a variant of a grounded theory approach [162] to learn about participant experience and clarify the results from the surveys and system usage).

Social Support for Exercise Survey (SSES) was used to measure the perceived levels of social support prior to the study. The scoring approach followed what is prescribed by the authors of the instrument [145]. The PAGE-Q, which was used to measure perceived levels of group cohesion, was modified to make its items better match the context of the study. The PAGE-Q produces measures reflecting perceived competition, interaction and communication, and cooperation each consisting of multiple items. To ensure validity of the modified survey, the reliabilities of each of the items in the measure were assessed. The competition measure consisted of three items (ex. “The experience with the Pebble smartwatch display made you want to be the healthiest person in this group”). All three items in this measure were reliable with Cronbachs Alpha at 0.89 (M =5.17, SD =1.32). For the cooperation items consisting of six questions (ex. “The experience with the Pebble smartwatch display led to many conversations about physical activity and exercise”), the alpha was 0.910 (M =2.59, SD = 0.70). And finally, for the two questions forming the cooperation measure an alpha of 0.938 (M =4.48, SD =1.69) was obtained.

As the primary focus of the analysis was to understand how the experience with the watchface indicators influences physical activity behaviors and engagement with the system in the context of groups, Pearson’s correlation analyses were used to explore potential links between group/individual characteristics and physical activity levels as well as engagement with the system. T-tests were used to confirm the significance of observed correlations and identify categories.

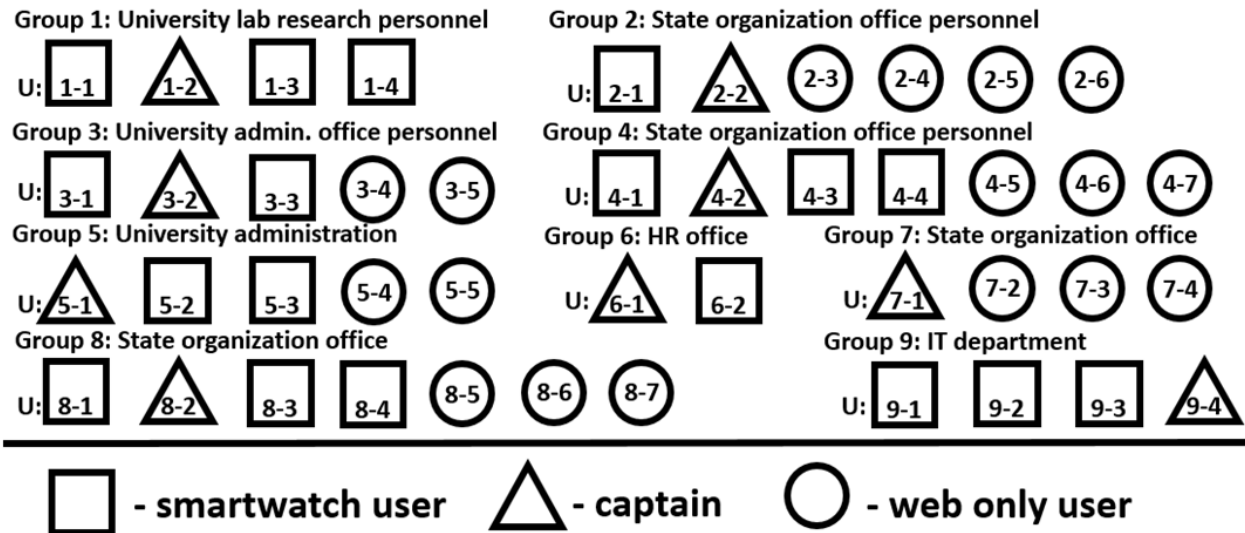
4.6 Results

This section describes the results from the statewide deployment of FitAware. The results are both quantitative and qualitative offering a mixed-methods perspective on the user experience with FitAware. Parts of the subsections 5.5.1, 5.5.2, 5.5.3,5.5.4, 5.5.6 and 5.5.7 appear in the proceedings of PervasiveHealth 2018 [41] , some parts of the subsections 5.5.1, 5.5.3, 5.5.4 and 5.5.5 appear in the proceedings of ACM GROUP 2018 [42].

4.6.1 Participation

Of the 27 participants that were set up to use the smartwatch three dropped out in the first three days (one of the three dropped out because she already was part workplace walking group that used Fitbits and did not want to wear two devices on the wrist), leaving 24 participants that completed the 8-week long study (see Table 4.1). Of the 24 participants that finished the study, 23 yielded usable system tracking data (u1-4 had a smartphone with faulty Bluetooth, preventing data from being received from the smartwatch), 21 responded to the survey and 20 participated in the post-survey debriefing interviews.

Table 4.1: Recruited teams and their composition (all captains were smartwatch users).



4.6.2 Connected vs Mixed Groups

Upon investigating the survey responses for the SSES a strong correlation between the group size and the degree of perceived social support ($r = 0.496$, $p = 0.022$) was detected. Groups with more members reported higher levels of perceived social support. Further analysis revealed that there is also a significant difference in terms of the SSES responses between the groups with four smartwatch users (g1, g8 and g9) and other groups with fewer smartwatch users, ($t(16) = 2.636$, $p = 0.018$).

Interviews reveal that the more connected groups namely g1, g8 and g9 had members that asked each other to go on walks (u1-3: “We would we often ask each other to go on walks... like in the afternoon if I’m going out of work which I tend to do anyway I’ll stop by that office where they ‘all live’ and ask if they wanna come with me”). Which led to lunchtime

walks (u9-1: “I walk with them sometimes I walked with u9-4 at lunchtime frequently”) or regular walks at designated place (u8-2: “so I would try once a week hey team, hey let’s go walk the track and I would get me and u8-1 and u8-4 would all be the ones who would go consistently”).

Conversely, for the ‘mixed’ groups the interviews revealed a situation where participants felt disconnected from their group (u5-1: “I didn’t care and I didnt feel like I was part of the team and we werent getting out and walking”) and pointed out that not engaging in group activities demotivated them (u2-1: “you know we really didn’t we do things together and we rode in my opinion for whatever reason we never really came together as a team is not that really didn’t get it, I think if we had done more things together maybe and really kind of encouraged each other maybe I would have been more interested”).

With regard to the glanceable feedback from the watchface the survey responses to a question inquiring about whether participants felt encouraged to engage in physical activity from the watchface indicators (“The information from the indicators encouraged me to engage in physical activity”) found that the average ($M = 6.0$) for the groups using only smartwatches (g1, g8 and g9) was significantly higher than the average of the other groups ($M = 4.33$, $t(20) = 2.352$ $p=0.029$).

Further results also reveal significant differences for the two groups and thus for the sake of convenience we will refer to g1, g8 and g9 as “connected” groups and the other groups as

“mixed”.

4.6.3 Smartwatch Wear Consistency

Since the system relies on users regularly receiving glanceable feedback we measured user adherence to wearing the watch and counted active days of wearing for each user. For active days we considered the days during which the continued steps increase for at least 8 hours during the day (8am-8pm) with periods of inactivity (no progress change) shorter than one hour (time necessary to charge Pebble). We devised this particular approach for counting days as active due to all of the FitAware users being full time employees. On average, the 23 participants had 5.22 (SD = 0.29) active days of smartwatch use per week (see Figure 4.1). Debriefing interviews revealed some of the reasons for not wearing the watches which included leaving it charging (“Forgot it was charging”) and forgetting to put it on (“Simply because I would forget to put it on.”).

A significant difference ($t(16) = 2.375, p = 0.03$) was observed between the ‘connected’ groups and ‘mixed’ groups for the consistency of wearing the smartwatch. The average number of active days per week for the two groups remained steady throughout the 8 weeks (See Figure 4.1).

In addition, we examined differences between groups in terms of social support. Overall, the users active days significantly correlated with the perceived social support ($r = 0.502$,

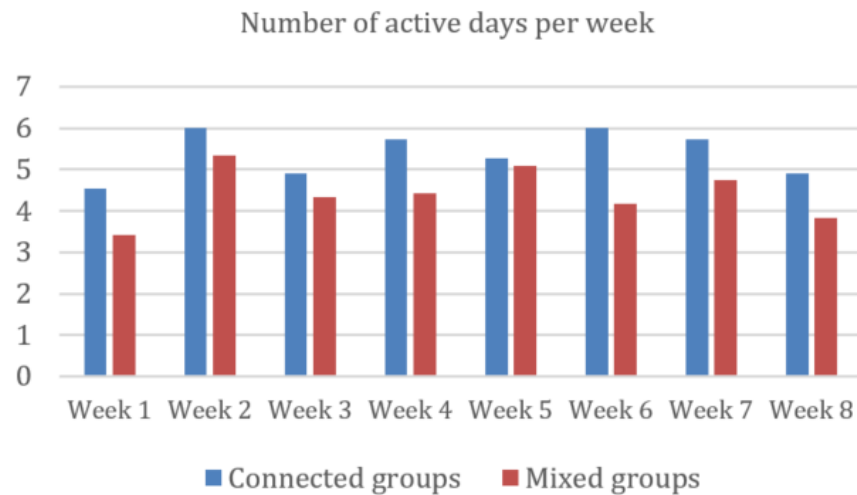


Figure 4.1: Connected groups wore the smartwatch more consistently.

$p = 0.028$) provided by the smartwatch app as well as the interaction and communication dimension from PAGE-Q ($r = 0.49$, $p = 0.025$). The results are suggesting that the groups with higher levels of perceived group cohesion had more active days.

Interviews revealed one factor that potentially helped the 'connected' groups in achieving higher consistency in active use of the smartwatch were reminders from the group captains (u9-2: "u9-4 said 'I don't think you u9-2 are syncing' so I would check it and make sure it was syncing, make sure I had something on the graph") that checked on their group member's progress in order to decide if they need to check in person (u9-4: "If they were really low on steps I would go and definitely check with them to see if they are actually not active or like they have like other issues."). We also learned that the workplace meetings for the group members provided opportunities to inquire about any program related issues preventing the

watch from being connected to the phone (u1-3: “We talked about it a lot like at meetings or just in passing with people, cuz sometimes like one person’s you would see one persons phone wasn’t syncing, so we would talk about that or we would talk about how... where are you ranked in the group. I think u1-2, at least a few people would use app to see like who is pulling the group up so high that was also a topic of conversation”).

Conversely, interviews showed that some members from the ‘mixed’ groups did not feel motivated to wear the watch (u5-1: “I went to put it back on again, a couple days later it wasn’t charged I didn’t charge it[smartwatch], didnt do anything and I think by this time I didnt care anymore to be honest”) and experienced weak group cohesion (u5-2: “we never were together as a group, we did walk together maybe once or twice”).

4.6.4 Glancing at the Watchface and Peripheral Awareness

As FitAware relies on glanceable feedback being frequently received we investigated the reasons for glancing as well as frequency. In terms of the primary and secondary reasons for looking at the FitAware watchface, the survey results reveal that users typically looked at the watchface because of the personal steps and time indicators as well as incoming notifications (See Figure 4.2). User response to survey questions about frequency of glancing at the watchface show that 7 users do so between 4 and 5 times per hour, 4 users more than 10 times per hour and the rest 2-3 times per hour or less (see Figure 4.3). One participant that responded with “10+ times/hour” explained that, as a captain, she wanted to ensure

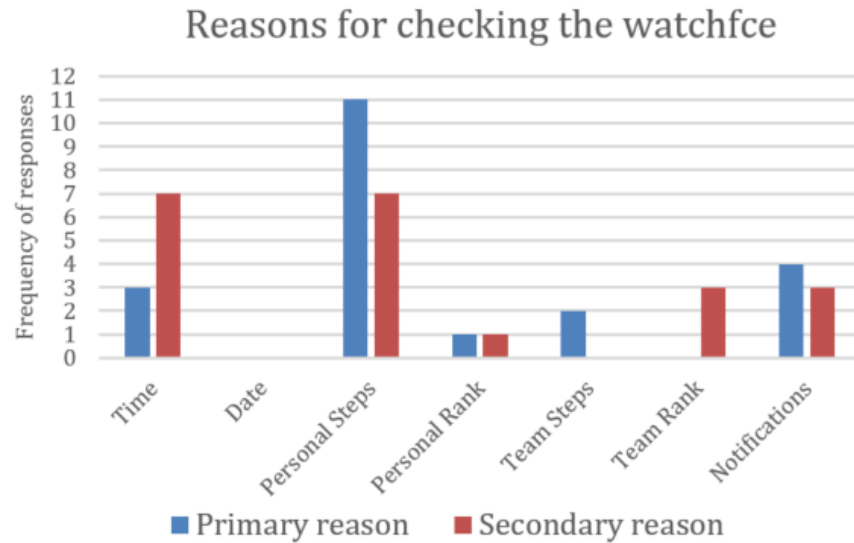


Figure 4.2: Primary and secondary reasons for checking the watchface.

that the group members were contributing steps (u8-2: “Well, I’m the team captain so I was checking that everybody was remembering and syncing properly”).

Participants rated the likelihood of noticing indicators for personal steps, personal rank, team steps and team rank at 6.62, 6.20, 5.90 and 5.62 on a scale from 1 to 7 (See Figure 4.4). Responses for personal steps and team rank were significantly different ($t=4.088$, $P < 0.01$) suggesting that on average users were more likely to visually notice personal steps than team rank when looking at the watchface.

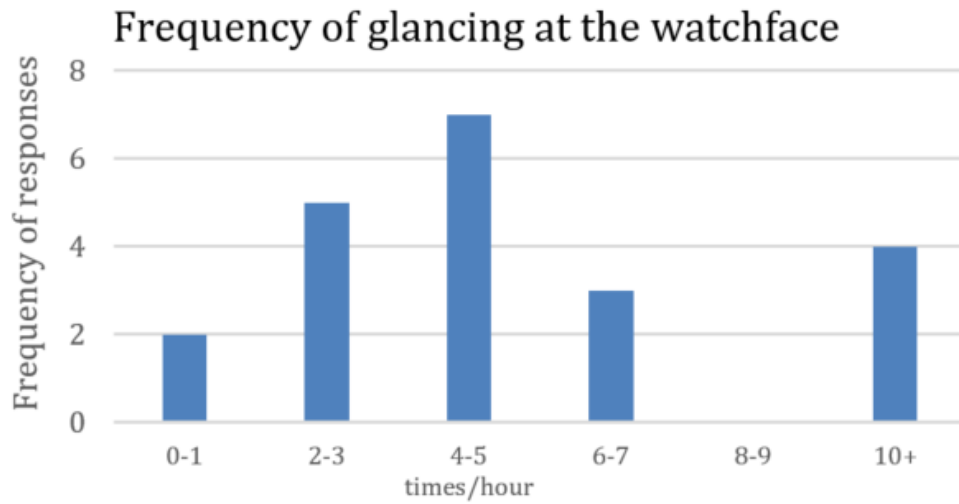


Figure 4.3: Most users self-reported looking at the watchface many times each hour.



Figure 4.4: Results from the survey and the accuracy of measured awareness based on recall for typical indicator values at the end of day.

4.6.5 Personal and Group Information Awareness Levels

4.6.5.1 Noticing Changes in the Indicators

Noticing changes in the indicators is desired as it will contribute towards increasing awareness from the feedback. Users' degree of agreement that they noticed changes for personal steps, personal rank, team steps and team rank is 6.10, 5.38, 4.76 and 4.62 on a scale from 1 to 7. Responses for the personal steps indicator are significantly higher than team rank ($t=4.088$, $P < 0.01$), team steps ($t=3.229$, $P=0.03$) and personal rank ($t=2.096$, $P=0.043$). The user responses are reflecting frequency with which the indicators update. Personal steps, for example, updated almost continuously (the indicator would update in response to detected steps within seconds) as opposed to other indicators that only updated every 15 minutes.

4.6.5.2 Self-reported Awareness

Users rated their awareness for the feedback from the four indicators comprised of personal steps, personal rank, team steps and team rank at 6.33, 6.24, 5.38 and 5.14 (on a scale from 1 to 7) correspondingly. Analyzing for significant differences for the responses shows that users reported significantly higher awareness for personal steps than team steps ($t=2.955$, $P=0.005$) and team rank ($t=3.344$, $P=0.002$), also the responses of personal rank are significantly higher than those for team steps ($t=2.979$, $P=0.005$) and team rank ($t=3.369$, $P=0.002$), which is suggestive of stronger within-group awareness.

4.6.5.3 Measured Awareness

To measure awareness of feedback from the indicators, the survey asked participants to recall indicator values for a typical day. 21 survey participants provided responses for personal steps and personal rank, 19 for the team rank, and 17 for team steps. Shapiro-Wilk normality tests showed all 21 participants exhibited distributions close to normal for personal steps, but 4 participants did not have normally distributed end-of-day values for team steps due to some group members self-reporting progress ($P < 0.05$), and 4 participants did not provide answers for team steps. Thus we were able to measure team step accuracy for the 13 participants.

For all participants with normally distributed 'end of the day' indicated personal and group steps we define accuracy as $A_s = \frac{|S_r - S_m|}{S_r} * 100\%$ where S_r is the value reported by the user and S_m is the median end of the day value for the active days (i.e. the actual end of the day, typical or most frequent value). For the ranking indicators we measured accuracy differently since the values are often repeated. We define *ranking accuracy* as $A_r = \frac{R_r}{R_1} * 100\%$ where R_r is the frequency of occurrence of the reported rank and R_1 is the frequency of occurrence of the most common rank that was displayed on the watchface at the end of the day time indicated by the user.

Accuracy for personal steps, personal rank, team steps and team is 88.7%, 87.5%, 81%, and 62.6% respectively, see Figure 4.4. Independent samples t-tests reveal no significant difference between goals and reported steps ($t = -1.749$, $P = 0.088$). We found significant differences

between team rank accuracy and the other three indicators but no significant differences between personal steps, personal rank and team steps. This is suggestive of less overall awareness for the team rank than the other three indicators.

Variances for the accuracy measures for personal steps, personal rank, team steps and team rank are 1%, 3%, 4% and 9% respectively. Correlation analysis for team rank accuracy responses reveals significant correlations with the median of steps displayed at the end of the day ($r=0.504$, $P<0.05$) and competitiveness in the group ($r=0.61$, $P<0.01$). There is a significant correlation between the proportion of the active days during which the team rank was on the 'pedestal' (top 3 places) and accuracy of the team rank guess by the team members. The average accuracy of team rank accuracy results for the participants whose end of the day team rank indicator was in the top 3 for the most time (frequency of 50% or above) was 84.11% while other participants showed an average accuracy of 42.7%. Two tailed independent sample t-test analysis shows significant differences in the accuracy of the responses between these categories of participants ($t=4.005$, $P < 0.01$). The participants in top 3 all came from the groups that had at least 3 active Android users. On average the members from these groups reported significantly higher competitiveness than participants from other groups ($t=2.388$, $P=0.027$), as well the median of steps displayed at the end of the day ($t=2.289$, $p=0.034$). There was no significant difference in the active days between the two categories of participants nor in Android app use. There were also no significant differences in terms of the self-reported awareness or noticing changes of team rank between

these categories of participants.

4.6.6 Group and Individual Awareness Factors

4.6.6.1 Personal Steps

The personal steps indicator provides continuously updated feedback of daily steps. Responses to questions about noticing changes and being aware with regards to the indicator both reveal significant correlations with the number of active days of wearing the watch ($r = 0.527$, $p = 0.023$ and $r = 0.602$, $p = 0.005$ respectively). There were no correlations with other measures that we captured in the study including group cohesiveness and social support for exercise. The results suggest that users have a higher awareness of personal steps and are likely to notice changes as they wear the watch regardless of group size, support, or cohesiveness.

4.6.6.2 Personal Rank

The indicator for the personal ranking shows a numerical value based on user's current daily step count in comparison with other members'. Survey results show that the responses to the question about competitiveness ("The experience with the Pebble smartwatch display helped you do the same things the healthiest people of this group were doing") correlate with the survey responses about noticing changes ($r = 0.49$, $p = 0.024$) and being aware ($r = 0.460$, $p = 0.036$). These correlations suggest that competitive users tended to notice rank

changes more consistently.

4.6.6.3 Team Steps

In order to determine teams steps, the system calculates the sum of group member steps and provides an awareness of collective daily progress. A survey item asked participants how often they noticed team steps. Survey responses for noticing changes in the team steps significantly correlated with the cooperation ($r = 0.511$, $p = 0.018$) as well competition ($r = 0.683$, $p = 0.001$) dimensions of the PAGE-Q. These correlations suggest that a stronger sense of cooperation and competition correlates with more attention towards noticing changes in the team steps.

4.6.6.4 Team Rank

Team rank indicator provides feedback about group's rank in comparison to other groups and is based daily steps. Survey results show that responses to the question about noticing changes in the team rank ("I noticed changes in the team rank") indicator changes significantly correlate with PAGE-Qs measure of competitiveness ($r = 0.494$ and $p = 0.023$). This result suggests that user competitiveness correlates with them noticing changes in the team rank indicator.

4.6.7 Influence of the Awareness on Group and Individual Behaviors

4.6.7.1 Personal Steps

The interviews reveal that, regardless of group, users learned about how many steps their routines contribute (u1-2: “I couldn’t get out of the house in the morning and into my office without 3000 steps, so I knew that that is how much it would show up and start the day with”, u2-1: “To put a load of clothes in the washer I’m taking 35 steps going from upstairs to downstairs into the washer”), spotted situations of prolonged physical inactivity leading to initiation physical activity (u1-4: “I was just thinking about it so I’ve been sitting here for a little while, oh well yeah you have 2000 steps, probably should get up and walk around the building”), and monitored success towards achieving the daily goal (u8-2: “I’m very competitive but when I looked at my watch and saw that I only had 4000 steps and it was almost noon I almost had a heart attack so you have to have 5000 step by noon if you want to have 10000 back by the end of your work day so you can get 15000 steps by the end of the day all together”).

4.6.7.2 Personal Rank

Interviews with connected groups participants reveal that they reacted to personal rank changes even when the step count was high (u1-4: “Yeah so if I had like 10,000 steps and I’m still ranked third then it made me want to get more and because I had already done a lot

and it is still as third”) and tried to maintain higher ranking through more walks (u1-3: “I would always try to be number one as much as I could so I would like to go on longer walks and you know also the weather was changing it was kind of timed nicely to spring so you could do more and more activity”). Some admitted to just shaking their hand in an attempt to improve their personal rank (u1-3: “I remember one time I went to bed and I had gone to the bathroom and I was 1 and I went back into the room then I was 2, so lying in bed I was like this [shakes her hand] [laughs] and husband was like ‘what is going on??’ So I would modify my behavior to be number one again.”) leading to a friendly banter with the group captain (u1-3: “And I told u1-2 about it and she got annoyed – ‘You are cheating!’”). Others remembered surprising situations where their rank was low despite high personal step count (u1-4: “I played the volleyball tournament all day and I was tired I was very tired and I still like 4th out of 4, I took a picture of mine with the camera. I was supposed to go, I had almost 16,000 steps and I was tired and sore and I was still only 4th.”).

The observations of the personal rank also led to friendly banter between group members (u9-3: “u9-4 would come in start complaining about it [not being number one] ‘how did you beat me last night?’ that sort of thing [and] I would just smile at her usually ‘u9-4, you know I walk more than you do’”) However, for another group, noticing personal rank did not result in any reactions (u5-3: “I saw it, but it would be like ok cool, but it wouldn’t register in terms of ‘oh I have to be number 1’. I would see it I would recognize it but that wasn’t going to motivate me to be number one in the group”).

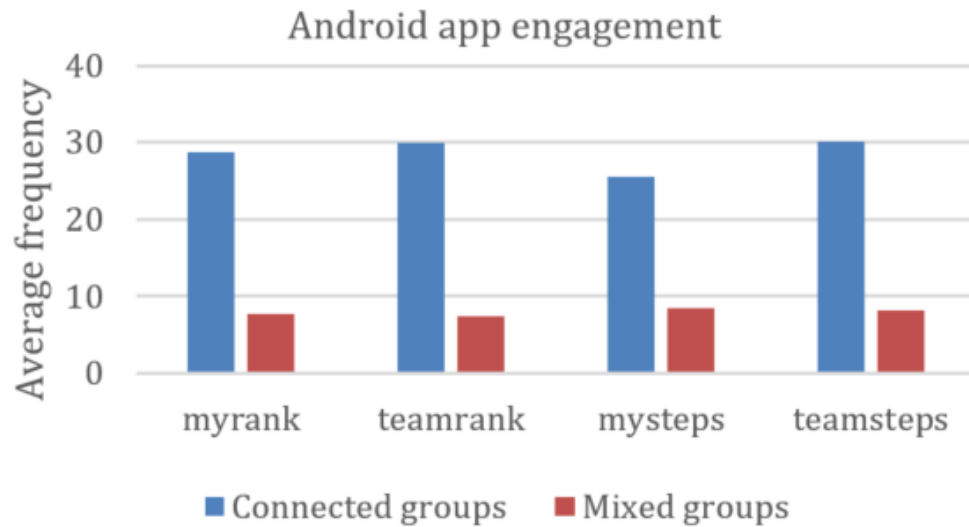


Figure 4.5: App engagement frequency throughout the 8 weeks. Participants from the connected groups had significantly higher engagement levels.

It is also notable that the members of the connected groups demonstrated awareness of who is at what rank (u1-2: “Yeah like I’m usually I’m always number one in the morning because I’m the one that’s up in the morning and then u1-3 would sometimes overtake me cuz she gardens a lot in the evening and u1-4 overtake me because she walks to and from work and also walks her dog a lot she hikes on weekend”) and had a general tendency to be curious about their members’ rank (u1-1: “We would kind of help members of the connected groups put their personal steps in the context of the collective steps (u1-3: “Basically I would be subtracting my steps from the team steps to figure out how much of my steps was the percentage. I just wanted to see how much ass I was kicking”) and use that information as a motivating factor (u1-4: “If I noticed that my steps were pretty far behind everybody else, I would try to have more steps or if I had a lot of steps and I wanted to stay high ranking I

would try to do more steps”).

The interviews show that the captains from the connected groups looked at the team steps to check on their group members’ progress to make sure they were active (u1-2: “If I thought our cumulative step count was low for the day I would go and check to see if someone wasn’t updating.”, u8-2: “ sometimes I would check and make sure that the other people were syncing correctly because I can see that on there if it’s 2 in the afternoon and u8-1 has had 800 steps I know that something is wrong so I can check that on there[companion app]”, u9-4: “If they were really low on steps I would go and definitely check with them to see if they are actually not active or like they have like other issues that we can help with”) and for knowing who is contributing the most (u1-3: “at least at least a few people would use the app to see like who is pulling the group up so high that was also a topic of conversation”). Some users checked the team steps chart and felt motivated to walk more if they were close to the leader (u9-3: “If I saw I am number 2 there[watchface] then I looked the chart [companion app] ... I usually like to look at the chart... and saw that I was close enough to maybe be number one, that would encourage me to walk more”) also the chart served as a way to learn about group members’ physical activity habits leading to adoption of novel behaviors (u9-1: “It[team steps chart] made me aware of how long I sit without moving and so then I was aware of ‘Oh hell I sit still for 3 hours at a time’ and you know other people are moving around all morning and so that was a health change for me.”).

4.6.7.3 Team Rank

Interviews show that captains of connected groups were attentive to team rank changes (u1-2: “I mean yeah I would notice that, I’d especially notice if we were usually we were about number 3 out of 57 that I would notice if we, like we were 2 or 3 out of 57 so then I would notice”) and acknowledged success to group members (u1-1: “u1-2 would send ‘Guys, we are 1st out of all 57 groups!’”) as well as enjoyed seeing it (u8-2: “Every single day it says we were team member 1 out of 57 and I really liked seeing that!”).

Regular participants, including those from the connected groups, did not pay as much attention to the team rank (u1-4: “I noticed it but it wasn’t it wasn’t like my primary focus”) as they paid more attention to their own progress (u1-1: “The team ranking was not one of the things that really stuck out in my mind most of the time. I was more concentrating on my steps.”). In some cases participants were discouraged by the overly frequent changes in the team rank (u7-1: “I would see it fluctuate and I wouldn’t get much of a reaction out of me because of that”, u2-1: “to me they changed so much it just started not being very motivating”) as well as by lack of knowledge about the groups against which the ranks were computed (u9-3: “It was unlikely for me to look at the team rank and I think I said this later on, I didn’t have a good feel for how many teams were actually actively participating. who are all these 57 teams maybe if I knew more about them or... where they all active?”).

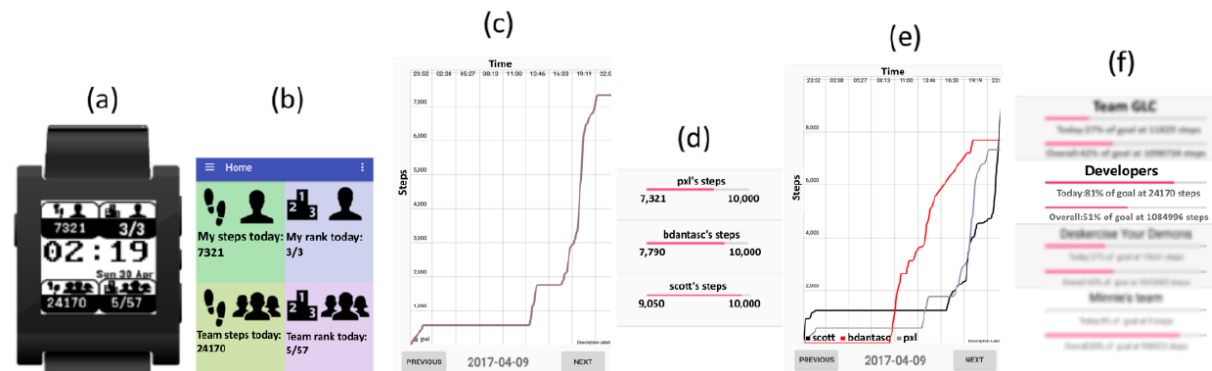


Figure 4.6: From left to right: a) FitAware Pebble smartwatch watchface; b) companion app home screen; c) personal step view plotting steps vs time; d) team view individual rank with group member steps and goals; e) day view group member steps for steps vs time; f) team list with goals, daily, and total steps.

4.6.8 Companion App Engagement

The companion app view for the personal steps (see Figure 4.6 b) allows users to see a cumulative chart for any given day. In terms of the frequency of opening that view the connected groups opened it significantly more times than the mixed groups (t-test for the sample means is significant at $P=0.03$). Interviews did not reveal utility of this view.

The companion app's personal rank view extends the watchface indicator by including information about specific user steps as well as the progress towards daily goals (see Figure 4.6c). Participants from the connected groups opened the 'my rank' view significantly ($t(16) = 2.393, p = 0.029$) more times than the participants from the mixed groups (see Figure 4.5). Interviews show that 'my rank' was used to get detailed step-count information about

their group members (u1-2: “I know what my rank is but I don’t actually know an absolute number of steps for each person unless I go to my app and really look that up.”). The detailed information from the app provided more specific context for competition (u8-1: “I would access the app on my phone to see who was where and then, of course, I would try to compete with them”). Team captains also used it as a way to make sure their group members were tracking steps (u8-2: “I would check and make sure that the other people were syncing correctly because I can see that on there, you know if it’s 2 in the afternoon and u8-1 has had 800 steps I know that something is wrong so I can check that on there and text her to the make sure it is working out correctly”).

From the perspective of engagement with the smartphone companion app’s team steps view, members from the connected groups opened it significantly more times than members from the mixed groups ($t(16) = 2.469, p = 0.025$). Interviews reveal that the members of such groups would look at the steps of their teammates (u9-3: “We’re just pointing out things to each other like ‘hey look’ you know like ‘u9-4 started right here she started halfway up today, how did that happen? and stuff like that.”).

The companion app’s view for the team rank provided a comprehensive list of teams and allowed users to check current day’s and overall ranks and progress towards group’s daily and overall goals (see Figure 4.6d). Interviews reveal that captains of the connected groups checked the overall rank (u8-2: “towards the end sometime it would be team number 4 out of 7 for a little while and then I had to check to make sure we weren’t overall team 4 out

of 57 cuz I would have been horrible”) and then motivated their groups to be active (u9-4: “towards the end we were like the top one or two so and then were almost losing it so then we would I would almost like nudge them every day and go to them and say you know the program and say ‘we are almost there, we should be winning’ ”) as well as to ensure group members connectivity with the smartphone (u8-2: “Usually I was checking my overall team rank I always wanted to know if we gone up sometimes I would check and make sure that the other people were syncing correctly”).

4.6.9 Physical Activity Levels

To assess the physical activity levels, we measured the number of weeks for each participant during which the average daily steps for the week met or exceeded the individual goal. Results show that the all of the participants on average exceeded or met their daily individual goals for 4.82 (SD =2.85) weeks (see Figure 4.7). It is notable the that the result is significantly ($t(20) = 3.16, p = 0.005$) higher for the ‘connected’ groups ($M = 6.3$ weeks) than for the ‘mixed’ groups ($M = 3.33$ weeks). Furthermore, all members from the ‘connected’ groups met their goals for at least 5 weeks (with the exception of u9-1 who suffered a serious illness during the study).

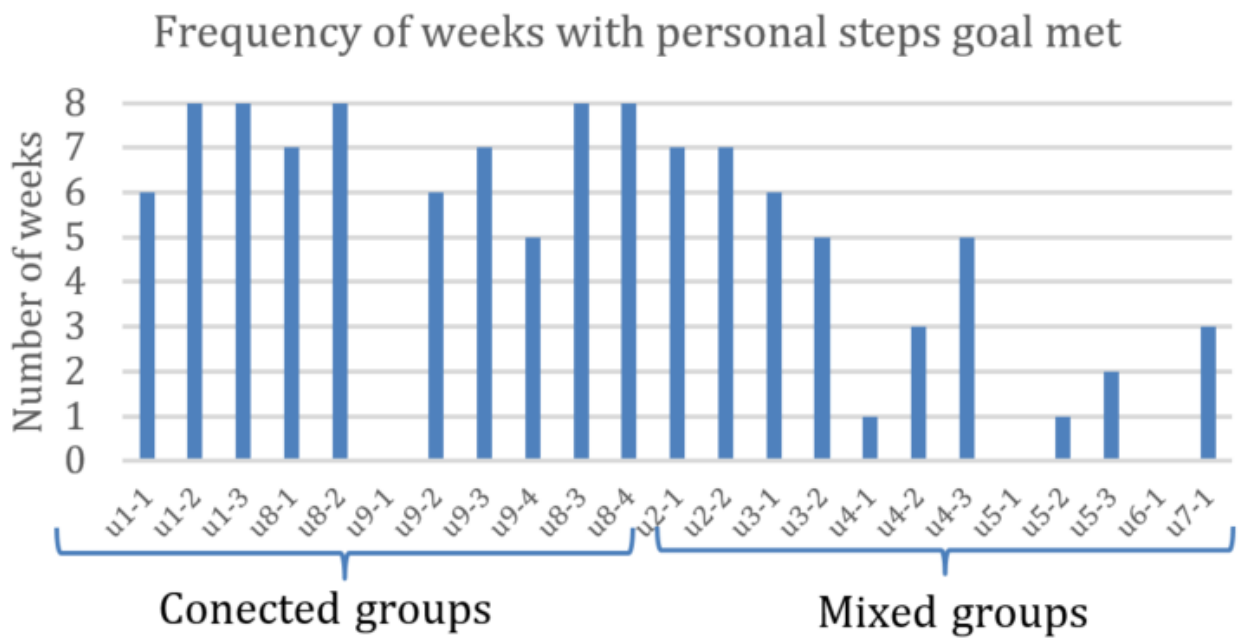


Figure 4.7: 'Connected' groups had significantly higher number of weeks during which their average daily steps met or exceeded daily goals.

4.6.10 Thematic Interview Transcript Analysis

Twenty participants took part in the semi-structured interviews. Interviews were 28.8 (SD=4.28) minutes long and resulted in over 700 meaning units associated with the various aspects of the participant experiences with FitAware, the program, and other participants. Over 29% of the meaning units (n= 206) were related to the interpersonal factors (See Table 4.2) and contribute to a theme of “Interpersonal Factors” and categorized under three sub-themes, each containing 89, 59 and 58 meaning units. The second largest theme focuses on various aspects affecting the day-to-day use of FitAware and (“FitAware Use” as seen in Table 5.3) is represented by 188 meaning units divided into two sub-themes of 97 and 91 meaning units. The next theme of 155 meaning units is split into two sub-themes of 82 and 71 meaning units and focuses on the user awareness of the indicators on the watchface (“Watchface Feedback Awareness” as seen in Table 4.2). The remaining 154 meaning units (herein: MU) capture participant experience with the updates in the glanceable indicators on FitAware and contribute to the theme of “Feedback Update Reaction and Comprehension” (see Table 4.3) which includes two sub-themes with 89 and 65 meaning units in each.

4.6.10.1 Interpersonal Factors

The sub-theme of “Competition and Cooperation” (See Table 4.2) is an aggregate of five categories each of focusing on various aspects of the competition and cooperation that took place during the 8 weeks of the study. The first category (“Captains Motivating and Facili-

tating Group Member Tracking Adherence ”) captured how the motivated captains ensured that participants in their groups wore smartwatches and tracked physical activity (“Well, I’m the team captain so I was always, you know, checking... only four of my 7 members had the watch... but I like to keep an eye on make sure that everybody was remembering [to wear] and that everyone was syncing properly”). The remainder of the categories capture the experiences of competition to best in the group or against a peer in the group as well as cooperation to contribute to the group progress in order to win against other groups. It is notable that six participants discovered that they are competitive despite thinking otherwise about themselves (“Yeah but I don’t consider myself a competitive person but then this watch did reveal that I am a competitive person”).

The second sub-theme (“Communication and Interaction” as seen in Table 4.2) is a composition of five categories that cover various aspects of communication and interaction within the groups. The top category in this sub-theme captures participant interactions manifested in comparing and viewing their physical activity progress together via the companion app or the smartwatch (“We’re just pointing out things to each other like ‘Hey look’ you know like ‘u9-4 started right here she started halfway up today, how did that happen?’ and stuff like that.”). The other four categories capture how participants would walk together, discuss progress over the weekend, talk about physical activity and wellness related topics and how the captains would encourage their teams either in person or electronically via emails or text messages.

The last sub-theme (“Barriers”) of “Interpersonal Factors” is represented four categories that reveal various barriers that adversely affected group dynamics. The issue of not everyone having the smartwatches in the groups was brought up by six participants (“It motivated the people on my team who had the watch, but the people who didn’t have the watch they didn’t care as much.”) so was the phenomenon of having limited interactions with certain group members (“She[captain] put u9-1 on the team and I didnt talk to u9-1 very much at all during the competition actually”). Members of one group revealed that they did not feel like a team (“So it was more about what I was... what I was accomplishing... cuz I didn’t feel like the team was really a team”) and that their interest declined (“I tried but it was like we weren’t really a team and we weren’t really, it was just I just didn’t care and I’m sorry to say that but it just didnt it just didnt you know like ‘It’s okay I tried, I have worn it to see what works”).

Table 4.2: Table segment: Interpersonal Factors, FitAware Use and Feedback Awareness.

Themes	Sub-Themes	Categories	N	P	Example Meaning Units		
Interpersonal Factors (n = 206)	Competition and Cooperation (n = 89)	Captains Motivating and Facilitating Group Member Tracking Adherence	27	8	Well, I'm the team captain so I was always, you know, checking... only four of my / members had the watch... but I like to keep an eye on make sure that everybody was remembering[to wear] and that everyone was syncing properly.		
		Group Competition	23	9	I would always try to be number one as much as I could, so I would like go on longer walks and you know also the weather was changing it was kind of timed nicely to spring so you could do more and more activity		
		Team Cooperation	19	6	When u9-1 didn't have her charger we all we all chipped in and tried to get it done		
		Becoming Competitive	11	6	Yeah but I don't consider myself a competitive person but then this watch did reveal that I am a competitive person		
		Peer Competition Withing Group	9	3	I wouldn't say that makes me competitive, it just gives me a goal to annoy u9-4 and that's when i would feel competitiveness.		
		Communication and interactions (n = 59)	Viewing Progress Feedback Together	15	5	We're just pointing out things to each other like 'hey look' you know like 'u9-4 started right here she started halfway up today, how did that happen?' and stuff like that.	
	Walking Together	14	5	I would send encouraging text messages and that every so often we would do a walking meeting but it's not that we would schedule to walking group... so we were less formal about it			
	Captains Encouraging Groups	12	5	If we were 1 out of 57 and I would text everybody and say 'good job' when we come in on a Monday for instance we always give a recap of what we did over the weekend and that that was one of the first things that would come to my mind			
	Weekend PA	10	7	We would walk around the park and you know we would say what we had today as a meal and they would find healthy options a healthy way to make them better before we would all share the recipes			
	PA & Wellness	8	3	So it was more about what I was... what I was accomplishing... cuz I didn't feel like the team was really... a team			
	Barriers (n = 58)	Group Cohesion	21	3	I tried but it was like we weren't really a team and weren't really, it was just I just didn't care and I'm sorry to say that but it just didn't it just didn't you know like 'it's okay I tried, have worn it to see what works'		
		Declined engagement	17	3	It motivated the people on my team who had the watch, but the people who didn't have the watch they didn't care as much.		
		Not Everyone Had Pebble Watches	11	6	She[captain] put u9-1 on the team and I didn't talk to u9-1 very much at all during the competition actually.		
Limited interaction		9	6				
FitAware use (n = 188)	Adherence Factors (n = 97)	Utility of Smartwatch Features	43	13	I would always leave my phone at my desk which is a good distance away and you know my watch pick up phone calls it would pick up text messages which was great I didn't have to put my phone on me just in case of emergency happened.		
		Sync Issues	28	12	The watch did not seem to be connected to the to the application and I didn't notice it and then early on I didn't really know how to fix that until I learned that if I went into the phone and I logged out and logged back in then it would reconnect.		
		Habit of Wearing	26	11	I just got into the habit of like just having it I can go to the shower and come back and whenever, just wear it, i do miss it -- not having it on my hand now.		
		Non Specific	30	16	Oh just glancing down and looking at it		
	Watchface Glancing Frequency Factors (n = 91)	Personal Steps	22	15	I would just check it 4 or 5 times an hour or so that's how that that, you know where I just be like 'how are my steps doing, do I need to get up, do I need to walk around, do I need to move around?'		
		Time and Date	17	13	I was looking at the time mostly... Again, because I'm a watch wearer		
		Notifications	14	7	When it buzzed that caused me to look at it if that makes sense.		
		Personal Rank	8	6	I want to know... so if it's a competition and I want to know if I'm first in my group.		
		Watchface Feedback Awareness (n = 155)	Typical Personal Steps Values (n = 82)	End of The Day	48	18	At the end of the day 10000 to 11000 ...10:30 11:00 at night.
				Morning	24	14	Usually in the morning I'll get up and walk on the treadmill so I usually have to 2 to 3 thousand steps before I get to work.
Lunchtime	12			9	Well, at lunch I try to walk at lunch, so at lunch I would make sure I had like 4 to 5 thousand.		
Typical Personal Rank, Team Rank and Team Steps Values (n = 71)	Personal Rank		26	14	Most of the time it was 2 out of 5.		
Team Rank	24	11	I think for the most part yeah yeah there were days that 3 or 4 were the norm but for the most part 1 or 2...				
Team Steps	21	14	I was thinking everybody was closer around 10,000				

4.6.10.2 FitAware Use

The sub-theme of "Adherence Factors" (See Table 4.3) contains three categories focused on various aspects influencing participant adherence to using the smartwatch. The top category ("Utility of Smartwatch Features") encapsulates how various standard smartwatch features

Table 4.3: Table segment:Feedback Update Reaction and Comprehension

Themes	Sub-Themes	Categories	N	P	Example Meaning Units
Feedback Update Reaction and Comprehension (n = 154)	Reactions to Changes (n = 89)	Seeking Additional Information on Group Progress	30	17	If I had looked at the watch and I was number one and then I looked again and I was number 2 then I would say 'Oh one of those people beat me', I would go look at who it was [in the app].
		Personal Rank Encourages PA	18	10	I would modify my behavior to be #1 again . And I told u-12 about it and she got annoyed -- 'You are cheating'
		Personal Steps Encourage PA	19	9	if I found myself very close to 10000 it made me walk more.
		Using Companion App to Resolve Tracking Issues	15	8	On the phone itself I just it was probably just trying to make sure that things were working and talking.
		Positive Emotions	7	5	I was always really impressed with the number of steps I was capturing.
	Noticing changes (n = 65)	Tracking Issues	23	10	Sometimes I would wake up and it would say that I had had 17000 step before I even put my feet on the floor it like wasn't resetting itself and that happened once to every single one of my team members with the Pebble.
		Team Rank	20	9	I did notice that change...the highest we had at one point was like for 3 but it was I thought it all the way down to 17 or 18.
		Personal Rank	11	8	I would notice... you know I would see that it would change yeah... especially like I've been outside doing stuff all day I might be up to 1, if I was 2 like you know..
		Personal Steps After PA	11	6	I know now I know what I'm requiring of my body just to walk to walk up the driveway it's about 50 steps so I thought that was very beautiful and very interesting.

positively resonate with the day to day needs of the participants. Some examples include the ability to receive notifications while away from the smartphone (“I would always leave my phone at my desk which is a good distance away and you know my watch pick up phone calls it would pick up text messages which was great I didn’t have to put my phone on me just in case of emergency happened”), to ability to use it as an alarm that vibrates the smartwatch (“I even wore a night cuz I like the alarm so I use that... I miss that piece.”) as well as to tell time (“Well, I used it to tell time a lot.”). Another positive factor is the formation of a habit for wearing the smartwatch (“I just got into the habit of like just having it I can go to the shower and come back and whenever, just wear it, I do miss it – not having it on my hand now.”). On the negative side, some participants experienced intermittent watch-to-smartphone Bluetooth synchronization issues (“Sync Issues”) which would disconnect the smartwatch from the companion app (“The watch did not seem to be connected to the to the application and I didn’t notice it and then early on I didn’t really know how to fix that until I learned that if I went into the phone and I logged out and logged back in then it

would reconnect.”).

The sub-theme “Watchface Glancing Frequency Factors” represents five categories that capture the common reasons causing participants to glance at the smartwatch display. The most common category (“Non Specific”) captures an observation from sixteen participants that they would look at the watchface without any specific goal (“Oh just glancing down and looking at it.”). Other common reasons for glancing at the smartwatch screen include checking personal steps (“I would just check it 4 or 5 times an hour or so that’s how that that, you know where I just be like ’How are my steps doing, do I need to get up, do I need to walk around, do I need to move around?”), time (“I was looking at the time mostly... Again, because I’m a watch wearer”), notifications (“When it buzzed that caused me to look at it if that makes sense.”) and personal rank (“I want to know... So if it’s a competition and I want to know if I’m first in my group.”).

4.6.10.3 Watchface Feedback Awareness

The sub-theme of “Typical Personal Step Values” captures participants’ recollections of the personal step values throughout the day. Participants described what they would typically see at the end of the day (“At the end of the day 10000 to 11000 ...10:30 11:00 at night.”), in the morning (“Usually in the morning I’ll get up and walk on the treadmill so I usually have to 2 to 3 thousand steps before I get to work.”) and around lunch time (“Well, at lunch I try to walk at lunch, so at lunch I would make sure I had like 4 to 5 thousand”).

Participants also recalled typical values for the other indicators which includes personal rank (“Most of the time it was 2 out of 5.”), team rank (“I think for the most part yeah yeah there were days that 3 or 4 were the norm but for the most part 1 or 2”) and team steps (“I was thinking everybody was closer around 10,000”).

4.6.10.4 Feedback Update Reaction and Comprehension

The sub-theme of “Reactions to Changes” aggregates five categories that represent the types of reactions that followed after users noticed the changes in the indicators. The top category (“Seeking Additional Information on Group Progress”) described how the participants sought additional information for observed feedback on the watchface (“If I had looked at the watch and I was number one and then I looked again and I was number 2 then I would say ‘Oh one of those people beat me’, I would go look at who it was [in the app].”). Other participant reactions included feeling positive (“*I was always really impressed with the number of steps I was capturing.*”) and encouraged to engage in physical activity after noticing changes in personal rank (“*I would modify my behavior to be #1 again . And I told u12 about it and she got annoyed: ‘You are cheating!’*”) and personal steps (“If I found myself very close to 10000 it made me walk more.”). Some participants would noticed syncing issues react to them by opening the companion app (“*On the phone itself I just it was probably just trying to make sure that things were working and talking.*”).

In the sub-theme of “Noticing Changes” there are four categories representing participant acknowledgements of noticing changes in the watchface indicators related to tracking issues (“Sometimes I would wake up and it would say that I had had 17000 step before I even put my feet on the floor it like wasn’t resetting itself and that happened once to every single one of my team members with the Pebble. ”), team rank (“I did notice that change...the highest we had at one point was like for 3 but it was I thought it all the way down to 17 or 18”), personal rank (“I would notice... you know I would see that it would change yeah... especially like I’ve been outside doing stuff all day I might be up to 1, if I was 2 like you know... ”) and changes in personal steps after physical activity (“I know now I know what I’m requiring of my body just to walk to walk up the driveway it’s about 50 steps so I thought that was very beautiful and very interesting.”).

4.7 Discussion

This section discusses the results in the context of the research questions and the associated hypothesis outlined in Chapter 1. This section also presents a series of implications from the perspectives of the body of prior knowledge that informed the design and development of FitAware.

4.7.1 Revisiting Design Objectives

A significant portion of the effort towards addressing RQ1 (*How does a smartwatch centered system, with a design focused on conveying individual and group physical activity via passive updates, facilitate participant engagement in a group dynamics-based community intervention?*) focused on the design of FitAware. This sub-section discusses the five design objectives that were conceived and applied to design and develop FitAware with a focus on leveraging the unique capabilities of smartwatches to facilitate physical activity behavior change.

Display daily information with frequent glanceable updates. This design objective was in part influenced by the following observations from the literature: smartwatch users glance at the watchface several times per hour [67, 66] and frequently updated feedback can generate user interest in the presented information [129] encouraging checking habits [67, 10, 11]. The evaluation results show that the frequently updating indicators on the watchface contributed to high levels of perceived and measured awareness of information. In particular, the personal step count indicator not only provided users with high awareness but also served as a major reason to glance at the display thus aligning with the literature that informed the design objective. Furthermore, from the McCrickard IRC framework [110] standpoint, the use of frequently updated and inherently non-interruptive indicators resulted not only in high levels of comprehension (as demonstrated by the awareness levels from the feedback) but also appeared to facilitate (based on the interview findings) reactions from change to the personal

rank, team steps and team rank indicators. These results validate this design objective and provide evidence suggesting that frequently updated smartwatch watchfaces can serve as a high comprehension and high reaction means of conveying wellness feedback.

Time and date should be visible elements. The results of the study revealed that time checking was one of the core reasons for glancing at the watchface which confirms the findings from prior research with regards to the reasons for glancing at the smartwatch display [138, 32]. Interviews and surveys revealed that upon glancing at the watchface the participants would notice all of the four indicators presented on it – this aligns with Gouveia’s findings [67] that also demonstrated that smartwatch users would look at the wellness related feedback despite the initial motive of just checking the time. FitAware users also reported that they enjoyed the utility of the smartwatch (time and notifications) and how it helped them in their day to day situations – clearly a positive factor towards promoting higher engagement with the smartwatch based feedback. These findings contrast with the results from the studies that used dedicated fitness tracker devices (without the added utility of notifications, time and date etc.) where users perceived them negatively partially due to the focus on one feature [147, 52]. Overall, the results validate the design objective and encourage the idea of retaining the utility features of smartwatches as they can help with the use adherence and ultimately led to higher feedback awareness.

Continue watchface updates when offline. The rationalization of this design objective originates from need to avoid negative perceptions of the accuracy and credibility of the displayed

feedback as it has been shown to lead to reduced user engagement [92, 147, 119]. While for the most part, the participants did not report any accuracy issues with the exception of occasional reports about syncing and accelerometer sensitivity issues, several users expressed their skepticism about the relevancy, credibility and importance of the team rank indicator as it was computed based on the progress of all the teams in the intervention which included self-report based users completely unfamiliar to the FitAware users. The team rank indicator received significantly less attention and ultimately led to lower comprehension levels. Thus, while this design objective is validated it should be added it is important to not only “shield users from perceiving accuracy/credibility issues by ensuring continuous updates but it is also important to avoid feedback that lacks transparency with regards to how it is computed.

Extend the feedback presented on the watchface. Motivated by the literature suggesting the importance of providing more extensive and deeper feedback [27, 67, 66] the design objective prescribed that the companion smartphone app included detailed feedback expanding the one on the watchface. The results revealed that the participants (especially from the connected groups) used the smartphone app to gain additional details about the closeness of the competition or to see how their group members accumulate their steps throughout the day. The instances where participants reacted to the rank changes by seeking details on standings show that this design successfully manifested and exemplified Gouveia’s recommendation stating that smartwatch glanceable feedback should act as a queue for deeper engagement with the feedback [67]. In summary results validate the design objective, how-

ever delegating more detailed feedback to the smartphone app introduced the added barriers inherent to the smartphone ergonomics (e.g. retrieving from the pocket, unlocking the screen etc.) [5, 6] thus, potentially reducing such engagement instances in less motivated groups (mixed groups). This could be particularly problematic in the instances where participants seek simple normative feedback [67] (ex. “How many more steps do I need to take to beat my competition”).

Optimize Information presentation on the watchface around the underlying behavioral strategies and the display format. This design objective was conceived as a way to deal with the two-fold challenge of translating the behavioral strategies into glanceable feedback and determining how to present it within the constraints imposed by the smartwatch display. The behavioral strategies conveyed by FitAware were dictated by the group dynamics-based strategies used in effective interventions [48]. As prescribed by the Carron & Spink conceptual team building model [21], the group process category of strategies (ex. competition, cooperation) was picked as the feedback to display as they unfold over time. Furthermore, FitAware display also included the individual level progress awareness as it also helps facilitate self-monitoring, goal setting and feedback [102]. In terms of the presentation style of the feedback it was dictated by constraints imposed by the Pebble display (low resolution and monochrome). Specifically, due to these limitations the watchface layout followed the approach prescribed for High Throughput Textual Displays [140] (such displays seek to update users via static and simple textual visualizations combined with minimalistic icons)

as well as the general small display guidelines [107]. The resulting watchface displayed four numerical indicators for both individual as well as the group strategies and the results of the surveys and interviews revealed that the participants had almost no issues perceiving the feedback both in terms of noticing and readability (with an exception of a few users with eye sight issues and with regards to the team steps indicator when it displayed five or even six digits). It should be noted that a similar design approach was shown to be effective by King et al. [88] where the results of a study reveal that users prefer “analytical” displays that present information in an easy to interpret way (as opposed “aesthetic” displays that present feedback in a quasi-artistic manner which made it more difficult to interpret the conveyed information). However, the numeric representation made it difficult to deemphasize potential negativity of the conveyed feedback (ex. “You are last in the team”), which, for example, negatively affected one the users. In fact, it has been shown that negative feedback is significantly less motivational (if not demotivational) than positive [99, 121, 25] and it is recommended to represent it such that the potential negativity of it is obscured [25]. Overall, this design objective, while helpful in the initial stages of the design, needs more detail and granularity with regards to how the feedback should be represented – certainly a matter worthy of future explorations (especially in the light of newer and more capable display types used in current smartwatches).

4.7.2 Revisiting the Hypotheses

The three hypotheses associated with RQ1 are revisited in the context of the results from FitAware evaluation:

Smartwatches presented to users as part of a group dynamics health intervention program will be regularly worn and used under certain conditions.

The quantitative results demonstrated that the overall adherence was high and sustained throughout the eight weeks. Interviews revealed that participants had either formed routines for wearing the smartwatch or continued their prior habits of wearing a watch or a fitness tracker. It should be noted that the positive perceptions of the smartwatch functionality such as notifications was a contributing factor for remembering to wear the device. In terms of the interpersonal factors, both quantitative and qualitative results indicate that the groups with active captains demonstrated higher adherence to smartwatch use. The interviews suggest that the regular interactions in the form of encouraging and motivating exchanges with the team captain played a significant role. In contrast to this, the interview with the group (G5) revealed that low sense of group cohesiveness negatively affected adherence to use. Overall, H1 is confirmed for groups that are cohesive and led by an active captain.

Participants, as they regularly look at the watch display to check the time, date, and notifications, also notice the glanceable, physical activity and ranking updates on the watchface.

Survey and interview results revealed that participants regularly glanced at the watchface with the frequency and motivation (personal steps, notifications and time) similar to those identified in other research [138, 32]. Furthermore, the interview and survey results demonstrate that participants upon glancing at the watchface also noticed all of the indicators (except the date indicator which was too small) including those that conveyed group and individual related feedback thus also confirming the preliminary findings by Gouveia et al.[67] where smartwatch users reported noticing wellness feedback during the glances motivated by the need to check the time. Despite the ease of noticing the indicators, it is notable that credibility of the team rank indicator acted as a negative factor (the credibility of team rank indicator was lower due to the fact that it included the rankings of the teams that tracked progress manually) and disinterested participants from paying attention to it. This observation can be explained by the results from prior research suggesting that the negative perceptions of the feedback credibility/accuracy negatively affect user engagement with the technology [92, 147]. In summary, H2 is mostly confirmed with the exception of the team rank indicator.

Regular observations of the group process related information presented on the watchface influence health behaviors, engagement with the companion smartphone app, and awareness of the personal and group information.

The results show that the participants developed awareness of their daily step count progression and reacted to low step count values with increased physical activity. Participants from the connected groups were more attentive to the personal rank changes and reacted

to them by engaging in physical activity, by seeking more information on the companion smartphone app and by interacting with their group members. The team rank indicator, as well as the team rank companion app, were primarily appreciated by the captains of the connected groups as a way to ensure their progress, as a reason to reach out and communicate with their group members to encourage more physical activity. These results support the findings of Gouveia et al. [67, 66] suggesting that the preferred means of receiving wellness related feedback is through glanceable interactions lasting no more than 5 seconds. In terms of McCrickard's framework on notification classification [110], the results suggest that watchface based glanceable and non-interruptive feedback can lead to high levels of comprehension as it was demonstrated via the awareness levels of the presented feedback. Furthermore, the participant behaviors triggered by rank changes or observed low step count suggest that such glanceable updates can facilitate user reactions without the downside of causing interruptions. Overall, it can be concluded that H3 is confirmed for the connected teams.

4.7.3 Implications

Attainable Goals. The results in terms of the awareness and reactions to the glanceable indicators reveal that the personal steps indicator was beneficial as the participants in addition to developing awareness of the daily step count progress also appeared to notice and react to critical values (e.g., when close to a goal). These observations highlight how the inclusion of the individual level feedback facilitated the same behavioral strategies that fitness trackers

such as Fitbit are known to be effective at facilitating (e.g., self-monitoring, goal setting and feedback) [50]. The interviews also reveal that participants particularly cared about the situations when close to their daily goal and reacted by engaging in physical activity – a behavior predicted by the research on motivational aspects of goals [100]. Furthermore, these findings also support the early findings and design suggestions by Gouveia et al. [67] suggesting that users notice and react to small attainable goals and that smartwatch watchfaces should convey attainable goals more explicitly.

Glanceable Feedback Priority As evidenced by the surveys, data logs, and interviews, FitAware users formed awareness of both individual and group level feedback and reacted to changes in the indicators (personal rank in particular). The results also revealed that participants seldom used the companion app and primarily received feedback from the glanceable watchface. These observations bolster Gouveia et al.’s [66, 67] findings that wellness tracker/smartwatch users primarily tend to just glance at the wellness related feedback. However, the results also reveal that – especially in the case of the connected groups – some participants would feel compelled by the glanceable indicators to seek more in-depth feedback found on the companion app interface. While this is posited as a desirable property for the glanceable feedback where, via frequent updates and appropriate presentation, it queues users to seek deeper feedback [67], in the case of FitAware the deeper feedback was only available via non-glanceable means (users had to access the interface on the smartphone or the web). This is problematic for the cases where the users seek simple extra details, such

as differences in progress between the nearest competition, because such feedback can be accommodated in a compact and glanceable way. Overall, these observations suggest that while smartwatch based glanceable feedback is a compelling mechanism for facilitating behavioral strategies, more work is needed towards making such feedback expandable in more efficient and less burdening ways.

Negative Perceptions of the Feedback: Research shows that negative feedback based reinforcement is significantly less motivational and generally not recommended as a design approach for technology based solutions [25]. In the case of FitAware, the underlying limitations of the Pebble display dictated a design approach that relied on simple numeric indicators for the feedback that, while being demonstrably glanceable and easy to interpret, also had a side effect of sometimes being perceived negatively. This observation uncovers a challenge of balancing between the simplicity/transparency of the indicators and the abstractness necessary to camouflage the potential negativity associated with the feedback. This conflict is reflected in the literature: on one hand abstract and aesthetic designs are suggested as a way to conceal negativity [99, 121, 25, 25], and on the other hand, studies warn against such approaches as they may fail to convey feedback in transparent and easy to interpret ways [88].

Comprehension and Reaction via Smartwatch Glanceable Display. The results of the study, based on the measured awareness, interviews, and survey responses, shows that the participants regularly glanced at the FitAware smartwatch display, and, while doing so, they com-

prehended the presented information and reacted to the changes in the feedback. While these results are in line with the Gouveia et al. [67, 66] findings suggesting that wellness tracker and smartwatch users mostly just glance at the feedback, from the perspective of the IRC framework [109] the observed results suggest that smartwatch based displays offer a novel means of facilitating user reactions and comprehension from the updates. It appears that the design focused on leveraging the habitual [11, 10] and frequent [138, 32] glancing behaviors of users combined with the inherent ergonomic advantages of smartwatches [103], allowed to facilitate high levels of comprehension and reaction (as per McCrickard's IRC framework [110]) via non-interruptive glanceable visual updates. While the results of FitAware evaluation provide evidence for the high comprehension argument (as demonstrated via measured and perceived awareness), the interviews provide indirect evidence that frequent glanceable updates can also facilitate high levels of reaction from the non-interruptive updates. These findings encourage future research focused on the reaction aspects from the glanceable watchface-based updates.

Smartwatch Utility. As shown via the survey and interview results, one of the main reasons for glancing at the smartwatch display was motivated by its daily utilitarian features (ex. time and notifications). These findings are similar to results from the literature on smartwatch use [138, 32] reporting that users frequently glance at the smartwatch to check the time and notifications. In terms of the day to day experience, the participants expressed positive attitudes towards the smartwatch use experience and, in several cases, expressed interest in

buying one. FitAware users enjoyed the convenience of the Pebble smartwatch primarily due to the large time indicator as well as the notifications for phone calls, calendar events, SMS and emails. The interviews and surveys also revealed that regardless of the glancing reason the participants would notice the group and individual feedback presented on the watchface which is similar to the results from a preliminary study by Gouveia et al. where the users also reported noticing wellness feedback after glancing at the time indicator [67]. Furthermore, these results present a stark contrast with the studies where the wearable devices only offered wellness tracking capabilities (ex. older Fitbit models) as the participants using such trackers lost in interest in wearing them due to reasons such as lack of interest and discomfort [52, 147]. It is possible that with the added convenience of smartwatch functionality these users would have perceived the same fitness trackers more positively. Overall, it can be concluded that the extra functionality bundled with the mainstream smartwatches can "bribe" users into wearing them more consistently due to the added convenience in their daily lives. This can be helpful for increasing user engagement and adherence with the wellness tracking and feedback aspects of smartwatches.

Social Translucence. The interview analysis revealed that noticing changes on the smartwatch display would lead group members to look at more detailed progress on the companion smartphone app – this is a positive result that, as prescribed by the team building conceptual model [21, 46], contributes to the group process leading to improved group cohesion. The interviews also showed the sheer physical presence of the smartwatch on the wrists would

sometimes trigger spontaneous conversations thus further contributing to the group process (communication and interaction – strategies not explicitly included in the FitAware design). These observations suggest that, in the case of groups that with a shared physical space, FitAware can contribute to social translucence – a property necessary for establishing group awareness in socio-technical contexts [36]. For the 'offline' group dynamics-based community interventions (relying on health practitioners/staff to facilitate group processes) having a system that can automatically facilitate social translucency can be very helpful. From the public health perspective, a FitAware-like system can make such interventions more appealing from the *adoption* and *implementation* [64] perspectives as it will allow the public health practitioners to delegate the task of facilitating group processes to the system.

Importance of Team Captains. One of the core distinctions between the 'connected' and 'mixed' groups was the role of an active captain. Captains in the 'connected' groups kept track of the overall team progress and encouraged (in person, via SMS and email) their team members to be more active and to track steps. It can be concluded that the captains, motivated by the automatically generated feedback, started acting as transformational leaders in their groups motivating collective effort towards advancing in the team rankings – such behaviors are highly desirable in behavior change interventions [12]. With FitAware-like systems in the context of group dynamics-based interventions [131], public health practitioners can rely on the automatically generated feedback to assist in establishing transactional leadership with relation to the group captains – such kind of leadership is very important as it

builds a foundation for the transformative leadership [9]. Thus, FitAware-like systems can help public health practitioners *adopt* and *implement* [64] interventions like FitEx.

Chapter 5

Assessing Design Considerations

The previous chapters of this dissertation discussed the design, development, early assessment, and evaluation of FitAware, which, when combined with lessons from related work, contributed to a series of design objectives for building smartwatch systems to promote group dynamics-based physical activity intervention. The results of the statewide deployment have shown that users glance at the watchface frequently, leading to engagement with the presented information – often leading to positive behaviors such as increased physical activity or friendly interaction with peers.

This chapter introduces a set of five design considerations derived from the design objectives as well as the FitAware evaluation results from Chapter 4. The design considerations provide guidance for creating systems that facilitate behavior change via non-interruptive updates in the form of watchface-based glanceable feedback for physical activity behavior

change promotion. The remainder of this chapter describes the efforts at assessing the design considerations. The considerations were used in a junior-level mobile software development class, with observations presented in this chapter.

Given the initial connections to smartwatch design education described in Chapter 2 and our early CS education papers at SIGCSE [37] and FIE [40], it seemed important to revisit the ways in which smartwatch-related lessons are communicated to students learning mobile software development and interested in understand and leveraging the inherent ergonomic advantages of smartwatches. This chapter presents ways that the design considerations, derived from the initial design objectives revisited in the light of results of the FitAware evaluation, can be used in educational settings and describes early results from deployment in a classroom setting, outlining next steps toward generating guidelines that can be used in professional and educational settings.

5.1 Deriving Design Considerations

The prior chapter concluded by discussing the results of the FitAware evaluation in the context of the five design objectives that guided the design and development of FitAware. This chapter seeks to introduce a set of design considerations based on the initial design objectives updated in the light of the results of FitAware evaluation and the change in the landscape of mainstream smartwatches. Following Pebble's bankruptcy, the only remaining mainstream smartwatch platform with fully programmable watchface capabilities at the time

of this dissertation is Google's Wear OS (formerly known as Android Wear OS). The Apple Watch allows application programming but not full watchface design, and platforms like Fitbit and Garmin allow limited configuration that they sometimes refer to as programming. As such, many of the guidelines are targeted for Wear OS, but they seek to be generally applicable to any smartwatch platform.

Overall, based on the five design objectives from Chapter 3 and the results of FitAware evaluation from Chapter 4, the following five design considerations were produced (see Appendix C for more details):

1. ***Delegate prominent watchface space for typical (smart)watch functions.***

This design consideration is derived from the second design objective (*Time and date should be visible elements*) and, because the mainstream smartwatches (unlike Pebble classic) offer bigger displays with much higher resolution, it is generalized to include any utilitarian glanceable feedback (not just time and date).

2. ***Provide frequently updated glanceable summaries.***

Based on the first design objective (*Display daily information with frequent glanceable updates*) this is design consideration emphasizes the fact that the indicators should provide just the summaries because of the fourth design consideration as it suggests providing additional details about the summaries.

3. ***Present users with information about quickly attainable goals.***

This design consideration is derived from the observation that revealed how the participants using

FitAware cared about the moments when they were close to improving in the rankings or to achieving their daily steps goal. Furthermore, the findings from Gouveia's preliminary study on different watchface presentation types also revealed that smartwatch users paid attention and reacted to attainable goals [67]

4. ***Allow users to quickly obtain extra details of the summaries.*** This design consideration is based on the fourth design objective (*Extend the feedback presented on the watchface*) but it modified to reflect the observation from the FitAware evaluation that the users often sought extra feedback that could be accommodated on a small display (e.g. "How far am I from my nearest competition?"). Furthermore, this design consideration takes reflects the fact that the current mainstream smartwatches provide interactive watchfaces where users can access extra information via simple tap or swipe gesture. Research on mobile device usability suggests that users are likely to engage with a device if the anticipated action can be accomplished as a micro-interaction (less than 4 seconds in duration) [5]
5. ***Delegate non-glanceable details onto the smartphone*** Finally, the fifth design consideration is a derived from the preceding one as it recognizes that not all feedback can be accessed via micro-interactions and on a small display (ex. detailed charts or tables that require scrolling) and therefore feedback of this kind should be delegated to the companion smartphone app.

5.2 Motivation and Methods

Our early teaching style was largely shaped by the technical capabilities and limitations of the Pebble smartwatch. However, the design considerations outlined in the last chapter seem to uniquely capture the lessons that are important for smartwatches for community health monitoring. The design considerations were used in the classroom setting, moving toward design guidelines that can be used and evaluated in classrooms, by design teams, and in consulting settings.

The five design considerations were integrated into a homework assignment in a junior-level mobile software development class at Virginia Tech. The objective of the homework was to design a FitAware-like smartwatch-centered system that would tackle the nationwide epidemic of physical inactivity by channeling individual and group dynamics-based behavioral strategies through the available mediums of delivery (smartwatch and companion smartphone). As part of the homework description (see Appendix A) students were given necessary resources to familiarize with the set of behavioral strategies. Students were also given a range of available information that they could capture and convey as part of the behavioral strategies. The assignment asked students to produce high fidelity wireframes applied to a set of predefined general scenarios that had to be developed to simulate the behavioral strategies in action.

The student submissions were graded based on the quality of wireframes, scenarios, and evidence of applying the behavioral strategies. The second part of the assignment provided

students with the five design considerations (see Appendix B) and asked them to revise the designs from the first part. As part of this assignment students were also asked to document their use (non-use) of the design recommendations via a web survey (see Appendix C).

The degree of adherence to the design recommendation was measured using a set of basic rubrics (see Appendix D) established by three HCI experts with experience teaching the course. Each element of the rubric represented a minimal understanding of the recommendation, reflecting whether a student understood its meaning and applied it in at least a minimal way. The experts agreed that each element of the rubric was both relevant and unambiguous.

5.3 Findings

This section highlights some observations from the homework assignment, toward understanding whether the design considerations were reasonable and what some areas of refinement and further exploration might be. In the course, thirty-four students finished the entire assignment, submitted their revised designs, and completed a brief survey. This section reflects on the degree to which students showed a minimal understanding of each of the design considerations.

5.3.1 Design Consideration No.1

- **Delegate prominent watchface space for typical (smart)watch functions.**

Of the 34 total submissions, 26 students included a time indicator for their watchface design that had a height of no less than 10% of the total screen height. Four students included time indicators smaller than 10% and three did not include it at all. Figure 5.1 illustrates a comparison of a watchface that fully complies with the recommendation against one of the three that does not. It should be noted in the survey responses the students that did not follow this recommendation seemed to have misrepresented it (“I implemented this on the smartwatch by showing familiar and consistent screens”) or misunderstood it (“I’m not sure what this recommendation really mean. Does it mean that I have to implement a watch face that show my app information on the smart-watch all the time?”).

5.3.2 Design Consideration No.2

- **Provide frequently updated glanceable information summaries.**

Of the 34 students, 14 include more than one glanceable indicator for both individual and interpersonal feedback. The rest of the students either included only personal feedback indicator, while delegating the interpersonal feedback to active notifications or used non-glanceable summaries. Figure 5.2 illustrates a difference between a watchface that uses



Figure 5.1: Left: prominent space reserved for time and weather functions. Right: does not even contain time.

multiple glanceable indicators and one that uses single non glanceable summary. Based on the survey results all of the students claim to have followed this recommendation.



Figure 5.2: Left: group and individual feedback represented by glanceable indicators. Right: only personal feedback and in a non-glanceable way.

5.3.3 Design Consideration No.3

- **Present users with information about quickly attainable goals.**

Of the 34 students, 11 included glanceable indicators for quickly attainable goals. Two students chose not follow this recommendation claimed a conflict with their original app design (“I decided not to follow this guideline, because I designed my app such that the app displays either a daily goal or a long-term goal. Since the goal changes on a daily basis, breaking the goal into smaller goals may cause confusion to the user.”); “I decided to not follow this guideline, because I felt it didn’t fit very well with my original goal design. Goals in my application are created by the user, and the user can customize the goal, but does not receive recommendations.”). The remaining 21 students used non-glanceable, disruptive means of presenting attainable goals or presented vague messages. Figure 5.3 shows an example of watchface that uses glanceable non-disruptive indications to indicate an attainable goal against a watchface that is hidden behind a dialog conveying a vague message.

5.3.4 Design Considerations No.4 & 5

- **Allow users to quickly obtain extra details of the summaries.**
- **Delegate non-glanceable details onto the smartphone.**

From 34 students, 24 produced designs that allowed access to additional details with a

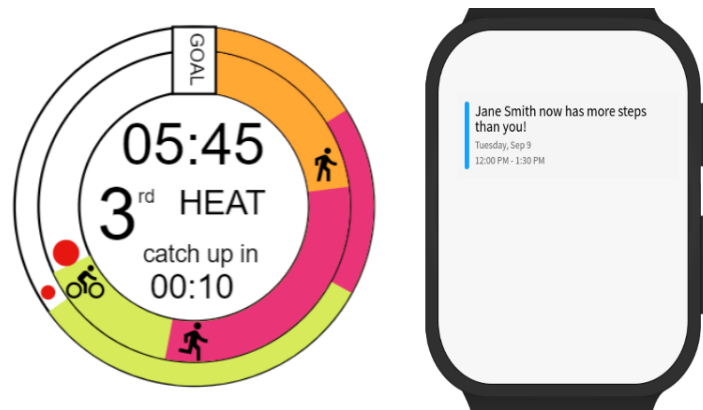


Figure 5.3: Left: attainable goal indicated on the watchface in a glanceable manner via short text and red dots. Right: vague statement presented as a non-glanceable disruptive notification.

simple tap or a gesture. Three students did not include this functionality despite claiming to have done so in the survey. Three students included extra detail dialogs but in the form of notifications that are not issued by user inputs. The remaining four students provided access to additional details but either with multiple interactions or presented information that is not related to the watchface glanceable indicators (see Figure 5.4).

The last recommendation was followed by all students except one who simply duplicated all of the smartwatch interactions and design into a smartphone format.

One chose not to follow and decided to cram it all on the watchface: “From my perspective, this guideline is somehow similar to guideline 2 but guideline 4 shows more detailed information for the users at a quick speed. I don’t think I include this guideline in my design because I don’t think, for instance, the users will [be] staring at their smartwatch and count

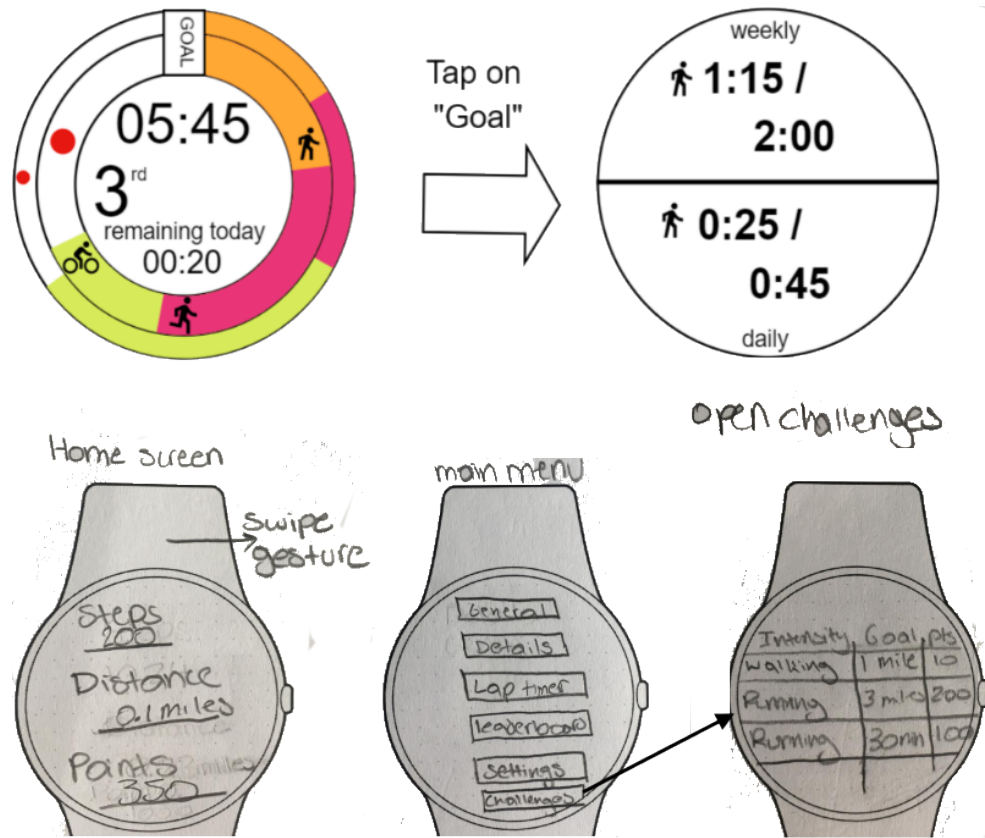


Figure 5.4: Top: single tap invokes a glanceable dialog with details about 'goal'. Bottom: Swipe then tap sequence to a non-glanceable dialog with challenges.

for their remaining steps. I placed all progress information on the watchface.” But ironically, this student included only the time indicator; he acknowledges it but chooses not to follow it: “I am not following this guideline but it is very useful for designing app. It can motivate the user to achieve their goal.”

5.4 Discussion

The student comments with regards to the third design consideration (“I decided not to follow this guideline, because I designed my app such that the app displays either a daily goal or a long-term goal. Since the goal changes on a daily basis, breaking the goal into smaller goals may cause confusion to the user.”; “I decided to not follow this guideline, because I felt it didn’t fit very well with my original goal design. Goals in my application are created by the user, and the user can customize the goal, but does not receive recommendations.”) are symptomatic of a barrier towards internalizing the behavioral aspects (for example the fact that an individual is best motivated by attainable goals [100]). It should also be noted that the students had limited opportunities for gaining sufficient depth in understanding the behavioral theories as primary means of learning was via the supplemental material bundled with the assignment (See Appendix A). A logical approach of ensuring better understanding and internalization of the necessary behavioral concepts by the computer science students could be derived from the iterative approaches commonly used in interdisciplinary teams designing and developing technologies for behavior change [88, 77, 74]. Such approaches can be particularly useful in project driven classes that focus on producing socially relevant software products as such classes emphasize the importance of understanding the needs of the clients [17].

5.5 Next Steps

Overall, it was instructive to see the student reactions to smartwatch design considerations for health-related systems. The ongoing explosion of work in this area, both in academia and industry, highlights the need for educational approaches that help prepare future designers and developers to produce quality interfaces that meet the growing demand.

While we were encouraged by the educational experience, we acknowledge that our initial assessment highlights the need for more specific advice that is rooted in scientific findings. For example, based on the results we propose updating the design considerations into design guidelines such as the ones below (with changes in bold text) for the first two guidelines:

1. *Delegate prominent (**no less than 10% of the**) watchface space for typical (smart)watch functions.*
2. *Use **at least 50% of the space to** provide **multiple** frequently updated glanceable summaries.*

Similar to the full list of design considerations in the appendix (see Appendix B), the updated guidelines should highlight findings that support and clarify them. For example, the guideline of using at least 10% of the watchface for typical smartwatch functions should clarify that this includes information like time and date, and should support this number through research about readability thresholds. Updates of this sort will shift the advice from general design suggestions to more actionable design guidelines, while highlighting the scientific findings

that are emerging in this field. A full reporting of these changes will be targeted for a publication in the ACM SIGCSE Conference for maximal visibility to the relevant computer science education communities.

Chapter 6

Conclusions and Future Directions

This chapter draws conclusions based on the design, development, deployment, and study results from the previous chapters and proposes future research directions. This dissertation has made contributions within the domains of human-computer interaction, health and wellness, and computer science education. As outlined in Chapter 1, this research sought to answer the following research questions and associated hypotheses:

- RQ1: How does a smartwatch centered system, with a design focused on conveying individual and group physical activity via passive updates, facilitate participant engagement in a group dynamics-based community intervention?
 - H1: *Smartwatches presented to users as part of a group dynamics health intervention program will be regularly worn and used under certain conditions.* Largely confirmed especially for the 'connected' groups (see 4.6.3). The thematic analy-

sis revealed that for the most part participants enjoyed wearing the watches and established habits for wearing them (see 4.6.10.2).

- H2: *Participants, as they regularly look at the watch display to check the time, date, and notifications, also notice the glanceable, physical activity and ranking updates on the watchface.* This hypothesis is largely confirmed with the exception of team steps. Participants did notice the other three indicators (See 4.6.5 & 4.6.10.4)
- H3: *Regular observations of the group process related information presented on the watchface influence health behaviors, engagement with the companion smartphone app, and awareness of the personal and group information.* This hypothesis is mostly confirmed, especially for the groups that had more than four smartwatch users. (See 4.6.7 & 4.6.10.4)
- RQ2: How do the novice designers interpret and apply the design considerations to design group process based smartwatch systems that promote physical activity behaviors?
 - H4: *Design approaches can be exemplified, during an in-class project assignment design and development.* This is mostly true for the first, second and fifth design recommendations but not true for the third and fourth (See 5.3)
 - H5: *Students will show evidence of good understanding of the five design approaches.* This is mostly true for the first, second and fifth design recommendations

but not true for the third and fourth (See 5.3)

Chapter 2 of the dissertation presented prior and related work that served to inspire and guide the directions of my research. The chapter highlighted effective behavioral strategies for promoting health and wellness on the community level and discussed the challenges associated with channeling behavioral strategies due to the interaction burden associated with the technological mediums of delivery. Chapter 3 described the design, development and pilot evaluation of FitAware – a smartwatch-centered system that uses a non-interruptive medium via a frequently updated glanceable feedback (inspired by the results from prior work in Chapter 2) to promote awareness for group and individual feedback during community physical activity interventions. In Chapter 4, FitAware was evaluated as part of a statewide intervention to reveal that a smartwatch based glanceable display can provide awareness of group and individual progress and thus allow for channeling of the behavioral strategies underpinning community physical activity interventions.

6.1 Contributions

The contributions listed below are a result of the design, implementation and evaluation of FitAware in the context of a statewide community physical activity intervention. The use of smartwatch based glanceable display as the primary medium of feedback for both group and individual behavioral strategies is novel and the path taken across the design,

implementation and evaluation stages of the work presented in Chapter 3, 4 and 5 offers the following contributions to the domains of HCI, Public Health and the associated disciplines:

FitAware The working system composed of the web, smartphone and smartwatch components was used by 27 individuals as part of a statewide intervention for 8 weeks. The design and implementation of the system following the design objectives offer a working approach for implementing multicomponent systems for conducting and evaluating behavior change interventions.

Watchface Glanceable Feedback Capitalizing on the inherent ergonomic advantages of smartwatches, the approach for facilitating user awareness for both group and individual levels of feedback directly on the glanceable watchface is novel and the evaluation results of this approach in Chapter 4 suggest that it can help overcome some of the barriers association with the web, smartphone and fitness tracker based mediums of feedback. The design aimed at leveraging the inherent 'glanceability' of smartwatches enabled high levels of comprehension and reaction by leveraging self-interruptive behaviors of the users and their preference for glancing.

Group Process via Smartwatch The results from Chapter 4 illustrate that the smartwatch based systems can successfully leverage the glanceable feedback to facilitate the group process related strategies in the context of group dynamics-based interventions. The results also suggest that the physical presence of the smartwatch in the context of collocated group members

can help establish social translucence, which, in turn helps facilitate group processes such as interaction and communication, ultimately resulting in better adherence and engagement thus demonstrating that group dynamics-based strategies can be facilitated via technology based mediums. Furthermore, this observation suggests that the in-person community based interventions can be simplified by adopting smartwatches because the feedback mediated via watchface can reduce the dependence on public health practitioners to be involved, thus making such interventions more scalable while also easier to adopt and implement.

Importance of Team Captains The results of the evaluation demonstrated that the team progress related feedback from FitAware encouraged team captains to act as transformative leaders with relation to their group members. The teams with such captains performed significantly better with regards to the engagement and the daily physical activity goals. These observations illustrate the importance of group structure in the context of technology mediated interventions. The results also demonstrate that with good group structure, smartwatch based systems can encourage captains towards acting as transformative leaders. From the public health perspective, these findings suggest that the automatically generated feedback can reduce the workload of public health practitioners as it can effectively act as a virtual transactional leader – a critical role reserved to the practitioners in context of "offline" interventions [44].

Design Considerations Informed by the body of knowledge discussed in Chapter 2, the design objectives discussed in Chapter 3 and the results of the evaluation discussed in Chapter

4, design considerations were proposed and assessed in Chapter 5. The five design considerations are aimed at helping future designers and developers utilize the advantages of smartwatch based system in building systems helpful for facilitating behavior change strategies. These design considerations were assessed in the context of a mobile software development classroom setting in order to gauge how well these considerations can be understood and applied by students. The results of the assessment suggest a need towards exploring more design and client centric pedagogical strategies to help students better comprehend the behavioral factors critical for understanding and applying the design considerations.

6.2 Future Directions

This dissertation sets the stage for follow-up research within several areas, as outlined here:

- *Exploring Other Watchface Types.* The design, layout, colors, dimensions and the types of the indicators presented on the FitAware watchface were largely constrained by the display type, which in the case Pebble falls into the category of High Throughput Displays [140] as it only has two colors and low resolution. Despite these limitation, the results reveled high levels of comprehension and reaction [110] as indicated through awareness levels and reactions to glanceable indicator changes. The mainstream smartwatches of the present day predominantly feature full color, high pixel density and round touch displays capable of conveying complex 2D and even 3D graphics. Future research in the domain of smartwatch based systems for group dynamics-based

interventions focused on facilitating group processes [21] could explore novel ways of leveraging the new capabilities of mainstream smartwatches to further improve user comprehension and reaction [110].

- *Cultivating Leadership Behaviors.* The results of FitAware evaluation from Chapter 4 reveal the importance of group captain leadership behaviors with regards to group member engagement and physical activity. More active captains acted as transformative leaders and regularly encouraged their group members to stay active and engaged. Future systems can increase their effectiveness if designed with a goal to encourage leadership behaviors from group captains. One potential approach could be to offer awareness of the individual behaviors as it has shown to be effective in the context of online collaborations with socially translucent mechanisms for individual contribution awareness [101]. The future designs can also consult with the research on voluntarism which states that leaders can be encouraged via recognizing and rewarding their leadership behaviors [125, 126].
- *Design for Social Translucency.* The results in Chapter 4 revealed that the smartwatch acted as socially translucent mechanism leading to social interactions – a highly desirable behavior from group dynamics perspective as it helps sustain group process which in turn helps achieving higher cohesiveness of the group as a whole. Systems designed for group dynamic-based interventions should consider social translucency as gateway for facilitating group processes. One example of facilitating social translucency was implemented with a highly visible activity tracker that would gradually engrave patina

across the band in response to physical activity [94]. In the context of workplace interventions where the groups often share spaces, social translucency can be established with ambient display installations that convey appropriately tailored feedback.

- *Positive Framing of Group Feedback.* The work in this dissertation focused on a competitive environment where participants seek to meet goals and surpass other individuals or teams in their performance. Many people resonate with this type of motivation, but other people don't like competition and appeared to perceive ranking feedback negatively. Such negative perceptions are undesirable it has been shown that users react to positively framed feedback much better [99, 121, 25, 25]. Future research should investigate how to sustain the balance of conveying group process strategies such as competition and cooperation while avoiding negative perceptions.
- *Health and wellness programs.* The FitEx program provides an opportunity to bridge the ideas in this dissertation to communities that could benefit from increased health and wellness opportunities. Continued work should build on the results in this dissertation toward finding good solutions for these communities.
- *Computer Science Education.* The assessment of the design considerations uncovered barriers towards understanding the underlying usability and behavioral concepts. The constraints imposed by the class format limited the amount of knowledge students could receive about the usability and behavioral aspects underlying the design considerations. Future research could explore ways to integrate iterative design approaches

[88, 74] used by interdisciplinary research teams during the design and development of behavior change technologies. Such pedagogical approaches are likely to help students better internalize the design considerations ultimately become better designers and developers.

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Appendix A

Homework Description

Introduction

Overview of the assignment

In this assignment your task is to design a smartwatch-centered system that tackles the nationwide epidemic of physical inactivity. You will be asked to exemplify the system design through high fidelity prototypes of the resulting user interface applied to a set of predefined scenarios.

The strategies that tackle obesity

The design that you are going to come up with is supposed aid a family of effective physical activity interventions in channeling evidence-based behavioral strategies which help in increasing and sustaining physical activity levels. While the strategies are intuitive and simple to grasp, it is critical that you study them in detail and ensure solid understanding prior to getting started with the design. The descriptions of the strategies are to be found [here](#).

Who needs the system

There are numerous large scale annual physical activity interventions where users are recruited in long term programs that promote adherence to nationally recommended levels of physical activity (ex. 150 minutes/week of moderate physical activity, 10,000 steps/day). Typically, participants receive devices for *self-monitoring* (ex. FitBit for counting steps, minutes etc.), then they *set goals* and receive regular *feedback* on their performance. Additionally, in an effort to make such programs more engaging and effective, participants are encouraged to invite friends thus enabling additional mechanisms for positive behavior change such as *competition, cooperation, interaction and communication*.

How the system will be used

The system is going to be distributed by health specialists that will identify target groups of participants in the community and invite them to use the system for 8 weeks. Interested individuals will be asked to form a small team of 3 to 7 users sharing existing social connectedness. The teams will receive assistance in installing the system and learning how it works. The users will also receive help in setting up their individual and collective goals and will be briefed on the objectives of the program. You can assume that the users will keep the system installed on their devices for the entire duration (let's say 8 weeks).

Typical users

When designing a system interface prototype it is critical to know who the system is designed for and in what environment it is going to be used. In this assignment you can assume that the typical users are going to be individuals with sedentary lifestyles who are reasonably engaged with their devices. Most of the teams will be composed of such individuals and the members of such teams are assumed to frequently and regularly intersect in a shared space with plenty of opportunities for small talk/jokes etc. You can also assume that such teams might be loosely familiar with the members of other teams, but for the most part they will be completely unfamiliar with the other teams because the system will be used statewide or even nationwide.

Assignment Details

Scope

You will be designing the 'front end' of the system and your main goal is to maximize the effectiveness of the 'front end' in conveying the behavioral strategies to the users. You can assume that the 'back end' is already implemented and is ready for the 'front end' that you will be designing. You can also assume that the functionality with regard to registration and team formation is already implemented. The 'back end' communicates with clients by exchanging various physical activity related information. For the best result you should think about what information can convey behavioral strategies and how to present this information to the users. Thus, your job is to:

A) Manipulate the information shown below to convey at least three of [the behavioral strategies](#):

1. User's daily physical activity level for the moment (ex. Number of step at 3:31pm)
2. User's past physical activity history (ex. Number of steps for every 15 minutes since the beginning of the system use)
3. Group members' physical activity level for the moment (ex. Number of steps for each of the members in the team at 2:25pm)
4. Group members' past physical activity history (ex. Number of steps for every 15 minutes since the beginning of the system use for all group members)
5. Realtime push updates for when users' progress is updated and posted
6. Group members' physical activity goals and collective goal (sum of individual goals)
7. Realtime group member activity (walking, running, standing, biking etc.)
8. Any other options from Google Fitness API or sensor data.

The big picture

The general US population is experiencing a physical inactivity epidemic leading to obesity problems that are linked to lethal diseases and are costing the government approximately 119.9 billion dollars. Less than half of the US population meet the minimal recommended levels of physical activity (150 minutes/week). One of the proven strategies to increase physical activity levels of the general population is to through group dynamics-based community behavior change interventions, where naturally-occurring social groups (coworkers, friends and family, etc.) team up to leverage pre-existing interpersonal factors and social connectedness towards increasing their levels of physical activity. In this assignment your goal is to *a)* identify a method that this strategy can work and *b)* apply and demonstrate this understanding through a smartwatch centered system design.

The three competing behavioral strategies

Three established behavior change strategies are demonstrably effective in a variety of contexts including physical activity: *goal setting*, *self-monitoring* and *feedback*. Group dynamics strategies are built 'on top' of the above three strategies to further enhance their effectiveness and thus bring positive changes on the individual level and group levels. So how do these three strategies work?

Goal setting. When individuals set attainable physical activity goals (e.g., 10,000 steps/day), it helps them in establishing a long term vision which in turn acts as a natural source of self-motivation. Having specific goals drives knowledge acquisition towards optimisation of time and resources so that one can achieve goals more efficiently. Additionally, with clear goals in mind, physical activity becomes measurable with clear indication towards progress. Achievement of physical activity goals helps boost pride and build self-confidence while also converting what previously felt like a pointless grind into an enjoyable way of spending time.

Self-monitoring. The ability to regulate behaviors and emotions depends in part on the ability to flexibly monitor one's own progress toward a goal. Automatic capturing of physical activity (e.g., accelerometer on the phone) and continued presentation of the physical activity levels (e.g., step-count indicator on the watch) develops self-awareness leading to adjustment of behaviors, because self-monitoring enables mapping of the subjective perceptions of what is difficult (ex. "I feel so tired") or easy to the measured (objective) levels of physical activity (ex. An indicator showing 5,000 steps/hour").

Feedback. Effective interventions offer participants an external perspective (generated by a system or person(s)) on their performance that acts as yet another factor aimed at modifying one's behavior. Feedback, defined as "providing data about recorded behavior or evaluating performance in relation to a set standard or others' performance", is either positive (e.g. "You did better than 96% of Christiansburg", "Your team had its best day this week") or negative (e.g. "Your weekly average has been dropping for the past 3 weeks", "Your team is behind the pace to make it to the top") and is intended to offer individuals information that is easily interpretable (i.e., relatable to real life), impactful (i.e., makes one feel 'guilty' or 'empowered') and encouraging (i.e., implied behavior change adjustment should not be too difficult).

Group dynamics-based strategies

Group dynamics-based strategies leverage interpersonal factors that arise in small socially connected groups (friends, family, coworkers etc.) such as interest in each others life, mutual encouragement, sharing common interests and goals, tendency to spend time with each other. These factors provide an environment where individual behavior can be influenced through group dynamics-based strategies such as competition, cooperation, interaction and communication.

Competition. 'Competition is one of the most basic functions of nature' and in the case of physical activity behavior change, individuals in groups are influenced by the feedback that compares their progress to others'. In the case of small cohesive groups that compete among other similar groups, individuals react to feedback that compares performance on the group level by engaging in more physical activity and by encouraging their group members to contribute to the collective performance (ex. "Hey guys we have to beat that group!"). In cohesive groups (groups where the members are 'close' and familiar), the group members experience pleasant emotions when improving their comparative performance (ex. Becoming #1 in the group in terms of daily step count.), especially when it is accompanied by feedback that is shared with others. Such shared feedback and the ability to influence it through added commitment of physical activity leads to friendly banter (ex. "I totally smoked you!") and interactions often manifesting in increased attention to the feedback and seeking of opportunities to 'quickly overtake the competition' (ex. Checking to see how close the competition is with one's levels of physical activity) or to 'stay just ahead' (ex. Checking to see if anyone is catching up in the physical activity levels).

Cooperation. The cooperation strategy relies on the presence of a shared interest of the group members in achieving the instrumental objectives (ex. "Achieving the collective

Appendix B

Design Considerations

Design considerations

How to use them

The design considerations below are for your consideration and *you are required to think through* all of the considerations and demonstrate that via the survey. In terms following these considerations *it is up to you whether to do it or not*. It might be that you already applied one or more of them prior to the revision, it can also be that you don't find the one or more of the considerations appropriate/applicable/valid/(...etc) and finally, it might be that you find one or more of your considerations useful for your revision and apply. The takeaway here is that it is very important for you to show that you can critically think about the considerations and justify (in writing) whatever decision you make.

The Five considerations

1. Delegate prominent watchface space for typical (smart)watch functions.

Displaying, in a prominent way, of time and similarly desirable indicators that are found on most (smart)watches ensures that users can see familiar, expected and utilitarian indicators on the watchface at all times.

2. Provide frequently updated glanceable information summaries.

Displaying summaries of information such as physical activity progress levels, comparative progress levels (between individuals, groups etc) is a way to exploit the fact users frequently look at the watchface and have their eyes ready to capture peripheral glanceable information.

3. Present users with information about quickly attainable goals

Because users frequently check the watchface, presenting with quickly attainable goals might increase a chance of influencing their (or the groups as a whole) decisions. It is important to keep a balance between very challenging goals (For example reminding how far off the user is doing with relation to their record result of 5 years) and very trivial ones ("You group is only 1 minute away from the goal"). In summary, presenting users with quickly attainable goals has a potential to trigger physical activity behaviors, interactions between groups members as well as other behaviors.

4. Allow users to quickly obtain extra details of the summaries

Interactive watchfaces and notifications have the capacity to offer extra information via quick, under 4 second, interactions. This might help users seek more information

feedback due to the quick access time. This extra information should be quickly readable and strive to be glanceable in its nature to conform to the user's expectation that everything (accessing the detailed information and reading it) can be done 'very quickly'. A typical example of how this works is **watchfaces** with step count information: by tapping on the steps indicator, a dialog appears with more details about the steps progress.

5. Delegate non-glanceable details onto the smartphone

Smartwatches have a small screen and performing operation requiring longer operations (more than 4 seconds) that involve large amounts of complex information (Example: multi-column spreadsheet) would be perceived as cumbersome. For complex interactions, users would rather use the smartphone that has much more screen space for touch points and for presenting non-glanceable information.

The Survey

It is critical to demonstrate that you can critically think about the design considerations. In order to assess how well you thought through what the considerations are about, you will need to take the following survey -> [link \(Links to an external site.\)Links to an external site.](#)

In the survey, you will first answer, via multiple choice questions, whether you had already followed the consideration, decided to follow it as part of the revision or chose not to follow at all. Following the multiple choice questions, you will have to write for each of the consideration:

- a) Rationalization of your decisions with regards to the consideration (You must be very thorough here and make cogent arguments regardless if you decided to follow it, not to follow it or if you had already followed it prior to the revision. Think critically!)
- b) How the consideration was followed in your design (Describe explicitly how it was followed in terms of the wireframes, information presentation, and the underlying behavioral strategies)
- c) Your general opinion about the consideration (Again, critical thinking is key here).

Deadline is Tuesday (Nov 28th) before class.

Appendix C

Class Survey

Design consideration use assessment

Start of Block: Default Question Block



Your VT email:

Please indicate if you had any UI design experience prior to taking CS3714:

No experience (1)

Took a class that required UI desing. Indicate class: (2)

Other (3) _____

The Five Design Considerations

1. *Delegate prominent watchface space for typical (smart)watch functions.* Displaying, in a prominent way, of time and similarly desirable indicators that are found on most (smart)watches ensures that users can see familiar, expected and utilitarian indicators on the watchface at all times.

2. *Provide frequently updated glanceable information summaries.* Displaying summaries of information such as physical activity progress levels, comparative progress levels (between individuals, groups etc) is a way to exploit the fact users frequently look at the watchface and have their eyes ready to capture peripheral glanceable information.

3. *Present users with information about quickly attainable goals* Because users frequently check the watchface, presenting with quickly attainable goals might increase a chance of influencing their (or the groups as a whole) decisions. It is important to keep a balance between very challenging goals (For example reminding how far off the user is doing with relation to their record result of 5 years) and very trivial ones ("You group is only 1 minute away from the goal"). In summary, presenting users with quickly attainable goals has a potential to trigger physical activity behaviors, interactions between groups members as well as other behaviors.

4. *Allow users to quickly obtain extra details of the summaries* Interactive watchfaces and notifications have the capacity to offer extra information via quick, under 4 second, interactions. This might help users seek more information feedback due to the quick access time. This extra

information should be quickly readable and strive to be glanceable in its nature to conform to the user's expectation that everything (accessing the detailed information and reading it) can be done 'very quickly'. A typical example of how this works is watchfaces with step count information: by tapping on the steps indicator, a dialog appears with more details about the steps progress.

5. *Delegate non-glanceable details onto the smartphone* Smartwatches have a small screen and performing operation requiring longer operations (more than 4 seconds) that involve large amounts of complex information (Example: multi-column spreadsheet) would be perceived as cumbersome. For complex interactions, users would rather use the smartphone that has much more screen space for touch points and for presenting non-glanceable information.

Please answer whether you already had followed the consideration (prior to revision), followed it as part of the revision or chose not to follow at all.

	Already followed prior to the revision (1)	Followed it in the revision (2)	Chose not to follow (3)
consideration 1 (1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
consideration 2 (2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
consideration 3 (3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
consideration 4 (4)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
consideration 5 (5)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

For each of the considerations, you should write about...

a) Rationalization of your decisions with regards to the consideration (You must be very thorough here and make cogent arguments regardless if you decided to follow it, not to follow it or if you had already followed it. Think critically!)

b) How the consideration was followed in your design (Describe explicitly how it was followed in terms of the wireframes, information presentation, and the underlying behavioral

strategies) c) Your general opinion about the consideration (Again, critical thinking is key here!).

consideration 1 (1) _____

consideration 2 (2) _____

consideration 3 (3) _____

consideration 4 (4) _____


consideration 5 (5) _____

End of Block: Default Question Block

Appendix D

IRB

MEMORANDUM

DATE: August 16, 2017 

TO: Samantha Marie Harden, Andrey Esakia, Alicia Everette, NithyaPriya Priya Shivanthi Ramalingam, Meghan Wilson, Scott McCrickard, Thomas Edward Strayer III, Gregory Thomas Donlon, Shuo Niu, Stephanie Ann Breig, et. al.

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires January 29, 2021)

PROTOCOL TITLE: Smartwatch Notification within a Statewide Behavioral Intervention

IRB NUMBER: 16-264

Effective August 16, 2017, the Virginia Tech Institutional Review Board (IRB) Chair, David M Moore, approved the Continuing Review request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at: <http://www.irb.vt.edu/pages/responsibilities.htm>

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As: **Expedited, under 45 CFR 46.110 category(ies) 4,6,7**
Protocol Approval Date: **September 13, 2017**
Protocol Expiration Date: **September 12, 2018**
Continuing Review Due Date*: **August 29, 2018**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

Invent the Future

Date*	OSP Number	Sponsor	Grant Comparison Conducted?

* Date this proposal number was compared, assessed as not requiring comparison, or comparison information was revised.

If this IRB protocol is to cover any other grant proposals, please contact the IRB office (irbadmin@vt.edu) immediately.

Appendix E

FitAware Experience Survey

Default Question Block

The purpose of this research project is to understand your experience with the technology that was used during FitEx 2017. This research project is conducted by a Virginia Tech graduate student Andrey Esakia working under the supervision of faculty members from Human Nutrition, Foods and Exercise (Dr. Samantha Harden) and Computer Science (Dr. Scott McCrickard) departments.

As a registered user of this year's www.fit-ex.org you are invited to participate in this internet survey. Your participation in this research study is voluntary. You may choose not to participate in this survey. If you decide to participate, you may withdraw at any time. The procedure involves filling an online survey that will take approximately 10 minutes. The information from your responses will be used for strictly research purposes and kept confidentially. Results from the survey will contribute to the design and development of the next version of www.fit-ex.org. Results will also be used for research manuscripts regarding FitEx programming. To help protect your confidentiality, the surveys will not contain information that will personally identify you. The questions will be mostly multiple choice with few open-ended text entry options. We will ensure all of the survey data storage safety by containing it in a password protected electronic format. If you have any questions about the research study, please contact Andrey at esakia@cs.vt.edu. Should you have any questions or concerns about the study's conduct or your rights as a research subject, or need to report a research-related injury or event, you may contact the VT IRBChair, Dr. David M. Moore at moored@vt.edu

Consent to participate is implied with the submission of the survey.

Please specify your FitEx username:

During the past 8 weeks, how often, on average, did you wear your Pebble smartwatch?

- Every day
- 5-6 times a week
- 3-4 times a week
- 1-2 times a week

- Less than once a week
- Other

Please list your reasons for not wearing Pebble more frequently:



On average, how often did you look at the Pebble smartwatch display while wearing it?

- 0 to 1
time/hour
- 2 to 3
times/hour
- 4 to 5
times/hour
- 6 to 7
times/hour
- 8 to 9
times/hour
- 10+
times/hour
- I don't know

Your primary reason for checking Pebble smartwatch display was to check:

- Time
- Date
- Personal Steps
- Personal Rank
- Team Steps
- Team Rank
- Notifications
- Other

Your secondary reason for checking Pebble smartwatch display was to check:

- Time
- Date
- Personal Steps
- Personal Rank
- Team Steps
- Team Rank
- Notifications
- None
- Other



The time indicator on the Pebble smartwatch display was:

1 - Hard to read 2 3 4 5 6 7 8 9 - Easy to read Other

Regardless of why you looked at the Pebble smartwatch display, how likely were you to notice each of the following?

	Extremely unlikely	Moderately unlikely	Slightly unlikely	Neither likely nor unlikely	Slightly likely	Moderately likely	Extremely likely
Time	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Date	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Personal Steps	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Personal Rank	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Team Steps	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Team Rank	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Notifications	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Arrangement of the information on the Pebble smartwatch display was:

- Extremely confusing
- Moderately confusing

- Slightly confusing
- Neither clear nor confusing
- Slightly clear
- Moderately clear
- Extremely clear



Please rate the readability of the indicators on the Pebble smartwatch display:

	Hard to read					Easy to read	
Personal Steps	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Personal Rank	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Team Steps	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Team Rank	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

What health changes did you make because of the information from the Pebble smartwatch display? (select all that apply)

- Set daily/ weekly activity goals
- Planned my daily/ weekly walk/exercise
- Invited team member to walk/exercise with me
- Scheduled walk/exercise "dates" with a team member
- Made effort to sit less and move more

- Problem-solved my barriers to exercise
- Tried to make activity more enjoyable
- Chose healthier food and drink options
- None of the above
- Other

What health changes did your team members make because of the information from the Pebble smartwatch display? (select all that apply)

- Set daily/ weekly activity goals
- Planned daily/ weekly walk/exercise
- Invited team member to walk/exercise with me
- Scheduled walk/exercise "dates" with me or other team members
- Made effort to sit less and move more
- Problem-solved their barriers to exercise
- Tried to make activity more enjoyable
- Chose healthier food and drink options
- I don't know
- Other

The experience with the Pebble smartwatch display:

	Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree
1. Helped you do the same things the healthiest people of this group were doing.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. Made you want to be the healthiest person in the group.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. Fostered friendly competition within the members to stay as healthy as possible.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

	Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree
4. Lead to the group talk about things that are happening in our lives.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. Lead to sharing of personal stories among the group members.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6. Lead to discussions about the importance of regular physical activity.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7. Lead to conversations about how often the group members should do physical activity.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8. Lead to discussions about appropriate types of physical activity we should do.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9. Lead to many conversations about physical activity and exercise.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10. Fostered group cooperation towards achieving team progress.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
11. Fostered group cooperation towards helping each other to run the program smoothly.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>



By the end of a typical day, what were the values for the following indicators (see image below for reference) on the Pebble smartwatch display?

Number:

Personal steps:

Personal rank:

Team steps:

Team rank:

By the end of a typical day, how many times did the number for the personal rank change on the Pebble smartwatch display?

By the end of a typical day, how many times did the number for the team rank change on the Pebble smartwatch display?



The statements below ask questions about the **personal steps**, **personal rank**, **team steps** and **team rank** indicators during regular use of the smartwatch throughout the day. Please read each one and choose the degree to which you agree or disagree:

	Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree
1. I was aware of my personal step count.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. I regularly noticed changes in my personal steps.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. I was aware of my personal rank.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. I regularly noticed changes in my personal rank.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. I was aware of the team steps.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree
6. I regularly noticed changes in the team steps.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7. I was aware of the team rank.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

	Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree
8. I regularly noticed changes in the team rank.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9. The information from the indicators made sense.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10. I noticed changes in the information from the indicators when away (>50 ft) from my phone.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

	Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree
11. I was satisfied with the update frequency of the indicators.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
12. The information from the indicators encouraged me to engage in physical activity.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
13. The information from the indicators encouraged me to check the information from the smartphone app.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Did you have any other reactions from the indicators on the Pebble smartwatch display?
Please list if you did: