International Journal of Human-Computer Studies 142 (2020) 102501

Contents lists available at ScienceDirect

International Journal of Human-Computer Studies

journal homepage: www.elsevier.com/locate/ijhcs

Using smartwatches to facilitate a group dynamics-based statewide physical activity intervention

Andrey Esakia*,[a], Scott McCrickard[a], Samantha Harden[b], Michael Horning[c], NithyaPriya Ramalingam[b]

[a] Virginia Tech, Department of Computer Science and Applications, Blacksburg, VA, United States
[b] Virginia Tech, Department of Human Nutrition, Foods, and Exercise, Blacksburg, VA, United States
[c] Virginia Tech, Department of Communications, Blacksburg, VA, United States

ARTICLE INFO

Keywords:
Group dynamics
Health
Wellbeing
Wearables
Evaluation

ABSTRACT

Physical inactivity is a major cause of disease, both in the United States and globally. Physical activity interventions often use a multi-level and community-based approach combining individual and group-based behavioral strategies to promote physical activity and influence 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 individual-level behavioral strategies and de-emphasizing interpersonal aspects. This article focuses on the design and evaluation of technology aimed at facilitating group dynamics-based strategies for promoting physical activity within small socially-connected teams. This work introduces a multi-component smartwatch-centered system called FitAware that uses sensors to automatically track physical activity and leverage the advantages of the watch form factor to facilitate both group and individual level behavioral strategies via non-interruptive, glanceable, and frequent updates. This article describes the design and evaluation of FitAware in the context of an 8-week statewide physical activity community-based intervention.

1. Introduction

Individuals who adhere to regular physical activity tend to experience lower risk for diabetes, heart disease, various types of cancer, and many other diseases (Althoff et al., 2016; Miles, 2007; Sparling et al., 2000). The Centers for Disease Control and Prevention recommend no less than 150 minutes of weekly moderate-intensity aerobic physical activity to maintain a healthy lifestyle (for Disease Control et al., 2011; of Health et al., 2008), yet one in five adults in the United States meet these requirements (for Disease Control et al., 2014; Ward et al., 2013). Moreover, the Task Force on Community Preventive Services recommends *community interventions* due to their demonstrated effectiveness at improving physical activity behaviors (Kahn et al., 2002) 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 (Smith, 2018). These interventions typically combine both the individual (e.g., goal-setting, self-monitoring and feedback) and interpersonal (e.g., social support and social comparisons) behavioral strategies as mechanisms for motivating physical activity (Burke et al., 2011; Greaves et al., 2011; Khaylis et al., 2010; Michie et al., 2009; Tate et al., 2001; Thomas and Bond, 2014).

Community interventions are often delivered face-to-face, with health specialists (e.g, group leaders) facilitating the behavioral strategies (Ehlers et al., 2015; Irwin et al., 2016; Wadden and Foster, 2000). However, the approaches that seek lower cost and higher scalability, via the use of interactive technology-based mediums of delivery, tend to be less effective (Archer et al., 2012). Web based systems, for example, suffer from high dropout rates and low user engagement levels (Eysenbach, 2005). Smartphone based solutions are demonstrably better due to the use of sensors for automatic physical activity tracking and the convenience of the mobility (Klasnja and Pratt, 2012). However, low engagement remains an issue – smartphone wellness apps suffer from high uninstallation rates and low usage (Perrin, 2018b; 2018c).

Wearable fitness trackers, on the other hand, retain the convenience of the automatic tracking via miniaturized sensors and also offer the simplicity of the glanceable wrist worn wearable form factor (Gouveia et al., 2015; Munson and Consolvo, 2012). This works well because the

* Corresponding author.
E-mail addresses: esakia@cs.vt.edu (A. Esakia), mccricks@cs.vt.edu (S. McCrickard), harden.samantha@vt.edu (S. Harden), mhorning@vt.edu (M. Horning), nithyar@vt.edu (N. Ramalingam).

https://doi.org/10.1016/j.ijhcs.2020.102501
Received 1 February 2019; Received in revised form 20 December 2019; Accepted 22 June 2020
Available online 23 June 2020
1071-5819/

wellness tracker users predominantly just briefly glance at the wellness related feedback (Gouveia et al., 2015). However, most currently available wearable fitness tracker systems restrict glanceable information to feedback about the individual, delegating interpersonal feedback to the less accessible companion mobile and web interfaces. Many studies point to lack of motivation and lack of social connection as key reasons for the lack of success of wearable fitness trackers (Fausset et al., 2013; Lyons et al., 2014; Mercer et al., 2016; Shih et al., 2015).

These observations encourage us to think toward a solution that would combine the miniaturized sensory capabilities of fitness trackers with glanceable feedback for **both** individual and interpersonal levels of feedback. Implementing such a system would require a wrist worn fitness tracking capable device with a customized interface. While fitness trackers do not allow customization of the main display, the increasingly more mainstream smartwatches expand the physical activity tracking capabilities of fitness trackers by adding larger displays and, in the case of some of the platforms (Wear OS for example), fully programmable watchfaces. The trend of moving away from fitness trackers to smartwatches (Lamkin, 2018) underscores the motivation to investigate their use in the context of a group-based community physical activity intervention that leverages both individual and interpersonal levels of feedback.

This paper 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 an ongoing physical activity community intervention (Harden et al., 2016; 2020; Johnson et al., 2015). The design of FitAware leverages the fully programmable watchface display of Pebble that can be conveniently used to present customized glanceable feedback. FitAware is designed to provide users with high comprehension and reaction of daily step count progress via non-interruptive feedback updates on both individual and interpersonal levels. The FitAware system accomplishes this by presenting non-interruptive watchface updates in a glanceable fashion. The design approach is supported by the inherent information accessibility advantages of smartwatches (Gouveia et al., 2016; Lyons, 2015; Pizza et al., 2016), the self-interruptive behaviors of users, as well as the common usage habits of wrist-based wearables. The smartwatch component (see Fig. 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 among team members to improve their collective rank.

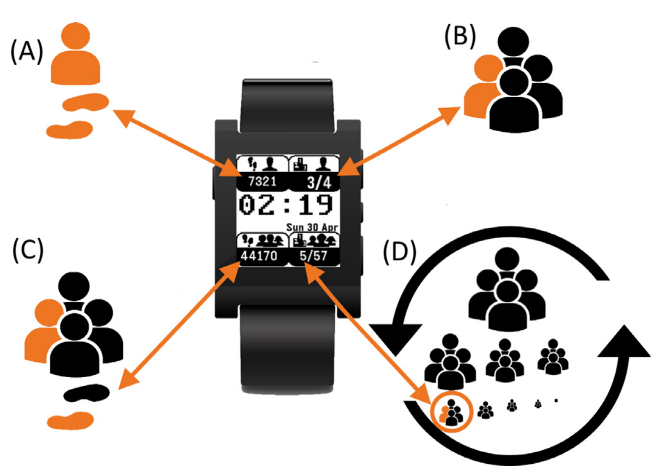


Fig. 1. FitAware smartwatch components displaying daily values: a) personal step count; b) individual ranking within the group; c) group member step count (sum of steps for all group members); d) group ranking comparing all groups in the program.

With this system we seek to explore the effects of such glanceable updates in the context of group-based physical activity interventions where small groups cooperate and compete against other groups towards a physical activity goal. Considering the shortcomings of other technology-based solutions to promote physical activity in group settings, the focus of our investigation is on exploring the effects of the smartwatch-based glanceable feedback on the participant experience in the context of group-based physical activity interventions.

2. Background and related work

The health complications caused by inadequate physical activity levels are associated with millions of deaths (Lee et al., 2012) worldwide and a multi-billion-dollar burden on the economy due to adverse effects on population productivity as well as the increased health-care costs (Ding et al., 2016). Community-wide, multilevel interventions are needed to reach a large proportion of inactive adults.

Community-based interventions often operationalize the community as a set of geographically collocated social groups that can be intervened upon in their natural environments (Kahn et al., 2002). Community-based interventions include strategies that acknowledge that individual behavior is influenced as a result of interaction with various types of social environments (e.g., organizational, interpersonal, socioeconomic, and cultural) (Merzel and D'Afflitti, 2003; Mummery and Brown, 2009). 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 (Brand et al., 2014). FitAware focuses on 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 multilevel, group-based interventions confirm that effective approaches typically use strategies for both levels of influence (Burke et al., 2011; Greaves et al., 2011; Khaylis et al., 2010; Michie et al., 2009; Tate et al., 2001; Thomas and Bond, 2014).

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 (Estabrooks et al., 2012). The interpersonal strategies employed by such interventions are based on group dynamics principles, which prescribe that groups with a given initial structure and environment can develop cohesiveness through ongoing interpersonal interactions (*group process*) such social interactions and social comparisons (Festinger, 1954) in the form of competition and cooperation.

Many group dynamics-based studies can be categorized as "offline" for not using the Internet or connected devices for any of the intervention aspects. 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 (Ehlers et al., 2015; Irwin et al., 2016; Wadden and Foster, 2000). As a way to mitigate these challenges, various technology-based solutions were explored.

Web-based mediums for health and wellness programs, while attractive due to the high percentage of US adults using the Internet (97% for adults under the age of 50 (Perrin, 2018a)) and low costs associated with implementing such interventions (Bennett and Glasgow, 2009), suffer from high attrition rates upwards of 50%. Such decrease in engagement is considered to be a 'fundamental characteristic' of web-based interventions (Bennett and Glasgow, 2009) and attributed to the burden of interaction with computers and web browsers (Eysenbach, 2005).

A majority of the US adult population own smartphones (Perrin, 2018b) and use them to access the internet (Perrin, 2018c). Today's mainstream smartphones offer sufficient capabilities to capture, store, retrieve, communicate, and present user physical activity progress related data (Lane et al., 2010; Patrick et al., 2008). A recent systematic review of 20 smartphone centered systems for promoting physical activity reveals that 12 used strategies for influencing on the interpersonal level from which 8 offered feedback on social comparisons (competition and cooperation) (Matthews et al., 2016). Overall, literature shows evidence that, in the context of the interpersonal levels of influence on physical activity, smartphones can encourage communication (Consolvo et al., 2006), progress sharing (Anderson et al., 2007), and social comparison (competition and/or cooperation) (Ahtinen et al., 2010; Ayubi and Parmanto, 2012; Chen and Pu, 2014; De Oliveira and Oliver, 2008; Harries et al., 2013; King et al., 2013; Lin et al., 2006; Van Dantzig et al., 2013) to increase physical activity. Smartphones have been shown to be valuable tools for supporting social interactions among members of a community (Horning et al., 2014) and for providing awareness of the activities of friends (Ganoe et al., 2010; Gui et al., 2017). However, in more pragmatic contexts users tend to uninstall apps after just one use in 25% of the cases (O'Connell, 2016) and in the context of health and wellness apps 75% of them are uninstalled after the 10th use (McLean, 2011). Apps are typically uninstalled due to notification overload (notifications that gain user attention come at a cost of interruption (Carroll et al., 2003; Cutrell et al., 2001; Czerwinski et al., 2000; Leiva et al., 2012; McCrickard et al., 2003a; 2003b; Pejovic and Musolesi, 2014; Sahami Shirazi et al., 2014)), advertisements (Felt et al., 2012) and, of note for this work focused on wellness apps, due to goal abandonment (Murnane et al., 2015). Furthermore, from the usability perspective the smartphone form factor can be cognitively burdening (Ashbrook, 2010; Ashbrook et al., 2008; 2008; Lyons, 2015) as it requires users to perform certain routine actions (e.g., engage with the phone and turn on the screen) before getting to the information, thus reducing the user interaction with the feedback from the app.

Wearable fitness trackers such as Fitbit are equipped with glanceable displays (or indicators in some cases), sensors that continuously and automatically collect physical activity data and provide self-monitoring capabilities (Evenson et al., 2015). A report from the US Department of Health and Human Services claims that wearable fitness trackers can increase physical activity (Committee et al., 2018). From the perspective of community-based interventions, fitness trackers are recognized to be advantageous from the reach and cost related points of view (Archer et al., 2012; Pellegrini et al., 2012; Polzien et al., 2007).

A study focused on engagement habits of 256 Fitbit users (Gouveia et al., 2015) revealed that a typical mode of interaction is just a brief glance at the display to receive feedback. A recent systematic review shows that the mainstream fitness tracking devices focus more on the individual level behavioral strategies (goal-setting, self-monitoring and feedback) and less on interpersonal level strategies (competition, cooperation, communication and social support) (Lyons et al., 2014) for which the feedback is always delegated to the companion smartphone and web interfaces (Mercer et al., 2016). A study in the domain smart apparel for running groups has pointed out that there are no wearable systems that provide quickly accessible real-time group progress feedback (Mauriello et al., 2014). In terms of the adherence to use, over half of the users stop wearing the trackers after two weeks (Shih et al., 2015) due to reasons such as forgetting to put it on, not forming a habit, poor aesthetic quality, and lack of social comparison feedback. 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 (Fausset et al., 2013).

In summary, from the perspective of group-based physical activity interventions, the primary limitation of fitness trackers is the lack of glanceable interpersonal feedback. Smartwatches can overcome this limitation and accommodate both individual and interpersonal levels of feedback (Giang et al., 2014; Gouveia et al., 2015; Pizza et al., 2016) while still maintaining the wellness tracking capabilities offered by fitness trackers. Our primary inquiry is motivated by this observation and it can be formulated as the following research question:

How does a smartwatch centered system, with a focus on simultaneously conveying individual and group physical activity via glanceable updates, facilitate participant experience in a group dynamics-based community intervention?

We hypothesize that the intervention participants will wear the smartwatch on a regular basis and receive group and individual feedback from the four indicators (See Fig. 1). We also hypothesize that the regular observation of the glanceable indicators will manifest into awareness of the feedback values as well as influence behaviors in terms of physical activity, interactions with their peers and engagement with the non-smartwatch components of FitAware. A more formal interpretation of hypotheses is as follows:

H1: Users will wear and engage with smartwatches as part of a group dynamics health intervention.

H2: Participants, as they regularly look at the smartwatch display will observe the information from the glanceable indicators and develop awareness.

H3: Regular observations of the group and individual related feedback presented on the watchface will influence participant behaviors with regards to the FitAware system, physical activity and peer interactions.

3. Designing FitAware

FitAware was developed based on a series of design objectives identified through observations that the current wearable fitness trackers, borrowing from the historically recognized ergonomic advantages of wrist watches (Martin, 2002), succeed at matching the common pattern of briefly glancing at the wrist-based wellness-related feedback (Gouveia et al., 2015; 2016) and that interfaces glanceable feedback thus ultimately helping to facilitate glanceable awareness – an approach that is considered to be advantageous for the persuasive technologies aimed at behavior change (Consolvo et al., 2008; Fortmann et al., 2014; Jafarinaimi et al., 2005). Furthermore, wearable fitness trackers have been recognized to be effective at increasing physical activity levels (Committee et al., 2018) and being cost effective from the public health perspective (Archer et al., 2012; Pellegrini et al., 2012; Polzien et al., 2007). However, the information that is accessible via the glanceable indicators on wearable fitness trackers only convey individual level behavioral strategies (Gouveia et al., 2015; Munson and Consolvo, 2012) and while only providing the interpersonal level behavioral strategy related feedback on the companion smartphone and web interfaces (Gouveia et al., 2016; Mercer et al., 2016), thus making it not glanceable because of the required interactions inherent to web (Eysenbach, 2005) and smartphone interfaces (Ashbrook, 2010; Ashbrook et al., 2008; Bayer and Campbell, 2012) ultimately not matching users preferred approach for accessing wellness related information. Below are the detailed descriptions of the four 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 (McCrickard et al., 2003b) 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 (Sahami Shirazi et al., 2014) both in general and in wellness tracking contexts (Munson and

Consolvo, 2012), a typical user interaction with wellness feedback is via brief glances under 5 seconds (Gouveia et al., 2015) which has been shown to be true in smartwatches as well (Gouveia et al., 2016) and frequently updated feedback leads to user interest in the presented information (Oulasvirta et al., 2012) and ultimately encourages checking habits (Bayer and Campbell, 2012; Bayer et al., 2015; Gouveia et al., 2016)

2. *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 (Oulasvirta et al., 2012) and can be helpful in minimizing perceived feedback credibility issues by presenting most up to date readings (wellness tracker users are known to be perceptive of accuracy/credibility of the feedback (Ledger and McCaffrey, 2014; Munson and Consolvo, 2012; Shih et al., 2015)).
3. *Extend the feedback presented on the watchface.* This design objective requires that the glanceable information presented on the watchface should accommodate 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 (Consolvo et al., 2006)) for behavior change technologies stating that users should be able to, and by Gouveia et al. (2016) observation stating that glanceable smartwatch feedback should act as a trigger for further, deeper engagement with the presented feedback.
4. *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.

3.1. 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 "agent"). 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 a 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 individual level strategies (self-monitoring, goal setting and feedback) with the successful interpersonal level strategies for community interventions (Estabrooks et al., 2012) with a focus on facilitating the group process (Carron and Spink, 1993) 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.

3.2. Implementation

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

FitAware was developed following an iterative design approach toward producing a useful and usable interface (Hartson and Pyla, 2012; King et al., 2013). We recruited a small team of participants with HCI background to use the initial system and provide feedback. After a year-long iterative design and implementation process, the refined system was piloted in the wild for 8 weeks among two groups of two (Esakia et al., 2017). We further upgraded the system based on the results of this deployment to the current version of FitAware.

3.2.1. Smartwatch component

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 144 × 168 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 by placing the visual indicators for the feedback directly on the always-on watchface and updating them every 10 seconds for the personal steps indicator and every 5 minutes for the other indicators. 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 (Mauney and Masterton, 2008). The indicators surrounding the time indicator convey both individual and interpersonal levels of feedback. As per the fifth design 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 Fig. 1): 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 1 as it shows how these indicators support the group process via competition and cooperation). The displayed values from the four indicators were logged and cached in the local memery of the smartwatch. The third design objective (*Continue watchface updates when offline*) was supported via caching of the group member step count values and then recomputing (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.

The final design objective (*Optimize information presentation on the watchface around the underlying behavioral strategies and the display format.*) was implemented following the requirement of incorporating the behavioral strategies on both individual and interpersonal levels and combining them together (as it is the case with effective

Table 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

interventions (Burke et al., 2011; Greaves et al., 2011; Khaylis et al., 2010; Michie et al., 2009; Tate et al., 2001; Thomas and Bond, 2014). 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 (Gouveia et al., 2016; Lyons et al., 2014; Mercer et al., 2016). The interpersonal level feedback is informed by the group dynamics-based principles used in effective group dynamics-based intervention (Carron and Spink, 1993; Estabrooks et al., 2012) and seeks to convey group feedback necessary to convey strategies such as competition and cooperation (also commonly used in effective technology-based interventions Matthews et al., 2016; Mercer et al., 2016). In terms of the effective strategies for accommodating the feedback on the smartwatch display we followed the recommended practices for small displays (Mauney and Masterton, 2008), adopted effective information visualization strategies for low resolution, small monochrome displays (Pousman and Stasko, 2006) and resorted to the "analytical" visualization theme which prescribes the use of simple to understand indicators (King et al., 2013) and finally, we used competitor analysis (Hartson and Pyla, 2012) to inform the aesthetic aspects of the design.

3.2.2. Smartphone component

The companion smartphone app offers detailed information expanding on what is offered on the watchface. For instance, the personal step counter (Fig. 2, 'c') is augmented with a chart that shows how the user arrived at the current step count throughout the day. For the team step counter (Fig. 2, 'e') the smartphone app offers a similar chart, but for all team members. For the personal rank (Fig. 2, 'd'), the app provides exact step count for all of the team members. And finally, for the team rank (Fig. 2, 'f'), the app provides a list of teams, their steps, and rankings. In terms of the app architecture, it runs a background process in the background responsible for syncing data with the server and the smartwatch. We set the interval of syncing with the smartwatch at once in 5 minutes. During each interval, the app performs the following operations: (1) it receives the log of displayed values from the smartwatch, (2) saves the logs in the local database instance, (3) attempts to send the logs to the web component (if successful the local database is reset, otherwise more log information is accumulated) and (4) attempts to update the watchface with the latest values. The app also capable of receiving push notifications containing new progress values from the web component. Upon receiving said notifications, the app caches the newest values in the local memory and attempts to sync the values with the smartwatch during the next 5 min cycle. All four detailed views use the data from the web component – this way we ensure that users receive the most up to date information.

3.2.3. Web component

The web component of the system served two purposes – (1) to offer a web interface for participants that do not use the smartphone/ smartwatch and instead resort to the self-report based tracking via a web browser, (2) to provide the cloud capabilities needed to update and store data generated by the smartphone and smartwatch users. The front-end of the website was developed with AngularJS and tailored around the needs of FitEx from both participant and facilitator perspectives. The web app allows users to manually track physical activity progress and view the individual as well as collective progress (See Fig. 3). The website also allows users to create an account, create/join a team, modify profile information, adjust goals, enter or modify progress for past dates. The website also features an administrator interface that allows FitEx facilitators to report progress on behalf of participants (this feature is needed in rural settings where internet access is limited). The back-end of the website was built using ExpressJS (a NodeJS web framework) utilizing MongoDB (non-relational database) for data persistence. We used Socket.IO (a popular library for realtime bi-directional communication via web-sockets) as the mechanism for exchanging information with the Android app. The back-end was configured to push ranking and team step updates to the clients every 15 minutes.

4. FitAware evaluation

This section focuses on the statewide deployment of FitAware and its evaluation with an emphasis toward addressing the three hypotheses related to the (H1) smartwatch regular use, (H2) awareness from the glanceable indicators and (H3) effects on the participant behaviors in terms of engagement with the system, peer interaction and physical activity.

4.1. Methods

4.1.1. Recruitment process

FitAware was advertised during recruitment of a statewide and group dynamics-based physical activity intervention. 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 the 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 a demographic variables and physical activity goals. Participation in the study was voluntary with no compensation for completion.

4.1.2. 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. It should be noted that the 27 participants also invited web-only users to their groups, which increased the total number of users to 44 people. However, the web-only users, tracked their progress via the web interface, thus not contributing to the real-time updates. 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 2 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 intervention's 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).

4.1.3. 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'), answer surveys inquiring about normal levels of physical activity (minutes/week), 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) (Sallis et al., 1987) which is used to capture an individual's 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 gain a perspective on the

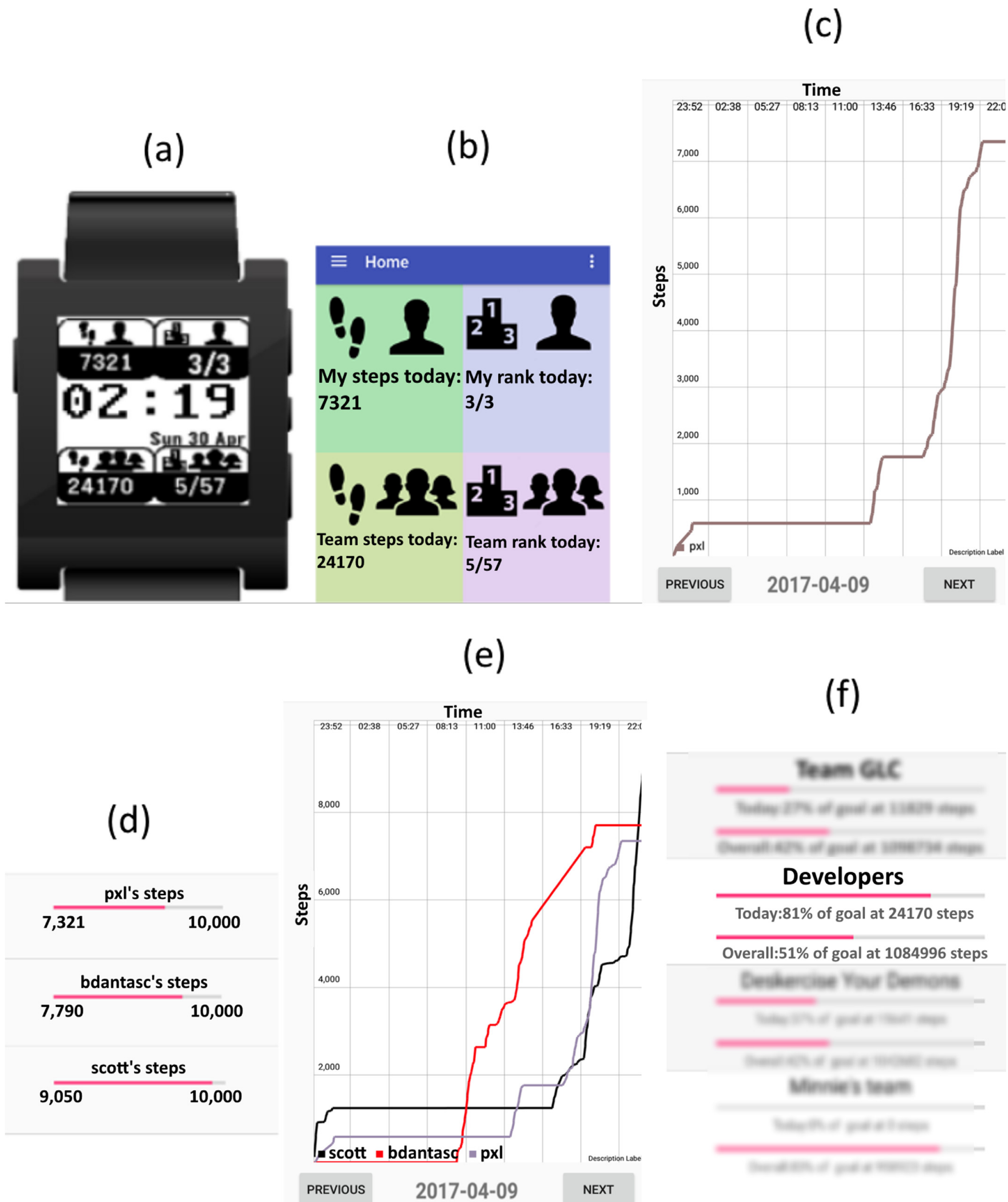


Fig. 2. From left to right: a) FitAware Pebble smartwatch watchface. b) FitAware smartphone companion app home screen: the screen contains four tiles, each offering a brief summary of a type of feedback. Tapping on the tiles opens the corresponding detail view. c) Personal step view: the screen shows a plot of the user's step count over time. User can view progress for past days, or zoom/pan for extra details. d) Personal rank view: the screen shows the rankings of group members, their steps and the overall goal. e) Team step view: the screen shows the step plots for all team members. Similar to the personal steps view, users can view past days and zoom/pan. f) Team list view: the screen shows the progress and goals of all teams, both daily and overall. By tapping on team name users can see a popup that shows the team's daily and overall rank.

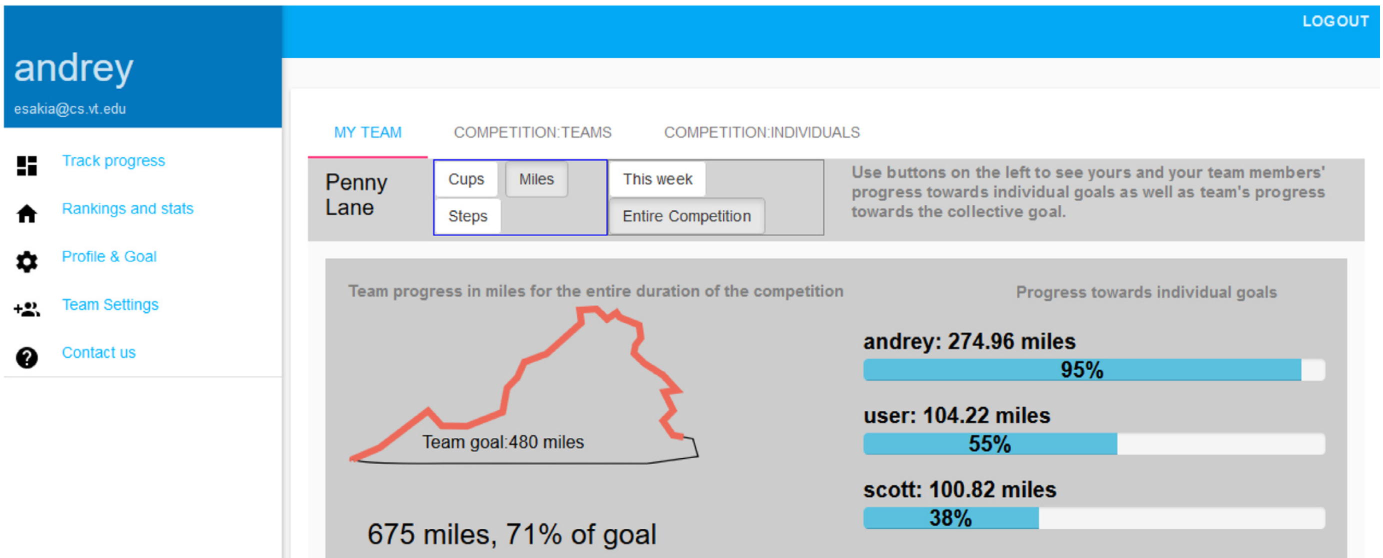
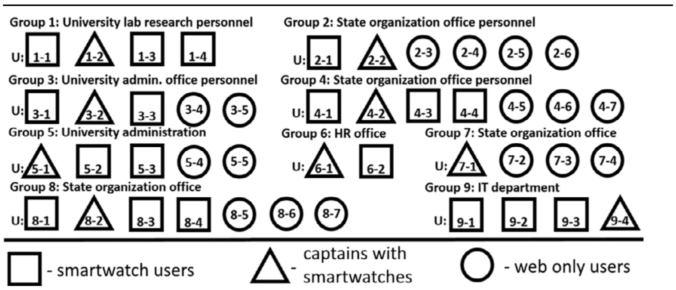


Fig. 3. Upon logging in the web users see a personalized dashboard that displays a summary of individual and interpersonal progress. The interface allows users to switch between different progress measurements (miles, steps, and cups) across different time-frames (this week and entire competition). The website also features a fruit and vegetable consumption tracker (a feature required by FitEx). For smartphone/smartwatch users, only the step count information was tracked. The equivalent miles were computed using the following equation: 2000 steps = 1 mile.

Table 2
Recruited teams and their composition (all captains were smartwatch users). Some teams included web-only users.



initial levels of social interconnected – a factor that can play an important role with regards to the three hypotheses as it can have an effect on the peer interactions and overall engagement during the intervention. The scoring approach followed what is prescribed by the authors of the instrument (Sallis et al., 1987).

4.1.4. Post-study procedures

At the end of the study, the FitAware participants were offered the chance to complete a post-study survey and a 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. 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) (Estabrooks and Carron, 2000) which is used to assess the levels of perceived group cohesion in the group via questions inquiring about competition, cooperation, interaction, and competition.

4.1.5. Data collection, analysis and survey design

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 (Willig, 2013) to learn about participant experience and clarify the results from the surveys and system usage).

In order to assess user experience, engagement and feedback awareness levels (as prescribed by the second hypothesis) with the FitAware system, we created a survey that asked the participants to identify the frequency of glancing at the watchface, primary and secondary reasons for glancing and the likelihood of noticing the indicators during those glances. Furthermore, the survey also asked the users to rate (on a Likert scale) the degrees to which they were noticing changes in the readings from the each of the four indicators and perceived awareness of the values. The survey items were created following the commonly used approaches in usability studies (Chin et al., 1988; Kirakowski and Corbett, 1993; Nielsen, 1994; Ozok, 2009).

PAGE-Q 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 group cohesion expressed via competition, interaction and communication, and cooperation each consisting of multiple items. Group cohesion plays an important role in group-based interventions (Carron, 1982) with a potential to have an affect on participant behaviors (H3) and experience with FitAware (H1 and H2). 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 Cronbach’s 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.

We captured user interactions with FitAware in terms of the steps taken while wearing the smartwatch and the interactions with companion app’s interface. We also captured the readings of the four indicators (See Fig. 1) displayed on the watchface. Both the steps and the indicator readings were captured every 5 min. The step count data, in addition to tracking physical activity levels, also allowed us to determine if the smartwatches were worn throughout the day (we will refer to such days as "active days"). For active days we considered the days during which the step count increased 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.

As the primary focus of the analysis was to investigate adherence to smartwatch use (H1), awareness from the glanceable indicators (H2) and the experience with the watchface indicators with regards to the participants behaviors (H3), 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.

4.2. Results

This section describes results of the mixed-methods evaluation from both quantitative and qualitative perspectives with an emphasis on the quantitative results.

4.2.1. Participation

Of the 27 participants that were set up to use the smartwatch three dropped out in the first three days. Reasons – already part workplace walking group that used Fitbits ($n = 1$) or did not want to wear devices on the wrist ($n = 2$), leaving 24 participants that completed the 8-week study(see Table 2). 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.

4.2.2. Two types of groups

We begin by illustrating how two distinct types of groups emerged from the results across the board. We view these groups as either "connected" (proactive team captain and all members equipped with smartwatches) or "mixed" (not all members equipped with smartwatches). The differences in the two types of groups manifest in the measures relevant to all three hypotheses.

Upon investigating the survey responses for the SSES a significant 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 didn't feel like I was part of the team and we weren't getting out and walkin") 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").

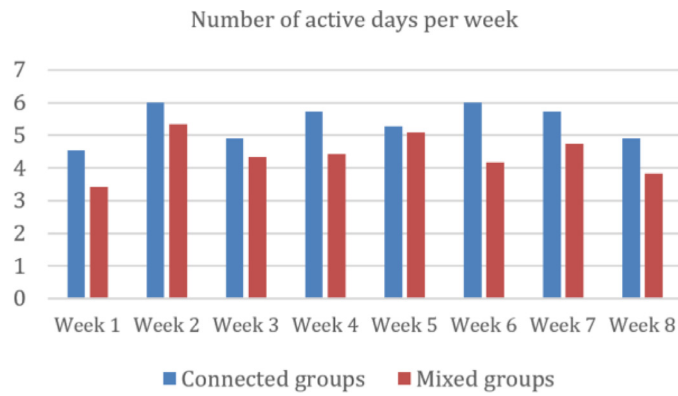


Fig. 4. Connected groups wore the smartwatch more consistently.

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 "connecte" groups and the other groups as "mixed".

4.2.3. Adherence to smartwatch use

As per our first hypothesis we measured user adherence to wearing the watch and counted active days of wearing for each user. On average, the 23 participants had 5.22 (SD = 0.29) active days of smartwatch use per week (see Fig. 4). 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 Fig. 4).

In addition, we examined differences between groups in terms of social support. Overall, the user's active days significantly correlated with the perceived social support ($r = 0.502$, $p = 0.028$) 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.

4.2.4. Glancing at the watchface and peripheral awareness

We investigated the reasons for glancing, frequency with which users look at the watchface as well as the awareness levels of the watchface indicator values as part of our effort to address the second hypothesis. 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 Fig. 5). 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 Fig. 6). One participant that responded with "10+ times/hour" explained that, as a captain, she wanted to ensure 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 Fig. 7). 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.

4.2.5. Noticing changes in the indicators

Noticing changes in the indicators is a factor toward establishing

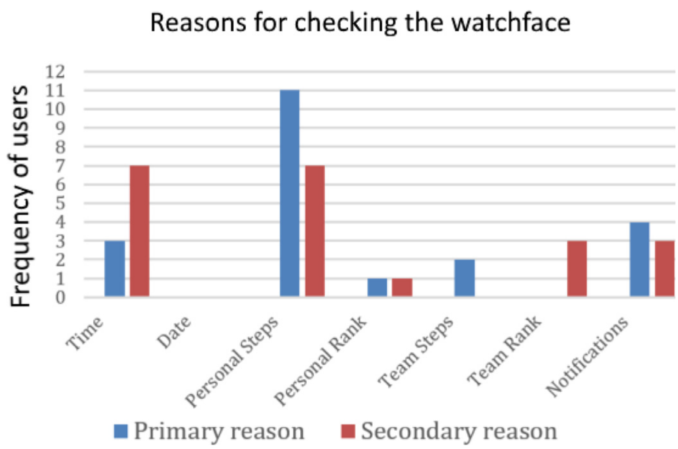


Fig. 5. Primary and secondary reasons for checking the watchface. Most of the users primarily checked the watchface to see their personal steps and the time.

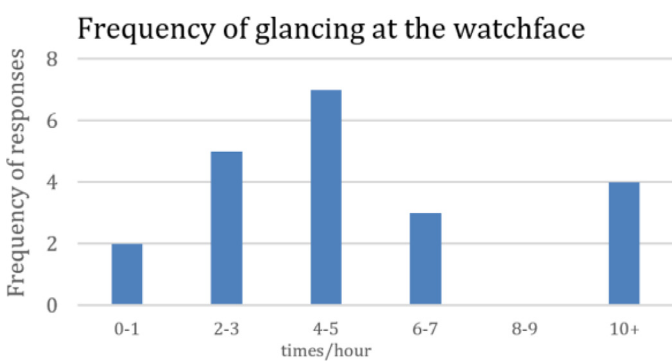


Fig. 6. Most users self-reported looking at the watchface many times each hour.

feedback awareness – we measured it as part of effort to address H2. As per survey results, 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 ($t = 2.096$, $P = 0.043$).

4.2.6. *Self-reported awareness*

In yet another survey measure aimed at addressing H2, 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 ($t = 3.369$, $P = 0.002$).

4.2.7. *Measured awareness*

Motivated by the second hypothesis, we also asked participants to recall indicator values for a typical day as part of the post-study survey. 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 (54%).

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 Sm 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 Fig. 7. Independent samples t-tests revealed 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.

Variance 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

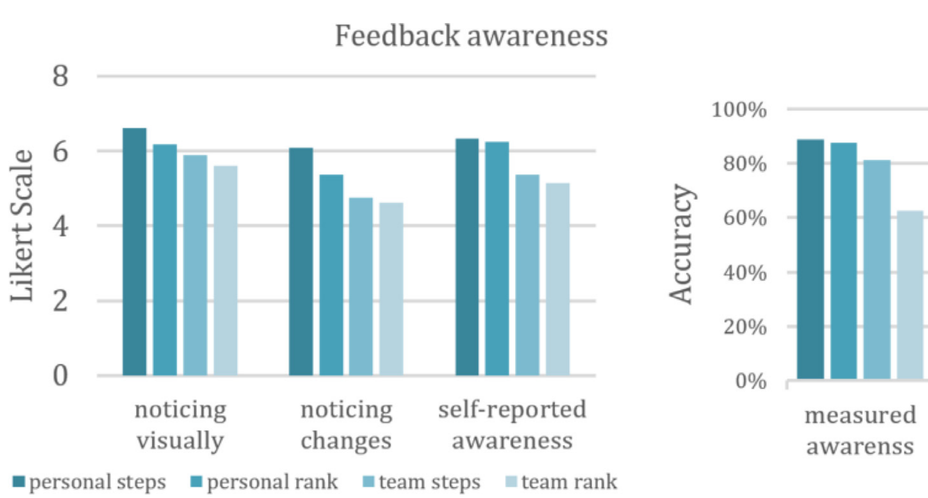


Fig. 7. Results from the survey and the accuracy of measured awareness based on recall for typical indicator values at the end of day.

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 the 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. For more detailed results we invite the readers to our paper focused on the feedback awareness aspects from the glanceable watchface indicators (Esakia et al., 2018).

4.2.8. Companion app and website engagement

As part of our effort to address H3 we measured manifestations of user engagement with the companion app by logging user interactions with the interface. On average the participants from the connected groups opened the app 115 times across 8 weeks versus 32 for the mixed groups. The website engagement was generally lower, at 10 average instances of opening the website (the default page is the dashboard as shown in Fig. 3) for the participants from the connected groups and 15 for the mixed groups. The difference for the website engagement is caused by the fact that mixed groups had web-only users that periodically tracked their progress via the web interface thus accessing the website more frequently. The companion app view for the personal steps (see Fig. 2c) 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 the utility of this view (Fig. 2c).

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 Fig. 2d). 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 Fig. 8). 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 a more specific context

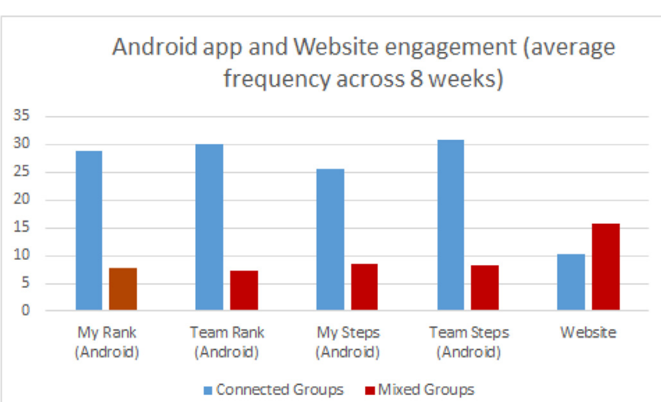


Fig. 8. Average number of times users accessed various sources of feedback across the duration of the study (8 weeks). Participants from the connected groups had significantly higher engagement levels with the companion Android app. The website engagement was higher for the mixed groups at the expense of web-only users.

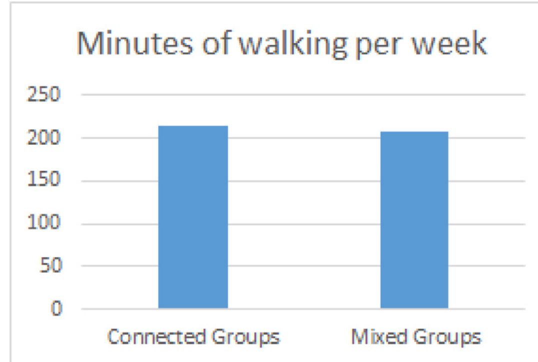


Fig. 9. Baseline levels of physical activity (minutes of walking per week) self-reported during the registration by the participants with smartwatches..

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 Fig. 2d). 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 we 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 member's 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").

4.2.9. Physical activity levels

As part of our effort to address the physical activity aspect of the third hypothesis 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 of the participants on average exceeded or met their daily individual goals for 4.82 (SD =2.85) weeks (see Fig. 10). The average daily step count for the participants using smartwatches was 10,617 steps (SD = 2672). 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). We also observed a significant differences between the two types of groups in terms of the perceived encouragement from the indicators, the survey responses to a question inquiring about whether participants felt encouraged to engage in physical

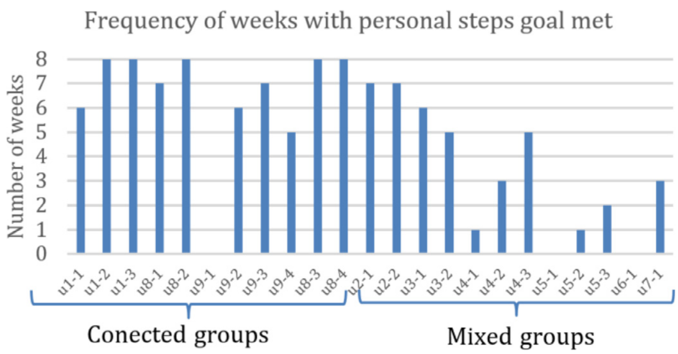


Fig. 10. 'Connected' groups had significantly higher number of weeks during which their average daily steps met or exceeded daily goals.

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 ($M = 4.33, t(20) = 2.352\, p = 0.029$). It is noteworthy that the differences between the two types of groups were not present in the pre-study registration responses to the question inquiring about weekly levels of physical activity. Based on the self-reported values provided by the participants, the average levels of physical activity for the connected and mixed groups were 214.1 (SD = 135.8) and 207.3 (SD = 223.55) minutes per week.

4.3. Qualitative data analysis

This section focuses on the qualitative data analysis of participant interviews from twenty participants. The 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 3) 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 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 3). 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) which includes two sub-themes with 89 and 65 meaning units in each.

4.3.1. Interpersonal factors

The sub-theme of "Competition and Cooperation" (See Table 3) 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 Facilitating 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

Table 3
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 7 members had the watch but I like to keep an eye on make sure that everybody was remembering 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 'u94 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'
		Weekend PA	10	7	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
		PA & Welness	8	3	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
	Barriers (n = 58)	Group Cohesion	21	2	So it was more about what I was... what I was accomplishing... cuz I didn't feel like the team was really... team
		Declined engagement	17	3	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 didin't it just didn't you know like 'it's okay I tried,i have worn it to see what works' it stopped working and now I don't know why and just I didn't care
		Not Everyone Had Pebble Watches	11	6	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
		Limited interaction	9	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
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
	Watchface Glancing Frequency Factors (n = 91)	Non Specific	30	16	Oh just glancing down and looking at it
		Personal Steps	22	15	Well 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 if it's a competition and I want to know if I'm first in my group
Watchface Feedback Awareness (n = 153)	Typical Personal Steps Values (n = 82)	End of The Day	48	18	Most of the time it was 2 out of 5
		Morning	22	14	Usually in the morning I'll get up and walk on the treadmill so I usually have to 2 to 3000 steps before I get to work,
		Lunchtime	12	9	well at lunch at 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	At the end of the day 10000 to 11000 ...10:30 11:00 at nigh
		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 yeah

Table 4
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	I guess 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	I was accumulating so for example most of the time my goal was 10000 I believe steps today so like if I called myself 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	but the steps are different the Fitbit had less steps No it wasn't significant, but it was, I knew that was a more.
		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 as well so
		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

person").

The second sub-theme ("Communication and Interaction" as seen in Table 3) 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 didn't 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 didn't it just didn't you know like 'It's okay I tried, I have worn it to see what works"').

4.3.2. Fitaware use

The sub-theme of "Adherence Factors" (See Table 4) 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 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.").

4.3.3. 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 10,000 to 11,000 ... 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 lunchtime ("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").

4.3.4. 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 10,000 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 17,000 steps 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[1]. "), 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.").

4.3.5. Influence of the four indicators on the behaviors

In order to address H3, which suggests that regular observations of the glanceable feedback influence participants behaviors, we performed a top-down analysis with a focus on the four watchface indicators in the context of physical activity related behaviors.

Personal Steps.The interviews reveal that, regardless of the 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 10,000 back by the end of your work day so you can get 15,000 steps by the end of the day all together").

Personal Rank Participants from the connected groups 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").

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").

Team Steps 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.").

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?").

[1] This was caused by a bug in our software that required the smartphone to be on during the transition between calendar days. The users that reported the bug all happened to be shutting down their phones before midnight. We informed the participants about this issue and instructed them to keep their phones on during the calendar day transition.

5. Discussion

5.1. Revisiting the hypotheses

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

Users will wear and engage with smartwatches as part of a group dynamics health intervention.

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 were 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 members (G5) revealed that a low sense of group cohesiveness negatively affected adherence to use. Overall, the verdict for H1 is dependent on the nature of the groups. The results for the cohesive teams with active captains suggest that the first hypothesis is confirmed.

Participants, as they regularly look at the smartwatch display will observe the information from the glanceable indicators and develop awareness.

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 (Desarnauts, 2015; Pizza et al., 2016). Furthermore, the interview and survey results demonstrate that the 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. This observation is inline with the preliminary findings in the study by Gouveia et al. (2016) where smartwatch users reported noticing fitness related feedback while checking 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 varied dramatically and included the rankings of the teams that tracked progress manually) and disinterest 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 reduce user engagement with the technology (Ledger and McCaffrey, 2014; Shih et al., 2015). In summary, the results suggest that watchface based glanceable and non-interruptive feedback can lead to physical activity progress awareness. The second hypothesis is largely confirmed for the personal steps, personal rank and team steps indicators.

Regular observations of the group and individual related feedback presented on the watchface will influence participant behaviors with regards to the FitAware system, physical activity and peer interactions.

The results show that the participants developed awareness of their daily step count progression and reacted to low step count values, or values close to their daily goal, with increased physical activity. Participants from the connected groups were more attentive to the personal rank changes and reacted 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 it helped them ensure collective progress, and use the observed values as a reason to communicate with their group members to encourage more physical activity. It should be noted that the examples participant behaviors triggered by rank changes or low step count values suggest that watchface based glanceable updates can facilitate user reactions without the downside of causing interruptions thus avoiding the negative effect of interruptions associated with interruptive notifications (Pejovic and Musolesi, 2014). Overall, it can be concluded that the third hypothesis is confirmed for the connected teams especially considering the fact that the participants from the connected groups, on average opened the Android app 115 times across 8 weeks and the website 10 times. In terms of the smartwatch engagement frequency, assuming a conservative estimate of two glances per hour for eight hours per day, the total number of glances across eight weeks is 896 or 617% more than the Android app and the website engagement combined, thus minimizing the possibility of the awareness developing from sources other than the smartwatch watchface.

5.2. Implications

Attainable Goals. User reactions to the glanceable indicators reveal that the personal steps indicator was beneficial as it helped them develop awareness of the daily step count and notice 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) (Evenson et al., 2015). The interviews also reveal that participants particularly cared about the situations when they were close to their daily goal. They reacted to such situations by engaging in physical activity – a behavior predicted by the research on motivational aspects of goals (Locke, 1996). Furthermore, these findings also support the early findings and design suggestions by Gouveia et al. (2016) suggesting that users notice and react to small attainable goals and that smartwatch watchfaces should convey attainable goals more explicitly.

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 (Choe et al., 2013). 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. For example the team rank indicator was disliked for very dramatic changes and hard to interpret values. 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 (Choe et al., 2013; Lin et al., 2006; Nakajima et al., 2008), and on the other hand, studies warn against such approaches as they may fail to convey feedback in transparent and easy to interpret ways (King et al., 2013).

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 (Desarnauts, 2015; Pizza et al., 2016) 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 (Gouveia et al., 2016). 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 (Fausset et al., 2013; Shih et al., 2015). 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.

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 (Beauchamp et al., 2007). With FitAware-like systems in the context of group dynamics-based interventions (Paul, 2008), 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 (Bass, 1998). Thus, FitAware-like systems can help public health practitioners *adopt* and *implement* (Glasgow, 2013) interventions like FitEx.

6. Conclusion

This paper presents a multi-component smartwatch centered system called FitAware to facilitate individual and group dynamics-based behavioral strategies in the context of an 8-week physical activity community intervention program. FitAware presents customized glanceable feedback about daily step count progress via non-interruptive feedback updates on individual, group, and cross-group levels.

The results of deploying FitAware as part of statewide community intervention, demonstrate that users tend to show high levels of consistency of wearing and thus creation opportunities for receiving the information from the watchface. In the case of groups that were more socially supportive, FitAware performed better with regards to channeling group dynamics-based strategies such as competition, cooperation, interaction and communication. We also observed high awareness levels for within-group feedback. Participant awareness levels for between-group feedback (team rank) revealed significant dependence on group characteristics. Participants in teams with proactive, competitive, encouraging captains exhibited measurably stronger team rank feedback awareness as well as higher activity levels and competitiveness.These results are encouraging as they show that passive glanceable watchface updates can facilitate awareness of the group fitness related feedback.

Overall, we find these results encouraging and useful for establishing potential future directions in the domain of smartwatch-based and group wellness focused systems. Specifically, we would like to explore user interfaces capable of conveying not only numeric but also abstract (graphical) forms feedback. A medium capable of conveying abstract visualizations can be leveraged to provide positively framed feedback and minimize negative perceptions inherent to numeric indicators. With an interface like this we would also like to explore various mechanisms for encouraging and strengthening the 'active captain' behaviors as they have been shown to positively influence the overall group results. A potential idea in this direction is to automatically capture and recognize captain's acts of voluntarism an d leadership with relation to their group members.

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