

# Use and Adoption Challenges of Wearable Activity Trackers

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## Abstract

Wearable activity trackers are becoming widely adopted, yet challenges continue to exist in effective long-term use and adoption. Existing research focuses mostly on the use and adoption challenges associated with technical- or device-related issues and respective workaround strategies. Little is known about how personal preferences and other individual characteristics affect use and adoption of wearable activity trackers. In this paper, we present a six-week user study of 26 users using physical activity trackers embedded in clip-on and smart watch physical devices. We describe novel implications of the usage patterns, including the need to help people be mindful of their physical activity trackers, to understand and further articulate gender differences in use and adoption of wearable devices, to incorporate big data analytics in informing and coaching people's practices, and to reframe data inaccuracy as a byproduct of mismanagement of expectations of the device's capabilities and its expected usage.

**Keywords:** use and adoption challenges, personal informatics, physical activity trackers, wearable activity monitor, mobile health

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## 1 Introduction

Physical activity has many positive health benefits. Research has shown that even 30 minutes of daily moderate-intensity physical activity can significantly reduce the risk of a variety of chronic diseases (e.g., cardiovascular disease, hypertension, diabetes, cancer, obesity, depression, and osteoporosis) and improve mental health and well-being (Penedo & Dahn, 2005; Warburton et al., 2006). However, personal (e.g., motivation), practical (e.g., time, accessibility to facility, cost), social (e.g., social support of families and friends), and environmental (e.g., weather, etc) barriers continue to hinder people's commitment to maintaining a healthy level of physical activity (Andajani-Sutjahjo et al., 2004; Chan & Ryan, 2009). Self-regulation strategies, such as self-monitoring, goal-setting, reinforcements, and self-corrective actions have been shown to increase physical activity participation in a variety of populations (Bandura, 1991).

In recent years, commercial technologies have emerged for automatically collecting data that can assist in self-regulation. For instance, tools such as Fitbit, MyFitnessPal, and similar options can monitor activity data such as number of steps taken, distance traveled, speed and pace, calories burnt, heart rate, skin temperature, perspiration level, hours slept, dietary information, etc. Despite the technical and commercial advances in wearable activity monitoring devices, the state-of-the-art devices tend to result in only short-term adoption and changes in motivation and behaviors (Klasnja et al., 2011). For this reason, Nike has recently cancelled the next iteration of its Nike+ FuelBand wearable activity tracker, shifting its focus to software interface design (Statt, 2014).

Existing research focuses mostly on use and adoption challenges associated with technical- or device-related issues and workaround strategies (e.g., Consolvo et al., 2008; Choe et al., 2014). Rooksby et al. (2014) described how personal motivations could affect the style of use and adoption of a wide variety of personal tracking technologies, and suggested that more attention should be paid to personal preferences and individual characteristics. In this work, we aim to uncover use and adoption challenges at the individual level that ultimately lead to dropouts (i.e., abandonment of wearing the tracking device).

This work makes a number of contributions to research on use and adoption of wearable activity trackers: (1) instead of producing activity goal reminders, the system should remind its user to simply wear and use the device; (2) gender differences of use and adoption of physical activity trackers have been understudied and must be considered seriously in future studies; (3) big data analytics should be leveraged to inform users beyond the conventional social networking features; (4) data inaccuracy is a direct byproduct of mismanagement of expectations of the device's capabilities and its expected usage.

Our perspective differs from the technological- and device-oriented focus of physical activity tracker and use by focusing on personal preferences and individual-related issues.

In this paper, we first provide an overview of how wearable interfaces for tracking physical activity participation have evolved, then turn to current challenges in their use and adoption with a specific focus on individual-related issues. We next describe our study that involves 26 undergraduate students using FitBit activity trackers over a period of 6-weeks. We discuss their use and adoption behaviors and challenges. Finally, we offer some suggestions for improving the design of activity trackers.

## 2 Related Work

A physical activity tracker is typically capable of tracking activity (e.g., step count) and other physiological information (e.g., heartbeat rate). The data is uploaded and stored on a server and is visualized in ways that allow users to gauge progress and gather incremental feedback. The data can also be shared with other users in a social media platform. The goal is typically twofold; the data visualization will provide enhanced awareness so that users are in tune with their most up-to-date activities, and the social sharing platform will provide additional support to motivate the individuals to keep up with personal activities (e.g., Consolvo et al., 2006; Toscos et al., 2006; Maitland et al., 2006; Ali-Hasan et al., 2006; Lin et al., 2006). Researchers have called the movement of tracking all aspects of one's daily life Lifelogging (Sellen & Whittaker, 2010), Quantified Self (Choe et al., 2014), or Personal Informatics (Li et al., 2010). In general, the personal health information that is collected at large scale and recorded beyond the conventional qualitative and narrative form affords design opportunities for data visualization, knowledge development, and everyday health support. The design space of leveraging tracking data to support and persuade health-related behavior change is enormous, involving issues and strategies with respect to capturing and accessing information, progress monitoring, feedback notification, motivations, learning, entertainment, and social support (e.g., Grinter et al., 2010; Klasnja & Pratt, 2012). We focus our review first on designs that aim at physical activities and then on challenges and barriers in use and adoption identified in previous literature.

### 2.1 Persuasive Interfaces in Wearable Activity Trackers

#### 2.1.1 Goal-setting and Feedback

The first step to accomplishing a task typically requires identifying a clear goal and the appropriate actions to achieve that goal. Locke and Latham (2002) developed the goal setting theory that established the positive effect of goal setting on task performance. When comparing to an objective without a clearly prescribed goal (e.g., simply urging people to do their best), they found that having a difficult goal consistently leads to higher performance, as long as people are committed to the goal and believe they have the ability to attain it.

In HCI, the design field of persuasive technologies has emerged to explore the potential for changing people's behaviors in "desirable" ways (e.g., becoming more healthy). Building from the concepts of goal setting theory, researchers have experimented with design concepts and prototypes that include goal-setting and feedback mechanisms. The resulting displays vary greatly. Some systems represent users' raw data activity in a form of a simple bar chart (e.g., Consolvo et al., 2006; Toscos et al., 2006; Maitland et al., 2006; Ali-Hasan et al., 2006). Some utilize gamification concepts—adopting the ideas of "levels", "scores", or "badges" for achievement—to motivate the users (Deterding et al., 2011). Others have created metaphorical abstract representations to symbolize the users' activity level. For example, Breakaway (Jafarinaimi et al., 2005) displays a digitally rendered sculpture that slowly deteriorates as time passes to encourage people to take a break from working too long at their computers. Virtual Aquarium (Nakajima et al., 2008), a system designed to improve users' dental hygiene, provides two forms of metaphorical feedback: a scrub cleans algae as users brush their teeth (immediate feedback), and the fish tank stays healthy if users brush their teeth regularly (long-term feedback). Spark (Fan et al., 2012) is an informative art display that visualizes physical activity using abstract art. In general, the positive effect of providing feedback to enhance user self-awareness and the sense of self-efficacy is well established. Furthermore, participants tended to prefer positive feedback to negative feedback (Lin et al., 2006; Nakajima et al., 2008; Consolvo et al., 2008; Choe et al., 2013). For this reason, most persuasive technologies share positive representations of physical activity data with their users.

#### 2.1.2 Reminder Notifications

Persuasive technologies that involved the use of reminder notifications were developed to address a variety of health issues (Bental et al., 1999). Researchers have studied how best to deliver health

messages and engage people in healthy behavior. Fjeldsoe et al. (2009) analyzed 33 studies that involve using mobile phone short-message service (SMS) to deliver behavior change interventions. They found that SMS-delivered interventions have positive short-term behavioral outcomes, but the studies also did not control for the timing of intervention messages or the number of messages. Noar et al. (2007) conducted a meta-analysis of health behavior change interventions of 57 studies published between 1989 and 2005. They found that study participants who have been contacted more than once with tailored messages performed better than those who have only been contacted once. It is worth noting that messages that emphasized positive attitude towards healthy behavior and one's self-efficacy were found to be more motivating than those focusing on health threats and risks (Noar et al., 2007). Additionally, tailored material is more likely to be read and remembered, presumably because it is perceived as more interesting and personally relevant (e.g., Brug et al., 1999; Fogg, 2003). In general, tailored health messages are found to be more effective than non-tailored materials or control conditions.

### 2.1.3 Social Comparison Strategies

In addition to visualizing and making aware of an individual's physical activity data, commercial and research prototypes have also explored the possibility to share an individual's activity, performance, and experience with their peers. It has also been shown that users will work harder on a group task if they perceive that their efforts to be instrumental in achieving the desired outcomes and that their contributions are identifiable and can be assessed by the group peers (Karau & Williams, 1993).

There exist two popular types of social comparison strategies that emphasize either competitive or cooperative aspects of sharing group data. Support for cooperative mechanisms is based on social psychology theories that have suggested that when individuals develop a strong identity with a group, they are more committed to the group goal and its success, and as a result, they tend to care more about the collective outcome and contribute more (Weldon & Weingart, 1993). For example, Fitster displays the distance a team had walked so far in terms of a route across a county/country, giving users a sense of group accomplishment (Ali-Hasan et al., 2006). In terms of competitive group mechanisms, there have been numerous attempts at integrating social networking platforms with motivating physical exercises (e.g., Anderson et al., 2007; Benford et al., 2006). In these cases, participants reported that they enjoyed the awareness aspects and competing against their group peers in achieving a higher physical activity level. For example, their users reported modifying daily commute route to walk greater distances in the hopes of beating previous weeks achievements.

In general, social comparison provides users with a way to compare their performance that provides stimulating challenges, encouraging teamwork, and supporting complement group goals and accountability. However, prior research has reported mixed results. Some users reported that they enjoyed the competitive nature of the design (Maitland et al. 2006), whereas others found it to be discouraging and felt it was unnecessary (Lin et al., 2006; Toscos et al., 2008).

## 2.2 Use and Adoption Challenges of Wearable Activity Trackers

All modern day wearable activity trackers implement a combination of features detailed in the previous sections. For example, FitBit, Nike+ FuelBand, and other physical activity tracker platforms all incorporated some form of goal-setting and feedback mechanism, notification features, and social sharing that allows users to share the tracked data with groups and/or other individuals. However, the evaluation of earlier research prototypes also strictly focused on short-term effects and did not focus on users' long-term behavioral changes (Klasnja et al., 2011).

For short-term usage, Bravata et al. (2007) evaluated the association of pedometer use with physical activity and health outcomes among outpatient adults. They found that across 26 studies (8 randomized controlled trials and 18 observational studies), pedometer users significantly increased their physical activity and decreased their body mass index and systolic blood pressure. Having a step goal was an important predictor of increased physical activity. Fausset et al. (2013) examined technology acceptance and adoption of activity monitoring technologies among older adults over two weeks. They found that the participants' initial attitudes were positive; but one person stopped using the technologies after the first day, another stopped after eight days, and two before the end of the two-week period. The participants were fine with the ease of use but reported concerns that included inaccurate data collected, wasting time, and uncomfortable to wear. McMurdo et al. (2010) examined the effectiveness of a behavior change intervention (using goal-setting strategy) with or without a pedometer in increasing physical activity in sedentary older women during a 6-month trial. Although both goal-setting and goal-setting with pedometer groups showed superior performance over the baseline group at 3 months, neither was longer statistically significantly different from the baseline at 6 months. In general, studies have found success in short-term usage of activity trackers, but the effects disappeared after 3-6 months.

In addition to inpatients, outpatients, and the elderly population, researchers have also studied a group of “extreme users” who participate in the Lifelogging and Quantified Self movement. Sellen and Whittaker (2010) defined the benefits of lifelogging systems in terms of five distinctive memory systems: recollecting, reminiscing, retrieving, reflecting, and remembering. They suggested people to track selectively instead of capturing everything, measure meaningful cues that might trigger different kinds of memories, clarify the aspects of memory they are targeting (e.g., recollection, reminiscence, etc) when designing for memory support, and capitalize on users’ own memories overcome weakness of the digital systems. Based on a survey conducted in Quantified Self forum, Li et al. (2010) derived a stage-based model of personal informatics systems composed of five stages (preparation, collection, integration, reflection, and action). Barriers in each of the stages include: (1) preparation: determining what information to collect and what collection tool to use; (2) collection: user-related (lack of time, lack of motivation, did not remember) or data-related (may rely on subjective estimation) issues; (3) integration: the format of collected data is different from the format necessary for reflection; (4) reflection: lack of time or difficulties retrieving, exploring, and understanding information; (5) action: most systems do not have specific suggestions on what to do next. Li et al. (2010) pointed out that most research focuses primarily on the collection and the reflection phase (e.g., Sellen & Whittaker, 2010), and there exists an opportunity to improve the other stages. Choe et al. (2014) studied how the Quantified-Selfers used existing technologies and built their own workarounds to overcome different barriers. They identified common pitfalls to self-tracking such as tracking too many things that led to tracking fatigue, not tracking triggers and context that led to not gaining insights, and insufficient scientific rigor that led to inconclusive results in self-experimentation. Rooksby et al. (2014) studied personal tracking practices and identified different styles of tracking including directive (accomplishing goals), documentary (documenting activities rather than changing them), diagnostic (looking for causes of symptoms), collecting rewards (scoring scores and registering achievements), and fetishized tracking (having a strong interest in gadgets and technology). They also found that tracking information is often used and interpreted with reference to daily or short-term goals. This points to the possibility that the lack of adoption or non-use could be related to personal preferences rather than strictly technological issues.

In summary, existing research focuses mostly on the technical- or device-related challenges. Considerably less research has focused on individual-related use and adoption challenges. In the following sections, we report a study that aims to complement existing understandings of use and adoption challenges of physical activity trackers.

### 3 Methods

We recruited 26 undergraduate students at a large American university (18 male, 8 female). Their ages ranged from 20 to 24 years old (median age: 21.5). Each participant received one activity tracker to wear. We asked them to use the device for six weeks in ways that they prefer. In order to assess the issues related to physical design of the physical activity trackers, participants were randomly assigned with two different types of FitBit activity trackers (i.e., 9 FitBit Forces and 17 FitBit Ultras). We chose to use FitBit in this study because it is currently the market leader in the fitness activity tracker space (FitBit 68%, Jawbone UP 19%, Nike+ FuelBand 10%; NPD Group, 2013). FitBit’s activity trackers (i.e., FitBit Ultra and FitBit Force) provide features that are similar to most other commercially available activity trackers such as Jawbone UP and Nike+ FuelBand. Table 1 shows the distribution of the FitBit devices, their physical design and tracking features. Each device has a different design, but both support the same tracking features. FitBit usage logs were collected from each user at the end of the study.



	Name	Type	Tracking Features	Participants
	FitBit Force	Watch-style	Motion, steps, distance, calories, and sleep	9
	FitBit Ultra	Wearable, clip-on	Motion, steps, distance, calories, and sleep	17

Table 1. Summary of two types of the activity tracker used in the study.

Before starting the study, participants answered a pre-survey of 7-point Likert scale questions (i.e., motivation to exercise, awareness of their physical activity level, and demographics information). After six weeks, participants were asked to answer a set of post-survey questions (i.e., motivation to exercise, and awareness of their physical activity level after having used the physical activity tracker for 6 weeks, whether they felt healthier, a degree of satisfaction of using the device, whether they would recommend the device to others, how frequently they checked their activity data using the FitBit dashboard (i.e., 1- *less than once a week*, 5- *several times a day*), and the use and adoption challenges they encountered during the six week period.

The open-text survey responses about the participants' use and adoption challenges were analyzed with an open coding approach through an iterative process. The first and second authors initially coded all the data collected. The codes were then discussed among all the authors to iteratively merge, refine, and identify the most prominent themes. Two rounds of iterations eventually converged into four themes as presented in the result section.

#### 4 Use Patterns

From the activity logs, we were able to calculate how often participants used the device over six weeks. Figure 1 illustrates participants' dropout rate during the study. About 25% of them stopped using FitBit after one week; 50% at the two-week mark; and 75% stopped using the device after four weeks. Only three participants used the device every day. The overall dropout rate result shows the usage difference among participants, and we were interested in identifying groups of people who showed similar patterns. To do this, we used k-means clustering to search for contrasting clusters among the participants based on the data we collected. To decide a starting point of k, we first performed the centroid hierarchical clustering on all seven survey items. This led us to cluster the participants into two groups (high and low usage groups); the k-means output showed that the clustering variables' means differ significantly ( $p < 0.001$ ). We obtained two clusters of participants, with 9 participants in the high usage group (3 FitBit Force and 6 FitBit Ultra users) and 17 in the low usage group (5 FitBit Force and 12 FitBit Ultra users).

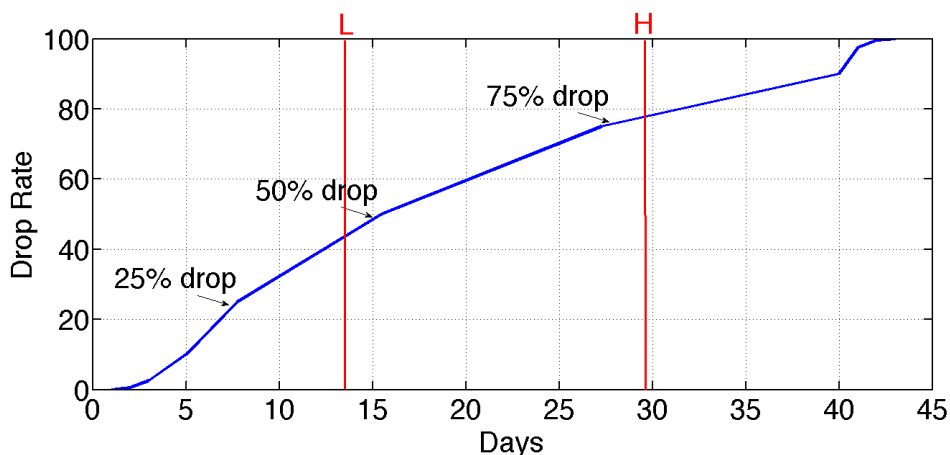


Figure 1. Participants' dropout rate over six weeks. The two red lines represent the average days of device usage by low usage (13.4) and high usage (29.0) groups.

Figure 2 shows the motivation and awareness between high and low usage groups in the pre- and post-surveys. Table 2 summarizes the statistical test results of survey responses between the two groups. Both groups showed positive initial motivation of using FitBit for tracking their physical activities. For awareness, the high usage group initially had lower awareness, but it improved over time.

*"This device has changed my perception about my exercise because it helped me become aware of the fact that I am less active. I was surprised by how much using the FitBit made me more motivated and competitive with myself. I really liked being able to see my own progress."* (P1, male, high)

Overall, the results indicate that more FitBit usage could lead to higher motivation to exercise, awareness of one's activity level. They also reported feeling healthier, more satisfied with FitBit, and were positive about recommending others to use FitBit.

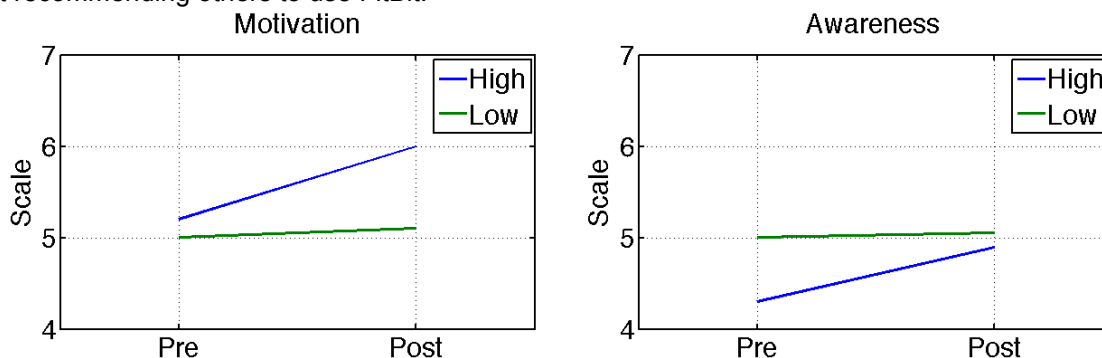


Figure 2. Differences in motivation and awareness between the pre- and the post-surveys.

Item	High (9)	Low (17)	F (1,24)
Device Usage (days)	29.0 (12.6)	13.4 (10.6)	10.5**
Dashboard Usage Frequency	3.5 (1.3)	2.1 (1.2)	4.7*
Change in Motivation	0.7 (0.6)	0.1 (0.3)	11.3**
Change in Awareness	0.5 (0.8)	0.05 (0.4)	3.8 <sup>+</sup>
Feel Healthier	5.0 (1.4)	3.0 (1.2)	11.2**
Satisfaction	5.2 (1.2)	2.3 (1.1)	33.1**
Recommend to others	5.8 (0.7)	2.7 (1.4)	30.5**

<sup>+</sup> $p < 0.1$ , \* $p < 0.05$ , \*\* $p < 0.01$

Table 2. Summary of responses (mean, s.d., and t-test) from the high and the low usage groups.

For the low usage group, their motivation and awareness were both positive at the beginning, but had stayed the same during the six-week period. This is probably due to the fact that many of them stopped using the device after the first couple of weeks (mean = 13.4 days).

*"I am in pretty good shape already. When I first received FitBit, I felt a stronger motivation to exercise more. However, this soon wore off after I found it inconvenient and often forget to bring it with me."* (P24, male, low)

Overall, our analysis clearly showed that higher FitBit usage led to more health benefits, and we were interested in the use and adoption challenges encountered by the participants, especially those in the low usage group that led them to stop using the FitBit.

## 5 Use and Adoption Challenges

It is worth noting that more than 17 of 26 (65%) participants stopped using the FitBit activity tracker after just a little over two weeks. In our post survey, we specifically asked them to share their experiences and feedback regarding the use of the activity tracker. We articulate the identified challenges in the follow subsections.

### 5.1 Issues with remembering

Twelve participants (12 lows) mentioned that it was difficult for them to be mindful of the whereabouts of their FitBits and remembering to carry them. They often forgot because it did not fit well with their already established daily routines.

*"I often forgot in the morning to put on my device as I was usually in a rush to eat and get to class."* (P4, male, high)

*"It was quite annoying for me remember to wear the device and also to charge it everyday."* (P18, female, low)

With already established schedules that may be hectic and difficult to manage, participants found it difficult to develop the physical and mental habit of using a new device regularly. They also frequently forgot FitBit if they kept it in their pockets. *Out of sight out of mind* is a challenge that many of our participants faced.

*“When I put FitBit in my jacket pocket, I often forget that they're there.”* (P3, male, high)

*“Every time I change clothes, take shower, etc., I have to remember to take it out of my pocket and put it on the new clothes I am wearing.”* (P19, female, low)

Even when remembering to carry their device, seven participants in the low group expressed a desire to receive more informative notifications or feedback information of their physical activity. They mentioned that the activity tracker does not provide tailored triggers that could remind them of the activity goals that they forgot to reach.

*“This physical activity tracker could be utilized more efficiently by notifying me on my smartphone or tracker when I am not on track to meet a goal.”* (P16, female, low)

It is worth noting that nobody in the high usage group complained about this issue, as we expect that participants in that group were already motivated enough to use the device regularly.

## 5.2 Issues with physical design and aesthetics

Eight participants (1 high and 7 lows) stated that the device was uncomfortable to wear even when exercising, whether it was worn on their wrists or hanging from their pockets. They felt that the device was cumbersome and intrusive when worn during their daily activities. Depending on the activity context, participants may not want the device to interfere with their physical activity.

*“Physical activity trackers should be inconspicuous. A lot of time I felt they should not be easily noticed by the users.”* (P4, male, high)

Three participants (3 lows) found it inconvenient that the device was not waterproof. They were concerned that they might accidentally damage the device with water, sweat, weather, or other liquids, which caused major inconvenience in carrying out their activities.

*“I usually have to do things like wash my hands, cook, and clean, and at work I have to work with food a lot. I can't wear it during then.”* (P10, male, low)

Two participants (1 high, 1 low) found that wearing it while sleeping was uncomfortable or it got into the way while typing at a computer.

*“I usually take it off if I'm using the computer because it gets in the way.”* (P16, female, low)

Another set of major concerns for female participants concerned the device aesthetics. Four female participants (1 high and 3 lows) said that they found the device to be bulky and unattractive, which prevented them from using the device regularly; they did not want to be seen wearing it.

*“It is not very attractive looking and so it is not preferable to wear it out.”* (P24, male, low)

This perception interacted with the typical design of women's clothing.

*“It is difficult to use FitBit when wearing a dress because there is no place to attach it to.”* (P18, female, low)

Depending on what the females were wearing, FitBit might not match the outfit, the occasion, or was simply seen as not suitable for a work environment.

*“If I wear jewelries or bracelets on my wrist, then I won't want to wear the FitBit.”* (P15, female, low)

*“The look of FitBit doesn’t always match well with what I wear.”* (P17, female, low)

In general, gender differences in the adoption of physical activity trackers have been understudied and are rarely reported. In our study, the female participants shared a number of distinct preferences and concerns in their use of FitBit, pointing to a need for further investigations in this area.

### 5.3 Issues with data management, integration, and sharing

Most commercial physical activity trackers allow users to selectively share their data with other individual users. However, given the prevalence of big data analytics available today, eight participants (1 high and 7 lows) mentioned that they wished to see better support for sharing and comparing activity data with others beyond the basic feature of sharing data among one’s social network.

*“Rather than saying that I took 100 steps today, let me know what the average person that is my height, age and weight walks a day and where I stand with them.”* (P12, female, high)

*“Some of control baseline would be helpful and would keep me going, so that I can be above average.”* (P21, male, low)

Four participants (1 high and 3 lows) mentioned they wanted to receive more interesting and diverse feedback on their physical activities that could be leveraged by smartphone capabilities. They suggested that linking the activity tracker to a smartphone, where it presents their activity progress information more frequently and in a more comprehensive way. For example, one participant in the low group mentioned that he did not find the device was fully integrated with the smartphone application, which he expected to see and receive more useful information of his fitness condition.

*“The tracker would work actively with an smartphone app that sends notifications, allows food input tracking, displays real time results, provides routes, and linked with others using the device. I feel like this would be a much more active experience and successful for users.”* (P22, male, low)

### 5.4 Issue with data accuracy

Five participants (1 high and 4 lows) reported that their device did not accurately record daily activities and calories burned. Four participants (1 high and 3 lows) encountered specific technical problems with the device; for example, it turned off or randomly reset itself. Three participants (3 lows) also complained about the limited tracking ability of FitBit. For example, they found that inputting their diet was difficult and time-consuming, and were not always able to find a comparable food on the list.

*“It got kind of annoying have to search through the food database for everything that I ate that day. Sometimes I could not find what I was really looking for or it took me a few minutes of searching to finally find it.”* (P19, female, low)

Two participants (2 lows) mentioned that they were also somewhat frustrated when they found that FitBit did not automatically record calories burned from other activities (e.g., weightlifting, treadmill walking, etc.) that did not involve actual walking movements.

*“Another way that FitBit was failed was one day I decided to walk on a treadmill as exercise. My progress was not tracked at all and I did not know the total number of calories that I had burned.”* (P8, male, low)

Consolvo et al. (2008) detailed the following primary types of perceived errors made by physical activity trackers: make an error in the start time, make an error in the duration, confuse an activity it was trained to infer with another it was trained to infer, confuse an activity it was not trained to infer with one it was trained to infer, fail to detect an activity it was trained to infer, fail to detect an activity it was not trained to infer, and detect an activity when none occurred. However, in their field trial, the participants did not feel that the system discouraged them from performing a particular type of activity as suggested by Consolvo et al. (2006). In our study, the participants were constantly confused by the fact that FitBit



appears to track *movements* instead of *motions*, and they were disappointed that many of their exercises that did not result in movements detectable by the trackers.

## 6 Implications for Design

### 6.1 Context-aware notification reminders

Existing notification mechanisms are typically employed to create tailored messages that remind people to maintain their activities (e.g., exercise or diet). However, a major challenge identified by our participants was remembering to keep the activity trackers with them. The challenge of a clip-on device like FitBit Ultra is that it is often left behind with the piece of clothing it has been attached to. With a smart watch interface like FitBit Force, participants ran into the challenge of needing to remove it because of the activities they are engaged with (e.g., washing dishes, showering, not suitable for work environment, etc). There also seems to be difficult tradeoffs in the size of the tracker. When the device is small and easy to carry, it becomes more fragile, less noticeable, and easily forgotten. When the device is bigger, it is bulky and uncomfortable to wear.

Note that while the participants often forgot to carry around their FitBit activity trackers, they almost never forget to carry their keys, wallets, and cell phones. One reason could be that they have had more experiences and longer period of adoption to incorporate these other artifacts into their daily activity routines. Another explanation may be that some objects are simply more critical to everyday activities and this motivates remembering habits. One way to address the issue of forgetfulness might be to embed the activity tracker into objects that people already carry with them all the time, such as key fobs, glasses, and smartphones. Furthermore, most of the commercial physical activity trackers offer Bluetooth pairing with smartphones to provide real-time synchronization and feedback. The smartphone could notify the user whenever the physical activity tracker is out of range, and thereby reminding the participants to wear them.

### 6.2 Accessorizing activity trackers

We identified important gender differences in the attitude of use and adoption of physical activity trackers. Most of the female participants reported concerns with the physical design of the trackers. Although aesthetics and look and feel are a primary concern, other practical inconveniences are caused by simply how female clothing are designed (e.g., dresses that have no pockets for the clip-on design, other hand and wrist jewelries that prevent the use of the smart watch design, etc), and in some cases, the expectations in their work environment.

These challenges are gender specific, and are neither perceived nor experienced by the male participants in our study. A possible solution would be to accessorize the cover for these activity trackers similar to the protective cases of laptops and smartphones, so that participants can change the look and feel of their physical activity trackers to suit their mood, outfit, or occasion. Another possible solution would be to make the device smaller and more affordable so that they could be sewed into the seams of their clothes; some clothing companies already embed devices such as RFID tags into their products. More recently, Ananthanarayan et al. (2014) presented a system that provides users with the ability to craft their own personalized wearable device. The goal is to make health technologies more meaningful to an individual and encourage higher appropriation. This could be a viable approach for those who are especially handy and capable of crafting. Future studies that investigate affordances of new form factors could result in new possibilities that could overcome these challenges.

### 6.3 WorkoutBuddiesLikeMe

Social interactions and interpersonal relationship are found to be vital to individuals' health and well-being (Berkman et al., 2000) and a significant determinant of exercise adherence (Sherwood & Jeffery, 2000). Most commercial physical activity trackers support conventional social networking features that limit information sharing and social interactions to people within one's social networks. There is no filters or suggestions based on one's age, sex, physical activity level, location, and so on. In our study, participants mentioned that they preferred to see trends and insights generated from big data analytics so they can be better informed about their practices instead of sharing and comparing their activity data with people they already know in their existing social network.

Online personal health information communities such as PatientsLikeMe (Frost & Massagli, 2008) already utilized the data analytics to reveal trends and symptoms that are related to a patient by his or her personal attributes. Physical activity trackers could benefit from this by aggregating information from the user base and allow users to identify and learn patterns from others who share similar personal and

situational contexts. In addition, the comparison data could be used to offer real-time training feedback to the participants while the exercise. For example, the physical activity tracker could detect that a user is jogging at a slower pace than the average population with similar personal (e.g., age, sex, height, age, diet, etc) and environmental (e.g., location, etc) characteristics and suggest the user to adjust his or her goals and jog at a slightly higher pace.

#### 6.4 Transparency and Trust in Activity Tracking

Prior studies have consistently reported user concerns with data inaccuracy that involves the trackers not recording what they are inferred to collect (e.g., Consolvo et al., 2008; Choe et al., 2014). However, this is less obvious with commercial trackers because most commercial trackers are ambiguous about what they infer to track. Their messages to the consumer are filled with overly ambitious goal of tracking *all* activities if the users wear them at *all* times despite the physical limitations of the device. In our study, participants did not discern data inaccuracy such as the miscounting number of steps, but rather, they were surprised by having to constantly learn and readjust of their expectations on what the device is actually capable of doing. In essence, the perception of *inaccuracy* is directly related to the *mismatch of expectation* due to the lack of knowledge on the device's technical capabilities.

Chalmers et al. (2003) observed similar physical constraints and limitations of wearable devices in uncertainty in sensing, limited coverage of communications infrastructure, and the transformations needed to share data between heterogeneous tools and media. They challenged ubiquitous computing's premise of seamless design and suggested an opportunity to make it a deliberate policy to reveal and use seams. By exposing the system's technical details to the users, it could reduce the ambiguity in the capability of activity trackers and empower the users to determine the most appropriate situations to utilize the activity trackers. Rooksby et al. (2014) studied personal tracking practices and found that tracking information is often used and interpreted with reference to daily or short-term goals. Therefore, it may be beneficial to reposition future physical activity trackers as sensing devices for a particular type of activity rather than a one-size-fits-all solution that is expected to be worn by users at all times.

### 7 Conclusion

In this paper, we synthesize current literature on persuasive mechanisms implemented in modern physical activity trackers and understanding of technological- and device-oriented use and adoption challenges. To understand how personal preferences and other individual characteristics could affect use and adoption of wearable activity trackers, we present a six-week user study of 26 users using physical activity trackers designed with clip-on and smart watch physical designs.

There exist some limitations to our work. For instance, our study involved only FitBit activity trackers. Therefore, the findings may not be generalizable to other newer activity trackers. For instance, it is likely that waterproof capability may become a standard feature in future activity trackers, and may no longer be a primary concern that could influence use and adoption.

This work has the following primary contributions: (1) we contrast existing notification mechanisms that remind people of activity goals with simply being mindful of wearing the device; (2) we uncover previously underreported gender differences of use and adoption of physical activity trackers; (3) we point to the potential of incorporating big data analytics to inform users beyond the conventional social networking features; (4) we reframe data inaccuracy as an issue of exposing device limitations and managing expectations. Our perspective differs from the technological- and device-oriented focus by examining the nuances of use and adaption affected by personal preferences and individual characteristics. Future studies that investigate affordances of new form factors could result in new possibilities that could overcome these challenges.

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