Why We Use and Abandon Smart Devices

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ABSTRACT
Smart devices are becoming increasingly commercially available. However, uptake of these devices has been slow and abandonment swift, which indicates that smart devices may not currently meet the needs of users. To advance an understanding of the ways users benefit from, are challenged by, and abandon smart devices, we asked a group of users to purchase smart sensing devices to advance themselves towards a personal, self-defined goal. We found that participants abandoned devices because they did not fit with the their conceptions of themselves, the data collected by devices were perceived to not be useful, and device maintenance became unmanageable. Participants used devices because they had developed routines and because devices were useful, satisfied curiosity, and held hope for potential benefit to them. We propose ways to reduce barriers, motivate use, and argue for envisioning an additional function of these devices for short-term interventions, in addition to standard long-term use.

Author Keywords
Smart devices; wearable devices; personal informatics systems; self tracking.

ACM Classification Keywords
H.5.2 Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Smart devices promise users a wealth of information that will enable them to become the best versions of themselves. This reasoning follows the line of thought that more information about one's activities will result in behavior change. For example, many activity trackers provide users with the numbers of steps taken that day on the pretense that knowing this information will cause lifestyle changes such as increased physical activity. For example, the Hexoskin, a tanktop with embedded sensors, has the tagline "Know More, Live Better" (http://www.hexoskin.com/). The implication of this tagline is that having knowledge of the metrics measured by this shirt – heart rate, heart rate variability, breathing rate, breathing volume, steps, cadence, and calories – will lead the wearer to a better life.

Given the promises made by the producers of these devices, one might expect the widespread adoption of activity trackers in a society so concerned with fitness and body image. According to one report [15], one in ten Americans over the age of 18 owns an activity tracker. However, of the people who do purchase activity trackers, many fail to use the devices long term. More than half of people who own activity trackers no longer use them, and a third of people who own trackers stop using them within six months [15]. This raises several questions. Who benefit from these devices? Why are people not using them? Particularly, what are the reasons people abandon them?

To explore these questions, a group of users were asked to purchase smart devices, sensors, and wearables to advance themselves towards a personal, self-defined goal. Participants were interviewed about their use after two months.

In this paper, we explore the above questions and expand on previous literature that discuss the motivations of smart device users and the barriers that they experience. We suggest ways to design smart devices to reduce barriers and to increase motivation to use smart devices. Finally, we raise a question as to whether the ideal of sustained long-term use is appropriate for all users and all goals.

RELATED WORK
Smart devices have been an area of focus for UbiComp and HCI for many years. We are using the term smart devices to refer to *devices that automatically gather information about*

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users or their environment to assist them in gaining knowledge about themselves and/or taking action. Other terms that have been used to refer to smart devices are personal informatics systems [16] and quantified self [5].

Routine and Motivation

HCI and Ubicomp researchers have studied ways to increase motivation to participate in healthy or socially desirable behaviors. Across various theories, a variety of factors are believed to contribute to motivation, such as personal affect (e.g. feelings), social interaction (e.g. cooperation), and task related (e.g. curiosity) factors [3]. Different individuals are motivated by different goals; in the case of health, goals may include maintaining one's own or another's health state or increasing wellness [12].

Researchers have explored the relationship between routine and motivation. Barretto et al. describe the significant effect of routine on the motivation of families to take part in environmentally friendly behavior [4]. Though routines sometimes serves as factors contributing to motivation, they can also be independent of or even in opposition to motivation. According to rational choice theory, consumers make decisions based on maximizing the benefit to them, based on their individual preferences, goals, and options [13]. However, routine and habit drive many decisions and behaviors, sometimes regardless of a desire to do something different [13]. Though routines regularly shape decisions, they are not completely fixed. In the case of environmentally friendly behaviors, Gram-Hanssen argues that, rather than due to environmental concerns, routines have changed historically as a result of the introduction of technologies as well as how the social organization of everyday life has shifted [13]. In particular, routines around ICT use change very quickly [13].

Studies of Smart Devices

Researchers have explored the ways smart devices can be adopted into routines or build motivation. Researchers have explored smart devices for purposes as diverse as encouraging more environmentally friendly behavior (e.g. [10]) and for home surveillance (e.g. [24]). Smart devices have also been explored extensively in the domain of health. Activity trackers have been used extensively in this domain, as have various sensors documenting other aspects important to health (such as sensors that monitor UV exposure [8]). Activity trackers and mHealth devices utilize a variety of strategies to encourage users: Klasnja et al. outlined the ways these devices encourage wellness, including tracking and feedback, goal setting, social influence, and gamification [14].

In addition to exploring a range of uses, researchers have explored a range of sensors, from commercially available sensors to prototypes such as Lim et al.'s shoe-worn pedometer that measures users' physical activity and provides feedback through varying intensities of light [18]. Some researchers have even allowed participants in studies to design their own input devices [2]. Another approach is to utilize a combination of commercially available and prototype interfaces. Examples of this approach are Walsh et al.'s StepCity, which used commercially available Fitbits as an interface for a social game that they designed [25], and Lin et al.'s Fish'n'Steps, a virtual pet that responded to the number of steps taken by participants wearing commercially available pedometers [19].

Studies Focused on Those with Acute Health Needs and Users who Have Integrated Devices into their Lives

Many studies have examined the use of smart devices with highly motivated individuals, such as those with acute health needs. One example is participants who have attended physical therapy, which were the population studied by Ananthanarayan et al. in the evaluation of a wearable prototype to assist in knee rehabilitation [1]. Another group of highly motivated people are those who may not have had specific physical disabilities or conditions but were recruited for their interest in increasing physical activity, such as participants in trials of UbiFit Garden, an activity tracker integrated with a mobile phone that provides users with a glanceable symbolic representation of goal adherence [6][7].

Another user base that has been studied extensively are users who had integrated smart devices into their lives at the point of study. Rooksby et al. interviewed a group of participants, the majority of whom were using activity trackers at the start of the study [13]. They found that personal tracking was enmeshed in these participants' lives (which they called 'lived informatics) and that people changed the tracker they used depending on their current short-term or long-term goal. Fritz et al. interviewed participants, all of whom were using activity trackers at the time of the interview [9]. Even under changing goals and practices over time, participants derived value and motivation from use of devices, even over long periods of use. Li et al. administered surveys and interviews to individuals engaged in personal data tracking and identified barriers that occurred through the different stages of using smart devices that they identified [16]. In another study by Li et al., participants who had been self-tracking for at least one month were interviewed about the questions they had about the data they collected [12]. Choe et al. investigated how a group of Quantified-Selfers (whom they define as an "extreme users") collected and explored personal data [5]. These users created workarounds to manage barriers of the technologies they used, and many built their own smart devices and systems. Implications from this study included ways to support users in self-experimentation and reflecting on data. A common finding in the studies described above is that participants successfully integrate the devices into their lives by either modifying the devices or their routines, and that they were willing to and interested in finding ways to work around device barriers.

Although many of the participants in the studies mentioned above had used trackers and integrated them into their lives

before studies began, we suggest that there is also a need to examine users who are not willing or able to integrate devices in their lives.

Studies Exploring Use and Abandonment

Some researchers have explored the use of devices among people who do not appear to be as willing to overcome device barriers. Shih et al. examined the ways personal preferences and characteristics affected use and abandonment of Fitbit activity trackers given to college students over six weeks [22]. Participants abandoned Fitbits quickly (65% stopped using them at two weeks) and had issues remembering to wear the device. Additionally, participants were unsatisfied with the passive nature of the system and wanted active triggers about reaching their goals. Some participants were also unsatisfied with the appearance and obtrusiveness of devices. Though this study explored users who are not highly motivated, users used devices manufactured by a single company, which does not expose barriers across devices.

Below, we describe a study in which participants who were not recruited based on acute health needs or having integrated devices into their lives were given funds to purchase whichever devices they wished to use. We explore questions around use and abandonment of devices.

METHOD

Procedure

Participants were recruited through convenience sampling at a technology company. At the start of the study, participants were surveyed to find what goals, objectives, and passions they were interested in addressing with smart devices. Participants were then given the opportunity to purchase up to $1,000 of smart devices to advance them towards a goal they were passionate about (see Table 1 for goals and devices). Participants were asked to choose their own goals based on the assumption that self-defined goals would motivate them much more than pre-defined goals. Participants were free to choose whichever devices they wished to purchase and were reimbursed. Some participants told other participants about the devices they had purchased, and because of this, certain devices were bought by many participants. Approximately two months later, participants were interviewed to discuss the devices purchased and the reasoning behind the purchases. Typically lasting about one hour, the semi-structured interview also ascertained if and why the devices were still in regular use, whether participants experienced any benefits or disadvantages from using the devices, as well as previous experiences with smart devices.

No monetary compensation was given to the participants, but they were permitted to keep any devices purchased.

Participants

17 participants (13 male) were recruited. The participants included engineers, interns, an executive assistant, and the partner of an employee. Five were in the age category 18-29, three 30-39, six 40-49, and three 50-59. Three had completed some college, ten had bachelor's degrees, three had master's degrees, and one had a PhD. Nine identified as Asian or Asian American, five as white, and three as other. One person identified as Hispanic/Latino.

Participants were recruited at a technology company. Their familiarity with technology was beneficial for multiple reasons. First, through their work and network, they were more likely to be aware of different devices and therefore likely selected a wider variety of devices than from a group unfamiliar with the landscape of smart devices. Second, these participants were more likely to know how to troubleshoot devices on their own, thus less likely to abandon devices due to technical issues. However, it is important to note that although the participants were comfortable with computing devices in general, they were not necessarily experts – or even knowledgeable – regarding the specific sensors that would advance themselves towards the goals (e.g. health, productivity) that they wished to pursue. In other words, participants may be able to troubleshoot the devices, but they will not necessarily know the best ways to apply the devices towards their goals.

Analysis

All interviews were audio recorded and transcribed. Detailed notes from interviews and transcripts were analyzed using open and axial coding by two of the researchers to identify emergent themes. The coding scheme was discussed and finalized. Once the coding scheme was finalized, all interview data was then coded and shared with the research team. As themes emerged, they were merged into the codebook.

RESULTS

Below we describe the sensors purchased, and why participants used and stopped using devices.

Participant goals and devices

What were participant goals?

During the initial interviews at the start of the study, participants expressed a range of goals, from increasing fitness to reducing pain to playing Ping-Pong better (see Table 1). Most of these goals (13) pertained to mental or physical health and fitness, two to improving performance at a sport, and three to improving productivity or focus. Given that participants could choose any goal, it is interesting that the majority chose health and fitness, which may be the result of the current marketing of commercially available smart devices.

Surprisingly, devices purchased often did not appear to map to goals. For example, P7 purchased the Misfit Shine, a wearable pedometer, although his goal was to reduce his neck and shoulder pain. This suggests that either users may not have the expertise of how devices would suit their goals or users may not have the expertise of how their goals can

be reached. Another possibility is that devices do not exist that matches some of these goals. This issue is explored further in the discussion.

What kinds of devices were used?

The majority of devices used were health or fitness sensors, corresponding to the majority of goals (see Table 1). Interestingly, though participants were free to purchase any type of device, the majority purchased wearable devices. Of the 49 devices used, 35 were purchased with study funds and 14 were obtained some other way during the study period or before the study had started (purchased with personal funds, purchased with work funds for a different project, found, or borrowed from a participant who had purchased the device).

Why Did Participants Stop Using Devices?

Participants abandoned almost 80% of devices purchased for this study within the first two months (see Table 2). Sensors were abandoned for a variety of reasons, primarily in three categories: devices not fitting with participants' conceptions of themselves, collected data not being useful, and devices requiring too much work and maintenance.

Did not fit with their conceptions of themselves

Participants frequently referred to other types of people (as opposed to themselves) for whom devices might be more useful. Most frequently mentioned were people with what were considered extreme fitness needs, such as those trying to lose large amounts of weight and athletes. For example, regarding whether her devices advanced her toward her goal of increasing physical activity, P12 said, "… I don't really need to know this information every single day. If I were an avid health freak, maybe, but I'm not." Participants also mentioned older adults as benefiting more from devices, as they were likely to have more health needs. Participants saw sensors as appropriate for others, not themselves, and therefore had less interest in using them.

Data collected was not useful

Participants perceived the data collected as not useful because they were *not interested in the level of information the data gave them*. Many participants mentioned that the number of steps they took was not interesting – including participants who had decided to purchase smart pedometers. Some reasons participants mentioned that steps were not interesting were that walking was not considered exercise (P10) or that walking did not impact mood, which the participant had actually learned by wearing the sensor (P9). Even sensors that were more specialized than pedometers were not seen as beneficial: the specialized sports sensors (94Fifty basketball and Babolat tennis racket) did not provide the information that participants found most useful (such as whether or not the basketball went through the hoop). Additionally, one participant who exercised 18 hours a week said, "How can a Fitbit measure [how fit I'm getting]? They don't know that. It doesn't really matter if I do a hundred sit-ups... a trainer, they tell you what is it that you [should] eat, how much sleep [you should] get, and what kind of quantities of protein you [should] eat versus vegetables, or things like that." Interestingly, the more

Id	Goal	Device
P1	Reduce neck pain	Lumoback
P2	Take body to the next level of fitness	Lumoback, Basis watch, Withings wireless blood pressure monitor, Mindfield eSense temperature, Mindfield eSense skin response, Heartmath Inner Balance-Lightning sensor
P3	Stay hydrated, feel at peak, reduce headaches	Fitbit
P4	Get better at basketball	Jawbone, 94Fifty basketball
P5	Detect heart issues, maintain healthy body & weight	MioAlpha heart rate sports watch, Metawatch*
P6	Be more fit, have more energy, lose belly	Muse, Mio Alpha, Fitbit, Withings scale, Metawatch*
P7	Reduce neck and shoulder pain	Misfit Shine
P8	Improve health and wellbeing	Samsung Gear 2 Neo, Withings wireless blood pressure monitor
P9	Feel good, determine the reason behind losing focus	Samsung Gear fit, Lumoback
P10	Increase productivity and mindfulness	Blood pressure monitor, Pulse rate and hypertension monitor, MIO Alpha heart rate sports watch*
P11	Increase energy level	Hexoskin, Pebble watch, Shine, Lumoback, Babolat smart tennis racket*, Zapp tennis racket, Metawatch*
P12	Increase activity for endurance and weight loss	Misfit Shine, Jawbone, Hexoskin
P13	Get better at ping pong	Garmin Fenix*, Pebble*, Moves app on phone, Lumoback
P14	Dream lucidly, improve posture and health/fitness	Fitbit, Lumoback, REM
P15	Increase activity, lose weight	Garmin Vivofit, Withings Scale
P16	Be able to run for 30 minutes, increase endurance	Mio Alpha heart rate sports watch, Misfit Shine
P17	Increase focus	Misfit Shine, Basis health tracker for fitness, sleep, and stress

Table 1. Participant goals and devices

* Device was personally owned or purchased for a different project

athletic participants did not find their devices useful, despite the perceptions of other participants that the more athletic types would be the ones who benefited most.

Other participants were *not interested in the collected data because they would know that information even without using the device.* P2 said, "If I go to bed at eight and count eight hours… I'm going to know. It's common sense. I went to bed at this time, and I woke up at this time." The devices did not provide any new or useful information to participants, so they did not see a reason to use the devices.

Another reason data was not useful to participants was because it was *unprocessed.* Participants did not know what to do with the data: as P12 said, "It gave me a lot of information, but I don't know what to do with any of this information.... My heart rate is this much. But I don't know what that means. Am I supposed to be within this range and this range? If I am, what does that mean?" P16 said "I don't know what to do with that sort medical data once I've collected it... I'm not in that kind of professional capacity to analyze the data." Through statements such as these, participants such as P12 and P16 expressed they lacked the skill and expertise to interpret data collected by the devices. Interestingly, they did not mention attempts to decipher data by utilizing online resources or healthcare professionals, even though some of this information (such as suggested ranges for heart range by age) is freely available online. Participants may not have realized that these resources were available and might need more explicit instruction on how to interpret data.

As described above, there was often no instruction or prompting given to users on how to analyze collected data. Participants were not interested in quantifying behavior just for the sake of getting a number; they wanted to know what to do with that number. As P16 said, "Wearing the watch doesn't help me to sleep better… I wanted to be healthy, but wearing the watch is not going to give me better sleep or make me healthier. It just tells me whether I have a good sleep or a bad sleep… it's not productive or useful." In this case, the data collected were not only unprocessed, but also *did not give the participant any actionable information*.

Status of device after two months	Percentage
Still using (at least four days a week)	20% (10/49)
Using for a 'non-smart' purpose (e.g. alarm function of activity tracker)	10% (5/49)
Not using but plan to use again in the future	22% (11/49)
Not using and no plan to use again	45% (22/49)
Ordered but did not receive yet	2% (1/49)

Table 2: Use of devices at exit interview

Even when devices gave users actionable information, some users were *unwilling or unable to take action.* This happened when participants could not meet device goals because of environmental factors, such as P1 (trying to reduce neck pain) who said, "I would take [the] LumoBack [posture sensor] off when I go home because at that point I'm with my daughter… I'm in all kinds of different positions. My posture sucks all night and I know that. I don't need to be bothered by it." Even when participants could alter behavior, some noted feeling that they did not have to meet goals set by the manufacturers of the device. Regarding meeting the default goal of 10,000 steps, P7 said, "I'm doing this for myself... If I get it, I get it. If I don't, I don't. In general, you just know you need to exercise more." The goals advocated by the device manufacturers did not possess greater authority than messages participants encountered promoting health behaviors on a regular basis. Participants did not perceive real repercussions to not satisfying the device and viewed advice from the device as suggestions rather than prescriptions.

Too much extra work/maintenance

Extra work and maintenance was a significant issue for many participants, especially because they were getting so little benefit. For example, P9 had been using the Samsung Gear Fit smart watch, to control his phone without taking it out of his pocket. He lamented that "just to have that one benefit [of controlling a phone] I have to: one, charge it. Two, wear it on my other wrist. And three, always make sure it's paired with Bluetooth. [Also], it's wasting my phone's battery to keep that Bluetooth connection paired and I'd have to charge [the phone] as well." Participants acknowledged that if the device had been more useful, they would have been willing to make more of an effort; when asked why he was not using his device, P10 said, "Other things. Other commitments I have to do. Not enough time. I guess I [would] make time if it's interesting enough. It didn't seem interesting enough." The devices did not yield enough value for participants to be willing to engage in the time consuming process of maintaining devices.

A *high frequency of maintenance* was a factor that greatly discouraged participants from use. The need to charge devices often was mentioned by many as highly inconvenient. Having to provide input to the device frequently (such as calibrating the LumoBack posture sensor or entering food into a food diary connected to the Jawbone) was also mentioned as an obstacle. Participants considered benefits when determining how much work they were willing to do; P5 questioned the value of smart devices, "... years ago, you [wore] a watch that you [wouldn't] have to charge for a whole year. We are going back. It's okay [with the phone] because it replaces [your] laptop partially… What is that on the wearable that would offset that inconvenience of recharging every few days…?" Some participants turned off the "smart" functions to reduce the need to charge devices. P10 said that his Mio Alpha heart rate watch "charges fairly often if I was using

the heart rate monitor. After a point… I would use it more like a timepiece rather than a heart rate monitor."

Another way the use of smart devices was too much extra work was when use *did not fit with routines*. Participants did not remember to or want to do seemingly low-effort activities such as tapping devices to put them in a mode to track sleep. Some participants grew tired of bringing tablets around with them as their phones were not compatible with devices. They also mentioned that it took time to get into a routine of use, even to remember to put on a device; "Even a watch, it's taught. It's trained. I've been wearing a watch since I was six. It's a learned behavior. I'm comfortable wearing a watch. If I don't wear a watch, I feel naked. I feel something's missing. But, with a wearable, I just don't have that patience to train myself to learn to wear it. I think the biggest thing is the benefit. I just don't see that much benefit." P7 acknowledged that it was possible to train himself to remember to wear the device, but given that there was so little benefit, it was not worth doing.

Some participants managed to develop a routine, but once they *fell out of the routine*, even for a day, they often did not recover. Three participants mentioned vacation affected their use: P17, who periodically lacked Internet on vacation, said, "You kind of lose interest after you lose that first instance of focus on it. After I went on vacation… I didn't care anymore because I had stopped looking at it for four or five days… it lost all appeal to me." The device running out of charge was also a reason many fell out of routine: as P9 said, "… I forgot to charge it one day, and I haven't charged it since. If it was always charged, I think I'd still wear it." Some participants explained that they felt a sense of relief when they fell out of a routine: P14 said "Once I went a few days without it: it was like 'I guess I really don't need it to survive'… you're like, 'It feels good not to have to work out. It feels good without something buzzing at me to tell me my posture is crappy.'" Sometimes, the realization that they felt relief or did not miss the device after falling out of a routine led participants to consciously abandon the device: P12 said "I just forget about it, and I guess that started the decline of me wearing it to bed, because I realize it's not changing my life. At that point it was like, I'm not wearing it, and it's not making a difference at all... so why am I bothering wearing it?" Again, the lack of benefit from using the device led participant to abandon the device rather then attempting to reintegrate it into their routine.

Participants hesitated to expend effort adjusting devices or the mental energy to become accustomed to *uncomfortable* devices. When a device was extremely uncomfortable, it was often abandoned hastily, even when participants were interested in the information tracked. Several participants said they were not used to wearing jewelry or bracelets and the device felt uncomfortable. Another element considered uncomfortable was when devices had to be worn tight around the body to function properly (such as the LumoBack, Hexoskin, and heart rate monitors). Tight devices were perceived as even more uncomfortable when bands were made of rubber and participants sweat in them.

Similar to uncomfortable devices, *obtrusive* devices required extra work from participants. For example, P10 said that he stopped using a wireless blood pressure monitor after a single use because, "It was too big. It was cumbersome. It was difficult. It was not as mobile as I expected it to be." Conversely, some participants wore devices that were perceived as unobtrusive even when they did not see much value in the data. For example, P12 said that "I think what makes me like the Shine [activity tracker] most is just because it's so effortless. I don't think about it at all. See, because I don't even remember it's on me, and I rarely ever check it anymore. That's the only reason why I still keep wearing it." Even though P12 didn't check her device and did not benefit from the data collected, it was very unobtrusive, and she therefore continued to wear it.

The challenges of individual devices described above were compounded when participants had multiple devices, and participants had a negative perception of *maintaining multiple devices*. Interestingly, almost all participants spent well under $1,000 on devices, and most purchased two or fewer devices. When asked why they did not purchase more devices, many said that they did not want to experience the burden associated with multiple devices; P14 said, "I just didn't want to wear that many things... I didn't want to give my entire life over to these devices." Participants also referred to a general sense of having too many responsibilities in their lives that manifested in a desire to have fewer devices. When asked why he did not like wearing devices, P11 said, "It's just one more thing. We have so many things in our lives right now." Similarly, P10 said, "I have other commitments. I have other things that I do. There are things that I have to do for those things. This piece of technology should enhance what things that I do outside rather than take up my brain space..." Like other types of work, not getting any benefit was the reason that multiple devices caused so much frustration: "Carrying these two, three devices, I used to keep track of the charging... Eventually I thought, 'What is the point of doing all these things?'" (P13). Each additional device resulted in another set of maintenance activities for participants.

Why Did Participants Use Devices?

Few devices were still being used at the exit interview, and even fewer at the time of this writing. Participants explained what kept them using devices through the course of the study, even when eventually abandoned.

Useful

A subset of the participants had experiences where the device was *useful*. We categorize the ways the devices were useful as major benefits and minor benefits, and momentary small benefits and benefits from "non-smart" features.

Three participants experienced *major benefits.* P1 (who at the time of this writing had stopped using the device but

intended to wear it in the future) wore the LumoBack posture sensor for chronic neck pain. She thought her posture had improved significantly from her use of the device. She attributed her better posture to instantaneous feedback but also because she was strengthening the muscles involved in correct posture. P10 (who had stopped wearing his device, but planned to use it again in the future) learned to control his anxiety and breathe deeply in social situations from using the device. P15 said her device helped her get more healthy and active and lose weight.

Some participants experienced *minor benefits* after they stopped wearing the devices, such as being more conscious of posture, getting up to walk around during the day, or taking the stairs instead of the elevator.

Many participants mentioned an increased awareness of physical activity while wearing the devices, which we see as a *momentary small benefit*. While wearing the devices, some participants initially tried to increase step counts. Another participant used the Phyode W/me, a heart rate sensor with a breathing app, to increase mindfulness during the day. While participants appreciated these benefits when they occurred, they did not necessarily persist.

Participants also experienced *benefit from "non-smart" features*, such as seeing the time or setting alarms. Several participants continued wearing smart devices as watches and either turned off or did not view the smart functions. Conversely, smart devices worn on the wrists that did not show the time (such as the Fitbit Flex) were abandoned by some participants who did not want to wear multiple devices and therefore chose a watch over the device.

Curiosity and novelty

As has been found in other studies (e.g. [20][23]), the novelty of a device affects use. In this study, the novelty of the device and curiosity about the device and data was a compelling motivator for participants to begin using devices, and many participants experienced enjoyment from playing with a new "toy." However, as P10 said, "[during the] first few days, it was a new thing so it was novel enough that I didn't mind that extra hassle. After a while, that negative impact was too much." For many participants, a drop off effect occurred as novelty diminished and the cost of maintaining the device became irritating.

Curiosity was often sated after participants discovered some quantified number about their activities. P13 said, "After a point I get a rough estimate as to how much I am walking every day, so I don't need a step counter to tell me… I've got a mental map." Like P13, others lost interest in using devices once they developed a sense of what data would be generated when they engaged in various activities.

The drop off effect was less apparent for a participant using a device sporadically: "Fitbit is for day-to-day use, and the Garmin Fenix [a GPS navigator and activity tracker] is only for a particular use, and at a particular time… the number of times I go for hiking is maybe once a week… so I don't mind carrying that extra device, only for that hiking purpose... But for the FitBit, it's a day-to-day activity. After a point, it loses its relevance." It appears that since the device was for a dedicated activity, the participant was able to overlook issues with the device that would have prevented him from using it for an everyday activity. Had he gone hiking more regularly, he thought it was likely that he would be bothered by the obtrusiveness of the device.

Hope for potential use

Another factor that kept participants using devices was hope that the current capabilities of devices would be extended someday with new ways to process recorded data.

Participants hoped that data would benefit themselves, and some also mentioned that they hoped their using the technology would lead to benefits for others. A few stated plans to devise their own algorithms to correlate different aspects of their behavior. However, none of the participants had designed these systems at the time of the interview.

This hope for potential use kept some participants using and increased the frequency with which they used devices after they had lost interest in the novelty of the data, even when data was not useful to them. This expectation for future benefit led participants to stop using devices that did not store data. Because the potential benefit came from data, devices that did not store data were less desired.

The hope for use of collected data may be why most participants placed a great deal of importance on accuracy, despite many not viewing the data. The desire for accuracy impacted which devices participants chose and kept using. Although P10 had been benefiting from using his heart rate monitor to learn about how to manage his anxiety in social situations, hearing that the device was inaccurate was one factor that led to his abandonment of the device. He explained that he "felt cheated" when he heard that the device was not accurate, and that it bothered him because "If [the heart rate measurements were] not objectively accurate, I was going by some number they produced and I didn't know whether to believe it or not." He went on to say that he still used the strategies he had learned from using the heart rate monitor, but had "stopped relying on the sensor". Even though the number "did not seem that off" to him and he had not verified that the device was inaccurate, the chance of the device being inaccurate was enough for him to stop trusting the data generated by the sensor.

Developed routine of use

Despite neither receiving benefit nor having their curiosity satisfied, participants would sometimes persist in using a device because they had developed a routine of doing so. For example, when asked why he still wore his Misfit Shine even though he no longer viewed the data, P17 said, "I think I just developed a habit over the last couple of months... I guess I just put it on to put it on." Even when participants saw little use, they still wore it "because it's kind of a habit now" (P17). Participants justified continuing

the "habit" with a variety of reasons, including getting use out of something that they had purchased. Additionally, as long as these devices were not obtrusive and did not require extra work, participants would continue using the device until an issue arose that interrupted the routine, such as maintenance activities or travel. This suggests that once people begin to use a device, they may be likely to continue using it simply because they grow accustomed to doing so.

Seven participants were still using devices at the end of the study. P1 and P15 still used their devices because they found them *useful*. P17 did not look at the data from his Shine but had developed a *routine* of wearing it. P6, P7, P12, and P13 wore their devices to satisfy *curiosity* or because they saw *potential use*. This suggests that though curiosity faded for many participants, some continued to be curious about their data, which sustained their use. It is interesting to note which types of devices were still being used compared to how many were purchased. Of two smart scales used in the course of the study, both were still being used. Of thirteen activity trackers used during the study, six were still being used two month later, half of which were the Misfit Shine (the activity tracker that was noted by participants as requiring very low maintenance). Out of thirteen smart watches used over the course of the study and the six posture detectors, only one of smart watch and one posture detector was being used at the end of the study. These numbers suggest that participants were more likely to continue to use activity trackers, particularly unobtrusive ones, than smart watches (many of which had similar functions as activity trackers, such as counting steps). One possible explanation for this discrepancy is that activity trackers required less charging and also were less bulky.

Limitations

We acknowledge several limitations to this study. First, giving participants funds to purchase devices may have affected their choices and use of devices. One participant mentioned that he would have valued the device more if he had spent his own money and felt that he had to "get [his] money's worth." Providing participants with funds may have had the opposite effect for others; some said that they used the device or felt an obligation to exercise because of the study. However, many who were using devices for those reasons had stopped by the time of the interview.

Moreover, two months is not necessarily long enough to see if users have adopted a device (or would abandon a device shortly after the study ended). However, most of the participants who were still using devices were not overtly committed to continuing use. Waiting longer to interview participants would have meant that the exact reasons for continued use and benefits would have faded. The reader should therefore not assume that the users fully adopted the ten devices that *were* being used at the exit interview.

Furthermore, participants used a slew of devices. The devices had varying functionalities and affordances and therefore impacted the experiences of participants differently. However, allowing users to select their devices allowed them to buy the device that was potentially most useful to them, thereby increasing the chance that they might benefit from them. This approach also resulted in similar findings across different types of devices (such as issues with charging), which strengthens their significance and likelihood to apply to other similar devices.

Additionally, seven participants had used smart devices previously, though not for an extended amount of time. Future studies should examine people with less exposure to smart devices, as they might display different patterns of use and motivations and barriers to use.

Finally, not surprisingly, some participants, especially the engineers, expressed very technology-positive views. Future studies would be well served to examine people with mixed attitudes to technology. Additionally, it is likely that being in a technology company affected the opinions and experience of participants in this study. For example, it is possible that a greater familiarity with the way a device works (and should work) could lead to increased frustration over a device not working properly or being designed poorly. It is important for researchers to explore the experience of participants with other backgrounds and work experience. This study also focuses on a group limited in terms of diversity. In particular, the sample was primarily male, and this gender ratio may have affected the devices purchased as well as their use and abandonment [22].

Given the limitations described above, we make no claims to experimental validity, or to any objective "truth" in this work. While the responses that we observed do not constitute a ground truth, however, they are both "real" and "useful" in that they represent a diverse sampling of wearable device usage that has been driven by the preferences of the subjects, rather than a top-down, experimental structure. We contend that the collected data represents an important first look at some of these identified behaviors and attitudes. We believe that the themes and observations that arose from this data are useful markers of technology adoption strategies and motivations.

DISCUSSION AND DESIGN IMPLICATIONS

In this paper, we present a study describing how participants used and abandoned a variety of smart devices. Below we provide design recommendations to lower barriers and increase motivation. Though many of these suggestions can lead to long-term use, we stress the importance of considering designing for short-term use.

Lowering Barriers for Users

When users were able to develop a routine of use that was not obstructed by extra work or maintenance, they kept using devices, even when perceived benefits were minimal. While this is not a novel finding, our contribution is to emphasize the enormous importance of lowering barriers of use of use for users who are not highly motivated. We outline some ways to lower barriers of use below.

Encouraging routines

It is key to help users develop a routine from the first use, as participants who were unable to develop a routine of use abandoned devices more quickly than those who were able to do so. One way of encouraging routines is latching on to an existing user's routine, for example outfitting a watch that the user wears every day with a smart device. Designers should also examine ways to incentivize users to develop routines. One approach may be to harness curiosity by revealing different metrics (e.g. steps walked, hours slept) as rewards for regular use. This would assist users in developing routines of use while simultaneously prolonging curiosity, a strong but short-lasting motivator for use.

Minimizing maintenance

Charging and other types of extra work/maintenance often led to participants falling out of routines, after which they would never use the device again. It seems clear that these devices need to be designed to avoid this pitfall. The amount of time and effort needed to charge a device was an enormous issue for participants. One especially popular device in the study, the Misfit Shine, was appreciated due to not needing to be charged (it operates on a coin cell). We recommend that designers consider power approaches such as coin cells, which do not require charging, or other approaches that require minimal charging.

Participants felt especially burdened by multiple devices, even when each did not require much effort individually. Additionally, a segment of the current market appears to be splintering into single-use devices (e.g., a bracelet that measures UV exposure- http://www.junebynetatmo.com). Based on the data from this study, we contend that a single device should do as much as possible and allow users to ignore or turn off the unused features. Of course, packing more functionality into one device while seeking ways to charge the device less is a major engineering challenge.

Appealing to identity

Marketing and branding also played a role in whether or not participants embraced their devices. Participants felt that smart devices such as activity trackers were for the "avid health freak" (P12) and not for them. Marketers show impossibly slender models practicing yoga poses on the beach after jogging a dozen miles, but the lifestyle depicted in these images can alienate the user who does not affiliate with this image. Previous studies have advised that devices be designed so they do not cause users to feel "out-of-character" [18] or that casings for trackers be accessorized to fit user's "mood, outfit, or occasion" [22]. We take these suggestions a step further to suggest devices be presented to users with language and images that fit their lifestyles and conceptions of themselves. For example, the rubber Fitbit band resembles a LiveStrong band, which may be more appropriate for those who identify with an athletic persona. Alternate casings allow users to wear Fitbits that better match their identities, such as a designer who allows users to "Transform [the] Fitbit Flex tracker into a super chic accessory" (http://www.fitbit.com/toryburch). Designers should consider the types of images the individuals using it wish to project in designing the appearance of the device.

Increasing Motivation for Users

However, even if all barriers were lowered, people like some of the participants in this study might still not engage in long-term use of devices for a variety of reasons. These devices and the data they generate simply do not fit their needs or motivations. In fact, it appears that barriers to use, such as extra work or maintenance, are especially problematic because users perceive so little benefit from the devices. Participants were unwilling to sacrifice personal comfort or convenience for the marginal benefit they got from these devices. They were not satisfied seeing data for the sake of seeing data after initial novelty wore off, nor were they willing to correlate data or create the rich systems seen in studies of highly motivated users (e.g. [5], [16]).

Additionally, participants did not have the expertise needed to find, interpret data, and create plans for action from their devices. For example, though many participants had health-related goals, few expressed an understanding of what types of devices would be appropriate for their health goal, how to interpret data generated from devices, and what kinds of actions they should take based on the data. The following four recommendations arise from the most commonly expressed desires of our participants. We contend, in all of these cases, a unifying theme for a desire that *rather than the user, the device should handle the work and complexity.*

Employ user language

Currently, many devices present users with raw data (e.g. number of steps). Users wanted a summary using terms and language they understood, rather than raw data. They do not want to interpret the data themselves. Rather, participants voiced interest for something like a report card, which told them whether they had done well or poorly that week. Designers should investigate ways to provide this type of 'report card' feedback to users, such as by comparing steps one week to the previous week or to peers.

Consider proactive feedback

Users did not want to have to remember to look at devices, as it was not a part of their regular routine and thus served as 'just another thing to remember.' Notifications could be useful to these participants, particularly if location or activity sensing is incorporated to minimize the chance of disrupting an important activity.

Coach the user

Some participants did not have the knowledge or skills required to take action and wanted to be coached with actionable feedback. For example, the participants who purchased sports sensors (the smart basketball and the tennis racket) were not satisfied with sensors that showed them the angle they had shot or hit the ball- they wanted devices that would actually instruct them to swing and throw with a better outcome. Designers should consider the possibility that users may not know how to achieve their

goals or even how to start – incorporating some kind of coaching would benefit this class of users.

Involve the user's personal history

Participants did not want to do calculations to determine their progress or keep track of their historical data, but did want devices that were tailored to their personal history. P1 wanted a system that could factor in that when she had poor posture a certain percentage of the day, it often resulted in pain, and tell her when she was approaching that percentage. Participants felt that personalized suggestions would be much more useful than generic suggestions.

Provide Concrete Motivation

Some participants requested functions or capabilities that lie beyond the current limits of science. Some commented (semi-jokingly) that sensors would be useful if they could determine the exact time they would die and what behaviors could prolong their lives. Another participant, more seriously, said that he wanted a sensor that would tell him concretely that he would have a certain outcome, rather than offering vague assurances that he might feel happier. While this may not be feasible due to uncertainty in the outcomes of different actions, it may be helpful to utilize probabilities to motivate different behaviors (for example, 'If you exercise one more day a week, you are 90% likely to live 1 year longer'). Though these probabilities may still be considered too vague for some users, they can be more concrete than they are currently.

Reconceptualizing Abandonment as Short Term Use

The recommendations above are particularly pertinent to encourage long-term use of devices (though we believe they are good practice in general). Designing for long-term use is vital for devices that must be used regularly (e.g. such as glucose monitors) or for users who are willing and interested in using devices long term.

Despite the benefits of long-term use of devices, our analysis leads us to believe that there is an under-explored class of smart devices, particularly for wearables: those that might be beneficial for short-term interventions. This approach challenges the dominant paradigm of designing for long-term, continuous use and echoes Rooksby et al. that posit, "to track over the short term is not necessarily to give up or fail" [21]. Participants experienced many benefits from short-term use that may, indeed, lead to long-term changes. Yet these devices are marketed for continual and everyday use. Even when the participants had learned something useful or made a behavior change, participants internalized abandonment of devices as failure.

Additionally, elements of devices that are obtrusive or even irritating may be extremely helpful in the short term but unsustainable in the long term. Some users benefited when devices were obtrusive- such as posture sensors that buzzed when they detected bad posture- but sustained use of these devices annoyed them in the long run and led to abandonment. While not appropriate for all users and all devices, short-term use is appropriate for those interested in devices to satisfy curiosity as well as those who wish to alter routines or behaviors. Obtrusiveness and deviation from routine are not as off-putting when occasional. Curiosity and the desire for novelty can continue to be satisfied when participants are not jaded by continual use.

We stress that short-term use and abandonment can be an effective use of smart devices when users are able to more deeply understand or alter habits and routines. Unlinking abandonment of devices with failure raises bigger questions about the intended future of these devices: is the goal to create smart sensing systems that are continuously relevant and useful to a user or is the goal to create a device that supports a user's need even if that need is temporary? Can we allow learning about ourselves to occur in spurts and not only as a continual everyday process? Do we envision a future where we are dependent on our devices to keep us on track or do we see these devices as a tool for learning how to manage our lives and health ourselves? We propose embracing a short-term intervention mentality to broaden the market for these devices, while supporting designs better suited to the lived practices of the everyday user.

Already, the amount of electronic waste has a staggering effect on the environment as well as the individuals who live where technology is processed and recycled (e.g. [27]), and the amount of time electronic devices are used before they are discarded continues to shorten [26]. In pursuing this area of research, it is important to reflect on and explore ways to create devices that will be used short term and discarded in an environmentally and ethically responsible manner, such as through the use of water-soluble electronics [28].

CONCLUSION

In this paper, we present a study detailing a group of participants' motivations, practices, and reasons for abandonments of smart devices for a group of participants. The paper contributes novel reasons that users use and abandon smart devices. By allowing participants to choose devices and then interviewing them several months later, we were able to see the ways people integrated devices into their lives or abandoned them and the factors for doing so. Based on what we learned from these participants, we present design recommendations to lower barriers and encourage use. We also acknowledge that long-term use may not be feasible for some users and purposes and propose short-term interventions as one way of increasing the usefulness of devices for users. These findings have implications for the design of the next generation of smart devices that more closely meet the needs of users.

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