UNIVERSITY OF CALIFORNIA, SAN DIEGO

Designing Personal Health Technologies: An Ecological Approach

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by

Laura R. Pina

Committee in charge:

Professor Willian G. Griswold, Chair
Professor Gillian R. Hayes, Co-Chair
Sanjoy Dasgupta
Ranjit Jhala
Kevin Patrick
Nadir Weibel

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The Dissertation of Laura R. Pina is approved and is acceptable in quality and form for publication on microfilm and electronically:

Co-Chair

Chair

University of California, San Diego

2015

DEDICATION

To my family: Ellen Rosenzweig, Edmundo Pina, and my wonderful sister Sonia Pina. And also to my extended family, I would have not made it this far without you: Sandra Rosenzweig, Michael Taylor, Rachel Carroll, Shana Carroll, Edduys Bernal, and many others. Your are all example of dedication, determination, and kindness.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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VITA

2004-2008	Bachelor of Science in Computer Engineering, University of Washington
2008-2009	Awarded the GEM Consortium Graduate Fellowship
2008–2015	Research Assistant, University of California, San Diego
2009-2011	Awarded the National Science Foundation (NSF) Graduate Fellowship
2011	Masters of Science in Computer Science & Engineering, University of California, San Diego
2011-2012	Awarded the Google Hispanic College Fund Fellowship
2012-2014	Teaching Assistant, University of California, San Diego
2014-2015	Awarded the UC Presidential Dissertation Fellowship
2015	Doctor of Philosophy, University of California, San Diego

ABSTRACT OF THE DISSERTATION

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Professor Willian G. Griswold, Chair
Professor Gillian R. Hayes, Co-Chair

The increasing capabilities of sensing and mobile technology are enabling to us gather more health data than ever. This data helps us understand personal health, reveals factors that affect personal health, and informs the design of personal health tracking systems that tackle health concerns. The reliability of personal health technologies has allowed for deployments outside of the lab and in uncontrolled environments. Users can track their health with these tracking systems as part of their daily life. These deployments reveal that sustainable and long-term use is currently difficult and that users are struggling to track and reach their health goals using these systems. This dissertation posits that the current design lens is too narrow. The current design lens solely focuses on addressing the health concern and excludes the context where health concerns and activities that affect our health take place and where tracking is performed. To address these shortcomings this dissertation demonstrates how widening the design lens to consider the relationships between the user, the health concern, and the social and physical context in which the health concern takes place allows designing for more sustainable use. This dissertation explains and demonstrates how using an ecological framework reveals interactions and relationships between all the different aspects that affect a given health concern, tracking it, and how to design to considering the ecology the user is part of and where the health concern takes place. To demonstrate the importance of taking an ecological approach to designing personal health tracking systems insight from four studies are presented. Based on the insights from these studies, this dissertation closes with takeaways that inform the design of future personal health technologies that will lead to more sustainable, long-term use.

Chapter 1

Introduction

1.1 Motivation

The importance of physical activity, diet, sleep, and mental health is well documented [28, 99, 185]. Recent research has shed light on the rise of chronic ailments such as, weight-gain, diabetes, cardiovascular diseases, and stress [67, 173]. The costs for these diseases in terms of human life and medical expenses are staggering. In 1998 it was estimated that 9.1% of all US medical expenses, $78.5 billion dollars, was spent on overweight/obesity attributed expenses [117]. At the root of many of these ailments, especially the physiological ones, is the fact that a growing proportion of people increasingly live sedentary lifestyles in conjunction with consuming calorically dense meal [28, 99, 153, 185].

While there is no single solution that addresses these chronic ailments, the conventional wisdom suggests that people can avoid them by changing their day to day habits. In other words, if people were to eat less and exercise more, it is possible that they could live healthier lives. The key questions then become: how do people change their habits and how can we design tools to help them do it? In the abstract, tackling health related concerns and changing behavior requires people to understand their current habits, reflect on them, and then identify areas of improvement [44],[62], [74], [177]. This approach, called self-monitoring, is useful in many health concerns, such as, weight-loss, diabetes, and mental health understanding [192, 213]. Given that many chronic health conditions can be avoided by getting people to change their daily habits, and given that self-monitoring is a key to behavior change, it stands to reason that creating tools that increase the efficacy of self monitoring can help people (and society at large) avoid many future problems.

1.2 Designing for self-monitoring

Self-monitoring helps with people be mindful of their habits. It helps them recognize what needs improving on and what behaviors have improved. Successful self-monitoring requires people to explicitly keep records (i.e., recording every instance related to the health habit in a physical diary) and not rely on mental tallies. Keeping mental tallies is insufficient because peoples memory recall and autobiographical memory is imprecise [79, 192]. As a result, if people only rely on their memories when tracking their activities, they run the risk of misestimating important behaviors. In particular, people often over estimate how many calories they expended during exercise and under estimate how many calories they have consumed [27, 98, 55]. Thus, without explicit self-monitoring, weight-loss efforts could turn futile. Additionally, explicit self-monitoring helps people to reflect on their progress and focus their attention on moments of improvements. Creating opportunities to objectively reflect on improved behavior is important because our memory – as an evolutionary survival mechanism – remembers negative experiences better than positive ones [79].

That said, self-monitoring is difficult and those attempting to do so face two sets of challenges. First, being able to record and capture detailed information with precision is difficult to do [27, 192]. Second, identifying which strategies to use in order to improve ones behavior and when to use them is also very difficult. These challenges, and the advocated solutions, have led researchers to explore how to leverage different types of technologies to assist with health self-monitoring [27, 192].

Self-monitoring are common across health concerns from mental health, to medication adherence, to diet monitoring [192]. To explain these barriers, let us look at self-monitoring for weight-loss. Before the era for wearable and mobile technology, physical diaries were used to record all activities related to diet and exercise [28], [196]. The diary's physical form made it cumbersome to take everywhere. Additionally, it was difficult to find information of the variety of ingredients and meals consumed right after consuming a meal. The learning curve was extremely steep, at the beginning every item had to be thoroughly researched. Once a representative list of items had been recorded, an additional hurdle came from having to make mental calculations to estimate caloric value of portion consumed compared to caloric value of serving size found. This required a lot of mental comparisons and calculations (or take in addition to a diary, a calculator).

A key to capturing health habits accurately, such as diet, is to record an eating episode as soon as it occurs. However, because of the physicality of the weight-loss journal, the diary was not taken everywhere. In fact, there is a high tendency to record every eating and physical activity episode at the end of the day—all at once [28]. Consequently, journaling an entire day worth of activities at the end of the day led to inaccurate self-monitoring, especially when relying on memory to recall portion size of foods consumed [28, 27, 192]. This approach to self-monitoring is extremely cumbersome and puts a huge burden on the person to know how and when to record habits. Thus, despite the benefits of self-monitoring, there are many barriers using a physical diary to record habits.

1.3 Leveraging mobile and wearable technology to improve self-monitoring

Motivated by the growing capabilities of mobile smart phones and wearable sensors, researchers in the HCI and Ubicomp community are exploring how to make self monitoring easier for users by offloading some of the burden of self-monitoring from the user and toward technology. For example, mobile phones can store a food and physical activity database with their representative caloric values. This feature means users will not have to scour for information to find the caloric value of common physical activities and food items; creating a mobile phone application for tracking means that users do not need to carry an additional tool only good for record keeping (i.e. a physical diary). In this new form, tracking is available at users fingertips. Users can now focus on actually tracking and assessing behavior as opposed to researching and estimating their caloric consumption or expenditure.

The above postulate has led to a rich and growing body of research exploring how to leverage personal, wearable mobile and sensing technologies to assist with self-monitoring. The evolution of these tracking technologies can be described through four archetypes that build on each other. These archetypes are: (1) user-driven tracking; (2) sensor-driven tracking; (3) Ecological Momentary Assessment (EMA); and (4) Ecological Momentary Intervention (EMI).

Broadly speaking, *user-driven* tracking facilitates tracking by leveraging the capabilities of smart mobile phones while still relying on the user to record any activity. *Sensor-driven* tools relieves the user from tracking regularly occurring habits by using wearable sensors (e.g. accelerometers) to infer the users particular behaviors. *User-driven* and *sensor-driven* technologies are primarily passive forms of tracking; they live in the background and rely on the user to take action. In the case of *user-driven* tools, the user needs to access the tool and enter information; *Sensor-driven* tools track unobtrusively in the background without much user input. Tracking technologies evolved and have become more proactive. *EMA* and *EMI* systems send reminders and interventions to users throughout the day, requiring a response from them. The following subsections give an overview of each of the four archetypes.

1.3.1 User-Driven tracking

User-driven systems focus on assisting users to track any health aspect about themselves. As its name implies, these system archetype relies on the user to record his or her habits of interest. Much like physical diaries, user-driven systems require users to initiate the tracking process and record their activities. Unlike physical diaries, user-driven systems tend to have databases of information that eliminates (or largely reduces) the need for users to spend time researching and quantifying their tracked activities. The fact that user-driven systems store a user's data digitally means that it is now easier for these systems to create charts, visualizations, and summaries of the user's activities. Additionally, the mobile nature and the double purpose of the device – now being a phone and a tracking tool – made tracking more accessible.

User-driven tracking has explored how to assist with smoking cessation [178, 187, 192], understanding awake habits that affect sleeping habits [17], physical activity [109], dieting for weight-loss or diabetes [46, 47, 127, 203], and for emotional awareness and mental health [132]. Even though the motivation and purpose for each of these systems is different, the end-goal is the same: these systems aim to facilitate awareness and self-reflection.

For example, ShutEye focuses on helping users to track their habits during waking hours that can affect their quality of sleep. Users track habits that are known to affect sleep quality such as: caffeine consumption or amount of physical activity [17]. With respect to tracking diet, there is a wide range of intentions and approaches to designing user-driven tracking systems. Some of them focus on having a populated database with rich options [7, 212], others such as DECAF and MAHI use photos to track eating habits [46, 127].

Before the rise of digital tracking, it was painstakingly difficult for users to create charts and summarizations. Many of these systems can now offload the task of creating charts and summarizations and automatically create them for the end user. One such system, PONDS, summarizes food intake by visually highlighting foods by fiber, vegetable, fruit, and protein [8]. On the visualization front, ShutEye also contains a peripheral display on users' phone's wallpaper. This wallpaper provided a summary of the activities that were tracked and overlapped them with the sleep and wake times of the end user. This overview of the tracked data helped trackers get a bird's eye view of the relationship between their sleeping patterns and tracked sleep-related habits [17], making it easier for users to focus on reflecting and self-monitoring.

The strength of user-driven tools is that they help users understand their current habits and reinforce moments of self-reflection throughout the day. Even though this approach heavily relies on the user, the act of recording can create moments of self-awareness throughout the day; in many instances these moments are very powerful on their own and crucial to improving a user's health concerns [213, 28, 208]. On the other hand, some behaviors are simply difficult to track on a regular basis and can lead to tracking fatigue. In short, user driven technologies can provide users with valuable opportunities for self awareness and reflection, but only when users are not overly fatigued from using them.

1.3.2 Sensor-Driven tracking

Sensor-driven technologies seek to relieve users from the burden of tracking and allow them to review and reflect on the inferred habits to then identify what are the next steps to take.

In its most pure form, sensor-driven tracking takes the load of tracking completely off of the user. In this approach a user wears a single, or a set of, wearable sensor [134, 135, 117, 115, 124]. Data from sensors are then used by these systems to detect and infer habits and behaviors of the end user. This approach alleviates the burden of constantly tracking and can assist users to capture behaviors that are less visible (e.g. mental health).

A great amount of work has been done to infer the physical activity of users by using a myriad of sensors, sensor such as wearable cameras and accelerometers [117, 118, 195, 197, 198]. Systems that can infer the physical activities of users have diverse uses. They can assist users with their personal health [115] or help elderly people by detecting when they have fallen down [122]. One of the most representative systems in the space of physical activity inference is the Ubifit system [45]. Ubifit used a wearable multi-sensor device to detect whether users were walking, running, cycling, using an elliptical trainer, or using a stair machine [45]. Lester et al. took this work further by estimating the caloric expenditure of inferred activities [117].

Sensor-driven tools are also used to track sleep and the factors that affect it. Lullaby focused on sensing attributes of the bedroom environment by using sensors to capture data related to it temperature, light, and movement to provide a comprehensive overview of the end user's sleep hygiene indicators [104]. Another system by Abdullah et al. sought out to use phone usage patterns, such as times of phone interactions, to infer sleep duration, and other factors related to sleep and circadian rhythm [3].

It is important to mention that these four archetypes build on top of each other and most of them are hybrids of the four archetypes. In fact, one of the strongest design guidelines that are highlighted in many of these systems is that sensor-driven tracking should offload some of burden of tracking one's behavior. However, relying on pure sensor-driven tracking will make the system fall short of its purpose as people have diverse habits and ways to go about life. To address this restriction and important design guideline is to allow improving and complementing habits inferred from sensor-data with user-driven tracking information [43].

Both user-driven and sensor-driven tools call for users to understand the data that has been collected and reflect on them. To that end, a great deal of work has focused on exploring how to summarize and visualize the data that has been collected by these systems. For example the Ubi-Fit Garden, which was an important component of UbiFit, used a garden metaphor to visualize users physical activities[45]. In the garden, each type of flower represented the stage of a physical activity goal and its size represented how well that goal was being met. Another approach learned that data visualizations are useful to users for information seeking, and that the abstract visualization of the same data are preferred for peripheral awareness and public display purposes [60].

There are common lessons learned from the deployments of user-driven and sensor-driven systems. One such lesson is that trackers often struggle to remember to track, assess their current state, and identify when to activate their set of behavioral strategies when faced with an undesirable behavior.

Additionally, there are many health concerns that require users to put into action a set of behavioral strategies. Doing this requires users to both recall a set of behavioral strategies and *identify* when to use them. For example, people with mental health disorders such as severe anxiety or depression are taught a set of coping mechanisms. These coping mechanism are to be put into action when the person recognizes a potential trigger event. Using coping strategies is difficult because people have to remember which strategies are available and then identify which strategy is appropriate for a given time or place. These challenges remain present even if users are using tracking tools aimed at helping them be aware of such events. These set of steps are extremely difficult, and adherence is low [192].

When users struggle to identify when to use the correct behavioral strategy, then tracking may fall short of its potential; assessing users' current state is part of the tracking process. But assessing is not always straightforward. In the case of mental health, when treatment and support needs to be determined by a specialist, self-assessment is based on global, retrospective self-reports that occur during a clinical visit. But as explained previously, this is not well suited to address behavior over time, across different settings, and in the real world as it limits the ability to accurately characterize and understand user's behavior on a day-to-day setting. One of the benefits of tracking behavior is that instead of relying on general, retrospective reports we can understand our behaviors within the dynamic of our real world. However, user-driven and sensor-driven tracking can fall short of fulfilling these needs because self-assessment and tracking can be difficult for many health habits.

Furthermore, there are habits and activities that are difficult to capture through sensor-data. In these instances, systems rely on mediating the tracking by assessing, or experience sampling, the current behavior. This approach allows for leveraging the strength of sensors but mediating the results through momentary assessments. To address these needs, the next version of systems focused on exploring features that proactively assess and support users while they go about their daily lives.

1.3.3 Ecological Momentary Assessment (EMA)

EMA, also known as Experience Sampling Method (ESM), evolved from user-driven and sensor-driven tracking as these two systems heavily relied on the end user to remember to track. EMA evolved as a need to improve the accuracy and frequency of self-monitoring. With EMA systems, the load of remembering to track is offloaded to the system. The hypothesis here being that if EMA systems prompt users with a particular question, then the answer can be captured immediately [192]. This guarantees an immediate and systematic record about a particular habit (or experience, such as, an anxiety trigger event) [192]. Compared to user-driven tracking tools, which facilitates tracking, but relies on users to initiate (i.e., user-driven), EMA's proactive approach seeks to: (1) make tracking more consistent by reducing user forgetfulness and inconsistency; and (2) make tracking more accurate by reducing the reliance on the user's autobiographical memory to recall a particular event [187, 192].

EMA systems interact with users by reminding them to track a given behavior or by asking users about their current state. The ecological aspect of EMA refers to the fact that these systems prompt for – and receive – information about users during their day to day lives, and not during clinical visits or via retrospective memory recall [192, 213]. The momentary aspect aims at avoiding tracking error and biases associated with retrospection by delivering a short question and have trackers reply *in situ* (e.g., during the activity of interest or real situations) [75, 187]. The prompting mechanism is also considered momentary because of the quick response nature of the questions, thus gathering data without much disruption to the end user's life. Last, the assessment aspect comes from the end user's self-report that is gathered from the delivered question [192]. Self-assessment prompts could be the only form of tracking in a system, or it can complement and inform user-driven or sensor-driven approaches.

Assessments can be delivered to users in four ways: (1) sampling on a fixed interval schedule, such as every 30 minutes; (2) sampling on a random interval schedule; and (3) sampling in response to user initiative — where the user is told to make a data entry whenever performing a particular activity.

The types of assessment also vary, they can consist of: (1) set of questions; (2) Likert scale to measure the dimension of perceived situation (e.g., affect, motivation, concentration); (3) or just a prompt to track a particular habit [192, 187]. Both the type of delivery mechanism and the type of assessment are selected based on the research question of interest.

Excessively prompting users can become a nuisance for users and thus cause tracking fatigue. To address this limitation, Klansja et al., Froehlich et al., and many others, sought out to determine the optimal number of prompts that balances the accuracy of reports against the annoyance of receiving multiple prompts [41, 72, 96, 110]. These researchers found that increasing the frequency of prompts increased both accuracy and user annoyance. They determined that 5 to 8 prompts per day strikes the right balance between accuracy and annoyance [110].

Looking specifically at how EMA has been used to improve health tracking, EMA has been used to study pain, mood, anxiety and anxiety disorders, eating, sleep, gastrointestinal disorders, smoking cessation, and alcohol consumption [54, 75, 81, 133, 146, 147, 186, 192]. In the space of mental health, EMA systems have helped users become more aware of their stress levels, and the reminders of strategies helped users increase how often they practiced relaxation techniques throughout the day [146]. Looking specifically at reminders to track, Bentley and Koblar compared tracking frequency between users receiving reminders to track and users not receiving reminders [19]. In They found that reminders increased food logging from 12% to 63%; other health indicators, such as, mood increased as well [19, 20]. A similar outcome came about when children with high-risk asthma received text to remind them of their asthma triggers [216]. In this case children who received text messages had higher adherence rates to their medication regimes than the treatment group, and they took more preventive measures to avoid severe asthma attacks [216].

1.3.4 Ecological Momentary Intervention (EMI)

The next step from assessing in situ is to offer *support* in situ (i.e., during detected moments of needs). These types of systems are called Ecological Momentary Intervention (EMI). In principle, EMI is an extension of EMA and they share the same definitions with respect to ecological and momentary apply. The key difference is that instead of momentary assessments, EMI systems offer momentary interventions. Usually, the intervention is delivered during detected moments of needs, or opportune moments [87, 163], based on historical user-driven tracked data or sensor-driven data. The key feature of EMI systems is that it provides assistance as people go about their day (i.e., in real-time), and in their natural setting (i.e., real-world) [87, 163].

EMI can take many forms; the intervention can be based on previously tracked data or through real-time sensing inference of behaviors. For example, delivering relaxation techniques when a cardiac rehabilitation patient is stressed, or delivering coping strategies to alleviate depression [29, 160]. Mobilize! and MobileHeartHealth used data from the user's heart rate and phone interactions to determine when the user was under duress and to delivered relaxation techniques when needed by the user [29, 144].

The growing number of sensors, data aggregators, and capacity of mobile phones, is moving from straightforward tracking and assessments to also intervention. For example, devices like GoogleGlass [1], in connection with biosensors, can potentially infer affective states and deliver interventions through the lenses of the glass [86]. Being the

[1] https://www.google.com/glass/start/

most recent evolution of tracking, there is much more to be done. That said the potential of helping people practice new behaviors and skills during their day-to-day experience is showing potential [163].

1.4 The need for an ecological design

All four of the archetypes presented above seek to enable tracking by making it more frequent, occur ubiquitously throughout the day, and be present in users' natural setting (i.e. not in a laboratory setting). Now, more than ever, people have access to and are interacting with tracking technologies; they do so while they work, while commuting, through digital social networks, and at home [22].

To summarize, the motivations underlying the aforementioned archetypes are twofold. First, they seek to make it easier for users to track in order to increase their level of self awareness. Second, they explore how to leverage and repurpose existing wearable technologies (e.g. smart phones, wearable sensors etc.) in order to make tracking systems more usable and effective for users. The implicit hypothesis underlying these studies is that as these systems become more user-friendly, then users will increasingly and naturally incorporate tracking and self awareness into their lives. This, in turn, will enable trackers to address their health concerns.

This hypothesis has at least three implicit assumptions on how these tools will be used in real-world settings. First, it assumes that access is the main barrier to tracking: by making it easier to track, users will use these systems more often. Second, it assumes that when reminders and interventions are delivered in-situ users will be able to act in-situ. And last, it assumes trackers will be able to address and improve their health by using the feedback and insights these wearable tracking systems offer.

With these assumptions in hand, immense progress has been made in creating tracking tools. Deployments in the wild have contributed to our understanding of how to design tracking technologies to address health concerns. Yet, significant issues around sustainable adoption remain. Two such shortcomings of these studies are that the unit of analysis is too narrow (i.e. the user and the tool) and that they do not consider users' real world lives and settings.

The unit of analysis in the extant literature is the user and the tracking technology. This design lens shies away from considering how the tracking technology fits into users lives as well as how tracking interactions occur throughout a user's day. For example, it does not consider how users traverse through different environments throughout the day (e.g., between work and home) and that every environment has particular characteristics that may constrain, or enable, how users attend to their health, or how they can respond or act on feedback from these tracking systems. Second, it does not consider how interactions with other people, such as, family and coworkers, affect tracking. Furthermore, given that people use and own multiple devices (e.g., mobile phone, ipad, laptop) the use of a tracking technology should not be examined without considering its interconnections with other tools and technologies used by an individual [51, 157, 156]. There are many ways to expand the unit of analysis and without a framework to define what aspect of users' lives should be considered when designing tracking technologies, the choices of what to focus on could be unlimited. In order to constrain the seemingly endless number of design considerations, we now turn our attention to the concept of *ecologies*.

1.5 Designing for Ecologies

These potential external factors and the interactions between users and their environment can be more formally analyzed and understood using an *ecological* perspective. Broadly speaking, *ecology* views an individual as part of a complex network, or interconnected system, that includes other individuals as well as their physical surroundings [2]. In HCI, *ecology* (or ecosystem) broadens the unit of analysis to examine how multiple factors including cultural, social (e.g., other people), and physical and digital artifacts (e.g., tools, devices) interact with each other and with users [148, 68, 92, 90, 103, 22, 23, 48].

In HCI, an ecological framework has been used as a way of understanding users' interactions with artifacts or with multi-artifact systems. In other words, we cannot fully evaluate how users use artifacts without considering how artifacts fit into a larger ecosystem [189]. An ecological framework makes visible the dependencies, interactions, and interplay between the environment, artifacts, users, and information [168]. This concept allows us to make the unit of analysis as broad as desired but, depending on what element of the ecosystem is placed at its center, different relationships and dependencies will become more prominent. By placing different elements at the center of the ecosystem, several perspectives on ecologies have come to fruition [148, 68, 103, 22, 23, 15, 92, 90, 48]. We will focus on ecological frameworks that are related to designing tracking technologies that assist users with their health concerns. In particular, I focus on ecological frameworks that center the design lens on people in social-technical settings. These ecologies are: *information ecologies* [148], *product ecologies* [68], *personal ecology of interactive artifacts artifact* and its derivatives [103, 22, 23],and *distributed cognition* [92, 90].

In the case of *information ecology* (Figure 1.1, Nardi and O'Day put human activity at the center, where human activity is served by technological services [148]. They define information ecology as a "system of people, practices, values, and technologies in a particular environment" [148]. They sought out to move the design lens of a single person and her interaction with technology to capture the notion of that information is obtained based on the relationship between people, artifacts, and the particular environment in which interactions take place [148].

Forlizzis *product ecology* centered the design lens on the product, or artifact, to explore the social experience of a group of people interacting with a single product,

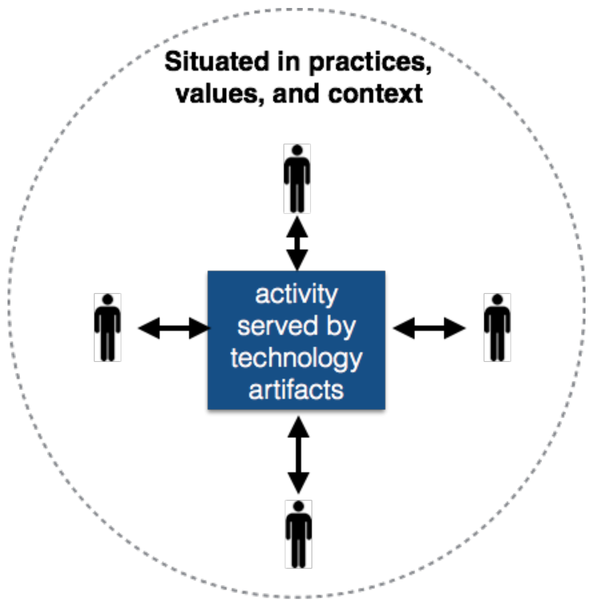

Figure 1.1. Information Ecology

whether it be together or one person at a time in a public setting [68] (Figure 1.2). This point of view brought to the surface how users and artifacts mutually adapt when they are interacting in a particular local environment [68]. There are three interesting design insights we can take from this work. First, it sees the environment as a place containing artifacts that shape roles, social norms, human behavior, and other devices are used and exist in this environment [68]. Second, environments affect how artifacts are used and in turn, using artifacts changes individuals and the context of use as a result [68]. And third, people may adopt artifacts more readily when social attributes are part of the artifacts design by reducing the level of stigma users may feel when using certain artifacts publicly[68].

A different ecological lens places the user at the center of the ecology as part of a network of connected digital artifacts. Jung et al's ecological framework focused on how a person uses several technologies and devices to complete a particular task [103] (Figure 1.3). A *Personal ecology of interactive artifacts* is defined as the set of all artifacts, with some level of interactivity, that the a user owns, has access to, and uses [103]. Bødker

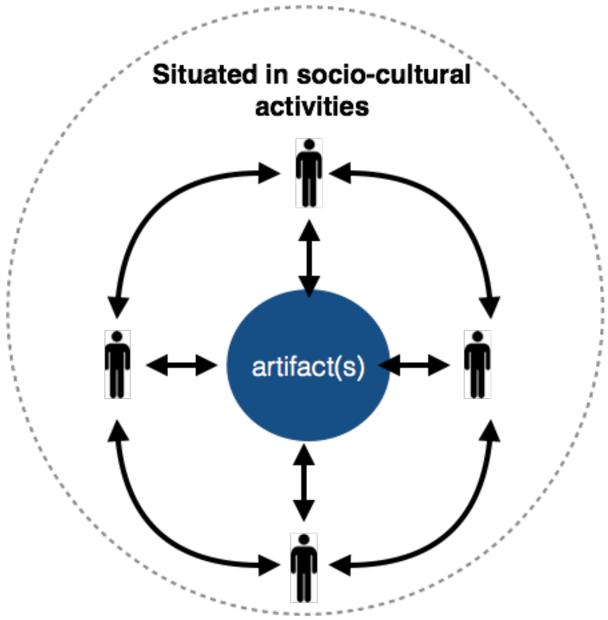

Figure 1.2. Product Ecology

and Klokmose extend this concept by looking at how people perceive and incorporate artifacts to their existing ecology [22, 23]. This design lens centers on the individual and also offers important insights. First, it reminds us that the current design lens needs to incorporate mutual influences between artifacts and macro-level factors such as social or cultural ecosystems [103]. Second, it is important to allow for users' interactions with the artifact to be flexible such that they can be used in tandem with existing artifacts [103]. Third, to consider these ecosystems to be dynamic as the set of artifacts changes when new artifacts are introduced and others are eliminated. Fourth to consider how these artifacts will be used over time, and not for a particular, restricted set of tasks as the constant interplay between artifacts changes depending on users are tracking part in [22, 23].

Bardram and Hutchins center the lens on the collaboration among people and artifacts. They study how interactive artifacts and physical space are organized to support collaboration [13, 14, 92]. Instead of designing for individual responsibilities

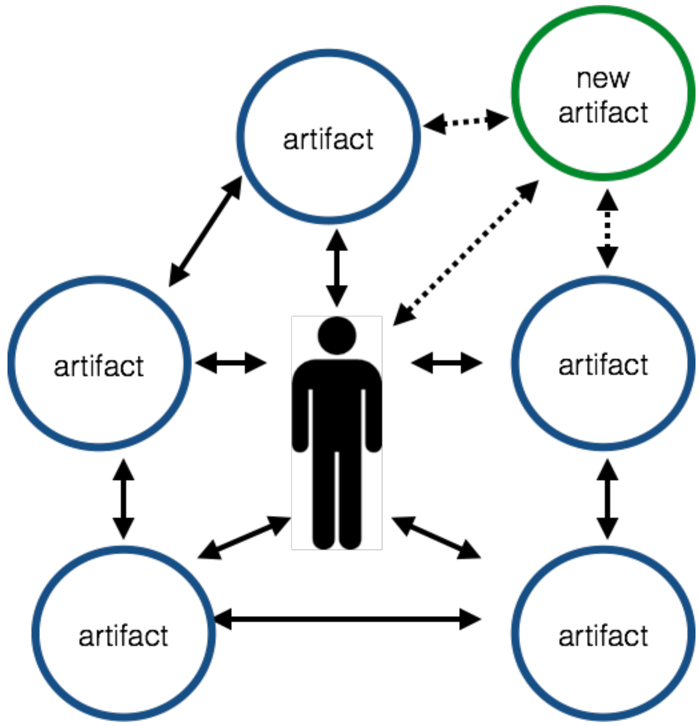

Figure 1.3. Personal Ecology

in a collaborative ecosystem, Bardram designed technological systems based on the collaborative activity [13, 14]. His intention was to allow members of an ecosystem to be able to roam through a physical space and be able to switch and change devices, but still have access to the same information, regardless of where they were or what tool they were using to access the information [13, 14].

In the case of *distributed cognition*, the ecological framework centers attention on how knowledge is distributed between people and artifacts [92] (Figure 1.4. In *distributed cognition*, members of the ecosystem have a different set of skills as well as different responsibilities, but together they collaborate around a shared activity [92]. Furthermore, it also it highlights how artifacts also contain knowledge–implicitly or explicitly [92]. In other words, distributed cognition considers knowledge as an internal and external behavior shared between artifacts and people working together to complete a particular task [92]. This entire ecology creates a cognitive ecosystem [92].

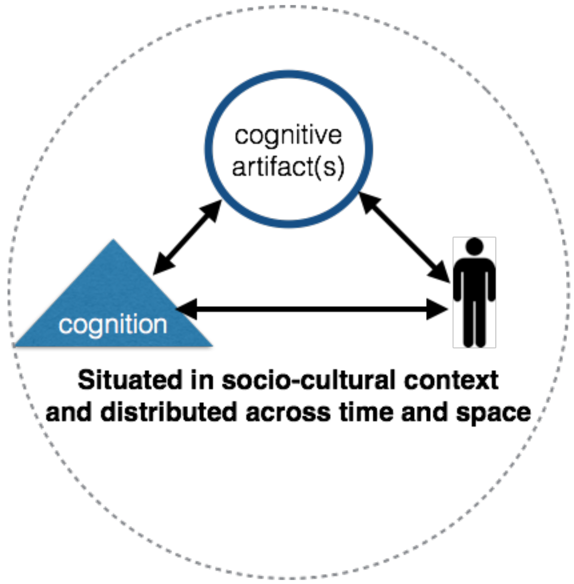

Figure 1.4. Distributed Cognition

This design lens offers three relevant insights. First, artifacts contain information used by more than one user, and as such, artifacts need to be flexible enough to allow people to arrange, integrate, and align the artifact based on their activity [90, 92]. Second, a single interaction is part of a broader interdependent system of people and artifacts[90, 92]. And third, this ecological point of view highlights how collaboration is an activity occurring between people and artifacts in a dynamic way, such that there is time dependency between past activities and completing current activities [90, 92]. As we will discuss in future sections, this ecological point of view is particularly useful in complex collaborative systems involving multiple people and artifacts (e.g., families).

Moving from a broad HCI and design perspective to focus on health, Honari et al. have focused on discussing health from an ecological perspective. Honari defined *health ecology* as an ecology that examines the health of individuals and of communities at the intersection of the environment, the physical and social space, and the social and technical conditions at a micro and macro level–all occurring in a dynamic way [24]. Taking the perspective of Honari's *health ecology* and reviewing the body of work discussed at the beginning of this chapter, we can see that the an ecological approach to designing health technologies is lacking.

As discussed at the beginning of this chapter, the current unit of analysis is too narrow; it has solely focused on improving tracking and adherence to tracking. Looking at the definitions of EMA and EMI discussed earlier in the chapter, Shiffmans et al., Heron's et al., and Patrick's et al. points of view on ecology provide assessment and interventions in everyday settings [87, 163, 187]. Although these are important and valid starting points towards designing health technologies, it falls short in considering all the interplays and interactions discussed above.

1.6 Taking an ecological approach to the design of tracking technologies

Now that we have laid the groundwork for an ecological analysis, let us look at the current body of work of health related tracking from this new perspective. Overall, the current body of work falls short of considering the physical, social, or the current mental load of the user and just focuses on improving the ability to track. This approach faces two risks. First, it runs the risk of offering ineffective support and interventions by not taking into account the user's ecology and the constraints it creates. Second, the support might be delivered to one of the ecologies the user is part of, but not one related to the health concern. By narrowly focusing on how to provide support without considering users' ecologies, we risk designing systems that are insensitive to users' needs. The potentially seamless use of tracking technologies may result in further complicating users' lives. This issue becomes even more poignant with in situ systems (i.e., EMA and EMI). The reason is that these systems initiate the interaction with users, and thus, they insert themselves into users' lives without notice.

In fact, in some of their work, Grimes and Kientz highlight how the design of systems addressing health issues need to consider other stakeholders besides the person of concern [76, 107]. Grimes and Kientz call for designing technologies with a more holistic point of view, instead of just focusing on the user and the tracking system as the principal components to addressing health concerns.

The *new* ecological perspective broadens the unit of analysis and allows examining what are other factors that undermine the frequent use of these health tracking systems. This perspective opens the discussion to asks questions around issues not accounted for before, such as: how does the physical environment constrain how people can attend to their health? Are all contexts the same or are there ones where people can attend to their health better than others? Are there socio-cultural norms that affect or make it difficult to track or respond to reminders or interventions? Do the health concerns go beyond the individual? Are there common or mutual health impacts between an individual and other people in her social network (e.g., family)?

This new ecological perspective also allows us to examine and ask these same questions in the other direction: how can we leverage all of these design factors to improve health, awareness, and tracking? Can these factors be leveraged such that tracking becomes easier? Are there affordances in the physical or socio-cultural contexts that we can leverage to lower the barrier of tracking even more? If family members depend on each other, can we design these systems around the family as a unit rather than focusing on each family member individually (one at a time)? How can family members help each other track and lower the burden on relying on one person to do everything? The new framework brings to the surface all these other aspects not accounted for with the original, narrow unit of analysis discussed at the beginning of this chapter.

1.7 Thesis Claim

Now that we have reviewed the wider lens an ecological framework offers, we can create a more general definition to guide us through the rest of the dissertation. In general, we can view *ecology* as a social setting where individuals interact with others and/or as a physical setting bounded by roles, rules, and responsibilities. Furthermore, there is a mutual relationship between health habits and the ecology in which they take place.

I claim that addressing health concerns using an ecological framework helps creating tracking systems adequate to the user's environment conditions and social settings. Considering the ecology in which the health concern and the act of tracking take place will create the conditions for long-term, sustainable tracking. In this dissertation I demonstrate the importance of considering internal and external factors, such as, cognitive, physical, social, and cultural dynamics in the design of health tracking systems improves the understanding of the space. Furthermore, I claim that analyzing the results of a health tracking deployment from an ecological perspective offers rich insights that will improve the design of future systems.

1.8 Overview of Dissertation

This dissertation focuses on exploring users' ecology as part of the design of different types of health tracking systems. In particular, we focus on four different types of ecologies: (1) young adults and weight-loss during college life; (2) health concerns for office workers; (3) the family as a collaborative ecosystem; and (4) in situ support for families in the setting of their home.

Chapter two analyzes the results of a two-year deployment of an EMA user-driven tracking system. The focus of the study was to assist young adults who are transitioning from living with their parents to living independently. We positioned the student at the center of the ecology bounded by the practices, cognitive skills, and social norms during college. In particular, identify challenges of tracking aspects of weight-loss, such as, diet and exercise, during student-life. These results highlight that users need more than just reminders in order to track, they also need help with time management, planning and social-cultural norms that constrain when and how students are able to track.

Chapter three explains ecologically driven design for sensor-driven EMA. This chapter presents the process of designing in-situ support to decrease sedentary bouts in the workplace. To design for the workplace environment, we centered the design lens on the office worker where the worker was constrained by the practices and socio-cultural norms of the workplace. Designing for this settings requires us to address and balance the tension between work priorities and health concerns. This chapter shows that reminding users throughout the day to take short breaks from sitting is insufficient. Instead, we must take into account their current pattern of work, understand when are the good times to take breaks, and how often users take breaks on their own. Systems seeking to decrease sedentary bouts in the workplace must always allow the focus and attention to be on their work and not insert suggestions for breaks over focused work. Additionally, this chapter highlights the benefits of leveraging existing artifacts in the workplace rather than adding other artifacts to deliver information. Leveraging used artifacts, such as the user's computer monitor, allows systems to deliver support to where the user's point of focus resides instead of adding additional steps to receive reminders.

Chapter four moves the design lens from an individual in her local environment to a collective of individuals in a collaborative setting (e.g., families). In the case of families, the health of children is related to the health of parents and vice-versa. This relationship is reinforced in family-based behavioral training that address the challenges of children with neuro-developmental impairments, such as, ADHD (acro). There is growing evidence on the long-term benefits and impact of addressing a child's neurodevelopmental needs from a family perspective rather than just focusing on child behavioral support. To understand how to design for family-based behavioral training, we placed the distributed cognition between family members and the artifacts used for behavioral tracking at the center of the ecology. This ecology is bounbed by the practices, skills, and familial roles in families. This chapter presents insights on how to design for collaborative tracking, specifically highlighting how the act of tracking occurs in a set of smaller tracking tasks distributed across time, space, and family members (each with different roles and levels of understanding of the program).

Chapter five dives further on the topic of designing for families to tackle one of the issues uncovered in the previous empirical chapter. Specifically, we focused on the challenges of maintaining behavioral strategies parents experience during moments of tension with their children. During moments of tension, parents struggle to diffuse the tension and simultaneously maintain consistency in the strategies and behaviors learned. In the design process of this system we centered the ecology on moments of duress in the household to consider the multiple spaces (e.g., bedroom, living room) these moments of duress take place. We focused on designing for the home because it offers particular restrictions with respect to the multiple rooms and locations where these moments of tension take place and how each calls for delivering a behavioral intervention in a different form. This study serves as an example of designing in situ support for parents helping their children and looking at the home as a collaborative place.

1.9 Contributions

The final chapter presents a reflection on the dissertation claim with respect to each of the empirical chapters. This chapter closes with a discussion on insights and lessons learn from using an ecological framework for designing health tracking technologies.

This dissertation presents and discusses the wide array of factors that become visible when taking an ecological approach to designing health tracking technologies. In addition to providing support for the dissertation claim, we identify a set of factors considered to be critical in the future design of tracking systems. These are:

- the act of tracking actually decomposes into four activities distributed across time
- these four activities can occur in different contexts and tracking technologies must meld themselves to the different settings in which these small tracking activities take place
- the act of tracking can be distributed across a collective, where each member of the collective has particular roles and skills to add their contribution to a single tracking moment

Chapter 2

Social-Mobile Approach to Reduce WeighT (SMART)

2.1 Introduction

Crucial steps to losing weight are improving diet and increasing physical activity [28, 99, 185]. However, relying on our capacity to recall and mentally monitor diet and exercise leads to overestimating caloric expenditure [55] and underestimating caloric intake [201]. Not only are our recall and estimation skills weak, but also there are awareness and reflection aspects that are strengthened by taking a moment to annotate and review our behaviors [28, 213]. Therefore, accurate tracking calls for more than relying on our mental abilities, we need a way to log and track our habits.

Until recently, the means to accurately track were paper-based. However, paper-based tracking is fraught with challenges. Paper-based tracking is cumbersome to transport, requires multiple steps (e.g., doing constant arithmetic to estimate caloric intake compared to caloric expenditure), and given that the data is in paper-form creating summarizations and charts is extremely time consuming and difficult.

On the other hand, the growing capabilities of wearable and mobile technology has led to exploring how to leverage the affordances of digital technology to ease the process of tracking. For the case of tracking, the capacity of mobile technologies allows users to have access to: a database where user can add foods and exercises with their corresponding caloric value to reuse as needed, to create a list of most tracked items for easy access, and last, summarizations and visualizations become easier to create and are part of the technology rather than heavily relying on the tracker to create them. These affordances relieve trackers from the onerous steps of tracking through paper-form and allow trackers to focus on the act of tracking, and hopefully, achieve weight-loss. These promising tracking technologies have flooded the marketplace, yet little is known on how these technologies are adopted and integrated to people's lives.

2.1.1 Early Work in Technology-Assisted Tracking

Technology-assisted tracking, ease the process of tracking but still rely on users to enter and track behaviors. While one could posit that automated, system-driven tracking lessens the efforts to track, automatic tracking, especially of caloric intake, remains to be improved [18, 197]. Furthermore, relying on automatic tracking decreased the moments of self-awareness and reflection that come through user-driven tracking.

To inform the design of tracking technologies, two approaches have been taken. The first employs interviews and surveys. This approach teaches us about the weaknesses and strengths of current user-driven tracking technologies and sets the roadmap for the next design issues to address. The second approach builds and deploys tracking tools to test whether the tool improves tracking and helps improve a specific health problem. Each of these approaches provides valuable insights, and our work builds on them.

Survey and Interview Studies. Four separate studies examined the state of tracking and the barriers to successful tracking for the purpose of building design guidelines for tracking technologies [35, 47, 119, 180]. To do so, the authors interviewed and surveyed individuals with various motivations to track and using various tracking technologies. Overall, these studies found that participants struggle with: remembering to track, merging and organizing multiple sources of tracking, and reflecting on their behavior based on data tracked [35, 46, 119, 180]. Looking specifically at diet tracking, Cordeiro calls attention to the difficulties users face when tracking homemade meals or meals in a social gathering [46]. Furthermore, Li's set of trackers were interested in tracking multiple behaviors at once and because of that their tracking interests would change, however, the current tracking infrastructure was not equipped to adapt to these changes [119].

With the exception of Cordeiro, the participants in these were either extreme trackers (i.e., very advanced trackers with lots of time invested on making the tools work for their tracking needs) or were technologically savvy people with a curiosity to tinker. With the exception of participants in Cordeiro's work focusing on diet, the rest of the participants tracked other aspects of their life, such as, work productivity or financial behavior [46, 180]. The variety of tracking needs and interest led to the use of a variety of tracking tools, including spreadsheets or tools running in the background of a computer to log number of applications in use and amount of time they are used while open.

Putting all these studies together creates a set of general design guidelines for tracking technologies. Our study, rather than focusing on heterogeneity to create generalizable design guidelines narrows the question to focus on designing tracking technologies for weight-loss. Moreover, we look at the design implications for long-term tracking use. Our contribution lies in discussing qualitatively and quantitatively a set of people with similar experiences and weight-loss motivations employ user-driven technologies to lose weight over a two-year period. That said we our study has overlapping results and we revisit and expand on these results in later sections of this paper.

Design-and-deploy studies. Our study evaluates the use of tracking technologies over time. Several projects before ours have performed controlled, longitudinal studies to test if a tracking tool assisted with a particular health goal. These studies evaluated a novel approach to tracking or repurposed an existing technology, such as, texting, to test if it can be used to deliver behavioral interventions or as a mechanism for tracking.

PONDS was a mobile application that sought to reduce the effort and time it took users to track their caloric consumption [9]. Instead of tracking the how many calories were consumed, PONDS instead tracked food elements (e.g., grains, fruit, and vegetables). In a lab study of PONDS with 24 participants, the authors focused on testing likes and dislikes of PONDS, as well as the time it took to enter and search for food elements. Participants found the macro-level overview of food they consumed helpful and that this format would encourage them lean to towards foods with more whole grain and fiber. However, they found it mentally taxing to discern which food category to track, especially when the meal had multiple ingredients [9].

Three studies, Chick Clique, Houston, and Fish N' Steps used pedometers and a mobile application to track users' step counts and encourage users to achieve their step count goals [42, 124, 200]. Overall, their results show the potential for pedometers and mobile tracking applications to increase daily physical activity. The longest of these studies was Fish N' Steps with 19 participants [124]. This system was deployed for 14 weeks (4 weeks of baseline data collection, 6 weeks of groups competing with each other based on daily step count, and 4 weeks where participants were not competing against each other but still using the pedometer)[124]. During the 4 weeks of competition, the fascination of the competition subsided after the first two weeks. That said, 14 of the 19 participants increased their daily step count between the baseline phase and the competition phase and maintained their new daily step count during the 4 weeks after the group competition [124]. These findings show the potential for pedometers and mobile phones to improve tracking and increase physical activity.

Other studies have investigated text messaging as a mechanism for tracking and supporting behavior-change [39, 165, 216]. Looking specifically at weight-loss, a 16-week randomized control trial with 65 participants evaluated whether tailored text messages could assist with weight-loss [165]. This study consisted of delivering behavioral interventions and tracking reminders through text messages. Participants were sent timely weight-loss information and were asked to report their weight, exercise, and dietary goals on a weekly basis. At the end of the study, the intervention group lost 3.16% more weight than the control [165]. While the weight-loss is modest, this study shows the potential of a weight-loss program assisted through text messages reminders. Nonetheless, it remains unknown if this intervention led to long-lasting changes [165].

Looking at designing for diet tracking, photo-journaling represents an alternative to tracking one's caloric consumption. Two mobile application-based systems, MAHI and DECAF, were deployed using this approach [46, 127]. MAHI focused on helping newly diagnosed diabetes patients adjust to a new health lifestyle [127]. Being diagnosed with diabetes call for: learning new eating habits, the relationship between food and glucose, and how to track glucose. At the end of the study, both DECAF and MAHI users reported they would forget to use the mobile application to track-an issue we also return to [46, 127]. That said, MAHI users achieved more diet-related goals and had a stronger sense of control over their new lifestyle compared to a control group [127]. Furthermore, participants with calorie tracking experience reported DECAF made tracking foods easier, and it lessened their feelings of failure and judgment [46]. Looking specifically at changes in weight, MAHI and DECAF did not focus on weight-loss and therefore, weight-loss was not assessed. Participants using DECAF for weight-loss purposes though, were unsure if photo-journaling would fulfill their needs [46].

With the exception of Patrick et al., and by design, these study do not examine the long-term impact of user-driven tracking technologies, especially with respect to weight-loss [165]. Furthermore, these studies lasted at most 4 months. Thus, user-driven tracking technologies remain to be evaluated in a long-term, naturalistic setting. Our study, takes the first step on mapping the uncharted territory of long-term use of tracking technologies. We specifically look at the experience of user-driven tracking technologies in a long-term weight-loss study.

2.1.2 Open Questions: Use of tracking technologies in the long-term

Building from the above insights we explore the following questions. First, do mobile tracking applications help users lose weight in the long-term? Second, do trackers use these mobile applications in the long-term? If so, how do they leverage these tools? To answer these questions we ran a two-year randomized control trial to examine whether user-driven technologies can lead to weight-loss. With respect to the first question. Preliminary results found that the treatment group did not lose weight by the end of the two-year study. Our paper tackles the remaining question but from a different angle. In particular, we look at why these tracking technologies did not assist with weight-loss, where these tools assisted with tracking and where they were ineffective in assisting with tracking.

Our insights are based quantitative and qualitative data gathered from interviewing 19 intervention and 18 control participants, as well as surveying 40 intervention and 35 control. These participants were part of a two-year randomized control trial with 404 subjects. The following sections introduce the study, explain methods for collecting data and our analysis, and close with results and discussion.

For our interviews, we interviewed both treatment and control. Interestingly, we learned two things. First, that both the treatment participants, and especially the control participants, were using tracking tools not part of the study. In hindsight, it makes sense that the control group sought out their own resources to track and lose weight-they were as motivated as treatment participants to lose weight. Furthermore, during our qualitative analysis we discovered similar themes and patterns between the treatment and the control. Given the similar experiences of the two groups our qualitative insights and discussion present insights of the analysis of the two groups merged together. By merging the raw data we hope to find stronger findings that address our questions about understanding what were the barriers participants experienced in using tracking technologies in a long-term, naturalistic setting.

2.2 Overview of Longitudinal Study

2.2.1 Motivation

Young adults undergo a number of life-transitions and must learn to adopt and adapt through a series of social transformations. The typical college student transitions from adolescence to young adult while in college. During this life-transition is when risky health behaviors are shaped, including physical inactivity and poor diet habits. Prevalence estimates of health-risk behaviors among adults 18 to 24 years in 2003 demonstrate that 43.2% reported insufficient or no physical activity and 78.4% of respondents reported suboptimal daily fruit and vegetable intake [136]. A recent survey of 3,200 undergraduate and graduate students demonstrated strong associations between overweight and obesity and insufficient physical activity, poor dietary habits, and poor stress management [149]. Furthermore, in the past decades prevalence of obesity has increased substantially among young adults independent of sex, age, educational level, racio-ethnic status, and geographic location [53]. Current estimates of overweight and obesity in the young adult population is at a prevalence of 40% [136]. Despite that alarming number little research has been performed to evaluate the relationship between these common young adult transitions and weight status; however, available data suggests that the interaction is dynamic and reciprocal. The issues with weight-gain in turn leads to increased risk of cardiovascular disease, diabetes, and other health issues [40, 111, 66, 138]. These issues though, take decades to fully manifest themselves, thus, they are not in the peripheral vision of a young adult. We posit that intervening during the adolescent-adult transition on these recognized, modifiable health-risk behaviors may be crucial for preventing chronic disease.

2.2.2 Social-Mobile Approach to Reduce WeighT (SMART)

While there is consensus on the promise of these technologies for behavior change, further research is needed on how mobile technologies can be used to overcome the challenges listed above and to improve health outcomes [162, 59]. We sought out to address these issues through user-driven technologies. Given the high use of mobile applications among young adults [112] and the growing capabilities of smart mobile phones we sought to explore how can user-driven tracking through mobile applications. The results presented are based on SMART: a technology-based two-year randomized control study of 404 college students. Students participating in the study were recruited from 3 universities in Southern California from the undergraduate and graduate student body.

Participants were randomized in two groups. The control group had access to a static website with basic health and nutritional facts. The intervention group received support through several channels. The channels include a Facebook page and a blog connected to it with information posted by a health coach, mobile applications in conjunction with text messages, and occasional meetings a health coach if participant was gaining weight. Each channel had a specific purpose and focused on specific on addressing specific theories of weight-loss and behavior-change. Our paper focuses on the particulars of the mobile technologies, which include: text messaging, pedometer, digital scale, and web browser-based mobile phone applications. For more information on other components of the study see Patrick et al. [164] and Merchant et al. [139].

2.2.3 Participants

Participants were recruited from three southern California universities. To be eligible participants had to meet the following criteria: a) age 18 to 35 years, b) Facebook user or willingness to begin, c) owns a personal computer, d) owns a mobile phone and uses text-messaging, e) body mass index (BMI) between 25 and 34.9 kg/m2, and (f) willing to attend required research measurement visits in every 6 months for two years [164]. The study had a rolling start date; participants were recruited and entered approximately in cohorts.

2.3 Methodology for our Sub-Study

After a year, both treatment and control reached their recruitment numbers (i.e. each group had 202 participants). We interviewed intervention and control participants to maintain a balance approach. On the intervention side, we wanted to learn how intervention participants were going about integrating tracking, health, and weight-loss efforts into their day-to-day activities. On the control side, we were interested in learning how members of this group were going about their health and weight-loss, especially, since they were as motivated as treatment participants at the beginning of the study.

Specifically for our sub-study, participants were intercepted at the end of one of their measurement visits and those who agreed to be interviewed were given a $25 Target gift card for their time. Additionally, researchers attempted to reach a broad pool of participants by interviewing participants from two of the university campuses in the study. The total interviews were 19 intervention and 18 control. We interviewed participants at various time points of their tenure in the study. That is at: the year mark, year and a half mark, and end of the study. On average, the control interviews lasted 35 minutes and the treatment interviews lasted 60 minutes. The interviews from the control group were shorter because we did not ask all the specific questions regarding the intervention tracking tools.

The interviews were conducted in a semi-structured format. Researchers had a set of open-ended questions but dived further into topics depending on participants' experiences with tracking technologies. The questions of the interview covered: motivation to join the study, previous experiences with weight-loss, how they stay motivated now, how and when do they use the tools, and how they seek social support. The questions to the control group were similar to the interventions' questions but there was no mention of the intervention tools deployed as part of the study.

In addition to the in person interviews, we sent two sets of surveys with similar questions (one for the treatment and another for the control) to reach out to more participants than the ones that had a greed to speak to us in person. From this, we gathered 40 responses from the treatment and 35 responses from the control. Participants were reimbursed for their time responding to the survey by being added to a raffle to win $20 gift card from target. We awarded twenty gift cards to each group, and we selected the winner randomly.

2.3.1 Analysis Approach

We took an iterative approach to the qualitative analysis. In the first round, treatment and control interviews and surveys were analyzed separately as it was assumed they had different experiences based on the setup of the study. At the end of this first around of analysis, the authors identified overlapping themes across groups and similar experiences regardless of the group the participants were part of. For example, the control group also used commercially available mobile applications that focus on tracking and weight-loss. Furthermore, in terms of weight-loss, a similar pattern emerged at the end of study, there was no significant difference between the treatment and control group.

Our original research questions were around understanding the experience of the intervention group fitting in tracking into their daily lives. After identifying similar experiences in both groups, our research goal changed to understanding the underlying mechanisms that led to participants struggling to use tracking tools to fulfill their needs. In the remaining iterations of the qualitative analysis, we merged the raw data from both groups. By merging the raw data we hoped to find stronger findings that address our questions about understanding what were the barriers participants experienced in attempting to lose weight and track their health longitudinally over two years. All rounds of analysis were led by one of the authors and at least two other authors were involved in the discussion process at every iteration of the analysis.

With respect to the interventions data, our analysis used data examined the use of the tracking tools. We do not have access to data from the commercially available tools participants used during the study.

2.4 SMART Applications and Usage

All applications were built for mobile and desktop browsers. Taking the browser approach allowed us to make the application platform independent and stable for a longitudinal study. This decision was especially crucial at the time of development because at the time, the start of the art of mobile technology was not at the state of handling rich interactions as it is today in 2015. On the mobile browser version, we created shortcuts on users' home screen to simulate the appearance of a native application. All intervention participants installed the applications during their first assessment. Although there were four mobile applications deployed, we focus on the three most used: GoalGetter, BeHealthy Challenges, and TrendSetter.

Mobile tracking applications were specifically built for this study; their design was driven by theories of behavior-change and weight-loss [164]. These principles include: self-monitoring, intention formation, goal setting and goal review, feedback on performance, and self-efficacy [164]. Other components of SMART, addressed other principles of creating healthy habits. The Facebook page assisted with problem-solving and social support. Through SMART's Facebook page participants could discuss struggles and get feedback from each other participants as well as from the health coach organizing the information on the page. For more information on the Facebook component of SMART see Merchant et al. [139].

Below, we compare and contrast the applications with respect to:

- *Granularity of tracking:* This dimension classifies the application based on the detail of tracking. Fine tracking involves tracking quantitative, continuous values, such as, calories consumed or expended. On the other hand, coarse grain tracking involves tracking healthy habits and corresponding accomplishments but not specific health indicator values.
- *Frequency:* This dimension is based on the frequency of tracking, such as: daily, weekly, while others require once a month tracking.
- *Modes of tracking:* In our study, there were three tracking modalities: mobile or desktop browser version of the application, and text messages.

Table 2.1 summarizes each application with respect to the above dimensions and the behavioral strategies that drove its design.

Table 2.1. Summary of application with respect to tracking dimensions

Mobile application	Behavioral Strategy	Tracking granularity	Frequency of tracking	Ways of inputting data	Reminders	Additional assistance given
GoalGetter	Goal-setting	Coarse	As often as participant desired, recommended at least weekly	Desktop or mobile browser	None	None
BeHealthy	Intention formation	Coarse	Weekly or monthly	Desktop or mobile browser	SMART Facebook page	Sporadic small rewards for completing monthly campaigns
TrendSetter	Self-monitoring	Fine	daily or weekly	Desktop or mobile browser Text messages	Text messages	Scale and pedometer

Figure 2.1 shows the usage of TrendSetter, GoalGetter, and BeHealthy through the two-year study. In particular, this figure shows the average use of the application per month in the study. Our study had a rolling start date, in this graph though, participants' data is aligned to match all their interactions to their first day in the study.

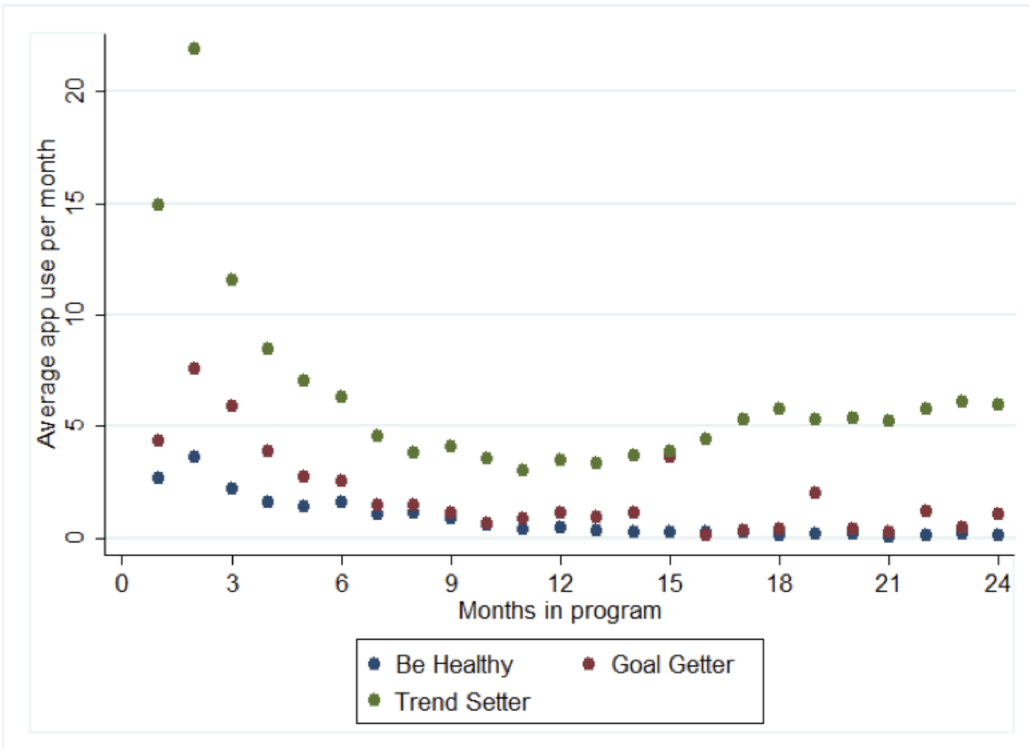

Figure 2.1. Average application use per month

GoalGetter focused on helping users set, maintain, and review goals. Participants could set any type of behavioral goal, such as, exercising threes times a week. Setting a goal included selecting: start-date, end-date, and intermediate steps to track towards completing the goal. There were some recommended goals at the beginning of the study but every tracking event was user-initiated: participants had to set the goal and remember to update it. Participants could update as frequently as they set the intermediate tracking steps to be. The recommended frequency of tracking was three times a week or weekly. Furthermore, on average participants selected to achieve a goal per month. Since the focus of GoalGetter was to log activities but not caloric values, this application is a form of coarse grain tracking.

After participants set a goal with its corresponding duration and intermediate steps, to track progress towards the goal participants would go to GoalGetter and mark as completed each intermediate step. Figure 2.1 shows the average intermediate steps accomplished. Looking at this figure we see that participants on average set and accomplished approximately 5 steps towards a goal the first month and approximately 8 in the second. At the end of the first six months of the study though, tracking goals decreased, and participants rarely accomplished goals from there on.

BeHealthy Challenges focused on intention formation. Through this application participants were exposed to short-term or low-effort activities around food and exercise. Examples of activities were: taking the stairs instead of the elevator for a day, or adding a bowl of lentil soup to one of the meals of the day for a week. Through BeHealthy, participants are introduced to small changes that could then be turned into goals to complete through GoalGetter. The intention was to introduce small activities that if turned into daily habits have long-term health benefits. In addition to accessing the challenges through the application, announcement of the challenges were made through on SMART's Facebook page-which served as a reminder. The frequency of tracking depended the on the challenge, they could be: daily, weekly, or monthly. Tracking consisted of marking the challenge as complete, and thus, it was a type of coarse tracking.

As seen in Figure 2.1, of all three applications, BeHealthy was used the least. BeHealthy reached its usage peak at the second month of the study where participants on average used the applications 3 times during the month. Use declined steadily from there on, by the six-month mark, the average use dropped to 2 times per month. After a year, the usage dropped to a single use per month and a times zero. In our next section we explain the low interaction rate of this application.

One an important note to make is that some of the challenges turned into extended events called campaigns on Facebook. These campaigns were longer-term challenges and were usually around times of the year that lead to unhealthy habits. Examples of these events are: not eating candy for an entire month before Halloween, or increasing step count beginning of the New Year. The intention was to guide and engage participants to use the applications through these campaigns, especially BeHealthy. We learned that the interactions through Facebook stayed confined to Facebook. In other words, participants were interacting in these campaigns but not using BeHealthy to track it. Instead, they just used the Facebook announcements to participate and track these campaigns. Despite the lack of translation from interaction from Facebook to using the tracking tools, the Facebook page was successful in engaging participants within that space, for more information on how these campaigns engaged participants see Merchant et al. [139].

TrendSetter focused on self-monitoring. Participants could track any type of indicator. At minimum though, participants were encouraged to track weight, step count, and calories consumed. To make tracking easier, all treatment participants were given a pedometer and a scale at the beginning of the study. This was the only application that sent participants explicit reminders to track. These reminders were sent as a text message. Participants received three, separate weekly reminders on different days to track their weight, steps, and calories. In addition to being able to track through the application, participants could track by replying to the text message reminder with the corresponding information. This means, TrendSetter was the only application with an additional modality to track: tracking through text message. To view charts and summarizations of the health indicators that were being tracked (in TrendSetter called trends), participants had to view it through TrendSetters page. This application is the only fine grain tracking application as it focuses on tracking numeric values including weight, calories, and steps.

As 2.1 shows, TrendSetter was the most used. During the first month, participants on average were tracking 15 times a month. In the second month, the average increased to 20 times per month. At the six-month mark though, participants were using TrendSetter less than 10 times per month and by the end of the study, at two years, tracking averaged closer to 5 times per month.

Interestingly, though, when we focus on weight, step count, and calories and analyze each trend, a different tracking pattern emerges. Looking at 2.2 we see that weight, on average, was the most tracked of the three health indicators. Step count was tracked less than once a month at the 12-month mark but then it began to increase, and by the end of the study, on average, participants were tracking their steps at least twice a month. Last, we see that calories were the least tracked; tracking calories consumed was close to zero every month.

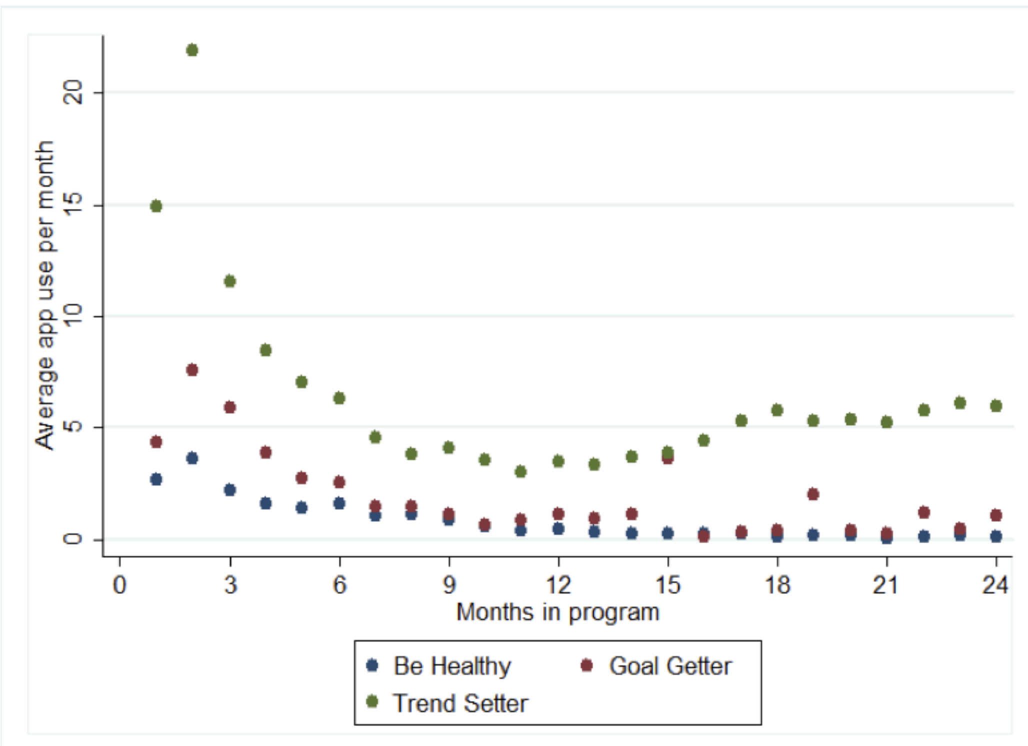

Figure 2.2. Average use of tracking through TrendSetter divided by Steps, Weight, and Calories

It is important to note for all three trends participants received weekly reminders but all the reminders did not start at the same time. The only reminder that was sent from the start of the study until the end was for tracking weight. The reminders to track steps and calories, though, began halfway through the study. It is important to note though, that the reminders did improve the tracking of steps but not for calories. One could ask, why is there such a difference between tracking steps and tracking calories? One reason is the number of steps required to track calories compared to steps. In the case of steps, participants had a personal pedometer. Therefore, when they received the reminder, if they were wearing the pedometer and wanted to track it, the only step required is to view the number of steps on the pedometer and reply through the reminder to track. However, counting calories is not straightforward, counting calories takes place every time a food is consumed. Additionally, our participants did not have a device to directly estimate calories as pedometers estimate steps. Furthermore, our applications were built before the avalanche of mobile applications with rich databases with caloric values for ingredients and foods. Thus, in order to track, participants had to keep a list of the food they ate, then search online for their caloric value, then do arithmetic to calculate portion consumed and sum of all meal calories, and then enter the sum value in TrendSetter or by replying to the text message. Clearly, the flow of tracking calories is cumbersome compared to reading one's weight off of a scale or step-count off of a pedometer. We hypothesize that there would have been a higher rate of calorie tracking if participants had access to a detailed food database.

On the other hand, tracking steps did increase when participants began receiving reminders and it continued to increase all the way to the end of the study. One of the reasons the step increased was because one of the Facebook campaigns was to focus on tracking steps for a month. The increase in steps, confirms what previous work had highlighted, reminders help with tracking. That said, it is also important to note that although participants received reminders to track their weight and tracked it throughout the entire study, the rate of tracking did decrease over time. Participants went from tracking their weight on average 4 times a month to less than 2 times a month by the end of the study. In our next section we discuss issues around tracking weight that came to the surface during our qualitative analysis.

Looking at these applications together, if our study had lasted 4 months like the longest in our related work - we could say that TrendSetter was used on average 7 times a month, GoalGetter 4 times a month, and BeHealthy twice a month. At the 6-month mark interactions begin to decline and it is also at this point where weight-loss begins to stagger [CITE GODINO POSTER]. By the 24-month mark interactions vastly decreased and the treatment group had regained the weight. These results reflect the reality of weight-loss: it is very difficult and there is a tendency to regain the weight lost [21], [56].

By the 24-month TrendSetter was being used on average 5 times a month, while GoalGetter and BeHealthy were used less than once a month. Of course, the lack of weight-loss by the treatment group and the decline in use of these tools does not necessarily imply that user-driven tracking technologies will never support weight-loss. As our ensuing analysis from participant interviews will show, our subjects encountered significant challenges with technology-assisted tracking, some of which may be surmountable. Furthermore, it leads us to explore why the use these tools decreased and what aspects of their design model were not helping participants track towards their weight-loss goals.

2.5 Barriers Fitting Tracking into Daily Life

Our original research question was to gain insight on how people utilize user-driven mobile tracking technology to lose weight and how do they go about fitting in tracking into their daily life. As we completed our quantitative it became clear that tracking was not sustained and that weight-loss was not maintained. Due to the modest quantitative outcomes of the study, it became apparent that we needed to understand the failure to integrate these technologies into their lives and where they fell short in assisting in the arduous process of weight-loss. Additionally, through our qualitative work we learned that both control and treatment participants were utilizing non-study tracking tools for weight-loss while the study was taking place. Therefore, given that both conditions made use of tracking applications, that both maintained weight, and that both struggled with tracking we decided to treat both groups as one during our qualitative analysis.

In the ensuing analysis, we identified seven significant challenges that participants encountered in integrating mobile tracking technologies into their daily lives. In this section we introduce each one and in the next section, we take a broader perspective.

2.5.1 Balancing engagement and long-term goals

The intention of BeHealthy was to expose participants to simple habits as a form of intention formation. In general, participants found these challenge entertaining. However, the spontaneity of these challenges made them difficult for participants to incorporate them in their pre-established daily routines.

> I would look at them and then sometimes I will accidentally log on in the morning and say oh try eating this for today. And then I will think about it and say probably I cannot.
>
> <T1 >

Several of our participants were not focusing on changing and tracking exercise and diets behaviors at the same time. The participants we interviewed focused on the aspect of their health they were most comfortable and confident about tracking. In the case of *T2*, at the time we interviewed him, he was focusing on physical activity, thus, if the challenges were focused on diet he was not interested in participating.

> I liked the physical activities one just because they were easy for me to do it ... Some of the food ones ... I would have to go out of my way to get those groceries sometimes I was less willing to do that. Some people might like cooking and trying all kinds of different things that way and other people like to exercise and play sports so I heavily leaned toward that.

<T2 >

Furthermore, participants we interviewed struggled to make a connection between the short-lived activities and their long-term weight-loss benefits.

> When I read them and stuff it's like random. No structure. If they had a week or a two-week challenge with exercise, like challenge yourself to walk this many steps. Like an ongoing challenge versus just focus on eating healthy once or like logging your steps for the next week.

<T3 >

Thus, these serial challenges were counter to habit formation and increased the overhead of tracking. Instead, participants were looking for a guided plan to help them lose weight. A possible alternative to explore is suggesting and presenting challenges based on trends identified in the tracked data. In other words, not present unrelated challenges spontaneously, instead, suggest activities based on current habits.

2.5.2 Desire to simplify accurate tracking leads to undesired outcomes, such as, eating packaged food

Our study was built and deployed before mobile applications had the capabilities to support rich interactions and before commercial tracking applications were readily available. As the study progressed, participants motivated to lose weight used commercial applications to track and apply concepts learned in the study. Interestingly though, despite these applications containing databases with wide variety of exercises and foods choices, participants still struggled to track.

The first barrier was around tracking homemade meals. Homemade meals are highly encouraged when it comes to weight-loss and general health. First, because the amount, type, and healthfulness of ingredients can be controlled, and consequently, preparing a dish at home is healthier compared to its frozen or restaurant equivalent [31]. However, participants struggled to identify which ingredients in the meal required tracking and how to quantify the amount consumed for each ingredient in one sitting. For example, in chicken stew, in addition to tracking the chicken, participants wondered how important it was to exactly track other ingredients, such as, tomato sauce, vegetables, oil and potatoes.

> T4: I had to start like counting some rough estimates because it wouldn't give me the exact counts ... Sometimes, it wouldn't have all the foods [ingredients] or sometimes, it would have similar foods [ingredients] but I wouldn't know if it was exactly the same.
>
> <T4 >

Second, participants were overwhelmed by the multiple choices for a single ingredient. For example, participants had to find the specific brand of bread they were eating in their sandwich because each brand of bread had a different caloric value. This problem was even more prominent, when users were tracking a generic meal or ingredient. This led to participants being overwhelmed from having to select from the multiple choices for a single item.

Second, participants were overwhelmed by the multiple choices for a single ingredient. For example, participants had to find the specific brand of bread they were eating in their sandwich because each brand of bread had a different caloric value. This problem was even more prominent, when users were tracking a generic meal or ingredient. This led to participants being overwhelmed from having to select from the multiple choices for a single item.

> Like it would list sometimes brand names or just different things and I would just kind of get confused about whether or not it was the actual thing that I ate ... there's just a lot of different variations on some kind of food. I would just like, I just wanted something that would be kind of like a quick library that would show rough calorie counts of certain foods and then maybe a way to help estimate how much you had so that way you're not ... it's my goal to have one cup of this or half-a-cup of that.

<T4 >

The current state of tracking is based on counting every food item and the amount. Tracking at that level of specificity added more complications to participants' lives, and outweighed the benefits of tracking.

> I just feel like that's too complicated for me and my life is already hectic enough that ... I don't want to be on my phone putting in I had a bag of baby carrots. It's only four not five [carrots].

<T5 >

This exact level of tracking discouraged participants to track. From an interaction perspective, exact tracking requires multiple steps. Cognitively, users have to do arithmetic to match the portion size consumed to the portion size available on the application. Then, find a way, through multiple clicks, to enter the amount consumed with respect to the portion size available on the application. From a tracking perspective, this design model is not rewarding healthy habits. Certainly, tracking the exact amount of certain foods, such as a muffin, is important but for baby carrots it is not. The capability of these technologies is not being leveraged so that based on the item being tracked the granularity of tracking adapts. These tracking technologies could have different tracking rules and guide users through tracking. For example, when entering an item like a muffin the tracking technology could request portion consumed but for baby carrots the tool would not request any additional information. That way, the process of tracking is rewarding healthy habits: leaning towards healthier foods requires less tracking.

Otherwise, there will be undesired consequence of tracking. In our study, when the efforts to track outweighed the benefits of tracking participants struggled to continuously track and slowly ceased to track. Furthermore, in the desire to track exactly our participants began to consumed packaged foods.

> I didn't like how time consuming it was. I found myself trying to eat packaged meals more often just because it was easier to see what the calories were. Then what I liked it was pretty easy to figure out if you had the time what you had eaten and how healthy it was.

<C1 >

Packaged foods make tracking viable for two reasons. First, they contain food labels, which make exact tracking straightforward. Second, many of these meals are contained in the databases of commercially available tracking applications. However, consuming packaged foods contradicts one of the highly encouraged steps we mentioned at the beginning of this section, consuming homemade meals.

2.5.3 The rigidity of current tracking applications does not support the diverse needs of users

The participants we interviewed had a wide range of experiences and knowledge around tracking. Half of the participants had gone through a weight-loss program or had tracking experience before our study. The experiences range from weight-watchers weight-loss program to maintaining and tracking a daily 1200 caloric intake. The other half of our participants did not have any previous experience around tracking. Surprisingly though, regardless of experience level, all of the participants we interviewed struggled to track.

> I think simple basic stuff like how to use dumbbells, like a little workout like the butterfly or something. There are ones that are basic. OK, who doesn't know how to use the treadmill? That one is just basically on time.

> But maybe on the StairMaster if you want to do something like, ”OK, go to level 7 for a minute.” And you do the different levels to get your heart rate beating. If you do that you burn more calories. Maybe stuff like that, how to use certain equipment.

<T6 >

Participants with no previous tracking experience struggled because they needed guidance. These participants needed help identifying what to focus on changing in their diet, or what workout routines were adequate for their current fitness level. On the other hand, participants with tracking experience were seeking assistance in making sense of the data they were tracking. These participants wanted to identify how to improve their exercise or diet based on the information they were tracking.

> At some points it felt like it was just the same thing that I’ve been doing before the study ... Maybe if there were someone else that could be, okay so ... To analyze your data. There’s nothing there, okay you have all these numbers here, what can I do? Needs to be going up or is it going down?

<C2 >

Participants like C2, understood the strength of reflecting on one’s habits but had reached a point where tracking was not offering new insights. This participant struggled to identify, based on his tracking, what were habits worth maintaining and what aspects of his diet or exercise needed to change and how to change them.

Novice and experienced trackers struggling to use these applications means that these tools do not address the learning curve around tracking. For novices, learning how and what to track is as important as tracking itself. Seasoned trackers, on the other hand, are seeking to get insights from the tracked data. The current design model of these mobile technologies, however, is rigid. These tools are not equipped to address the different needs our participants had around tracking.

Another example of the rigidity of the current design is the assumption that users will always track. Our longitudinal study sheds light to how participants struggle to balance tracking and other life priorities. Despite the motivation to lose weight, tracking becomes a low priority in several occasions. For example, T6 is an undergraduate senior struggling to balance classes, exams, and taking the necessary steps for life after college. Balancing all these responsibilities and the stress that comes with it, like participants like her to put her health on hold.

> And then finals week, and then you would be studying late. My eating habits were really bad. I was just looking for something that would change my lifestyle of what I ate, maybe finding time, even if it's just 20 minutes, to workout. Picking up little good habits. Maybe I had a little bit, but I would contradict all of that by doing something really bad. I work out, but then I'm pigging out and eating chips and ice cream.
>
> <T6 >

Clearly, there are times when people will fall of the wagon. Yet, the model expects constant tracking and when people are ready to reprioritize tracking, these tools are indifferent to users' state. The interactions and tracking options are the same as when the user ceased tracking. These tools are not aware of this context or equipped to adjust to users' lack of motivation to track or their confidence in their ability to resume tracking. These tensions highlight how the current state of user-driven tracking technologies is one-size-fits all. These tools are not able to identify differences in tracking needs, such as, tracking experience or how to adjust to the ups and downs of life that affect tracking.

2.5.4 Health coach can facilitate and maintain tracking

As mentioned previously, since the focus was evaluating user-driven tracking technologies for weight-loss, the intervention did not include meeting with a health coach regularly.

> I just felt like I was really overweight and I needed help. I realize since the study though that I need someone helping me, not just all by myself.

<T7 >

Even though no regular meetings took place, treatment participants met with the health coach behind the SMART Facebook page if they were struggling with their weight. Five of the nineteen treatment participants we interviewed interacted with the health coach in person and others interacted with her through the Facebook page. They all found these interactions worthwhile and insightful.

> It was nice because I could ask a question if I needed to you could email and say ”I'm not losing weight anymore,” which I did a couple of months ago and got feedback from that. The good things is that I could ask the question and ask it easily without having to make an appointment with the health center or a nutritionist on campus or something and wait several weeks for that. I could just send a quick email and I would get one back within a day.

<T2 >

In our study, the only information the health coach had access to was the weight and general habits based on surveys completed. The participants using mobile tracking applications with a database with a wide variety of richer foods and exercises to choose from wished the health coach had access to this information.

> It would be cool if the health coach could monitor that and see and then give you suggestions about your eating habits and what you can improve on

<T7 >

These participants wanted help from an expert to make sense of the data they were tracking. In other words, fine grain tracking for these participants ceases to offer benefits if they cannot gain new insights from the behaviors they are tracking. Although this is a small sample size, the positive experiences that came from presenting the information being tracked to the health coach highlights the potential of improving user-driven tracking technologies through interactions with a health coach.

As presented here and in the previous section, participants struggled to track alone, and needed help making sense of their data. While there is a potential to detect patterns in the data to offer improvement suggestions, health coaches posses the knowledge to address data interpretation hurdles. The combination of user-driven tracking and a health coach would maintain the strength of user-driven tracking technologies, that is, self-awareness and ease of tracking, and leverage the health coach to identify areas of improvement and habits to maintain. Future work should evaluate if user-driven technologies mediated by a health coach leads to better outcomes compared to an intervention focused solely on participants tracking through user-driven technologies.

2.5.5 Psychological deterrents of tracking weight

On average, participants tracked weight the most. That said by the one-year mark, participants were tracking their weight, on average, twice a month and this is the same time point when treatment participants' weight started to stagger. From this point on, weight tracking continued to decrease and participants slowly regained the weight they had lost during the first six months of the study. From the participants we interviewed, we learned that the lack of weight-loss led them to evaluate their overall efforts as failures. Thus, they were discouraged from tracking their weight.

> Weight only gets you so far. Sometimes you're losing inches and not weight. I would try to weigh myself once a week, but then I would also try to get away from the weight scale. Sometimes when you don't see results on the scale you get discouraged. So I was trying to get away from that.

<T6 >

> I dont like the weekly weigh-ins. I can see how it helps, but it only helps if youre doing better. If youre sliding back, yeah, its good. Oh, I got to get back into it. If youre really sliding back then it just further reminds you how much you suck.

<T8 >

> Just because the scale kind of... I don't know. I don't like the scale.

<T9 >

For many, tracking their weight was discouraging. As the study progressed, they were looking for other ways to evaluate their effort and successes rather than making weight-loss the only significant outcome. One of our participants began to rock climb. She noticed a change in her body composition but preferred not to weigh herself. She preferred to focus on her exercise and overall sense of well-being.

> I feel I'd rather judge my health by my feeling and if I'm, in terms of weight loss, how my clothes are fitting or am I able to perform my activities better or that kind of stuff. Which is maybe more qualitative, but I don't know. Some people get in touch with the number. I don't want to put myself in a situation like that.

<C3 >

Except for one of the control participants we interviewed that lost 25 lbs. during the study, the rest of the participants we interviewed expressed their dislike for tracking their weight. Furthermore, participants understood that there are many contributions that lead to weight fluctuati [21], [56]. Second, they also understand that weight was not the only representation of physical wellbeing. Given participants' hesitation to track weight, future research should explore what are other outcomes that can be tracked that correlate with the benefits of weight-loss. Having other outcomes to track aside from weight would give trackers the flexibility to chose which outcome they feel comfortable tracking.

2.5.6 Tracking reminders are useful, sometimes

In our related work, Cordeiro et al. discusses how people forget to track, and that consequently, tracking not only decreases but also becomes inaccurate [47]. Furthermore, the work done by Patrick et al. demonstrated how participants receiving tracking reminders lost more weight than the ones that did not receive reminders [165].

Our study confirms that reminders are crucial. As discussed in Section 2.4, TrendSetter was the only application sending reminders to track and had the highest usage. Furthermore, our qualitative findings confirm that reminders help participants be consistent with tracking.

> I think it's helped me a lot more with keeping up logging things in because when they send me that [reminder], I'm like, "Oh yeah, I have to log all this other stuff in too because I forget. So it's been really helpful.
>
> <T7 >

> I really like the text messages [reminders]. Those really keep you on track. They remind you to record your weight and how many steps you take with the pedometer.
>
> <T10 >

The reminders offloads the cognitive load of remembering to track to the technology. Reminders assist users with tracking, and therefore, help users to focus on the strength of user-driven tracking, self-awareness. We also learned that the time of the reminders also matters when it comes to helping users fit tracking into their lives. For example, for pedometers, participants wanted a reminder at the beginning of the day to remind them to wear the pedometer.

On the other hand, for tracking calories consumed, participants needed more frequent reminders. As we saw in Section 2.4, calories was the least tracked trend. One of the reasons, already discussed was how tracking calories is vastly more difficult than tracking steps or weightthere are devices that estimate these two outcomes. The second reason is that because we consume calories multiple times in the day, more than one reminder is needed. As participants discovered this weakness in our own tools they found other tools with the capability to send more than one reminder per day. Three of the participants we interviewed, found commercially available applications that were starting to support timely reminders.

> It's usually either right before or right after I've eaten. It's helped me keep track on my calories and then allowed me to understand, "Okay, this really is a lot of calories and this isn't," or how many calories am I taking in per day and understanding that. Because one thing that I've learned in the whole process too is that it's more about your diet.

<T11 >

Careful attention though, must be paid to the timing and the amount of reminders.

> Oh, for things like tracker step, unless I actually wore it. Well usually I will get the text in the middle of the day and then I will already forget to wear my pedometer so it wouldn't make sense for me to wear it at that moment and track the rest of the day.

<T1 >

As mentioned in the previous section when participants were struggling with weight-loss, reminders to track and tracking was discouraging. This tension not only happened with tracking weight but also came to the surface when receiving reminders to track steps or calories when participants were struggling to track.

> Yeah. It just made me feel bad and they text you [reminder to track]. They text you and they're like, "How much have you walked this week or how

> many minutes of exercise?" It's like I haven't been working out, so I just do not respond because it's nothing. They're like, "Your total this week was zero." Thank you.

<T8 >

Sending reminders when participants were struggling to track or other life priorities were causing stress created a negative reaction. In our replies to the reminders we even received replies that expressed frustration about the reminders. Participants we interviewed expressed that these reminders heighten their sense of frustration and failure when they were struggling to track or their habits were unhealthy as cause of balancing personal and academic responsibilities.

Furthermore, flooding participants with reminders desensitized them to the reminders. When participants received reminders out of context, reminders turned into a nuisance. One approach to address this tension is to view reminders as means to habituate participants to track. Therefore, once users are tracking regularly the reminders could decrease, and they could return when users' rate of tracking has decreased below a desired threshold.

2.5.7 Tracking food is antisocial

As mentioned before, there are benefits of tracking homemade meals and eating at restaurants is highly recommended to avoid. For our participants this translated into being strict about where to consume foods. The participants we interviewed following a strict plan, made them feel restricted.

> C1. There was a period of time I really did keep track of my weight and then tried to lose weight, and I think, right now I'm 186, I got down to 173, which was exciting. Then I realized that quality of life was really low because I was restricting myself a lot.

<C1 >

Participants like C1, felt they were restricting themselves because she was trying to only eat foods with low caloric value. They considered their quality of life low because their diet restricted them from enjoying foods in social gatherings, such as, eating out with friends. Other participants, like B4, struggled to track in social settings because he considered tracking in the middle of a social interaction to be against social etiquette.

> The idea of I'm sitting at dinner and I'm having a conversation and I have to interrupt a conversation because I remember crap, I forgot to scan that can and you tossed it into the trash. Let's dig it out before I forget. It's a nuisance and I realize that these are some of the issues that came up the first time I used it.

<C4 >

Many of the participants we interviewed felt uncomfortable tracking in public. The ones that noted they were struggling with their weight felt uncomfortable tracking publicly.

2.6 Discussion

Our qualitative results shed light to the reasons behind the lack of consistent tracking by our study participants. Our result bring to light issues to tackle now that tracking is ubiquitous, wearable, and mobile. The pervasiveness of tracking technology means that tracking is not an activity done in isolation, but rather, it intersects, affects, and depends on other aspects of life. Thus, the design considerations become twofold. First, we must continue to design tracking to simplify tracking process as much as possible and second, we must also design tracking technologies considering the larger ecology they are becoming part of. In this section we discuss the second type of design consideration.

Trackers need help integrating tracking into daily life. Tracking adds another task to attend to in addition to all the other daily responsibilities that people juggle. Thus, the struggle to remember to track clearly fits into the pattern of struggling to multitask and how we cannot rely on our memory to help us attend to a task at the right time and place [152]. Furthermore, tracking is especially difficult to integrate into daily life as it requires remembering to track multiple times during the day, not just once. Therefore, it makes sense that offloading the task of remembering to track increases tracking. Offloading the reminder aspect of tracking leverages the strength of these technologies, the ability to process information, while retaining the strength of user-driven tracking—users' ability to reflect, be self-aware, and make decisions.

That said careful attention must be paid to the timing of the reminders, and the frequency of reminders. Looking deeper into how reminders helped, we saw how even though participants received reminders to track their calories, tracking calories was close to nonexistent. As discussed, tracking calories is much more complicated than tracking steps or weight. Thus, if the subject of tracking is difficult to estimate and the interface requires precise tracking, then reminders do not help users sustain tracking. Furthermore, our results indicate that the timing and the quantity of reminders also matter. The timing of the reminders must be close and related to an event that requires tracking, otherwise they are out of context and irrelevant. With respect to the quantity of the reminders, the amount must be carefully chosen to avoid desensitizing users to reminders.

Trackers need help developing healthy habits. Despite the growing capabilities of mobile-tracking technology, tracking mastery is not easily attainable. The strength of these technologies comes in their capability to send reminders, have a growing set of nutritional and exercise options to chose from to track, and store data. However, these tools fall short in their ability to guide and help users learn how to track, but more importantly, how to create sustainable healthy habits.

The current model that drives tracking technologies focuses on pure caloric counting. In simple terms, it focuses on tracking calories consumed and calories expended.

However, this approach falls short of considering broader healthy living behaviors, such as, learning about portion-size control and the benefits of consuming 5 to 6 small portion meals compared to three large meals and then snacking along the way [126]. Similarly, for physical activity, while intense, focused exercise that includes cardiovascular and weight training is important, the increasing sedentary lifestyle the modern workplace has created has its own consequences [130]. Thus, in addition to emphasizing caloric expenditure from focused exercise these tools should help users incorporate short, low-effort physical activity such as, walks. This way, trackers can decreased prolonged sedentary bouts, increase movement but do not disrupt the workday. These changes, might not translate immediately to weight-loss but it could mediate the stresses and anxieties of having novice trackers jump immediately on the calorie counting wagon.

Furthermore, in the current model all calories are equal, but research is showing that protein, fiber, and healthy fats are good sources of calories compared to others [58], [174]. Rather than focusing on pure caloric counting, the strength of these digital tracking tools should be leveraged to create suggestions on types of foods and activities to incorporate that lean towards the above types of nutrients based on current habits being tracked. Being able to identify these caloric sources is where the strength of these tools can be leveraged. The affordances of these tools, compared to paper-form tracking, is that they can be design to provide immediate feedback and provide suggestions on what types of foods users can explore based on their current patterns. Again, one could argue that these approaches do not lead to immediate weight-loss. They could at least be a starting point towards making healthier choices and a healthier sustainable lifestyle.

A health coach can mediate user-driven tracking. In addition to the struggle novices experienced, the proficient trackers encountered another barrier. In their case, these trackers reached a point where they were not gaining new insights from reflecting on their tracked habits. The current state of the art of tracking technologies creates summarizing charts that give an overview of current behaviors. However, currently, these tools lack of the capability to interpret the data to offer suggestions and identify next steps to take.

In the meantime, if automatically detecting patterns and areas of improvements is difficult, our result suggests a health coach could perform this function. A health coach can mediate user-driven tracking by addressing the particular needs users have, especially when there is a variety of tracking expertise. So far, we have explored tracking through mobile and wearable technology as an individualistic and isolated endeavor. Now that tracking and the data tracked are ubiquitously available, the barriers for a health coach to view data tracked comes at much lower cost than previously possible. Until recently, health coaches relied on paper diaries and surveys from their patients to assess habits, tracking, and next steps to take. We posit it is worth exploring the role a health coach can play to mediate personal tracking. Taking this perspective, trackers leverage the affordances of using user-driven technologies to maintain health consistency and be self-aware and a health coach can help trackers make sense of the rich data being tracked and identify the habits that need to be modified.

Tracking technology must consider everyday constraints. Tracking technology's ability to ubiquitously allow tracking throughout the day motivated our study. This ability though, brings to light everyday tracking constraints. We learned that if there is lack of improvement tracking brings negative feelings that dissuade from tracking. In particular, we saw how participants disliked tracking their weight as the numeric value of weight could fall short of reflecting efforts made. With respect to calories, some participants shied away from tracking because tracking calories made them feel they were creating an unhealthy relationship to food. The hesitation to track indicators such as weight and calories, leads to thinking about how to handle failure track and how can we design tracking technologies around failure rather than the assuming successful, constant tracking.

Similarly, we learned how tracking infringes on socializing, as many social events involve food. Many participants decreased tracking or ceased tracking altogether because, for them, tracking affected their ability to socialize and therefore, their sense of overall wellbeing. User-driven tracking tools focus on facilitating the mechanics of tracking, however, we still need to explore how these technologies integrate themselves to a greater sense of wellbeing. Furthermore, it also suggests letting users change which indicators they choose to focus on and track. Identifying other indicators, metaphors, or models, such as, the ones we have discussed in this section, might give the opportunity to those uncomfortable with tracking aspects of weight-loss to continue working on creating healthier habits.

Furthermore, the lack of weight-loss or weight maintenance after the first six months of the study in conjunction with the decline of tracking through the applications also leaves us to ponder if there should be two types of design guidelines of tracking technologies: one to support weight-loss and another to support weight maintenance.

Creating tracking tools that allow making tracking part of daily life means tracking becomes another task to juggle and attend to throughout the day. The implication of tracking becoming a regular, daily task means that it will have phases where tracking will: fall to the background, become low priority, or lead to tracking fatigue. While it is difficult to tackle these issues, future work will need to address these issues.

2.7 Limitations

Further studies using applications leveraging the potential of the current state of the art is needed. Our applications were built before Android and iPhones could handle rich tracking. The fact that the treatment and the control behaved similarly calls for future attention not only how to design the studies but also explore how to create different design that avoid the weakness that this study experienced, where the control was using mobile tracking applications.

2.8 Acknowledgments

We would like to thank all the participants that met with us. Second, we would like to thank all the staff and personnel behind the longitudinal study.

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Chapter 3

Unbound

3.1 Introduction

Those living in developed countries in part as a result of the modernization of the workplace spend up to 15 hours a day taking part in some form of sedentary behavior without counting sleep time [78]. Although regular physical activity reduces health risks, sedentary behavior is a distinct and independent predictor of health [158]. It is associated with increasing risks of type II diabetes, cardiovascular disease, weight gain and cancer [167]. Fortunately, decreasing sedentary bouts by increasing the frequency of short breaks improves metabolic markers and cardiovascular health [83].

Sensing technologies enable tracking and monitoring of health behaviors (e.g., [118]) as well as reflecting on and changing of behavior (e.g., [1]). However, these devices are often used within the workplace, a context that is not deeply considered in their design and implementation.

In this work, we were focused on the design and use of personal health technologies within collaborative settings, in this case the workplace. Because of the high rate of sedentary work in modern offices, we chose reduction of sedentary behavior as the motivating case for this exploration. Office workers may have particular difficulty in taking breaks [84, 142, 182]. In part, concerns about interruptions [6, 49, 128] or lack of productivity may prohibit workers from feeling comfortable taking breaks. Switching between mental tasks-regardless of their length or cognitive load are costly and cause stress and frustration [128]. On the other hand, inserting breakswhich involve switching from mental to physical tasks rather than between mental tasksthroughout the workday improves productivity and creativity and reduces error rate, and skipping breaks can lead to stress and exhaustion [10, 167, 202].

To explore how to address these challenges, we first conducted focus groups and interviews to understand potential barriers to the use of technologies to reduce sedentary behavior in the workplace. The findings from this initial work informed the design of a technology probe [12], Unbound, an office-appropriate, context-aware tool to encourage breaks, which we then deployed for a month with five users.

The results of this work indicate that personal health tools in the office can enable workers to turn a general awareness of health concerns into actionable behavior change, support overcoming social stigma, balance short and long-term goals, and provide appropriate quantity and quality of information. However, the unique constraints of the collaborative office setting mean that particular care must be taken in the design and use of these technologies within the organizational context.

3.2 Related Work

Successful pilot interventions to reduce sedentary behavior in the office have often focused on modifying the physical layout of the office space. These strategies include introducing personal cycling ergometers [26] and standing workstations [73]. However, the acceptability of these interventions remains unknown [32, 159]. They require retrofitting the office with expensive equipment, which may be cost prohibitive. These changes also represent a stark departure from the traditional workplace look and feel, leaving open research questions for accomplishing similar success with minimalist adaptations to the built environment.

Related research in persuasive computing [65] and behavior change [44, 140] lay the groundwork for an approach that does not require medication to the built environment. Our work builds on this research by seeking to understand personal behavior change within a collaborative work context. For example, we use strategies suggested in the literature on behavior change, including facilitation of social change, reminders of specific behaviors to be performed, and building on small successes towards a larger goal [140]. Many of these same strategies have been deployed by other technological approaches. However, their number is too large to detail here. Rather, in this section, we describe some of the most related projects within the overall space of technology for behavior change.

Interventions using pedometers to increase activity are well documented and indicate that use of this simple tool statistically increases step count [26, 32, 77, 83, 199]. However, increasing active behavior is not necessarily the same thing as reducing sedentary behavior, the issue at hand in this work.

Additionally, users may begin to ignore advice from these systems once they recognize the advice does not always apply to their current situation [57, 142]. Context-aware technologies can support this kind of proactive engagement by taking into account the events, places, and people that affect behavior change [121].

One context-sensitive tool that holds promise for workplace use is the concept of glanceable displays [1, 44]. Because these displays can be made to visualize information in a way only understandable to the owner and can be used on personal devices, like mobile phones, they can be quite private. At the same time, shared glanceable displays that encourage workplace appropriate behavior change [123, 124] can render the need for activity legible to the entire office, thereby supporting efforts to facilitate social change within a collaborative space [143]. However, this social sharing must be done carefully to avoid concerns about professionalism within the office environment [123]. While these visualizations can improve awareness and reflection, which are key components to behavior change [38], they run the risk of their signals being lost by their passive nature. Thus, in this work, we were interested in understanding how the elements of glanceable displays that are salient and useful for workplace behavior change might be adapted to support a more proactive approach from the technology.

Other researchers have examined platforms for awareness that are subtler [97, 143]. For example, in Breakaway, prolonged sitting is indicated by a slouching sculpture whereas an erect structure indicates recent activity [97]. SuperBreak, took a more active but less visible approach, by inserting 20-second micro-breaks of hands-free interaction if the user was typing or using the mouse for more than 5 minutes to prevent repetitive stress injury [143].

These projects had limited user studiesBreakaway deployed with only one userand do not fully address the concerns of both prolonged sitting and the need for relatively invisible reminders. Two projects that did focus on these issues, SitCoach [50] and WalkMinder [89], both used mobile phones to provide reminders. However, their results show that users still had trouble increasing physical activity during the workday and that the phones was not the appropriate communication modality for the workplace the goals did not align with constraints in the workplace.

In this work, we seek to fill in these gaps, using what is known about behavior change and about workplace interventions to support a relatively invisible, workplace appropriate technology. We chose taking breaks as a study case to identify the underpinnings of creating personal health tools capable of melding personal health habits into social environments, such as the workplace.

3.3 Methods

We took a multi-method approach to understand the needs of the various stakeholders, the context in which they work, and the design opportunities and challenges. We first conducted focus group and individual interviews with 12 people over a period of 3 weeks. We then developed Unbound, a technology probe [94] that enabled us to further explore the potential designs for a personal health technology for use in the office. Finally, we deployed Unbound with 5 participants for 4 weeks to further unpack the issues at play when creating and using a personal health technology in a collaborative environment. In this section, we outline each of these methods.

3.3.1 Interviews

We interviewed 12 full-time office workers (10 female), between the ages of 20 and 40, holding administrative, clerical, or managerial positions. These interviews focused on how people go about their day at work, the cultural and social norms in the office space, and their perceptions about taking breaks during the workday. Interviews were semi-structured, allowing participants to lead the discussion to those issues most salient to their own experiences.

Interviews lasted approximately 60 minutes. They were conducted individually (n=6) or as part of two separate groups (n=6, 3 in each). At the close of each interview, we shared a variety of design concepts to seed discussion on how personal health tools could be used in the workplace to increase breaks. All interviews were audio-recorded with note taking tagged to the audio for analysis. Interview data was analyzed systematically using open exploratory thematic analysis [3]. In the findings section we refer to participants of the interview session as I1-I6 and focus group members as FG1 and FG2.

3.3.2 Iterative Design, Development, and Deployment

Following the initial interviews and focus groups, we conducted a series of cooperative design activities with potential users to build the Unbound prototype, described in the next section. We then deployed Unbound with 5 Fitbit [1] users (1 female) for 4 weeks, during which time we continued to iterate on the design based usage and discussions with participants. All participants worked full-time in an office environment. The mean self-reported time spent sitting at work was 7 hours per day (sd = 1hr). Of all work-related activities, all participants reported 'sitting at work doing computer work' as the most time consuming. In the findings section we refer to theses user as P1-P5.

We recruited Fitbit users for three reasons. First, it allows to infer prolonged sitting by translating physical activity data in real-time. Second, it eliminates the novelty effect of using a physical activity-tracking device and allows participants to focus on their reactions to receiving in situ cues in the workplace. Third, we wanted to learn how people that are interested in being healthy use these systems in their work routines, which is a basic step in the process of changing behavior [175].

During the first visit of the pilot study, we installed Unbound on each participants' work laptop (n=3) or desktop (n=2) computer. We also conducted the first of 4 weekly semi-structured interviews. This interview focused on current work routines and breaks, use of similar software or programs, perceptions of sedentary behavior, and understanding of the health consequences of prolonged sitting and demographics. At the end we offered training on what constitutes as a break as we learned from the first phase that participants confused short breaks, such as, talking in person to co-workers or taking the stairs instead of the elevator, with 30 minutes of low-intensity physical activity. Lastly, participants were given an overview of how Unbound functioned.

During the remaining three weekly interviews we discussed experiences and

[1] https://www.fitbit.com

reviewed charts of the logs collected by Unbound to dive into what were the inhibitors and what was supportive. The data discussed together was of their sitting bouts, times when they received a reminder, and times when our data shows they moved away based on the prompt or when they took breaks on their own.

Deploying a live prototype of Unbound allowed us to uncover additional tensions that did not come to surface during our interviews. Having participants use Unbound for 4 weeks gave them real experiences to reflect upon and discuss with us.

3.3.3 Analysis

The survey, interview, and log data were analyzed collectively to get a general sense of system use. We then iteratively analyzed the data deductively by comparing them with themes uncovered in Phase I. Specifically, we conducted close readings of the interview transcripts, and developing theme labels to describe the phenomena we saw in the data. We iteratively clustered related codes from across all of the phases of research into higher-level thematic groupings. New design considerations emerged from these higher-level themes.

By collecting data both formatively and through the deployment of a prototype system, we were able to get at issues that neither approach alone would enable. In what follows, we describe the resultant design for Unbound as well as our findings from discussions with participants around both current practices and those that emerged through the use of Unbound as a technology probe. Our discussion serves as a starting point for design implications for personal health tools situated in the workplace.

3.4 Conceptualizing Unbound

The feedback on the prototype in Phase I led us to provide the nudge on the computer's screen (see Figure 3.1). Our goal was to leverage where the focus of the user is at work looking at their computer to create the awareness of sitting only during detected prolonged continuous sitting. We wanted the nudge to fit into their work routine, not create an additional barrier to working. Additionally, we kept the reminders personal and subtle to avoid making users feel overwhelmed or judged by coworkers from obvious cues.

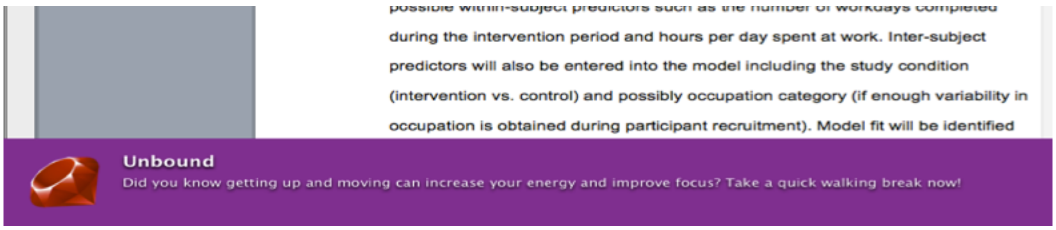


Figure 3.1. Text-based version of Unbound. Appears at the bottom of the user's monitor

Because there lacks consensus on the threshold of continuous sitting before it becomes detrimental [83], the time for when to present reminders was informed by Phase I interviews. Participants needed these reminders to work in tandem with their schedules and routines, which evolve around an hourly cycle. The first reminder was sent at 45 minutes of detected continuous sitting. A second reminder would be sent at 60 minutes only if we not detect movement within 15 minutes of the first reminder. The purpose of the second nudge at 60 minutes interval of uninterrupted sitting came from the discussion of a snooze metaphor in Phase I interviews.

As with the debate over how long is too long to sit, there is no strong definition in the literature as to what constitutes a break [83]. Thus, Unbound considers anything that involves a transition from sitting to standing and/or moving to be a break.

No other messages trigger regardless if the user moves after the second nudge. We hypothesized, that if users did not respond to the second nudge they were too busy to move away from their desk. A new message only appeared after another 45 minutes of continuous sitting.

Unbound's server queries Fitbit's server to retrieve physical activity data on behalf of the user every 15 minutes. This allows us to run calculations after every query to determine the interval of continuous sitting and detects the need for a new prompt based on calculated sitting time.

The client side of Unbound triggers on the first Fitbit sync of the day in the office, and from there on receives updates from Unbound's server every 15 minutes until the user logs off for the day. Based on sitting data aggregated by Unbound's server, the client sides triggers a in a form as a vertical bar at the bottom of the user's screen when its time to reminder the user about a break. We chose a bar to appear at the bottom of their screens based on the prototype discussion in Phase I. Participants did not want the reminder to appear in the middle of the screen. They wanted the reminder to appear on the bottom and not stay permanently we chose 30 seconds for the duration of the display. Based on the feedback during the deployment we made the bar more opaque, which allows users to view icons at the bottom of their screen and manipulate them through the display.

Based on related work and insights from Phase I, Unbound's cues were made of encouraging messages or concrete break suggestions appropriate for the workplace. Iteratively designing based on user feedback we deployed a second version of Unbound in the second half of the study. This version used color-coded messages in the place of text. It included three types of color-coded messages: orange for the 45-minute mark, red for the 60-minute mark, and green to acknowledge healthy behavior of sitting less (see Figure 3.2).

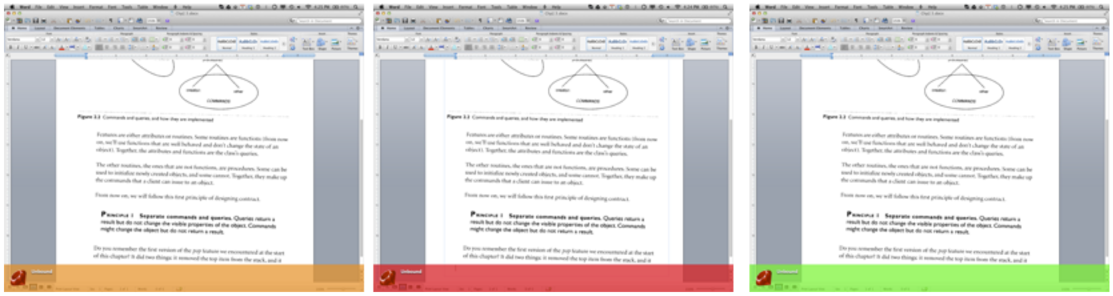


Figure 3.2. Text-based version of Unbound. Appears at the bottom of the user's monitor

In the next section, we explain the motivation for the color-based version. We piloted this version with the same participants.

3.5 Results

Despite a growing emphasis on health at the workplace-in part as a means for controlling healthcare costs-changing sedentary work practices in the US is still a struggle, particularly in collaborative office settings. When analyzed together, the results of our interviews, collaborative design activities, and the deployment study indicate four key issues surrounding the use of personal health tools in collaborative office environments.

3.5.1 Turning Awareness Into Action

All participants were aware of the health benefits of taking regular breaks and how menacing prolonged sitting is to their health, however, this does not translate into taking action. Except for one participant, all had tried taking breaks on their own and failed. Additionally, passive reminders may not make people mindful enough for behavior change. As one interviewee explained, paper-based tools posted in the workplace cease to encourage behavior change fairly quickly and are not in the place of workers attentionnamely, the computer screen.

> I have this little sheet on my wall with desk stretches because I know sitting is bad for you, but I don't ever look at it anymore because I'm

staring at the screen or stuff.

<-I5, an administrator in her 20s >

Turning awareness into action may require something more than a passive pamphlet. Interview and deployment participants alike described wanting relevant and encouraging information at the point of decision. To influence the decisions, these messages must provide actionable knowledge, such as encouraging text that provide details about why breaks are important and suggestions for breaks appropriate for the workplace. Text can be used as a persuasive tool to improve health behaviors right at the moment of need [64]. These contextual messages can add salience compared to general recommendations.

> I agree that making sure that people understand why it's important because a lot of us tune it out or don't realize it. [...] just having like facts of something that explains to you how it would affect your life.

<FG1, librarian in her 20s >

These strategies, however, are still very much grounded in a model of behavior change that focuses on the individual. To move awareness of healthy behaviors into action with an organizational setting, such tools must be considered at an organizational level. This reimagining could include a variety of approaches, such as gamification and social media style encouragement of shared effort, strict behaviorism models of rewards for performance, or implementation as part of an authoritarian mandate. Exactly how they happen is not the point so much as the need to match the strategies used to the organizational and leadership structure in place in the workplace. Just as other kinds of organizational changes require careful adaptation given the personnel, positions, and situations at hand, so do health related behavior changes and their associated technologies, have to match these workplace contexts.

3.5.2 Overcoming Social Stigma

Time is an incredibly scarce resource in the office workday. Office workers juggle a wide variety of work-related tasks, and the addition of health tasks that are typically thought of as the domain of leisure time only increases feelings of over-commitment with limited resources. Additionally, people can be afraid to take breaks that are not appreciated, supported, and understood by their co-workers and managers.

Interview participants were concerned that co-workers would think they were not productive if they stepped away from their desk regularly even for five minutes. For example, a female editor described admiring her supervisor for working at her desk continuously:

> You know what's so hard? Some of the women who are at a higher managerial level than I am, they work so much and they sit for so long and I really admire them.
>
> <I3, a grant editor in her 40s >

Despite the continual refrain in our initial interviews that being away from one's desk would be perceived as avoiding work and unproductive, during the deployment, users never described any social judgment from co-workers. The unstructured nature of Unbound's break suggestions enabled participants to fit breaks seamlessly into their work routines, such as by using the restroom, picking up items off a distant printer, or other errands around the office. Additionally, because we had access to movement data if a user had walked to and from a meeting no messages would be sent until a 45-minute of sitting bout was detected.

In medium or large offices, people can actually leverage the work environment to take breaks. Participants in both the interview and deployment studies described taking the stairs to chat with a coworker face-to-face, making sure to refill water bottles frequently, and other strategies that turned office appropriate tasks into healthy physical breaks. In some cases they even made changes in the environment to benefit not only themselves but the work group, such as, placing the printer in another room. These actions make break a legible component of work routines.

> I'm the one that's kind of forced people into the workgroup printer, because that makes people have to get up and go get their printouts, and they're resistant like you wouldn't believe. So that's the one thing that I have that I've tried to build into my workday just so I have to get up from my [work] desk every so often, but it's not very far away.

<I1, a female staff at a university in her 50s >

A particularly challenging area for social stigma in the office is around meeting times. These face-to-face engagements are some of the most collaborative work that happens all day in the modern office, and so workers very much depend on each other and a rhythm of work during these events. Unfortunately, meetings also tend to be seated affairs at which either the convener of the meeting or the highest-ranking person in the room dominates the timing of the event. This situation inherently makes taking physical breaks on ones own schedule challenging for the average worker. As such, participants described meetings as dead time for both productivity and for their health and noted during the deployment that the messages from Unbound could not be addressed. It was simply inappropriate to stand up in meetings, limiting the potential for a personal health technology to enact any kind of change.

> [..] when I'm in meetings it's a bit annoying, because I can't get up, and I wish I could get up and walk around a little bit. It would just look weird if I was sitting in a group and I stand up. Especially meetings here, normal meetings are an hour, and your threshold is an hour, some of them are two hours.

<P5, a 48 year-old program manager >

These findings indicate that when possible, personal health technologies in collaborative spaces should make suggestions that are appropriate for the current context. For example, if the user is detected to be seated at a desk with no appointments upcoming on the calendar, getting a drink of water or using a far away printer might be the best suggestion. If, on the other hand, the system recognizes the user to be in a meeting that has been going on for an extended period of time, a suggestion to drop a pen that needs to be picked up might be a subtle way to make a movement without interrupting the meeting unduly.

Offices are inherently social spaces. Despite concerns about sharing health related information in the workplace [123, 124], social support has been shown in other work to encourage behavior change [106]. In the office, purposeful social breaks already support organizational goals by strengthening social ties and improving collaboration [207].

> I have a friend who will drag me out in the afternoon and we'll run out and get a soda or take a walk. It's about, the Peet's is really close so it doesn't seem like it's intrusive on the workday to run over there and get something.
>
> <I2, a female staff at a university in her 40s >

As noted by this participant's remark, the combination of being friendly with a co-worker and having nearby options for a quick break can turn these into socially appropriate options for taking breaks. This finding indicates that personal health tools can be configured according to the social norms in an office.

3.5.3 Balancing Short and Long Term Benefits

Although maintaining a healthy lifestyle benefits productivity over the long-term, the daily demands at work often take precedent. Despite knowing this information, participants still equated breaks with lost productivity, because for many, sitting was equivalent to working.

> I have allowed my office system to take control of me so I don't go out at lunch I have breakfast at work as soon as I get to work, 99% of the time I have lunch at my desk and I leave at 4:30 pm.
>
> <FG1, female secretary in her 40s >

Neither innate awareness nor a tool like Unbound confirming how long a person sits can overcome the feeling of needing to work constantly. For example, participants in the deployment commented on the struggles of balancing accomplishing their work tasks and maintaining their wellbeing in the moment they received a cue.

> Generally, it's 'ok, I feel like I understand the principle' but I also understand all the tradeoffs and so forth I'm making in whatever, so it's just not that simple just to right now get up and take a break.
>
> <P2 a 66 year-old male administrator >

The choice to take a break-or not-can depend on the priority of the work task at the time a break is needed. For example, in our deployment, when participants engaged in low priority work tasks, they tended to take breaks in response to Unbound's prompts. On the other hand, during high priority work tasks, particularly those with close deadlines; they reported needing at least two reminders to take a break - more times than not determining that now is not an appropriate time to break.

> [...] our database server isn't running and our customers can't reach it and place order and it's affecting our business and we're working hard to resolve that. And yeah, it would be nice to get away or do something else for a little bit but this is a serious issue and we need to address this.
>
> <P1, a 39 year old data security engineer >

During these times of high stress, people may need breaks even more than during times of low stress, an issue that participants in our studies recognized. However, our pilot study confirmed that participant ignore their health needs in these stressful situations. Ignoring Unbound in these situations fitted in with their high stress behaviors.

> ... in the intense situations I ignore a lot of things that I should do to keep myself better for my health, it goes well beyond getting up and walking around. It's what I'm eating, how I sleep, everything is off.
>
> $<$P2 a 66 year-old male administrator $>$

Likewise, when being sedentary is actually an indicator of work productivity, Unbound's information had no effect in decreasing sitting time.

> In my work-life when I can actually get on my butt in front of that screen and stay there, its important to get into flow and stay there. Usually, everyone's interrupting me. So, if I can get to a quiet spot, it's important to stay still.
>
> $<$P5, 48 a year-old program manager $>$

The goals of proactive personal health tools can be in conflict with work goals, or at least the perceived implementation of working towards each of these goals. People may simply be unable to recognize and change their behavior, in the moment, due to their focus on work and not health. Likewise, the economic model that emphasizes short-term gains, so dominant in the US, filters down into the everyday experience of workers [38], making it impossible for them to emphasize long-term goals, such as increases in productivity from improved health and wellbeing. Thus, companies hoping to make health-related behavior change at the enterprise level must work to ensure that support is in place to encourage long-term thinking about health. Likewise, management incentives must be tied to not only the traditional work goals of their teams but also other goals [155], such as healthier behavior. On the other hand, personal health tools to be used in the workplace without enterprise support must be customizable to enable workers to balance these short and long-term expectations themselves.

Unexpectedly, participants appropriated Unbound to evaluate their workday automatically. The multiple reminder nature of Unbound had the surprising benefit of helping users time and structure their work tasks. For example, P1 always struggled at the end of the day deciding between completing a task and creating a break-point so that he could go home.

> It was nice I did like the idea of being able to see and towards the end of the evening that a project that I had thought would take a certain amount of time was taking me longer. At the end of the day here in this office when there's no windows. And a fake door, you don't have the time, there's not external time for what time a day it is.

<P1, a 39 year old data security engineer >

Additionally, participants leveraged the in situ cue in a small meeting setting. This allowed participants to keep meetings on schedule, enabling them to balance work and their health.

> [...] it's not so imposing that when I show someone how to do something that it takes over the entire scree, 'oh whats that red? It means I've been talking to you for too long.'

<P1, a 39 year old data security engineer >

Changing the culture of the office to support health habits, such as, taking breaks, and using visible in situ cues can enable breaks to be accessible to all workers viewing it, not just the individual using the personal health technology.

Users' prime concern was that the cue be subtle, private, and unobtrusive. Inline with this, we did not explore auditory prompts; participants were concerned this would be disruptive for themselves or for co-workers in shared offices. That being said, participants acknowledged that the computer screen was the appropriate communication modality for the workplace. Mobile phones are unsuitable for this setting given that participants place them in drawers or silent mode, and receive enormous amount of notifications with no time to read and sift through them.

> I get quite a bit of activity of my phone, and another one saying: 'hey it's time to move around,' it would just be a little bit extra noise I think.
>
> <P3, a 33-year old developer >

3.5.4 Ensuring Appropriate Quantity and Quality of Information

All participants in the deployment were aware of their sedentary practices and wanted to reduce it. However, when actually confronted with the Unbound system, participants struggled with their dual needs of persuasive and instructive information and the ability to interpret that information quickly and easily without a major cognitive task switch [128]. For example, based on our formative design work, we initially provided break suggestions. However, the lack of contextual understanding by the system coupled with its "orders" to act, frustrated many participants.

> I don't think it knows enough about my life yet in order to give me something that I would take, I don't take what it has to say too seriously.
>
> <P2, a 66 year-old male administrator >

Over time, the general visual cue became sufficient, rendering the text itself irrelevant. Participants recognized the need for simpler reminders that could be understood quickly, particularly when in the midst of another on-screen task.

> I'm totally not reading the text, the motion is the meaning. [...] noticing the motion that's kind of what's prompting me to move. [...] I'm not going to look at it closely. I'm not going to learn much from the text. Aside from, 'oh its time to get up.'
>
> <P5, a 48 year-old program manager >

The hectic onscreen environment of an office worker presents a variety of design challenges for persuasive interfaces. They must be minimal enough not to distract from the primary work tasks while being clearly understood. This understanding comes with the requirement for varying levels of information, such as the timespan of the messages:

> I'm totally not reading the text, the motion is the meaning. [...] noticing the motion that's kind of what's prompting me to move. [...] I'm not going to look at it closely. I'm not going to learn much from the text. Aside from, 'oh it's time to get up.'
>
> <P4, a 50-year old female publications coordinator >

Based on this concern, in the second half of the deployment, we replaced the text in Unbound with color-coded messages as a means of sharing time-based information. The colors used mapped to commonly understood levels of severity in the US, where this study was conducted (other colors might be more appropriate in other cultural settings). At 45 minutes of uninterrupted sitting users received an orange bar, a red at 60 minutes, and a green immediately after the user returned from a break to acknowledge the healthy behavior (see Figure 2).

Colors gave participants a sense of time progression and conveyed ramping urgency missing in the text version.

> I have felt a bit more of a ramping urgency in the ramping colors, the orange to red. Ive only seen red a few times. So that will get me up to go to the bathroom.
>
> <P5, a 48 year-old program manager >

In addition to color conveying escalation, participants preferred the ambiguous information provided by the colors. Text-based messages even though supportive, were perceived as judgmental.

> There's less judgment [with the color version]. This thing wasn't trying to get me do stuff. It was more like information. It's just colors. It's a status of my activity versus the text trying to be encouraging and for me, there [was] no mental processing. It was completely neutral, and that's nice.

<P3, a 33 year-old developer >

Even though Unbound had the ability to acknowledge positive behavior, users found it unnecessary.

> I don't think I need to know when I'm doing well. I just want to be corrected when I've forgotten, basically.

<P5, a 48 year-old program manager >

Because people may consider acknowledgement of activity immediately after taking action redundant, positive reinforcement could instead be integrated into reflective summaries of overall behavior [44], [140]. On the other hand, positive feedback served an important role in our deployment to ensure users that the system was functioning properly.

> I mean green messages is good in that it lets you know that it's working. Because, there was a day or two that I wasn't getting many messages. I thought: 'huh that's interesting' and then the green came, I knew it was listening.

<P3, a 33 year-old developer >

Positive and negative reinforcement each have their roles to serve in behavior change. In our work, participants viewed these elements in ways that are somewhat predictable of personal health technologies. However, the collaborative office environment also plays a key role here in that on-screen color indicators can be viewed by others in the office, as described in the previous section. Thus, subtle information that can be interpreted by those “in the know” provides users with a mutually intelligible excuse to end a long-running meeting or continue the discussion on a walk while preventing too strong a statement to be made to someone not familiar with the system-such as an external client.

3.6 Discussion

The sheer amount of time modern office workers spend in the workplace means that healthy habits and routines, including the use of health-related technologies, must take place in the office. However, personal health technologies have thus far largely been developed devoid of the expectations of the workplace. We propose to move personal health technologies from solely personal isolated tools to socially situated ones concerned with and designed for organizational contexts. The multiple methods used in this study allowed us to uncover issues surrounding the use of personal health technologies in the workplace. These issues emerge when individuals must balance personal and organizational goals, as well as short and long-term interests.

Care must be taken in both the design and deployment of individual technologies within collaborative environments. In our example, individual technologies are tools designed to meet personal health goals surrounding sedentary behavior, and the collaborative environment is a shared office space. CSCW has long concerned itself with collaborative tools in both collaborative and personal environments, enabling the application of this long history to the use of personal tools in collaborative environments. In particular, designers of personal technologies to be used in the workplace must consider how to balance the sometimes competing goals of the individual and the organization, just as has been done in work-based systems like knowledge management and communication tools [77].

Changing health-related behaviors, such as being sedentary, takes more than personal will and knowledge of the problems and solutions available. For offices workers in particular, behavior change takes place within the context of the workplace-an issue considered by organizations scholars (e.g., [169, 209]) but somewhat neglected within the persuasive computing and personal health literature. Personal health technologies have the potential to hide or disguise their engagement with the user when such engagement is inappropriate and to make legible certain activities, such as standing up in the middle of a meeting that might otherwise be deemed inappropriate. These dual capabilities open a range of possibilities for their use in the workplace not only for personal health but also for team building, productivity management, and other important organizational and personal goals.

3.7 Conclusions and Future Work

This paper describes the results of a multi-method project focused on the use of personal health technologies in collaborative workspaces. Our results provide important considerations for the creation and understanding of other persuasive applications and personal informatics tools that overspill into the workplace.

Our empirical studies reveal that in situ health cues must work in tandem with the concurrent demands, norms, and context of the office. In some cases, alleviating the tensions that arise with the use of these technologies may require changing the office culture. However, carefully designed technologies can enable delivery of information and that is appropriately (in)visible for the office environment and prompting of strategies that support personal behavior change within the context of the collaborative organization.

The continual interplay between re-prioritizing of work and wellbeing imply we cannot assume that in situ cues inspire users to take action immediately or at all. Thus, public health officials and researchers must engage with personal health informatics designers and researchers to design organization or nationwide policies and campaigns alongside their technological tools. Similarly, organizations wishing to implement enterprise-wide health-related behavior change, should consider a suite of tools in their approach, including technologies, policies, and incentives structures. Finally, tools should be designed with these kind of larger scopes in mind, bearing in mind that users are not always-and often cannot be-acting with full agency, freedom, and control when working in collaborative organizations.

The opportunities for future designs are immense in this area. For example, in an enterprise-wide deployment, integration with calendars alongside custom user configuration or learning algorithms could enable behavior change technologies to predict when meetings might inhibit taking of breaks and encourage additional activity before and after the meetings while remaining silent during the meetings. Likewise, peripheral displays in the office could be developed to share health-related information with officemates, while maintaining the personal, private and unintrusive aspects that were found to be requirements for work environments. We leave open for future work both these potential novel technological approaches and larger scale clinical trials of their effectiveness in the workplace.

3.8 Acknowledgments

We would like to thank all the participants that took part in the study.

Chapter 4

Designing for Family-based Behavioral Training

4.1 Introduction

Family-based behavioral interventions can be used to support a variety of mental health issues for children in the home [4, 5]. However, an examination of existing research in interactive health technologies for addressing individual health needs (e.g., [35, 43, 119]) as well as work focused on family health (e.g.,[33, 76, 82, 81, 108]) clearly indicates that families require special considerations. In this work, we were interested in understanding how to design technologies to support family-based therapies, including Behavioral Parent Training and Social Skills Training, for children with Attention Deficit/Hyperactivity Disorder (ADHD).

ADHD is one of the most frequently occurring mental health disability [205]. Although usually detected during childhood, it poses lifelong challenges for individuals with ADHD and their families and communities [12, 80]. People with ADHD struggle with maintaining focus on a task, have poor impulse control, and struggle with decision-making [16], Zylowska2009. These challenges stem from core differences in skills collectively called "executive functions." These include organization, planning, emotional self-regulation and self-monitoring, and are intrinsic to a wide variety of daily living, social, and professional skills.

Parenting a child with ADHD is extremely challenging [30, 193], and the struggle parents experience has immediate and long-term negative consequences [141, 211]. The task difficulty is further compounded by the likelihood that one or both parents have ADHD [61]. Times that are stressful for all families can border on chaos and catastrophe for families coping with ADHD. For example, at dinner, a child with ADHD may struggle to focus on his meal. His crying baby sister may increase his distractibility and may elevate his frustration and likely reduce his ability to regulate the noise level of his own voice: screaming for something else to eat, for his sister to stop crying, and for his parents to pay attention to him. The screaming and crying triggers an already stressed mother to yell at both children, further escalating the cycle of crying and yelling and triggering an exhausted father to throw his plate in the sink and walk out of the room. In a family without ADHD, at least one parentand sometimes even a childcan often calm these stressful family situations. However, parents of children with ADHD often cannot easily perform this role, and need other means to cope with the situation at hand.

Cognitive behavioral interventions can provide parents and their children training to improve their executive functioning skills and thereby improve the functioning of the family unit [101, 102, 114, 204]. In particular, these programs can help children and their parents cope with the symptoms of ADHD through tailored training for both parties that build on each other [184]. However, adherence to these interventionsand therefore their effectsoften decline over time [214, 215], leaving open major health research questions about how to support long-term adherence to training. In this work, we explored the opportunities and challenges for the design of collaborative, persuasive technologies for family-based behavior change.

4.2 Related Work

Although personal health informatics is ostensibly about the individual, even the quantified "self" movement has begun to consider the quantified "us," [131] and the issues and goals of these movements often apply well to group or family-based health. In particular, we consider how technologies must connect health strategies, actions, and progress towards goals [145]. Likewise, designs should collect data in ways that offer insights to users, are descriptive and understandable [43]. Finally, behavior change, whether of an individual or a group, is cyclic and iterative, and health technologies must allow for these stages, detect them, and support them [119] while putting physiological data in context of environmental and activity based data [120]. Moving beyond these issues, however, there are open considerations for how to design personal health technologies that are collective, particularly in relation to mental health and family functioning as in this work.

ADHD in particular tends to accompany other challenges for people in their relationships, communication styles, and social interactions. The behaviors to be changed and the data to be tracked are inherently for and about multiple people. Thus, we turn now to the related literature on family based interventions. Grimes et al. highlight the potential for designing around families rather than individuals [76]. Because families often share food and eat together, recalling food intake and tracking diet is easier as a family rather than individuals. One family member can fill in the gaps for the other [76]. Similarly, Neustaedter et al. found that coordinating, scheduling, and calendaring are crucial activities in families that call for different types of calendar views, such as: public and accessible or at-a-glance awareness with multiple access points [150].

Given that parents are the primary decision makers in the home, it is perhaps unsurprising that one solution seen in the literature is to focus on parents when designing for families (e.g., [81]). Specifically, within the ADHD research space, ParentGuardian used wearable sensors to detect when a parent was under duress and deliver behavioral strategies to help parents cope with stressful situations [170]. However, parents often struggle to track, aggregate, and present their child's health information to doctors [107, 125].

Taken together, this related work indicates that technologies can be used to support collective health monitoring for families but require special design considerations in their development. This work also leaves open research questions around the underlying mechanisms by which this support could work, particularly for long-term adherence. Thus, in this work we focused on understanding how families currently work to implement their lessons from cognitive behavioral training several weeks after completing training and how these practices might be leveraged and supported through innovative technologies.

4.3 Background on Behavioral Family-based Training

Parent training is an evidence-based treatment for children with ADHD [36, 37, 95, 166], but has challenges with long-term adherence [211]. The MTA Study (Multimodal Treatment of ADHD) parent training focused on psychoeducation, building effective home discipline programs and collaborating with schools [211]. The CUIDAR Project (CHOC-UCI Initiative for the Development of Attention and Readiness) [113, 114, 194] focuses on identification of behavioral difficulties and ADHD before children reach school age as well as both short and long-term intervention. Similarly, Positive Assertive Cooperative Kids (PACK) [184], is a twelve-week program that uses a combination of behavioral parent training and child social skills training built on the MTA and CUIDAR models and adds in the element of human-animal therapy through canine companions.

4.3.1 PACK Training Overview

Although PACK is a multimodal treatment that evolved over several years, we here briefly describe the elements most relevant to parent training and our research questions around long-term adherence for families. During PACK, parents meet on a weekly basis for 2 hours in groups of six families, and children attend social skills training twice a week for a total of 4.5 hours per week. Parents receive training on traditional behavior modification principles and techniques to address children's specific problematic behaviors through the use of positive reinforcement (e.g., positive attention), nonphysical discipline (e.g., losing privileges, time-outs), contingency systems (e.g., token economy and behavior charts), effective communication (e.g., giving directions), and problem-solving. In addition to these traditional BPT intervention techniques, the PACK parent curriculum also addresses common parenting challenges associated with raising a child with ADHD (e.g., problems with self-regulation, organization, motivation, and persistence). Parent sessions are led by a specifically trained parent educator and include didactic instruction, goal setting, role-playing, and homework assignments using standard manuals and protocols. Preliminary results have shown reductions in parent-rated severity of children's ADHD symptoms during the course of treatment as well as pre-to post-treatment improvements on measures of children's social skills, pro-social behaviors, and competing problematic behaviors [184].

Because PACK explicitly considers a dyadic relationship (parent and child) to be involved in the behavior change process, it served as a basis to broadly study how personal health technologies can and should be adapted or reconsidered in light of collective needs-in our case, family needs. In particular, we were interested in understanding how behavioral training that involves one child and one (occasionally but rarely two) parent(s) is implemented after the training phase. In particular, we were interested in understanding how families coped long-term with the addition of other actors-including additional parents (e.g., spouses, step-parents), caregivers (e.g., grandparents, teachers), and children (e.g., siblings, friends)-while attempting to maintain the training they received.

4.3.2 Implementing PACK in the Home

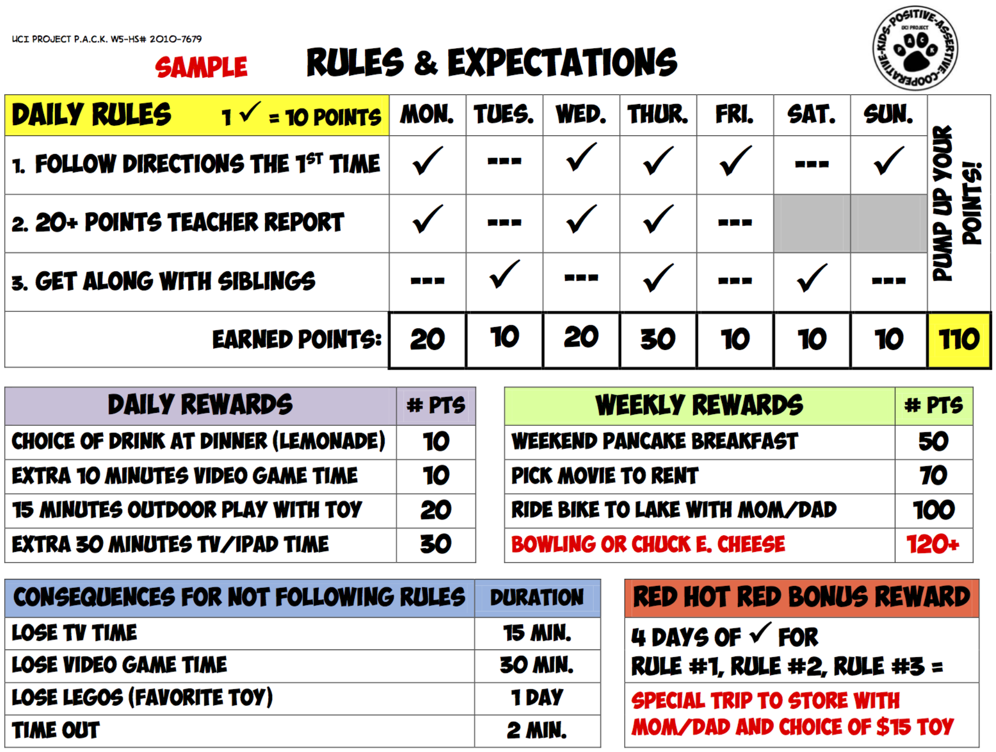
numerous potential interventions, and the PACK intervention itself was complex and involved multiple diverse types of lessons and tools. In our work, however, four primary tools were reported as being used by research participants dramatically more than the other elements of the training. Thus, we focus on those examples here to provide some indication or how PACK tools and exercises help the parent-child dyad reinforce the skills being taught on a weekly basis [184]:

- *PACK Good Sport Bucks:* a token economy used by parents to "catch" and reinforce positive behaviors and the specific "social skill of the week."
- *PACK Lingo:* a shared "language" between parents and children consisting of short, direct, and neutral verbal and nonverbal prompts for appropriate behavior (e.g., "calm hands/body" for fidgeting). Children were conditioned to respond to from the regular use in their social skill lessons (see Table 4.1).
- *Behavior Charts:* visual representations of contingency systems in which"earned" rewards are contingent upon targeted behaviors, typically placed in the child's room or on a shared wall and reviewed by parents with their children at least once per day (see Figure 4.2).
- *Checklists:* visual representations of specific, multi-step routines and tasks (e.g., going to bed, getting dressed in the morning) that guide them through a sequence of steps to facilitate self-initiated task completion (see Figure 4.1).

Table 4.1. Example of PACK phrases

Phrase	When to use
No extra words	Child not showing accepting, negotiating, talking back
Laser eye contact	When you want your child to look at you or someone who is speaking
Bubble Space	Child is invading personal space, too close to others
Quiet Coyote Sign	Hand sign that means its time to be quiet, not talking and eyes on speaker
1-minute warning	Give one minute before transitioning to the next activity, task, or event
Redo	Option to redo something s/he did the wrong or inappropriate way
Freeze!	Call to attention, should immediately stop what s/he is doing and redo the action (e.g., ignoring a greeting)

Figure 4.1. Example of PACK's weekly behavioral chart



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SAMPLE

RULES & EXPECTATIONS

DAILY RULES 1 ✓ = 10 POINTS	MON.	TUES.	WED.	THUR.	FRI.	SAT.	SUN.	PUMP UP YOUR POINTS!
1. FOLLOW DIRECTIONS THE 1ST TIME	✓	---	✓	✓	✓	---	✓	
2. 20+ POINTS TEACHER REPORT	✓	---	✓	✓	---			
3. GET ALONG WITH SIBLINGS	---	✓	---	✓	---	✓	---	
EARNED POINTS:	20	10	20	30	10	10	10	110

DAILY REWARDS	# PTS
CHOICE OF DRINK AT DINNER (LEMONADE)	10
EXTRA 10 MINUTES VIDEO GAME TIME	10
15 MINUTES OUTDOOR PLAY WITH TOY	20
EXTRA 30 MINUTES TV/IPAD TIME	30

WEEKLY REWARDS	# PTS
WEEKEND PANCAKE BREAKFAST	50
PICK MOVIE TO RENT	70
RIDE BIKE TO LAKE WITH MOM/DAD	100
BOWLING OR CHUCK E. CHEESE	120+

CONSEQUENCES FOR NOT FOLLOWING RULES	DURATION
LOSE TV TIME	15 MIN.
LOSE VIDEO GAME TIME	30 MIN.
LOSE LEGOS (FAVORITE TOY)	1 DAY
TIME OUT	2 MIN.

RED HOT RED BONUS REWARD
4 DAYS OF ✓ FOR RULE #1, RULE #2, RULE #3 =
SPECIAL TRIP TO STORE WITH MOM/DAD AND CHOICE OF $15 TOY

Figure 4.2. Example of PACK's weekly behavioral chart

In addition to these four key elements, other worksheets and tools were introduced in each session of the weekly training, such as creating contingency plans for potential problematic events and situations, problem-solving techniques, and steps for effective time-outs. Taken together, these materials served as common ground for the children and their parents as well as individual specific training for each. However, rather than just translate these materials into digital form, we sought in this work to truly understand how these materials-and others homemade by parents or adapted from school and clinical settings-are used in the home and how additional digital tools might be created with the same goals as the training programs in mind.

4.4 Methods

We conducted an interview study targeting long-term adherence and implementation of behavioral strategies taught through the PACK intervention. In this section, we detail the participants in this study, data collection techniques, and analysis used.

4.4.1 Participants

All parents interviewed completed the 12-week PACK intervention and had consented to be contacted for additional research studies (n=44, 2 fathers). Parents had completed the training between 3 months to 18 months prior to the interview. All responding parents (n=26, 1 father) with the exception of the father reported to be the primary caregiver during the PACK intervention. Primary caregiver is the parent responsible for attending the weekly parent training sessions, completing weekly homework assignments, and completing the questionnaires and outcome measures.

Over the course of a year, we interviewed 20 of the 26 parents who responded (see Table II insert). The remaining six parents, including the only father to respond, expressed interest but we were not able to finalize a convenient meeting time for them.

Two of the mothers interviewed were divorced from the fathers of their children. In one divorced family, both parents attended the parent sessions, whereas in the second divorced family, only the mother participated. Three of the mothers identified as single parent households. The remaining 15 were dual parenting households. Of the children whose parents were interviewed, 14 were boys and 6 were girls.

4.4.2 Interviews and Home Visits

We conducted semi-structured interviews with each parent participant. On average, the interviews lasted 60 minutes, with the shortest lasting 34 minutes and the longest 110 minutes. Seven interviews took place at homes of the families; five took place in

Table 4.2. Participant Demographics

Parent ID	Relationship	Parental Status	Other caregivers attending PACK	Age of child at completion of PACK	Gender of child
P1	Mother	Co-parenting	Father did not attend consistently	7.48	Female
P2	Mother	Co-parenting	Father did not attend consistently	9.45	Female
P3	Mother	Single mother	None	8.27	Male
P4	Mother	Co-parenting	None	7.97	Female
P5	Mother	Single mother	None	9.11	Female
P6	Mother	Co-parenting	Father	8.85	Male
P7	Mother	Co-parenting	Father did not attend consistently	7.48	Male
P8	Mother	Divorced	Father did not attend, Step-father attended	8.09	Male
P9	Mother	Co-parenting	None	7.63	Male
P10	Mother	Co-parenting	Father	6.88	Male
P11	Mother	Co-parenting	Father	8.46	Male
P12	Mother	Co-parenting	Father did not attend consistently	9.3	Male
P13	Mother	Co-parenting	Father	9.3	Male
P14	Mother	Single mother	None	10.22	Female
P15	Mother	Co-parenting	Father	8.03	Male
P16	Mother	Co-parenting	None	8.18	Male
P17	Mother	Co-parenting	Father	7.78	Female
P18	Mother	Co-parenting	Father	8.56	Male
P19	Mother	Co-parenting	None	8.98	Male
P20	Mother	Divorced	Father	8.3	Male

person outside of the home including at a school for children with ADHD, and eight were conducted by phone.

During the interviews that took place in homes, we also conducted a tour of the home. Parents shared artifacts related to implementing the training. Additionally, we asked parents to show us locations in the home that tended to be the sites of problematic behaviors. We took photographs in the homes but not of the family members themselves and included these photographs and any collected artifacts in the analysis. For the other five parents we interviewed in person but not at home, we still reviewed the materials they used to maintain PACK and included these in our analysis.

4.4.3 Analysis

Our analysis focused on the complex ecosystem of care present in PACK, including multiple family members, behavioral tools, language, information, and times and locations of care. In particular, we were interested in understanding how cognitive behavioral training is a distributed process. Thus, we conducted a distributed cognition analysis of this ecosystem with a particular consideration for how technological tools might be used to support the various ways the work of behavior change is distributed.

Distributed cognition looks at understanding: (a) the representation of knowledge internally in individuals and externally by off-loading some of the cognitive load to tools and artifacts in the environment [151]; (b) the interactions and propagation of knowledge between individuals and artifacts [93], [91], and (c) the transformations external structures undergo when operated on by individuals and artifacts [63]. As such, distributed cognition goes beyond understanding individuals in isolation to look at how a collection of individuals and artifacts perform a task across time and place [63]. Furthermore, distributed cognition helps understand how to map such distributed activities to functionality in the design of interactive systems [90]. This framework has been used to distill needs in networked work environments [179], software teams [63], and teamwork errors in the trauma resuscitation at a hospital [183].

Throughout the qualitative analysis process, we organized the data based on the three dimensions of distributed cognition: people, artifacts, and time. In an iterative process, we examined emergent themes within each dimension by which the work of family functioning is distributed. The lead author drafted memos for discussion to be shared among the research team as well as with a larger group of related researchers. Over several months, we refined our insights, returning to the data to look for corroborating and contradicting examples in both the interview transcripts and other materials. Finally, we brought on board the clinical researchers who had initially explained the PACK training to us, reflecting our findings to them and drawing on their insights into the research participants' experiences and the details of the PACK training.

4.5 Findings

Family-based behavioral training, like the program in the PACK intervention, takes place within the very pragmatic constraints of parenting. In most families, attending any type of training is difficult if one or both parents work and there are multiple children in the household-each with different schedules. Therefore, even though all caregivers in the family are invited, typically only one parent attends. This situation naturally, if not intentionally, sets up a dyadic relationship between the parent and the child attending the behavioral training. Throughout PACK training, responsibilities are divided between the parent and child; each working towards the goal of an improved relationship. Parents in our interviews described targeting and monitoring their children's behaviors, completing take-home exercises, maintaining charts and checklists, practicing using learned communication tools, and implementing each week's behavioral techniques. In turn, they described their children as applying each week's social skill with the goal of earning incentives for targeted behaviors (e.g., compliance, work productivity).

Outside of training, particularly over the long term, we see an even more complex ecology of actors: additional parents, grandparents, and other caregivers play key roles in improving family dynamics, even when they do not attend the training. Likewise, other children in the household become subject to the strategies and tools parents learned in PACK training. Although necessary, this situation challenges long-term adherence. In this more complex view, children and caregivers hold each other accountable and rely on each other to: communicate using the PACK lingo as learned in training, maintain the token economy (good sports bucks), maintain the behavioral charts, and give out rewards for improvements in behaviors.

In this section, we unpack these results in relation to each of the ways in which this work is distributed: across people, within and outside the family; through and around various artifacts both digital and not; and across time. This approach gives insights on the properties that arise from collaboration among family members and tools and how they occur over time.

4.5.1 Working as a collective: interactions mediated through behavioral training

Achieving behavioral improvements during and following intense behavioral training goes beyond the child and parent attending the training: it takes the entire family. In particular, we find that training must be understood and technologically supported considering as an enterprise involving the entire family. Technologies need to consider caregivers and siblings that did not participate in PACK because they play a role in maintaining the intervention. The following sections highlight how communication and coordination within the family and around PACK need to be considered.

Dynamics of maintaining behavioral training as a family

As described in 4.3.1, PACK includes a two-way complementary training. One of these complementary components was the 'PACK lingo.' This shared language helps families communicate clearly, concretely, and quickly in a neutral manner without falling back on ineffective methods of communication (e.g., scolding, lecturing). The two-way complementary curriculum draws attention to the ways in which the knowledge is distributed across members and how tools need to consider the distributed nature PACK creates.

> The 'stop, look, and listen' [...] It's the perfect thing of what we need to say. [...] It just tunes her in that she needs to stop and look at me [...] Oftentimes we just see her grabbing at things and fidgeting and so 'calm body' just gives us the perfect words that we needed to describe.

<P16 >

Additionally, we also learned parents used the 'PACK lingo' with their other children, even if they were not trained.

> My younger son, I also make him go through PACK program. I taught him the [PACK lingo] ... We do everything together, it's an easier way to do and it works.

<P15 >

On the caregivers' side, often only one parent-and no grandparents, aunts, or uncles-attended the training. In those few families in which both parents were active contributors, PACK provided a foundation from which to draw from even when the individual approaches were inherently different.

> The fact that we have this common ground now, that we can encourage each other toward, I feel like our marriage is really strong ... I know how rare that is. I just feel incredibly thankful for it. To be able to just use the

> same words and to encourage each other in the same techniques has had a huge impact on helping us really be on the same page.

<P16 >

> He [stepfather] went to most of them [training] we kind of bounce stuff back and forth between each other, when sometimes we differ on how we should handle it you know, that was kind of a struggle too. Because even though we've both been through the training he may see it one way and I see it different way, and we have to come to that median... But it's constant, you know. Trying to get everybody on board is a struggle, yeah.

<P8 >

Similarly, the token economy (Good Sport Bucks) explained in Section 3, set clear standards for rewards, and keeps everyone in the family operating on the same system for rewarding appropriate behaviors. This reward system allows families to define and understand what is appropriate and what is not, which behavior will be rewarded and which will not.

> We just have a jar for each girl and we're just putting poker chips in when they earn ... We have different color poker chips ... I think just the act of catching the positives is the most important.

<P16 >

The families that maintained a contingency system after the intervention ended did so with all children who are close in age, and not just with the one who attended PACK. Additionally, beyond simply implementing the parent-driven strategies across all children, families with older children often described creating opportunities for the older sibling to have a more assistive, parental role:

> And we do stuff like the 'family cooperation jar' where the big brother is babysitting, they all cooperate and they earn points as a group and as a group they get to go to do something. And then they (the other siblings) can buy toys too.

<P13 >

This type of family integration highlights how supporting a family-based behavioral intervention requires designing tools that support the entire family, including siblings and caregivers who did not participate in the training program.

Family members collaborated around maintaining the behavioral chart. Children not only cooperated by focusing on improving the targeted behaviors of the week, but also reminded parents to update the behavior and reward charts.

> The girls just fill in a check or a mark on the three things we're working on. ... The girls are motivated because when they get their points that day, they get a daily reward to pick from. They actually are the ones that help me keep it up, because they're always asking to do their chart. ... I really think that if they weren't reminding me all the time to do it, and they weren't motivated by it, then I probably wouldn't be able to keep it up. That really helps.

<P16 >

In the current paper-based system, all charts live at home and every child has their own. The current system makes it difficult to track improvements outside of the home. When behavioral improvements occurred outside the household, all parents described struggling to remember to update the chart. Parents who were able to maintain their charts relied on their children to remind them to update the chart once they were home.

> I say 'You need to help remind mommy so when I tell you that you've earned something, if I don't mark it down remind me later.' In the moment you're not going to go 'Oh you earned your reward.' Then I'm going to go write it down on the chart from where they got it. I'm busy with my other kid, homework, getting them to church, you know what I mean?

<20 >

Relying on each other, and allowing children to be active participants highlights to consider all members involved when designing technologies for the family setting.

Moments of tensions highlight how other caregivers participate, benefit, and learn about PACK even if they did not participate directly in its training. In this case, when one parent is struggling, the other can dynamically step in and reminds the parent struggling of strategies to handle the current tension.

> My husband in particular is having a really hard time, because he just is like, ”I’m just going to make her comply.” [] He wants to have the power and control so he starts becoming super stern, and then she just wants to fight that. We know that she does not respond well to just the authoritarian, we’re trying to just remind each other, ”Remember, this didn’t play out well last time.” He’s working on some of that, and then I think he’s ... I’m trying to remind him some more of that stuff. He’s been trying to remind me of some more of the consistency stuff.

<P16 >

As P16 expressed, each caregiver has different struggles, but they can learn from, and lean on, each other for support even if they have varying levels of expertise and experience with the behavior training. Likewise, when designing technologies that support a parent in coping with their own mental health challenges (or provide parents mechanisms to support their children), we should consider the entire family to be receiving and implementing the therapeutic and educational interventions-not just the single parent-child dyad.

The insights in this section highlight how PACK maintenance is distributed among the parent-child dyad and other family members. Having siblings and other caregivers participate in maintaining PACK underlines the need for technologies to support different types of users and roles; some members will be fully versed in PACK and others will learn along the way.

Maintaining training with different family dynamics

There are not always clear lines delineating the boundaries of the family unit. Inclusion of other caregivers, such as grandparents or hired childcare creates additional challenges for families and additional design considerations for technology researchers. For example, when and how should information about a child-rewards earned, discipline required, strategies to engage, and so on-be shared with other caregivers? Just as handoffs in healthcare can interfere with transfer of knowledge about a patient [5], handoffs in the childcare process can limit the consistency and effectiveness of behavioral interventions. Thus depending on the context, individuals normally not considered part of the family ecosystem, such as teachers, become part of it.

These blurry family boundaries are also present when parents are divorced. In "split parenting," the secondary caregiver could have substantially different engagements with the training compared to the primary caregiver and the children.

> My situation is different than the other parents in the class because mine is a divorced family. So my son goes between my house and his father's house, and our parenting styles are different. The environment is different. It's hard to implement something here and then he switches to another environment that's different there ... I don't have any control over there. My son tells me it's very stressful at his dad's.

<P20 >

These "split parenting" situations might lead to inconsistency in maintaining behavioral programs like PACK, and these family types must be accounted for when designing for family behavioral support. Tools for this setting must be adaptable and configurable for a variety of family dynamics-an issue that may seem obvious, but not well accounted for in existing tools and technologies.

The results of this entire section highlight two points. First, tools need to address non-trained family members and offer additional guidance, suggestions and insights compared to tools designed solely for the parent-child dyad that attended the training. Second, technologies need to accommodate for the shared accountability and coordination across family members, chronicle it, and highlight opportunities for this type of engagement and contribution.

4.5.2 Behavioral interactions mediated through artifacts

Physical artifacts, such as charts and rewards, can decrease the cognitive load of mentally tracking behaviors and rewards. They worked so well for many families, in fact, that they often chosen to implement them for all of their children-a decision that then added to the complexity of maintenance of these artifacts. In this section, we describe the opportunities and challenges seen in delegating a portion of family functioning and parenting into these tools, depending on users and other context.

Making tools visible and accessible

Families set targeted behaviors to track on the behavioral chart at the beginning of the week, ideally based on a family discussion about behavioral goals and rewards to be earned. However, all families struggled to find the time and place to update the chart and reflect with their children in a way that fits into the fabric of their daily routine.

> It was like we had it downstairs, by the kitchen table so we could see it while we ate. We put it on a bulletin board we'd put it here [living room] and nothing really worked because we kept forgetting to sum it up. I literally have it taped to the wall in each of their rooms with a pen hanging next to it so before they go to bed, it's the last thing I see when I turn off the light and so I can't really miss it.

<P18 >

Parents who succeeded in updating their charts over long periods of time following the training, like P18, placed the charts in locations where they spent one-on-one time with their children. Displaying visible behavior tools in these contextual locations allows family members to collectively reflect on children's behavioral progress. However, a wide variety of behaviors occur outside the home, such as in social gatherings, sports events, after-school programs, in the car, in restaurants, and so on. In response, parents described using a variety of approaches to make information accessible in various contexts. One mother relied on her son to remind her to update the charts when they arrived home; another mother created her own checklist for her mobile phone.

> don't have it sticking on my refrigerator anymore. Our life is too busy for me to sit here and do that. I have it on my phone, I keep a little chart on my own phone that says what things he's earned for the day.
>
> <P20 >

Having behavioral charts only accessible to the main caregiver weakens the parent-child collaboration. An individualized, single viewpoint denies children the benefit of viewing their behaviors and rewards on the large, visual wall chart. Secondly, a chart only available to a single member decreases the desired group awareness and the opportunity for other caregivers to collaborate.

Furthermore, even though families were given handouts to help children refresh their acquired social skills, all parents indicated it was difficult for their children to review the material. Similarly to the experience of their parents, children did not have the means to review their training outside of the home. The inability of children to review at a level that speaks to them, especially as they mature, led to children's decline of the behavioral maintenance.

> We could put, he could put in, what reward he is trying to earn that week and then he could look at it. But, just to keep it fresh in his mind. Oh yeah, I'm trying to earn this week.
>
> <P10 >

> For [my son], I think his hardest thing, but sometimes he'll say "I don't remember anything I learned at PACK." So I still will throw in the terminology he still remembers it because I still use it. But, I think a lot of the concepts got lost.

<P9 >

The above barriers call for a more comprehensive ecosystem, one that includes tools targeting the needs of children as active participants in the data gathering, editing, and reviewing process.

Making tools customizable

Because multiple family members assist behavior management, the artifacts mediating this process must be appropriate for different types of users. In the current paper-based system, however, it is difficult to translate information across environments (e.g. school and home) as well as across people (e.g., child and parent) using paper-based tools.

Half of the parents interviewed stated teachers were interested in maintaining PACK during school time. However, transferring and re-representing behavioral data depending on the type of caregiver is currently not possible. For example, a school related goal with home implications calls for parents to track data in a form that is useful for teachers. Likewise, home goals that have implications at school require teachers to track information differently for parents than for school purposes. In both cases, having information on a desired behavior from a different environment can be helpful for understanding current behavior.

> [His teacher] would have also other rewards for him if he were able to sustain something for a longer period of time. She would want me to track it for her. [...] It was almost like she wanted to have a record and she wanted to be able to point to some improvement.

<P19 >

Likewise, children benefit from understanding data tracked about them-and possibly even tracking it themselves. Enabling children to become more accountable for their actions is highly encouraged in PACK. Currently, however, the current ecosystem lacks tools that engage children. Consequently, children tend to forget behaviors and rewards because they have no means of view their information.

> If he had a chart to keep track of himself ... he could put in, you know, what reward he is trying to earn that week and then he could look at it. But, just to keep it fresh in his mind. 'Oh yeah, I'm trying to earn this week.'

<P10 >

These results indicate that a balance must be struck between the visibility of information and its accessibility: there is a need for different interfaces for different situations, intentions, and user roles. Additionally, data needs to be accessible across environments, and those who do the work of collecting it should benefit from its existence, echoing canonical work by [77]. However, the method for summarization, reflection, and understanding of the data differ depending on the type of caregiver (i.e. firsthand PACK learner vs. secondhand PACK learner, baby sitter, teacher) and the age of child. Thus, the tools used to implement strategies, track behaviors and rewards, must work around supporting these activities at a variety of levels for end-goal, comprehension, and knowledge of PACK.

4.5.3 Mediating behavioral interactions over time

Given the acute and episodic nature of parenting a child with ADHD, and the specific focus on mindfulness inherent in the parent training [188], supporting moments of tension is an unsurprising need for families. Considering how and when delivering support, however, raises some interesting issues.

Supporting members based on context

Similar work by Pina and colleagues [170], parents described wanting and needing just-in-time support during moments of stress and chaos. In our study, we learned an additional detail; in situations occurring at home, parents wanted other family members to be made aware. One parent described: "it's like taking an emotional room temperature" (P16). In PACK, the parent-child dyad attending learned how to empathize with the struggles of the other. Building on this progress, parents expressed they wanted to strengthen that awareness in difficult moments by explicitly translating emotions during moments of tension to encourage family members to help each other. A second approach for creating group awareness is to make other caregivers in the near vicinity aware so that they can assist the parent involved in the moment of tension with their child.

More interesting, however, our results indicate that parents need support during other distinct times. So-called downtime was a particularly salient concept for parents, which is also discussed in related work [170]. More specific, parents discussed wanting to review training materials and strategies during idle moments of the day, especially if they were related to their children, such as sitting in the waiting room during a doctor's appointment or waiting in the car before school pickup.

> Like I am waiting in the waiting room and I'll be looking some things up, or texting, or, things of that nature. [...] if I had access to that and I was needing that information, it's just more accessible than having it in a book at home.

<P1 >

Thinking about designing around downtime points towards exploring other moments of the day not normally thought of when supporting parents during moments of need. Aside from assisting with events related to with charts, behaviors, and language, there are opportunities to learn and reinforce the program. Exploring how to support moments, like "downtime," is worth exploring with respect to engaging secondhand PACK learners. These opportunistic moments could be used to show progress and what are opportunities for secondhand PACK learners to support behavioral improvements.

Additionally, a distributed cognition analysis highlights how even "in the moment;; support is not just delivered in the moment, but requires substantial planning beforehand and reflection after. In the next section, we describe the ways in which "real-time" support is distributed across time.

Reorganizing information based on context

PACK helps parents to design contingency plans to deal with potential triggers of undesired behaviors. Contingency plans support emotional regulation and consistency for the entire family. Creating and implementing contingency plans is the second most common hurdle PACK parents struggle with.

Parents were generally aware of the events or tasks that could trigger undesired behavior in themselves and their children. In principle, this knowledge can help parents prepare in order to avoid these conflicts.

> You know when your kids get a trigger. You know when you are going to have a fight with your child. I could tell you probably the time, the date,

> every single week that I know I'm going to fight with my child because they are my kids. When I know that, then I can go and seek an ultimate way to say something in a better and then try it.

<P14 >

However, most families struggle to create and implement appropriate contingency plans.

> I feel like I was given so many of the tools. I just think a lot of times I don't take the time or give myself the space to think about what I need to be doing as a parent. I think being proactive is a huge piece of it and not just being reactive.

<P16 >

As a part of PACKs training, parents were taught how to create contingency plans. This process required parents to: (a) break down the problematic event; (b) work backwards to identify its starting point; and (c) consider what steps to follow to avoid reaching the undesired boiling point. Given the high proportion of parents who are also struggling with their own executive functioning capabilities and high reactivity, parents need step-by-step instructions that they can easily recall–in the moment–during stressful situations.

> I find that it's difficult to remember what to do when you're in the middle of it. Because the child's acting out, you feel like everybody's staring at you like 'do something, your kids out of control' ... I can't even think. You know? And you want to yell as your first reaction, you go, 'you can't do that.' That's not going to help. What was I supposed to say again? ... if you had like something that could trigger, you know, even like flowcharts or something that you can glance at.

<P1 >

Most parents reported being able to remember the "first rule" of the training: "do not engage." However, only two parents, P1 and P18, reported being able to follow this rule and created a mechanism to support themselves during these stressful periods. P18 carried reminders of her child's rewards and would remind potential upcoming rewards in an attempt to shift her child's attention towards positive behavior; P1 would review photographs of the paper-based course materials on her phone while disengaging. The small number of parents who described successfully disengaging indicates that technological support even to just let parents know when a good time to step away is (such as is suggested by [170]) might be a substantial improvement.

Because parenting is unpredictable, parents described struggling to create a contingency plan for every potential triggering event and its associated undesired behavior. In practice, this requires parents to connect an appropriate strategy (from a set of strategies) to a particular situation they are likely to face, and to execute this plan very quickly in the heat of the moment.

> I remember her [clinician] telling us you know, write down what you're going to do when they don't listen. So you have to, right now, you have to do x and I put an arrow, you're direction right now is to do x. Then another arrow, if you choose not to follow my direction, your consequence is y. Right now, your consequence is y. So that I don't forget it because otherwise it's not that I don't want to, I can't think of it.

<P1 >

> He [child] needs to work on 'accepting' now, like I can click on accepting and read about accepting. And maybe come up with some other ideas of how to deal with it.

<P10 >

This reality suggests an opportunity to create an infrastructure to support parents by reorganizing PACK information and presenting it according to the situation at hand.

Designing for reflection

Family-based behavioral training programs, such as PACK, often require families to reflect on behavioral incidents in relation to their weekly behavioral goals. These periods of reflection give families a sense of progress, helping them to identify what has improved and what has not. However paper based charts, such as those described in Section 3, do not highlight behavioral progress, which areas to improve on, and what strategies and rewards were effective in the past.

Parents used a variety of tools-from extensive paper charts to sophisticated spreadsheets-to support this kind of tracking and reflection, with varying degrees of success. For example, one parent described the elaborate system for tracking a variety of data points in a spreadsheet:

> Yeah, I basically have an Excel spreadsheet. I look at whatever it is that I did for last week. I make a copy of the spreadsheet, make a new tab and then update it for the next week. It gets a little old. ... Like if it was just a simple web based form that I could just route that also give me some sort of tracking mechanism, it would be really lovely.

<P18 >

This same parent, however, lamented that simply tracking and recording data was not enough.

> For us, it's not just remembering to check off the charts and say, 'Hey, you earn this checkmark' or whatever. If you'd been coming up with the charts on a weekly basis and remembering to really re-think are these behaviors that we want the kids to work on this week or do we feel like they did it?

<P18 >

The biggest hurdle we identified throughout this study was the inability of parents to quickly review and reflect upon their children's behavior. Even the mother using

Microsoft Excel could not gleam and review historical data to offer insights on current behaviors.

> I really don't remember what he did a month ago. Once he had it, I don't want to keep extra pieces of paper with all the checkmarks on it once it's done. At the same time, I want to remember, hey, 'we had a problem' ... Then it will be a month later where his thought would slip again and I go, 'Oh okay well, I should probably come back to this' but how long ago did we really have this as a priority? Was it a week ago? ... is this something that I should be more consistent about and keep on longer?
>
> <P18 >

These results indicate that successfully responding to current undesired behaviors requires reflection about past behaviors. Current tools are unable to help families in this regard, as they are currently designed to aid in tracking the current, present state of affairs.

4.6 Discussion

ADHD is a neurodevelopmental disorder that is typically first evidenced during childhood but can cause impairment across the lifespan. Behavioral interventions aimed at mitigating the effects of ADHD on children and families focus on improving the relationship between a child with ADHD and his/her caregivers. Although these behavioral interventions are impactful, they are elaborate and can be challenging for families to implement and maintain. This complexity provides opportunities to envision how information and communication technologies might play a role in long-term behavior change and maintenance.

In particular, by examining the ways in which behavior-change is distributed across people, artifacts, and time, we see substantial differences in the potential for tools to support behavior during training as opposed to the weeks and months following training. As a necessary step to reduce the complexity of the behavior program for easy instruction and initial implementation, the training activities tend to treat the parent and child as a dyad. This dyad, in turn, uses their newly acquired social skills, strategies, and behavioral tools to manage ADHD and improve their relationship. Long-term implementation, however, requires evolution of activities and involvement of additional people, places, and tools.

The ecosystem surrounding long-term behavioral maintenance has two general characteristics. First, as in initial program implementation, the parent-child dyad strongly relies on each other and holds each other accountable. In this stronger tie, the child moved from practicing skills to actively participating in maintaining the behavioral charts-with parental consent. Second, the new ecosystem includes a larger set of people as part of the family structure, with more than one caregiver supporting the interventions, and more than one child being subject to the intervention.

The new ecosystem has multiple members-each with distinct roles. Each member interacts with one another (parents interact with other parents, children interact with other children, and parents interact with children). The number of relationships grows quickly with the addition or more people (two people have only one relationship to worry about and three people three relationships, but four people have six relationships, and six people have 16 relationships to maintain!). At the same time, each family member interacts with behavioral charts and other artifacts across different timeframes and spatial locations.

Addressing the needs of this ecosystem means technologies should offer different types of support for different types of users. For example, technologies should be designed for people who directly received the training as well as those who did not.

Families are complex structures with spoken and unspoken norms, power structures, and other organizational considerations [154]. Thus, technological tools for support must include notions of varying privileges for acting on and views of data. Additionally, individual family members will likely have varying levels of knowledge and understanding about the behavioral intervention, as well as varying levels of motivation and capabilities to implement it. Thus, technologies must support and encourage consistency through education and training as well as incentive structures and rules.

4.7 Conclusions

Shared knowledge, transmission of knowledge, distributed problem-solving, and the use of behavioral tools all help families manage ADHD. Using a distributed cognition framework to analyze design opportunities for family-based behavioral training, we see how these shared cognitive activities are distributed across people, artifacts, and time in the current system, highlighting opportunities for collaborative, mobile, and intelligent technological supports.

By making the unit of analysis the family, we identify the ways in which the quantified family differs from and is similar to the quantified self and even the larger quantified us. This work contributes to a growing literature that speaks to designing for a collaborative ecosystem of "users." In particular, this paper moves the perspective of personal health to one where family and individual health needs are the product of family members working together. As clinical, psychological, and educational interventions increasingly connect members of a household, technologies must support this interconnected and interdependent approach.

4.8 Acknowledgements

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Chapter 5

Designing to Deliver Parenting Strategies In Situ

5.1 Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is a hyperkinetic psychiatric condition. It is one of the most diagnosed in school-age children with an estimated prevalence of up to 11% [206]. Children with ADHD experience challenges in maintaining attention, forming and holding goals, and cognitive control [16]. One of the most promising treatments to help children with ADHD is Parental Behavioral Therapy (PBT). PBT gives parents the skills to manage and teach their children behavioral strategies that focus on self-control. It is an approach that includes both parents and children as part of the behavior-change process.

Figure 5.1. Behavioral strategy on phone and peripheral display

Additionally, it reduces parental stress and increases parental confidence. However, the barrier to its success is adherence, primarily for two reasons [217]. First, ADHD is hereditary, which means parents could be struggling with ADHD themselvesmost likely undiagnosed [69]. Second, parents of children with ADHD experience higher rates of anxiety, depression, and stress, which affect their ability to regularly practice PBT strategies [171].

There is an opportunity for technology to increase adherence to PBT. This work explores how to detect when parents are experiencing high levels of stress to provide contextually situated PBT strategies. To detect stress, we used Electrodermal Activity (EDA) as a proxy because changes in EDA represent physiological expressions of arousal. We focused on in situ support due to its potential to have long-term behavior-change benefits [116]. To understand familial needs and usage in real-world settings, we developed *ParentGuardian*, a working prototype deployed with 10 families over 14 days. This is the first study of in situ technological behavioral support for parents within the ecosystem around the child and not behavioral support for the child itself.

5.2 Related Work

5.2.1 Health sensing technologies

A variety of mobile and/or sensor-based technologies have focused on encouraging and supporting healthy behaviors [1, 104]. In particular, in the mental health space, research has focused on collecting rich data with the goal of monitoring, recollection, self- and automatic assessment of valleys in mental health episodes [15, 115, 176]. These systems have focused on easing the process of self-monitoring by automatically detecting activity or behavior, with in situ feedback [176]. Our research explores detecting stressful situations in the home to deliver PBT strategies to parents in moments of needs. Offering in situ support in moments of needs allows us to explore the intersection of *in situ* support and *teachable moments* [116] for families as an ecosystem. Our goal is to help parents in stressful situations by presenting strategies in context that lead to long-term behavior-change in the child.

In addition to exploring the concept of teachable moments in the context of detecting stressful situations and provide coping strategies, our work is also grounded on Ecological Momentary Intervention (EMI), where a system should be able to assess and offer just-in-time prompting for behavior-change [163]. Mobile Heart Health and Mobilize! explored how to offer mental health support when an undesired mental state was detected [29, 144]. We contribute to this space in two ways. First, we explore how to offer *in situ* PBT support based on a physiological proxy for stress, using Electro-Dermal Activity data. Second, we examine a novel format for the delivery of such a strategy.

5.2.2 Leveraging electrodermal activity as a physiological indicator of stress

To detect stressful moments, we explored changes in EDA. Wearable EDA sensors detect changes in skin conductance. The sensor provides a sensitive and convenient way of measuring high physiological arousal associated with stress, as it can be worn conveniently on the wrist [172].

The work using EDA has mainly focused on controlled experiments, pattern recognition and understanding what representative features of different types of signal should be used by machine learning algorithms to automatically detect changes in arousal and therefore, mental state. The work by Hernandez et al. categorized different types of calls with respect to the stress level manifested by the call center staff with the goal of offering pertinent management techniques [85].

AffectAura explored how to monitor emotional wellbeing by visualizing emotional states and allowing users to reflect and understand what circumstances led to positive and negative affect. In this project, one of the sensors used as input to detect stress was EDA [137]. Similarly, FEEL, a work-in-progress system, explored correlating EDA readings with mobile-phone social interactions. The goal of FEEL is to offer insight between users' activities and their corresponding physiological responses [11]. We seek to push this concept forward by using EDA to identify stressful situations and offer support *in situ*. Additionally, we explore how PBT could help in the heat of the moment with parents and their children.

5.3 Designing for ADHD Family Dynamics

Designing for families with ADHD is particularly challenging, because parents need help the most when under duress. Consider the following scenario derived from our data:

Melissa and Peter are parents of two children, and both children are in the early grades of elementary school, one of them diagnosed with ADHD. The pressures of raising children coupled with the struggles of coping with ADHD have led to increased stress and depression for Melissa. By attending sessions with a behavioral therapist, both parents and children were taught strategies for self-control, self-awareness, and positive and effective communication. Melissa understands the benefits of practicing these strategies with her children; however, she struggles to remember and be mindful of them. It is especially difficult for her during her evening 'rush hour'–the time she is simultaneously helping her children with homework and extracurricular activities, preparing dinner, and staying on schedule that leads to bedtime. Add to the hectic evening, a child struggling to focus, loses patience quickly, and struggles to not fall off of the chair. Melissa struggles to implement these strategies regularly. This sense of failure increases her stress. She wishes there was a way to remind herself of these strategies in moments of need.

Addressing all the needs presented in this scenario is difficult. We therefore focused on exploring how to deliver PBT strategies when a high level of stress was detected from the parent. We developed *ParentGuardian*, a mobile/peripheral display application designed to intervene with illustrative suggestions upon stress detection. The following sections explain how we designed around the strategies and the components of *ParentGuardian*.

5.3.1 Designing the interventions

We chosen the intervention strategies to use based on collaborations with psychologists and behavioral therapists focusing on ADHD and PBT [114] (see Table 5.1 and 5.2). Strategies fell into two categories: heat-of-the-moment and reflective. Heat-of-the-moment (Table 5.1) strategies suggest actions to take during moments of duress, such as, pausing before re-engaging in an argument with the child. Thus, we chose to trigger these when negative affect is detected in parents. The goal behind these strategies is to help parents become more mindful, resist negative emotional reaction, communicate effectively, and help teach self-control by example.

Table 5.1. Heat of the Moment Strategies

Heat of the moment strategies
Fill your lungs with air: Take three full, deep breaths
Silently count down from 5. Imagine each number changing colors.
Do you need a cool out? Disengage, walk away, take a 5 minute break.
You are your child's role mode. What do you want to teach?
Is my child pushing my buttons right now? How can I respond in a different way?
Stop, Look, and Listen.
Stay focused on the present, here and now, task at hand.
Choose self-control, over out of control.

Reflective strategies (Table 5.2) can be practiced at any time, and come in the form of reminders rather than actions. For instance, a reflective strategy might remind a parent to acknowledge the child's good behavior when the moment arises.

Illustrations are paired with the text of the strategy to create bidirectional associative links between 'seeing' and 'doing' over time [88]. Also, affect plays a role in learning and emotional response [105]. Therefore, after repeated reminders of the images linked to PBT strategies, it is possible to weaken the initial reaction and change the rebound effect such that parents, instead of reacting negatively, are mindful of the coping strategy to use [191]].

5.3.2 Designing in partnership with parents

Prior to the two-week deployment study, we met with parent participants to gain feedback on the strategies selected, their representations, and design ideas. During these sessions we discussed the combinations of the PBT intervention text and representative images sketched by a graphical designer. This approach ensured that the abstract,

Table 5.2. Reflective Strategies

	Reflective Strategies (Categorized by themes)
Modeling Behavior	Model what you want to see You are your child’s role mode. What do you want to teach? When your child wants to show you something, show interest and ask questions. It means a lot to them. Give your child lots of physical affection – children often like hugs, cuddles, and holding hands.
Planning for Consistent Behavior	Act, don’t react. What is my plan for this situation? (What to do and say). Be consistent. Be predictable. Be prepared. Let your child know what the consequences will be if they misbehave. Have realistic expectations. All children misbehave. If you’re upset, delay the consequences until you can act on it with full reason. This also gives your child time to reflect on the incident and what the consequence should be.
Acknowledgment of positive behavior	For every one bad thing you say, find 3 good points to highlight. It’s okay to have strong negative feelings. It’s what we DO with these feelings in the moment that matters. Accept that you are not perfect and will make mistakes. Allow yourself “redos.” Think about one positive thing your child did today. None of us are perfect parents. Be kind to yourself. Give your child descriptive praise when they do something that you would like to see more often, e.g., ”Thank you for doing what I asked straight away”. Give yourself time to unwind, every week treat yourself to something you enjoy.

graphical representation matched the text and could be supported in both a mobile interface and a hands-free, peripheral display. We met with all ten parents individually, with each session lasting one hour.

During these discussions, parents noted a preference for the representation of the strategy without the text on the peripheral display. Therefore, we intentionally removed the text from the version for the peripheral display. The phone application's version however, contained both, as this was considered the primary delivery channel.

For privacy concerns, parents did not want audio or video recorded, even if it was just to detect features such as speech prosody for stress detection, not actual word recognition. Thus, we relied solely on the wearable EDA bracelet to detect stress. Parents were also debriefed on what data we would collect, how we would protect their privacy and by whom (the experimenters), and how the data would be analyzed.

Due to the limits of a four-hour battery life for the system, we could only explore a specific time of the day. Parents expressed there were two periods in the day that were high stress with their children: during the morning routine of getting their kids to school and the evening, which includes homework time, extracurricular activities, dinner, and bedtime. We chose the latter for our study as it gave us a larger window of time to explore interventions–6pm to 10 pm. In future work, we plan to explore other times of the day.

5.4 System Components

ParentGuardian is a four-part system: a mobile phone, a peripheral display, an Electro-Dermal Activity (EDA) wristband sensor, and a cloud service for back-end data analysis. The system was designed based on our goals and the needs expressed by our participants. Figure 5.2 shows a diagram of the system.

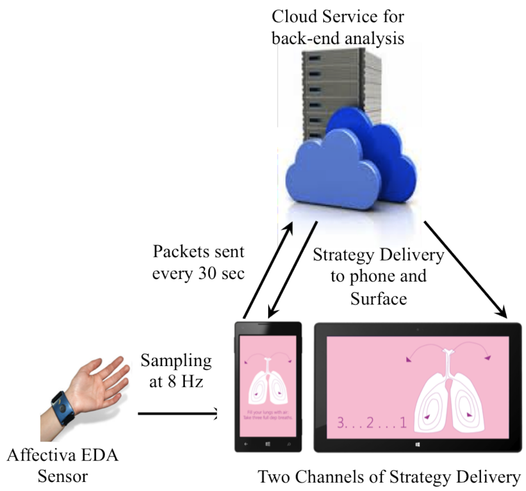

Figure 5.2. Components of ParentGuardian

5.4.1 Two channels of strategy delivery

The EDA wearable sensing technology collects data but does not include a display. Therefore, we chose two channels to deliver PBT strategies: the mobile phone and a peripheral display. The following sections explain their functionality and purpose.

Mobile Phone Application

The mobile Microsoft Windows Phone 8 application allows parents to review strategies at any time and place. Through this delivery channel parents view both reflective and heat-of-the-moment strategies with accompanying text as often as desired (see Figure 5.3). First, the phone application prompts parents to report their emotions approximately every 1.5-2 hrs (prompts can be ignored), and then to review both types of strategies. To avoid predictability of the strategies, the strategies presented after self-reporting appear in random order. Second, it connects to the EDA sensor via Bluetooth and streams data to a cloud service for analysis. Third, it delivers a heat-of- the moment strategy when a high level of negative arousal is detected.

Figure 5.3. Examples of strategies on phone: heat of the moment (left), reflective strategy (right)

We used the self-reports as ground truth for training our machine learning algorithms. In this version, there was no relationship between the self-report and which strategies appeared after self-reporting. In the future, we plan to explore leveraging self-reports to present pertinent PBT strategies.

The self-reporting tool used is based on Russell's Circumplex model, widely used across the affective computing community [137, 181]. The emotion is represented as two dimensions. The x-axis represents valence and the y-axis represents arousal. We used Negative to Positive to describe valence (x-axis) and High Energy to Low Energy to describe arousal (y-axis) as this was easier terminology for our users to understand.

Hands-Free Strategy Delivery

The peripheral display was built for Microsoft Surface RT tablet devices. The peripheral display is a direct response to parent reports of the need for a form of strategy delivery that could easily be viewed without having to look at their phones during the evening “rush hour”. The idea was also grounded on the usefulness of glanceable displays and findings on the typical distance between users and their phone [60, 161].

To follow the model explained in 5.3.2, the peripheral display presents the associated strategy illustration without the text. During idle moments it acts as a live picture frame showing images of landscapes around the world. When stress is detected, it delivers the same heat-of-the-moment strategy as the phone (see Figure 5.4). The illustration appears for 20 minutes.

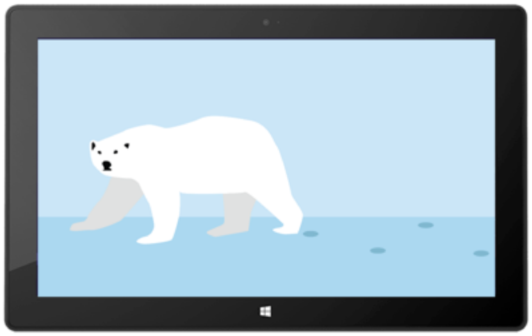

Figure 5.4. Examples of strategies on phone: heat of the moment (left), reflective strategy (right)

5.4.2 Sensing valence as a proxy for stress

The Affectiva Q Sensor [1](see Figure 5.2), which measures EDA along with accelerometer and body temperature , detects high states of arousal in parents using the *ParentGuardian* system. Data streamed from the sensor to the phone is then forwarded to a cloud service for analysis. The sampling rate was 8 Hz and features for machine learning were calculated on a 15-minute moving window. For each window, the system extracts multiple features: a count of data points, local min, max, mean, and the area of the signal's curve above the 75^{th}, 90^{th}, 95^{th}, 99^{th} percentile.

During this deployment, we used these features as input to an in house implementation of the Multiple Additive Regression Trees (MART) learning algorithm. MART is an efficient implementation of the gradient tree boosting method for predictive data mining (regression and classification) [70, 71]. The algorithm attempts to predict the state of valence (positive or negative) if the user were to self-report at that instant of time. In our current version, however, we cannot accurately predict the degree of valence, only if it is positive or negative.

[1]http://qsensor-support.affectiva.com/

Our MART algorithm was trained using EDA and self report data from a prior study with a different set of users [129]. We used 10-fold cross validation with the participant ID as a stratification key. When we first trained and tested this configuration, it resulted in a 91% accuracy rate. However, that accuracy was due to the participants from the previous study mainly self-reporting with positive valence (approximately 91% of the time), which resulted in the algorithm predicting positive valence every time. We tackled this weakness by balancing the data before using it to train. We balanced the data by stratifying the self-reports into 5 buckets based on the degree of valence they self-reported (x-axis of the 2x2 circumplex model). Taking the count of self-reports from the largest bucket we randomly duplicated self-reports in each of the smaller buckets until each bucket had the same number of self-reports. This process forced the learning algorithm to find other ways to detect negative valence and resulted in an accuracy rating of 78% using the 10-fold cross validation. We realize this is a weakness in our algorithm, so before we run another longitudinal study of *ParentGuardian*, we plan to collect and train on the parents' data to improve our detection.

Using the model explained above, if the algorithm predicted that the user would self-report as "negative valence" then our system sent an intervention to both the mobile phone application and the peripheral display. To prevent redundant interventions we restricted triggering interventions to only occur once every 20 minutes.

5.5 Two-Phase Study

The two-week deployment study was conducted in two phases, each lasting 7 days. During the first phase, parents used *ParentGuardian* without the sensor. This stage focused on self-reporting and familiarization with the tool. In the second phase, parents used the version of *ParentGuardian* with the wearable EDA sensor.

5.5.1 Participants

Ten parents participated in the study, 8 of them were mothers, with an average age of 38.4. For this study we focused on only one of the parents. All families were two-parent homes, with, on average, two children per household, all in the k-12 grades. To recruit the families, we used the ADHD assessment questionnaire [9]. Parents could complete the questionnaire for as many of their children as they desired. The questionnaires assessed the degree of ADHD behavior. The questionnaire included cut-off values by gender and age for what is considered ADHD behavior. We lowered the cutoff values slightly for the sake of the exploratory study. Participants were provided with three gratuities: one for the first brainstorming meeting, a second at the end of phase 1, and a third at the end of phase 2. Informed consent was collected.

5.5.2 Phase 1: Interventions without sensor

This phase allowed parents to familiarize themselves with the system and allowed researchers to gain insights on sending a coping strategy hourly instead of using EDA data to decide when to trigger an intervention. *ParentGuardian* consisted of the mobile phone and the peripheral display. They used the mobile phone to self-report and review both types of strategies during the day. The acts of self-reporting and gazing at intervention suggestions only took about a minute.

In the evenings, a heat-of-the-moment strategy was delivered simultaneously to the mobile application and peripheral display on an hourly basis from 6 pm to 10 pm. The order of the strategies was chosen at random to keep the content fresh and interesting (plus, one size never fits all).

At the start of week 1, we visited their homes for a tutorial on how to use the application and what to expect when a heat of the moment strategy was delivered to both the phone and the peripheral display. Parents were allowed to place the peripheral display at a location that was convenient for viewing. They chose location where they spend most of their evening hours, these were: the living room, kitchen, or family room.

5.5.3 Phase 2: Using EDA to detect stress

At the start of week 2, a home-interview took place to learn how our tool was supporting the behavioral strategies. We also updated the application and trained parents on how to wear the EDA sensor bracelet and to wear it between 6 pm and 10 pm.

In this phase, parents used the full version of *ParentGuardian*. Arousal data was collected from the EDA sensor worn by one of the parents. This data was streamlined and used by our machine learning algorithm to detect when to send an intervention. A heat-of-the-moment strategy was delivered simultaneously to the mobile application and the peripheral display based on detected need. Due to the novelty of the technology there were moments when signal was lost. Therefore, we sent one heat-of-the-moment strategy towards the end of the evening if no EDA readings were received throughout the entire evening, that way parents could experience at least one peripheral intervention. We randomly chose one of the nine interventions from Table 1.

Due to limited battery-life of both the phone and the sensor, the Bluetooth pairing had to be done manually by the user. If the sensor disconnected for more than 10 minutes between 6 and 10 pm, a notification would appear on the phone as well as on the peripheral display to remind parents to reconnect the phone with the EDA sensor. This was a major limitation in our study and is a problem for any wearable sensor today, but should be acknowledged. This did happen for some parents and it appeared in our logs.

At the end of week 2, a final interview took place to understand the feasibility and usefulness of triggering interventions based on detected arousal.

5.6 Results

We collected multiple types of data to help us understand the effectiveness and usefulness of our system. We collected approximately 220 hours of EDA data, and 60 hours of data were lost due to technical failures. On average, our system delivered a coping strategy twice per evening.

Due to the complexity and novelty of *ParentGuardian*, parent participants sometimes encountered false-positive prompting or were not prompted during moments of duress with their children (false negatives). However, false positives tended to be reported as “obvious” to parents and easily dismissed. Nonetheless, when *ParentGuardian* triggered a true positive intervention, parents stated the *in situ* awareness was profound.

On average, parents self-reported 3 times per 4-hour session. Parents found the self-reports inconvenient. Conversely, they also stated that it reminded them to be mindful of their mood, something they would not ordinarily do before.

We collected qualitative data via semi-structured interviews, log data around application use, and subjective data of users’ opinions and beliefs about the prototype. Transcripts of the interview were analyzed using grounded theory techniques to allow for themes to arise bottom up. The interviews took place in the home and included some observations. The following sections discuss findings from both phases.

5.6.1 Subjective Ratings

Parents completed subjective questionnaires at the end of each phase (see Table 3 INSERT). In general, parents rated the usefulness of the reminders to enter their mood, and the usefulness of the strategies and the display positively. Ratings at the end of phase 2 dropped, given that they had switched to automatic interventions based on EDA, but usefulness of the strategies was rated more positively in the second week. This is an interesting finding in itself as it suggests that contextual *in situ* support is more useful than hourly reminders.

With respect to the peripheral display, ratings of its usefulness went down the second week (see Table 3 5.3). Parents described their growing dissatisfaction as being related to the placement of the peripheral display, often not in the place most needed at the time of the intervention. Despite these challenges, the peripheral display did help parents recover from intervention cues missed on the phone. Thus, there is a need for more research on the best means for delivery of strategies in the context of the home.

At the end of phase 2, we also asked parents about the overall experience of using *ParentGuardian*. Using a scale of 1=not at all, 7=extremely), we asked them how effective the application was in helping them cope in the heat of the moment, and their response was positive (average=5.1). When asked how useful the strategies were, both in general and when presented in the heat of the moment, (both averages=5.1), they were equally positive.

Parents told us that they thought ParentGuardian was useful for learning coping strategies (average=5.1). There was no significance difference in self-report mood ratings between weeks 1 and 2.

5.7 Insights about Affect-Cued Interventions

In the following sections we highlight insights gained from the study. These insights offer future design opportunities for situated cues for parental support within the family ecosystem.

5.7.1 Benefits of Situated Support

Despite the need to increase our accuracy on detecting stress, parents found the just-in-time interventions profound. The in situ cues made parents aware of their physical

Table 5.3. Subjective Ratings

		Phase 1	Phase 2
Q1	How useful was the hourly reminder to enter your mood self-rating?	4.6	3.8
Q2	How useful were the strategies you went through after the self-report?	3.4	4.1
Q3	How easy was it to remember the intervention associated with an image when the displayed on the surface?	5.1	3.9
Q4	How easy was it to see the display in the room?	6.3	3.7
Q5	How useful was the display in reminding you of the strategies?	4	2.9
Q6	On a scale of 1-3 (1=once, 2=2-4, 3=5 or more times) how often did you visit the manually application daily?	1.3	0.8

and mental state. This awareness helped them recover more swiftly from the situation than otherwise.

> I heard my phone "ding" and I was too busy to answer it but I knew what it was and I visualized some of the prompts, mostly the "modeling" one and I went about my business then Patricia who has little messes all over the kitchen was asked to clean up after herself [...] well in this process of her cleaning she somehow is creating more messes for me and in the past I usually snap at her out of frustration but ... I didn't!!! I calmly explained how this makes more work for me and asked her to please focus on one mess at a time and get them cleaned up. It was so well received by her and I'm so proud of myself! Hopefully I can continue in this positive way.

$<$PG4, mother of two $>$

Parents also discussed how these situated cues have the potential to help them identify their stress triggers with respect to their children. Additionally, they expressed the potential to help them trace back their steps to learn how to avoid getting into the same undesired situation of duress.

> Like it made me aware of that I need to handle my stress differently. It made me aware of exactly which steps I'm taking to get me to be really stressed out, so it's like self-awareness. If you're stressed and you're screaming at people, you don't understand what's going on. You don't have time to understand what's going on, but if you're aware of the fact that you're stressed and first time it dings at you, you're like, "Oh, okay, I got it," and the next time, like a couple times, you're almost anticipating it to happen. Then you're controlling what you're doing up to that point, [...]

$<$PG6, mother of one $>$

These findings highlight the potential to further explore affect-based cues to delivery PBT strategies designed in conjunction with behavior-change concepts such as Ecological Momentary Interventions and Teachable Moments [20, 25]. Furthermore, unlike this study, health sensing has focused on applying the concepts mentioned above to design technology through the lenses of the individual in need. There is potential to explore how to design for these concepts from the perspective of indispensable stakeholders for behavior-change, in our case, the parents.

5.7.2 Trigger interventions earlier, during the escalation of stress

While real-time detection and prompting has the potential to improve adherence to PBT, the timing of the cue is crucial.

> It's not that you're stressed immediately, like you're super calm sit and drink your tea and then you're stressed the next second. It just builds up. Maybe a lot of people don't make a conscious effort and obviously, before I started paying attention to it, I wasn't making a conscious effort to control it. Maybe, if it's possible, to be able to tell you that you're getting there slightly earlier [...]"

<PG6, mother of one >

Parents expressed that, when prompted before detecting a full escalation of stress, they were more receptive to the intervention strategy. Delivering a prompt at the peak of negative affect is potentially too late to recover.

> It was more like, when you're really tired and you're really grumpy, and somebody says, 'oh, somebody must be tired.' So, I'm all upset trying not to yell at my son, and my son's throwing a little hissy-fit [...] And my husband walks in and shoves the cool down app in front of my face, and I'm like, "[...], get that out of my face."

<PG8, mother of three >

Detecting escalating stress levels is a technical challenge to explore in future work, as it requires identifying features that identify a moderate increase in the physiological signals instead of features that represent peaks of negative affect. The dynamics of stress builds quickly over time, and then after a certain point, it is too late. It is key to intercede while the level is increasing.

5.7.3 Learning moments are different from training moments

Presenting strategies in detected moments of duress is not sufficient for learning and instilling the connection between moment of need and the strategy. Even though parents found situated interventions valuable, learning and reflecting on the strategies should occur in different moments.

> To be honest, when you are in the middle of that kind of rush hour in the evening when I'm trying to get homework done [...], I just don't have the time at that rush, in that little hour to keep scrolling through the pages and looking through them.
>
> <PG5, mother of three >

Because ParentGuardian proactively reminded parents to review these strategies regularly, parents used the in situ cue to quickly view the prompted coping strategy but focus on coming back to a calm state to tackle the task at hand with their children.

> Once you start reading through them and once you get to the point where you've memorized them all, they are in the back of your head. It is kind of always with you, but there has to be that physical reminder or something that triggers it otherwise you might just forget.
>
> <PG3, mother of three >

5.7.4 Finding training moments

There are times when parents are more able to familiarize themselves with both types of strategies. For example, during idle times, such as in the early morning before the kids are awake, sitting during the child's extracurricular activities, or waiting in the car, parents in this study took advantage of the free moment to glance through instructional information.

> Because that's the time when your brain actually is free to think of other things. When you're racing against time during the evening stress hours, it didn't help as much.

<PG5, mother of three >

Even though all parents considered the regular self-reporting mechanism to assess mood and review strategies a nuisance after two weeks, the system's regular reminders simulated the concept of detecting idle moments. Parents benefited from these reminders in two ways. First, they reminded parents to reflect and review the strategies when they received them during idle moments. Second, if the self-report prompt appeared before diving into a known stressful situation, it helped parents assess their mood and remind them of the toolbox of strategies at their disposal.

> Yeah, in the car, waiting for the kids to come out of school. I know that David is going to be hyper, and I know he's going to be on-edge, and I know there's going to be something negative that happened at school, because these are givens with him. So, having the thing pop up and say, 'can I help you?' and me picking through them and saying, 'OK, I'll take three deep breaths.'

<PG8, mother of three >

Interestingly, our data shows parents did not open the mobile application on their own (i.e., without the prompt). There is an opportunity here to explore how to provide situated cues that remind parents to self-assess their mood and remind them of the strategies by expanding tools such as Place-Its or Dey's work [52], [190]. Exploring how to extend these tools in this manner could alleviate the nuisance of time-based self-assessment.

5.8 Limitations of the Study

There are four major limitations of this work. First, wearable EDA sensors are only capable of collecting and streaming data via Bluetooth. The sensors used in this study do not provide visual feedback about the state of pairing. Thus, we lost data intermittently as parents struggled to understand when the phone and the device were properly paired. Second, the sensor does not offer any form of user interaction. Therefore, we delivered the intervention through ParentGuardians mobile phone application and a peripheral display. In the future, we plan to explore the strengths and weaknesses around delivering strategies through an interface on the wearable sensing device itself and the two delivery channels we explored in this study. Third, after analyzing our data we learned our users tended to self-report with a higher rate of negative valence than the users we used to train our machine learning algorithm. Hence, parents reported that our detection algorithm missed negative affect moments that could have resulted in an intervention. In the future we need to train the algorithms with the actual users in order to personalize the intervention timing. Fourth, we have since learned how to better analyze EDA signals for stress detection. We plan to continue improving our detection methods in future work. That being said, we believe the system served as a legitimate probe to gain realistic insights on designing for the particular needs of parents under stress.

5.9 Conclusions

Parents are central to the education of their children, particularly when those children have significant behavioral challenges. However, due to the likelihood of parents living with neurodevelopmental disorders themselves and consequently elevated levels of stress, adhering to behavioral therapy strategies is difficult. Grounded on concepts from behavior-change and stress coping, this work focused on detecting high levels of stress in order to deliver parental behavioral therapy strategies.

This work demonstrates that in situ cues, such as those offered by ParentGuardian, can remind parents to implement these strategies during moments of need. However, the timing of the cue is crucial. Thus, systems to support parents coping with stress must detect peaks of negative valence as well as the escalation of a stressful situation.

Despite the demonstration of both feasibility and the potential for efficacy in this study, significant open questions remain. First, beyond in situ cues, there are other teachable moments in the day that can and should be leveraged. Future work should explore detecting idle moments for proactively prompting parents to reflect on and learn PBT strategies. Second, detecting negative valence based on EDA signals accurately still has a long way to go. Once the sensor suite and the algorithms are refined, a longer-term study is called for.

This work and the novel design of ParentGuardian focused on an unexplored component of the family ecosystem. We explored how to offer support to the parents in a way that benefits both the parents and the children. Additionally, this work provides a powerful case study for understanding how technology might support all of the members of a family, whose mental and physical health are intimately linked.

5.10 Acknowledgments

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Chapter 6

Conclusions

In this dissertation we explored how an ecological approach can be used as a framework for improving design analysis of health tracking systems. We investigated the approach by discussing different health concerns through the ecology in which they take place. Each chapter discussed a particular health concern, the ecological method used to analyze the problem, and the insights gained from addressing the health concern from an ecological perspective. These chapters have demonstrated the importance of taking an ecological approach, how to designed for an ecology, and what we learned from this approach. This closing chapter first presents a reflection and discussion with respect to each chapter in ecological terms, second discusses ecological takeaways based on insights from the four chapters collectively.

6.1 SMART: user-driven tracking for weight-loss

Chapter two discussed the results of a two-year deployment of an EMA user-driven tracking system, called SMART. This study evaluated how college students used a suite of mobile applications, including applications that reminded users to track, to attend to their health. SMART represents one of the largest and longest running randomized control studies on the impact of mobile technology applications and personal health. Perhaps one of the key takeaways of SMART is that losing weight and then keeping it off remains difficult for most people, as evidenced by the fact that at the end of the two year study, the average weight for individuals in both the treatment and control groups did not change.

This chapter used an ecological perspective to analyze how participants used user-driven tracking technologies with respect to their health practices, tracking skills, knowledge about their own health and how to address their health concerns, and the social norms of their daily lives.

Using this framework we learned the following. First, the efficacy of reminders is related to when during the day they are sent: reminding participants to track their step count at the end of the day, if they were not reminded at the beginning of the day to wear the pedometer, is not useful.

Second, in terms of skills for tracking caloric intake and expenditure, we identified that users need a requisite level of skill in order to track accurately. Furthermore, participants require an even greater level of self-monitoring skill if they are to reflect on their tracked habits and identify which steps to take next. This type of reflection is an important aspect of self awareness and it seems as if the introduction of technology alone does not reduce the learning curve that is associated with it.

Future systems can improve their performance if they can address the following barriers users faced when using SMART applications: time management, planning, transition users from coarse tracking to fine-grain caloric tracking, guidance on effective exercises based on participant's level of fitness. We found that if participants are not familiar with all of the necessary events that need to occur before to the act of tracking, then participants will not be able to track their habits.

Future systems can also improve their performance if they can design self-monitoring systems that can help users throughout the tracking process. In particular, systems can identify users level of experience and expertise in self-monitoring and adjusting the systems tracking based on users knowledge and experience in self-monitoring. Future research needs to explore how to customize tracking and integrate as part of the process of tracking guidance on how to plan, rearrange, and re-prioritize the user's life such that she can create the conditions to eat healthier meals and exercise at the level she feels confident doing.

6.2 Unbound: decreasing sedentary bouts at the workplace

Chapter three focused on Unbound, a system designed to address problem of sedentary behavior of office based employees. Office workers experience a tension between attending to their health and attending to their job related duties, and we incorporated this tension into Unbounds design. To do so, we centered the ecology on the office worker and her practices, which are bounded by the socio-cultural norms and the existing digital and physical artifacts of the workplace, a process discussed below. We began by studying how office worker navigated this tension prior to the introduction of Unbound. We examined the current practices office workers have around taking breaks and the tools they used to assist them. We learned, for instance, that even though our participants were aware of the benefits of taking short breaks, they struggled to remember to do it on their own. Another finding was that office workers used purely time-based artifacts to help them to take breaks; one of the shortcomings of these artifacts is that they do not consider whether the user took a break on her own. We also learned that the set of tools officer workers used tend were often disruptive to participants' workflow and a distraction to their coworkers. For example, some artifacts were noisy or they would freeze participants' computer screen thus making it difficult for users to productively work. Finally, we learned that even though these participants own a smart mobile phone, at work participants tend to turn the sound of their phone off and put away their phone in an office drawer; this behavior made it difficult to leverage participants' smart phones when designing a system.

After conducting this observational study, we created two important design requirements. First, we wanted to create a system that was aware of participants' movements so that Unbound would only remind participants to take a walking break after it detected a prolonged and continuous sedentary bout. This design requirement would reduce the frequency of unnecessary prompts to the user. Second, it was important to keep Unbound's reminders from being overly disruptive, but they had to be disruptive enough so that they were visible to the user. Based on these requirements we build an EMI system that uses sensor-driven data from a digital pedometer. Unbound detected, in real-time, continuous sedentary bouts and sent a reminder to take a walking break to users if it detected a prolonged stretch of sedentary behavior. Unbound delivered the intervention to participants' monitor–where participants' attention was already focused on. The notification appeared as a small bar at the bottom of the monitor, for 15 seconds, and then disappeared. This system was designed to minimize the number of unnecessary reminders and to be visible, yet not disruptive, to both the user and her co-workers.

From Unbound's initial deployment, we learned that the reminders were repurposed by users in a manner that was different from what we had hypothesized. Originally, we thought that the first reminder – at 45 minutes of continuous sitting – would be the nudge where participants would take action to take a break. Instead, participants used the first reminder as a cue to finish their current task in order to take a break 15 minutes later, when the second reminder arrived. Users also reported that taking walking breaks helped them become more efficient with time management and productive. This was in contrast to participants initial concern that Unbound would be distract from work. Finally, participants were pleasantly surprised that despite the notifications appearing on their screen, the notifications were very private: coworkers did not notice when they received the reminder or when they walked away for a short 5-minute walk. These positive findings aside, there were two important barriers to use that we uncovered. First, office works were worried about violating social-cultural norms in the office. These norms affected their ability to reduce sedentary bouts because participants felt that they could not stand or pacing during long group meetings, for example. Second, participants ignored all reminders when they were working under tight deadlines.

6.3 Designing for family-based behavioral training

Chapter four focused on designing systems for families completing a behavioral training program. This program teaches parents and children a set of skills that helps them address challenges children (and parents) who have Attention Deficit Hyperactive Disorder (ADHD) experience. In this intense, 3-month training, a parent and child dyad participates twice a week group training sessions. During these sessions, both the parent and child learn the same set of skills and strategies, but the lessons are tailored to each differently. At the end of this program, both the parent and child are equipped with a set of skills and behavioral strategies, but in practice they depend on each other to make the program sustainable at home. When families attempt to implement these lessons into their home, other caregivers and family members begin to play an important role in implementing these skills, even though they were not explicitly trained to do so. In short, despite all of the potential benefits of participating in this training program, families find it difficult to maintain and adhere to it in the long term.

To uncover the barriers of maintaining such a program in the home, and to understand how to appropriately design a tool to help implement this program, we centered the ecology around the collaboration and cognition between family members and existing cognitive artifacts used in maintaining this behavioral program.

In this study we learned that:

- Parents do not track their childrens behavior all at once. Tracking actually occurs in small steps over a period of time, and behaviors occur in variety of uncontrolled and fast paced situations. Given that parents are often multi-tasking and that they are often in the midst of a fast-paced environment, they only have time to make a few quick annotations. These annotations serve as a reminder to complete the tracking of a particular behavior later. Currently, these micro-tracking steps are difficult to achieve. To address these needs future digital artifacts should support these different types of tracking.

- Related to the above tension, we highlighted how different types of digital artifacts have different affordances and should be not be used over the other. Smaller digital artifacts, such as the mobile phone, should present the most important information for a particular context; overviews and detailed views of all behavior data should be presented in a similar artifact as used by families currently, like a wall-size behavior chart.

- In order for this behavioral training to be successful, multiple caregivers and family members need to collaborate with one another. This type of collaboration means that family members are tracking data about themselves, in addition to tracking behavior about other family members. However, family members have different roles within the family and differing levels of expertise across many domains.

6.4 Designing for in situ support for families at home

Chapter five is an extension of the previous chapter as it focuses on situations where parents, who are under a lot of stress, struggle with how to recall specific coping mechanisms when they are in a moment of duress with their children. To design for this particular issue, we focused the ecology on moments of duress between parents and children at home. To identify when to deliver a coping behavioral mechanism, we used an ElectroDermal Activity sensor and built a sensor-driven EMI system to infer moments of stress and then deliver interventions.

By placing moments of duress at the center of the ecology and defining the borders of the ecology by the practices and locations of families at home, we identified the key places where parents needed support and the type of system they required. Parents needed a form of portable, mobile support, and a form of hands-free support for the shared spaces such as the kitchen and the living room. To address this we delivered the intervention in two ways: we delivered coping strategies to the parent's phone and also to a peripheral display that parents could place wherever they wanted. Additionally, even though only one parent was wearing the sensor, we delivered the intervention to both parents if they were interested. We supported this last option because some parents told us that usually they rely on each other during moments of duress, but sometimes it is difficult to communicate feelings during these moments.

In this study we learned that:

- Parents in this study needed support right *before* the peak of negative affect; delivering the intervention during peak moments is too late.
- Parents preferred to learn about the strategies during idle moments of their day, such as, when they are in the car waiting to pick up their children from school at the end of the day. This indicates that systems need to take into account the users broader schedule and make her idle moments more productive for learning.

6.5 Takeaways

These studies have put the act of tracking at the center of the ecology, though the precise ecological lens differs by the problem at hand. From this perspective we can see that tracking is: a sequence of events over time, distributed through multiple contexts, and bounded by social settings. To explore the key insights from this dissertation further, we explore them from three different dimensions: temporal, social, and contextual. The following sections discuss viewing tracking from these three dimensions.

6.5.1 Temporal dimension: Designing beyond the moment of tracking

We observed that the act of tracking though is more than a singular activity. Instead, it occurs in four steps over an extended period of time. These related steps are: **moments of learning**, **moments of enablement**, **moments of action**, and **moments of reflection**. Figure 6.1 shows the order of these four events.

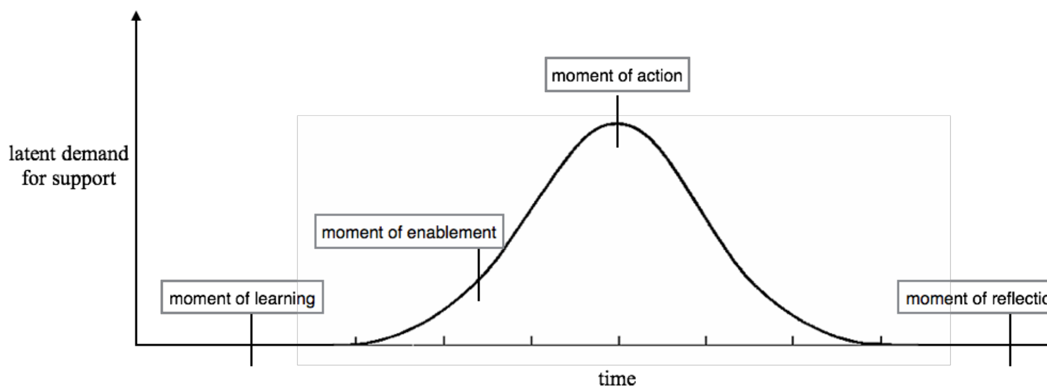

Figure 6.1. Temporal relationship between different moments of interactions

To explain why the act of tracking decomposes into multiple steps that need to be accounted for when designing systems, let us review some of the lessons learned from the studies presented in this dissertation. With SMART, we learned that participants needed help before and after tracking. In Unbound, we found that users used the systems first reminder to take a break as a cue to prepare for their actual break which would take 15 minutes later. In the case of families with children with ADHD, and in particular when parents are experiencing moments of duress, we found that parents needed support *right* before the moment of peak duress, and not during it.

These examples demonstrate how the act of tracking one's behavior actually consists of steps over time. The act of tracking contains multiple smaller events that lead up to the **moment of action** and in fact, go beyond.

A **moment of learning** is one where users are able to learn or review the concepts and strategies, concepts that are related to the behavior they wish to track, before they need to put them into practice. In these moments, users are able to absorb the information without having to make a particular decision or take some sort of action. In the case of SMART, participants were interested in learning about which foods to favor and which foods to avoid. With respect to exercise, participants wanted to learn what workout routines were appropriate for their fitness level. In the case of ParentCoach and our qualitative study on families, families wanted to review behavioral strategies *before* they actually need to put them into practice with their kids. In the case of families, these moments of learning, ideally, should occur in situations that are temporally connected to their children, such as waiting at their child's pediatrician's waiting room.

A **moment of enablement** is one where a reminder or intervention is actually delivered to a user; in the case of user-driven tracking, it is when the planning (or preparation) for tracking occurs. The moment of support occurs before an action takes place. Delivering support leading up to the moment of action rather than at the moment of action can help the user prepare to take action before the crucial moment occurs.

In the case of Unbound and ParentCoach, the **moment of enablement** is when the in situ support is delivered. Unbound's first nudge served as an advance notice. Unbound users use the time between the first and the second reminder to prepare to take a break, then, when the second nudge appears users are either ready to take a break or decide to wait another 45 minutes to receive a new reminder to take a break. In the case of ParentCoach, parents desired that the coping strategy be delivered *before* the peak of negative affect. For our parent participants, delivering at the peak of negative affect was too late: they were not at an aware state to digest the strategy and put the strategy into action. Participants in the SMART study experienced a similar situation. These participants were not able to track if they had not planned for the meal they were going to consume. Participants needed help planning meals and help with selecting the foods to buy and prepare at home. Additionally, they needed help with planning their workout times and their workout routines.

A **moment of action** has been the target of most mobile tracking applications. This moment occurs when the user tracks or acts on the reminder or intervention that was delivered to her. In the case of Unbound, the second reminder was when participants took a break, this was the actual moment of action. In the study of families, this is when they would put into practice the strategy delivered or when they would track the particular behavior of focus on the wall-chart, or reward a good deed with positive reinforcement.

A **moment of reflection** comes after the moment of action. Moments of reflection are ones when the user reflects on previously tracked data. These moments of reflection are enabled by the visualizations and summarizations created by these tracking systems. During these moments, participants seek to identify what were areas of improvements and what remains to be improved. Additionally, participants want to identify what the next steps to take are in order to prepare to start the cycle of tracking all over again. Moments of reflection have been explored in this space through visualizations and representations of the data tracked, such as, Ubifit Garden [1], and Spark [60] (discussed in Chapter 1). Identifying the next steps to take is a place we identify still needs further research; participants in our studies struggled to identify what are the next steps.

It is important to highlight that tracking is a long-term, cyclical process. The timeline shown in Figure 6.1 repeats itself. This cross-sectional image repeats itself and each of these steps represents multiple iterations on the same steps. For example, learning about healthier food options or about behavioral skills will take users multiple iterations and therefore, there will be multiple **moments of learning**. Furthermore, as part of the cyclical behavioral of tracking, selecting the next steps to tackle during the **moment of reflection** is important as it defines what the material is to learn during **moments of learning**, which also defines what will be delivered during **moments of enablement** and what will be the focus during **moments of action**, and last, what will be reflected on during the **moments of reflection**.

6.5.2 Context Dimension: Designing adaptively for different contexts

Now that we see that tacking occurs over multiple steps over time, it further becomes apparent that these smaller steps occur across a variety of contexts. Furthermore, we can see that even one of these moments such as the moment of action (in user-driven systems being the moment of tracking) decomposes into micro-tasks, or tasklet [25], [100]. Micro-tasking describes a small portion of an activity undertaken in situations characterized by limited available attention [2]. Furthermore, micro-tasking recognizes how uses carry out short and intermittent tasks that together become a completed task [100]. In this work, micro-tasking occurred in the form of *micro-tracking*, meaning that one step of tracking could start in one context and then completed in a second, separate context.

We observed there is a discontinuity that interrupts micro-tracking. In our analysis in Chapter 4, we identified how family members did not have a behavioral tracking system that is portable and accessible everywhere. Currently, their data resides statically on a wall-chart at home. A small set of the parents would make notes on their phone in one moment and then update the wall chart with this information when they arrived at home. Making a phone note is a form of micro-tracking, though this micro-track does not transfer to the wall-size chart at home. This means that parents have to remember to review their phone in order to update the wall-chart when they arrive home. This can be cumbersome and time consuming as parents have to rewrite the information on the wall-chart (and time is a valuable commodity for parents). That said, the form of quick note taking that took place is appropriate for the fast-paced, on the go context these parents regularly experience. A similar type of support can be thought of with tracking for weight-loss (discussed in 2): users can use a simple form of tracking while in transient situations and then transfer this information to a richer means of tracking when they arrive home. This two-step activity demonstrates how a single act of tracking occurs in more than one context, and that each micro-tracking activity can occur on a different artifact appropriate for the context. As this dissertation demonstrates, the current set of tools do not support micro-tasking.

One of the reasons people micro-task is because there are many situations where their attention is limited [25]. Because users' attention itself may be limited, the granularity of information captured or presented also needs to be simple, focused, and on point. As we discussed in Chapters 4 and 5, parents needed different levels of information granularity depending on the context in which they were in. Outside of their homes, parents needed a way to quickly review which strategies are appropriate for particular settings or which behaviors they should focus on tracking. For these mobile, fast pace circumstances parents wanted a simple, quick view of the behaviors they were focusing on tracking or behavioral strategy to use at that moment. When parents are at home (especially during the evening when they are helping their kids with homework, cooking, or spending time together in the living room) they can handle a larger picture, bird's eye view of the data. At home, parents wanted to view their current state of tracking with respect to the entire week or the entire month. Similarly, when delivering strategies parents preferred the delivery to be through a hands-free form of interaction when they were at home.

Similarly, in Chapter 2 we saw how in social events participants wanted a simple form of capturing information in a socially acceptable manner [47]. Afterwards, participants wanted a means to convert this high level of tracking to a detailed, caloric level value. However, the current set of tools make it difficult for participants to translate an image of food its caloric value.

Looking at all the steps and micro-tasks that together lead to tracking and self-monitoring, future work needs to support these different types of mechanisms. Weiser's view of ubiquitous technology highlights exactly this point: depending on the context and task, a different physical form factor should be supported [210].

6.5.3 Social Dimension: Designing adaptively for varying roles

In addition to tracking and self-monitoring occurring in multiple steps over time or in different contexts, the steps and micro-tasks can also be distributed across people, where a group of people collaborate on completing a particular self-monitoring task. In this dissertation, this type of collaborative tracking was discussed in Chapters 4 and 5 with respect to family members supporting each other towards maintaining a behavioral program.

In families, each parent and child had specific roles, skills, and knowledge. These differences are especially visible in the case of the family-based behavioral training we discussed in this dissertation. In our discussion, the parent and child that completed the behavioral program obviously understood how to maintain the program better than the family members (e.g, other caregivers, siblings) who did not attend training. When the training transitioned from the classroom and toward maintenance at home, other caregivers and siblings wanted to participate and contribute, but struggled to do so. In the current state of the tools, collaboration was difficult for other caregivers and siblings because their artifacts were not prepared for secondhand learners. For example, the untrained parent learning secondhand needed a different representation of the behavioral data; this parent also contributed parental effort differently than the parent that attended training. Similarly, child participation was encouraged and desired. Having children contribute to the tracking process means that the tasks around tracking and capturing behavior needed to be appropriate for the cognitive level of the child, as well as restricted to the level of access parents desire.

Like in WIISARD where data from emergency situations was displayed differently depending on the type of medical emergency personnel (e.g., doctors, firefighters, police) [34], different perspectives, interactions, views, and practices should be allowed based on the type of family member. In other words, collaborating family members need to share information, but view it from a different perspective. The same behavioral data needs different views and forms of interactions with respect to the type of family member (e.g. user). Furthermore, supporting the act of tracking as a set of smaller tasks that can include multiple members will also address and improve the issues around transfer and hand-off between caregivers– a similar problem that also occurs in hospitals [5].

6.5.4 Designing for Long-Term Evolution of the Tracking Ecology

So far, we have focused the ecology around the act of tracking and have demonstrated that the act of tracking actually decomposes and is distributed across time, contexts, and social settings. The discussion up to this point has focused on the day-to-day ecological aspects around tracking. Changing the focus of the ecology from day-to-day tracking to long-term tracking brings other issues to the surface. Addressing health concerns in the long-term requires restructuring, reorganizing, and reprioritizing activities that address the health concerns over other daily activities. Furthermore, self-monitoring and tracking is an iterative learning process that will be refined and acquired as the user continues to self-monitor.

Reorganizing and restructuring means the user's ecology will change. For example, the user will need to manage her time differently, prioritize activities and tasks related to her health concern, and change the setup of her environment. In tandem to reorganizing there is a process of learning how to self-monitor and track. Learning how to track means first, learning how to address the health concern, second, understand how and what to track, and third, reflect on the behaviors captured to identify the next steps.

These changes with respect to both restructuring and learning occur in stages. As the user navigates through the process of learning and restructuring, new challenges and needs arise. To shed light on these longer-term ecological changes, we present vignettes drawn from insights presented in this dissertation. We offer two vignettes, one from the beginner's perspective and another from a more experienced tracker. The first vignette is based on insights from Chapter 2 and Chapter 3.

Meet Ana, she is interested in losing weight, owns a smart mobile phone and finds mobile tracking applications appealing to help her track her weight, calories consumed, and calories expended. She understands that she needs to track the meals she is consuming as well as how much she exercises. The mobile application estimates caloric values for each activity. Furthermore, based on information she received, she understands that preparing meals at home is better than eating at restaurants. However, she quickly begins to struggle. First, she notices how she has not made the time to prepare home-made meals and that takeout makes it difficult identify how many calories she has consumed. She wants to lean on homemade meals but when she tries to cook she notices she needs to go to the grocery store and did not make time to go to the grocery store and cook. Furthermore, when she cooks at home she still finds it difficult to track the portion of all the ingredients she consumed compared to the portion of ingredients used for the entire recipe. Even when she eats meals prepared at home, she is still unsure if she is *eating the ingredients to maximize her allotted calories. With respect to exercise, she is also struggling, she does not know how to maximize her exercise time or how to track calories burned through exercise. With these challenges, more uncertainty comes. How does she address each of these steps? Does she have to address them all at once? How does she learn how to cook healthier recipes? Are all calories equal? Ana is feeling overwhelmed, the tracking application is not helping her tackles all these issues that precede the act of tracking.*

The issues described in the above vignette represents the multiple obstacles that need to be addressed before being able to track habits related to weight-loss, such as food and exercise. Ana struggled to track because of issues indirectly related to tracking, such as time management and not knowing how to cook meals that are healthy and satisfying. However, the current tools are not designed considering these issues. Ana, a tracking beginner, needs different support compared to a user that has found time to exercise regularly and understands how to track homemade cooked meals. With the issues presented, future work needs to address how to design for tracking beginners. Furthermore, designing for tracking beginners is the first step, as Ana acquires the set of indirect skills that will allow her to track she will then need help refining her skills around exercise and diet. Therefore, these tracking artifacts will need to evolve with Ana's understanding of self-monitoring and tracking.

The next vignette is based on insights from Chapter 4 and Chapter 5. This vignette discusses the experience of a user after tracking regularly. We used a different setting to illustrate how, regardless of the health concern, similar barriers around skill refinement and reorganizing occur.

Meet Carla, she is Allen's mother. Carla and Allen attended 3-months of the behavioral training. This program helped them improve their communication, taught them to empathize with each other, and how to tackle together behavioral challenges Allen *experiences. During the training phase the clinicians instructing the classes helped Carla identify what are the behaviors to focus on and track. Every week Carla would apply topics to track with respect to the behaviors she and Allen were focusing. Furthermore, at the next session Carla would get feedback on how she was tracking and new topics of tracking to focus on. When the program ended, Carla and Allen were motivated to continue using all the tools and strategies at their disposal. A few months pass, they have reached a plateau. They are trying to maintain the weekly and daily behavioral charts, as well as the reward token system for good behavior but they are not gaining new insights. After some time has passed, she is struggling, she is using the behavioral weekly and daily charts, however, they have plateaued. Carla and Allen have been tracking the same behaviors but they feel like they are not making progress. They are struggling to identify from the all behaviors being tracked across charts what has improved and what remains to be improved. Both Carla and Allen recognize it is time to focus on new behavioral aspect and revamp the tools to tackle new behaviors, especially as Allen is maturing.*

In the above vignette, Carla and Allen had overcome some of the beginner's tracking challenges describe in Ana's story. Carla and Allen are now at the point that they understand the basics of tracking, but they are struggling with refining their skills and identifying what needs to be rearranged. The artifacts used by Carla and Allen are not helping them identifying which are areas of improvements and which are not. In addition to these artifacts not distilling information to highlight accomplishments and behaviors that remained to be improved, Allen is maturing. As Allen mature issues he had before fade away, and new ones come to the fore. This scenario demonstrates how even though Carla and Allen are tracking, they have very different needs compared to Ana and the stage of tracking she is in.

These two scenarios represent trackers at different stages of tracking. At each stage there is a different need, a different level of expertise, and different set of challenges to overcome. To address the challenges at each stage, the user will (consciously or not) modify her existing ecology. As the user adapts her ecology, tracking artifacts need to adapt as well. At each stage, tracking systems need to support the user with respect to the level of expertise and experience around tracking. Addressing these different stages would help in two ways. First, it would help the user set reasonable expectations for the particular stage she is in. Setting expectations is important as trackers tend to experience failure because they set unattainable goals. Second, transitioning through different phases means the user will want to track at different levels of granularity, and the tracking artifacts will need to allow for more course, or fine, tracking granularity. Creating tracking tracking artifcts that adapt to the user's current stage will help make tracking sustainable.

Last, these stages evolve and are cyclical, the moments of tracking discussed in Section 6.5.1 and shown in Figure 6.1 will iteratively repeat themselves at every stage–will the difference the the skills, needs, and goals will be different. During these cyclical stages the user will struggle and will need support during setbacks. Designing for setbacks is another form of adaptability, tracking systems will need to consider how to support a user motivated but failing to track. Tracking systems will not only need to adapt when the user is moving forward but also when she experiences setbacks. Future work should explore how to design and address failure to track, and how to support users reengaging with the system and tracking.

6.6 Concluding remarks

This dissertation has contributed to the space of Human-Computer Interaction by examining how to design personal health technologies from a perspective that considers a broader set of factors compared to previously work, which tends to focus on the relationship between the user and the tracking technology. This dissertation has highlighted how sustainable use of personal health technologies to track and self-monitor factors such as, knowledge, time, social environments, physical environments, and in general, the user's context must be considered. This dissertation contains design guidelines to consider in future designs of personal tracking technologies.

Bibliography

[1] Flowers or a robot army?: encouraging awareness & activity with personal, mobile displays. In *Proceedings of the 10th international conference on Ubiquitous computing*, pages 54–63. ACM, 2008.

[2] *New Oxford American Dictionary*. Oxford University Press, 2014.

[3] Saeed Abdullah, Mark Matthews, Elizabeth L. Murnane, Geri Gay, and Tanzeem Choudhury. Towards circadian computing. In *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing - UbiComp '14 Adjunct*, pages 673–684, New York, New York, USA, September 2014. ACM Press.

[4] H. Abikoff. Cognitive Training in ADHD Children: Less to It Than Meets the Eye. *Journal of Learning Disabilities*, 24(4):205–209, April 1991.

[5] Joanna Abraham and Madhu C Reddy. Challenges to inter-departmental coordination of patient transfers: a workflow perspective. *International journal of medical informatics*, 79(2):112–22, February 2010.

[6] Piotr D. Adamczyk and Brian P. Bailey. If not now, when? In *Proceedings of the 2004 conference on Human factors in computing systems - CHI '04*, pages 271–278, New York, New York, USA, April 2004. ACM Press.

[7] Adrian Aguilera and Frederick Muench. There's an App for That: Information Technology Applications for Cognitive Behavioral Practitioners. *The Behavior therapist / AABT*, 35(4):65–73, April 2012.

[8] Adrienne Andrew, Gaetano Borriello, and James Fogarty. Toward a systematic understanding of suggestion tactics in persuasive technologies. In *Proceedings of the 2nd international conference on Persuasive technology*, PERSUASIVE'07, pages 259–270, Berlin, 2007. Springer-Verlag.

[9] Adrienne Andrew, Gaetano Borriello, and James Fogarty. Simplifying Mobile Phone Food Diaries. In *Proceedings of the ICTs for improving Patients Rehabilitation Research Techniques*, pages 260–263. IEEE, May 2013.

[10] Atsunori Ariga and Alejandro Lleras. Brief and rare mental breaks keep you focused: deactivation and reactivation of task goals preempt vigilance decrements. *Cognition*, 118(3):439–443, 2011.

[11] Yadid Ayzenberg, Javier Hernandez Rivera, and Rosalind Picard. FEEL: frequent EDA and event logging – a mobile social interaction stress monitoring system. pages 2357–2357–2362–2362, May 2012.

[12] William J. Barbaresi, Robert C. Colligan, Amy L. Weaver, Robert G. Voigt, Jill M. Killian, and Slavica K. Katusic. Mortality, adhd, and psychosocial adversity in adults with childhood adhd: A prospective study. *Pediatrics*, 2013.

[13] Jakob E. Bardram. Activity-based computing: support for mobility and collaboration in ubiquitous computing. *Personal and Ubiquitous Computing*, 9(5):312–322, January 2005.

[14] Jakob E. Bardram. Activity-based computing for medical work in hospitals. *ACM Transactions on Computer-Human Interaction*, 16(2):1–36, June 2009.

[15] Jakob E. Bardram, Mads Frost, Károly Szántó, Maria Faurholt-Jepsen, Maj Vinberg, and Lars Vedel Kessing. Designing mobile health technology for bipolar disorder. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '13*, page 2627, New York, New York, USA, April 2013. ACM Press.

[16] Russell A. Barkley. Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological bulletin*, 121(1):65–94, 1997.

[17] Jared Bauer, Sunny Consolvo, Benjamin Greenstein, Jonathan Schooler, Eric Wu, Nathaniel F. Watson, and Julie Kientz. ShutEye. In *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems - CHI '12*, page 1401, New York, New York, USA, May 2012. ACM Press.

[18] Oscar Beijbom, Neel Joshi, Dan Morris, Scott Saponas, and Siddharth Khullar. Menu-match: Restaurant-specific food logging from images. In *Winter Conference on Applications of Computer Vision (WACV)*, 2015.

[19] Frank Bentley and Konrad Tollmar. The power of mobile notifications to increase wellbeing logging behavior. pages 1095–1095–1098–1098, April 2013.

[20] Frank Bentley, Konrad Tollmar, Peter Stephenson, Laura Levy, Brian Jones, Scott Robertson, Ed Price, Richard Catrambone, and Jeff Wilson. Health Mashups. *ACM Transactions on Computer-Human Interaction*, 20(5):1–27, November 2013.

[21] John E Blundell, RJ Stubbs, C Golding, F Croden, R Alam, S Whybrow, J Le Noury, and CL Lawton. Resistance and susceptibility to weight gain: individual variability in response to a high-fat diet. *Physiology & behavior*, 86(5):614–622, 2005.

[22] Susanne Bø dker. When second wave HCI meets third wave challenges. In *Proceedings of the 4th Nordic conference on Human-computer interaction changing roles - NordiCHI '06*, pages 1–8, New York, New York, USA, October 2006. ACM Press.

[23] Susanne Bø dker and Clemens Nylandsted Klokmose. Dynamics in artifact ecologies. In *Proceedings of the 7th Nordic Conference on Human-Computer Interaction Making Sense Through Design - NordiCHI '12*, page 448, New York, New York, USA, October 2012. ACM Press.

[24] Thomas Boleyn and Morteza Honari. *Health Ecology: Health, culture and human-environment interaction*. Routledge, 2005.

[25] Joel Brandt, Noah Weiss, and Scott R Klemmer. Designing for limited attention. Computer science technical reports [online], Stanford University, 2007.

[26] Dena M Bravata, Crystal Smith-Spangler, Vandana Sundaram, Allison L Gienger, Nancy Lin, Robyn Lewis, Christopher D Stave, Ingram Olkin, and John R Sirard. Using pedometers to increase physical activity and improve health: a systematic review. *JAMA : the journal of the American Medical Association*, 298(19):2296–304, November 2007.

[27] Eric Brunner, Maneesh Juneja, and Michael Marmot. Dietary assessment in whitehall ii: comparison of 7 d diet diary and food-frequency questionnaire and validity against biomarkers. *British Journal of Nutrition*, 86(03):405–414, 2001.

[28] Lora E Burke, Molly B Conroy, Susan M Sereika, Okan U Elci, Mindi A Styn, Sushama D Acharya, Mary A Sevick, Linda J Ewing, and Karen Glanz. The effect of electronic self-monitoring on weight loss and dietary intake: A randomized behavioral weight loss trial. *Obesity*, 19(2):338–344, 2011.

[29] Michelle Nicole Burns, Mark Begale, Jennifer Duffecy, Darren Gergle, Chris J Karr, Emily Giangrande, and David C Mohr. Harnessing context sensing to develop a mobile intervention for depression. *Journal of medical Internet research*, 13(3):e55, January 2011.

[30] Regina Bussing, Faye A Gary, Terry L Mills, and Cynthia Wilson Garvan. Parental explanatory models of ADHD: gender and cultural variations. *Social psychiatry and psychiatric epidemiology*, 38(10):563–75, October 2003.

[31] Pierre Chandon and Brian Wansink. The biasing health halos of fast-food restaurant health claims: lower calorie estimates and higher side-dish consumption intentions. *Journal of Consumer Research*, 34(3):301–314, 2007.

[32] Josephine Y Chau, Hidde P van der Ploeg, Jannique G Z van Uffelen, Jason Wong, Ingrid Riphagen, Genevieve N Healy, Nicholas D Gilson, David W Dunstan, Adrian E Bauman, Neville Owen, and Wendy J Brown. Are workplace interventions to reduce sitting effective? A systematic review. *Preventive medicine*, 51(5):352–6, November 2010.

[33] Yunan Chen, Victor Ngo, and Sun Young Park. Caring for caregivers. In *Proceedings of the 2013 conference on Computer supported cooperative work - CSCW '13*, pages 91–102, New York, New York, USA, February 2013. ACM Press.

[34] Octav Chipara, William G Griswold, Anders N Plymoth, Ricky Huang, Fang Liu, Per Johansson, Ramesh Rao, Theodore Chan, and Colleen Buono. Wiisard: a measurement study of network properties and protocol reliability during an emergency response. In *Proceedings of the 10th international conference on Mobile systems, applications, and services*, pages 407–420. ACM, 2012.

[35] Eun Kyoung Choe, Nicole B. Lee, Bongshin Lee, Wanda Pratt, and Julie A. Kientz. Understanding quantified-selfers' practices in collecting and exploring personal data. In *Proceedings of the 32nd annual ACM conference on Human factors in computing systems - CHI '14*, pages 1143–1152, New York, New York, USA, April 2014. ACM Press.

[36] Andrea M. Chronis, Anil Chacko, Gregory A. Fabiano, Brian T. Wymbs, and William E. Pelham, Jr. Enhancements to the Behavioral Parent Training Paradigm for Families of Children with ADHD: Review and Future Directions. *Clinical Child and Family Psychology Review*, 7(1):1–27, March 2004.

[37] Andrea M Chronis, Benjamin B Lahey, William E Pelham Jr, Stephanie Hall Williams, Barbara L Baumann, Heidi Kipp, Heather A Jones, and Paul J Rathouz. Maternal depression and early positive parenting predict future conduct problems in young children with attention-deficit/hyperactivity disorder. *Developmental psychology*, 43(1):70, 2007.

[38] Jeff Coates, Ted Davis, and Ray Stacey. Performance measurement systems, incentive reward schemes and short-termism in multinational companies: a note. *Management Accounting Research*, 6(2):125–135, 1995.

[39] Heather Cole-Lewis and Trace Kershaw. Text Messaging as a Tool for Behavior Change in Disease Prevention and Management. *Epidemiologic reviews*, March 2010.

[40] Molly B. Conroy, Nancy R. Cook, Joann E. Manson, Julie E. Buring, and I-Min Lee. Past physical activity, current physical activity, and risk of coronary heart disease. *Medicine and science in sports and exercise*, 37(8):1251–1256, 2005.

[41] S. Consolvo and M. Walker. Using the experience sampling method to evaluate ubicomp applications. *IEEE Pervasive Computing*, 2(2):24–31, April 2003.

[42] Sunny Consolvo, Katherine Everitt, Ian Smith, and James A. Landay. Design requirements for technologies that encourage physical activity. In *Conference on Human Factors in Computing Systems, CHI*, 2006.

[43] Sunny Consolvo, James a. Landay, and David W. McDonald. Designing for Behavior Change in Everyday Life. *Computer*, 42(6):86–89, June 2009.

[44] Sunny Consolvo, David W. McDonald, and James A. Landay. Theory-driven design strategies for technologies that support behavior change in everyday life. In *Proceedings of the 27th international conference on Human factors in computing systems - CHI '09*, page 405, New York, New York, USA, April 2009. ACM Press.

[45] Sunny Consolvo, David W. D.W. McDonald, Tammy Toscos, M.Y. Mike Y. Chen, Jon Froehlich, Beverly Harrison, Predrag Klasnja, Anthony LaMarca, Louis LeGrand, Ryan Libby, Others, Ian Smith, and James A. Landay. Activity sensing in the wild: a field trial of ubifit garden. In *Proceeding of the twenty-sixth annual SIGCHI conference on Human factors in computing systems*, pages 1797–1806, New York, New York, USA, April 2008. ACM.

[46] Felicia Cordeiro, Elizabeth Bales, Erin Cherry, and James Fogarty. Rethinking the Mobile Food Journal. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI '15*, pages 3207–3216, New York, New York, USA, April 2015. ACM Press.

[47] Felicia Cordeiro, Daniel A. Epstein, Edison Thomaz, Elizabeth Bales, Arvind K. Jagannathan, Gregory D. Abowd, and James Fogarty. Barriers and Negative Nudges. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI '15*, pages 1159–1162, New York, New York, USA, April 2015. ACM Press.

[48] Andy Crabtree and Tom Rodden. Hybrid ecologies: understanding cooperative interaction in emerging physical-digital environments. *Personal and Ubiquitous Computing*, 12(7):481–493, March 2007.

[49] Mary Czerwinski, Eric Horvitz, and Susan Wilhite. A diary study of task switching and interruptions. In *Proceedings of the 2004 conference on Human factors in computing systems - CHI '04*, pages 175–182, New York, New York, USA, April 2004. ACM Press.

[50] Saskia Dantzig, Gijs Geleijnse, and Aart Tijmen Halteren. Toward a persuasive mobile application to reduce sedentary behavior. *Personal and Ubiquitous Computing*, July 2012.

[51] David Dearman and Jeffery S. Pierce. It's on my other computer! In *Proceeding of the twenty-sixth annual CHI conference on Human factors in computing systems - CHI '08*, page 767, New York, New York, USA, April 2008. ACM Press.

[52] Anind K Dey. Understanding and Using Context. *Personal and Ubiquitous Computing*, 5(1):4–7, 2001.

[53] William H. Dietz. The spread of the obesity epidemic in the united states. *Journal of the American Medical Association*, 282, 1999.

[54] Tara Donker, Katherine Petrie, Judy Proudfoot, Janine Clarke, Mary-Rose Birch, and Helen Christensen. Smartphones for smarter delivery of mental health programs: a systematic review. *Journal of medical Internet research*, 15(11), 2013.

[55] Glen E Duncan, Sumner J Sydeman, Michael G Perri, Marian C Limacher, and A Daniel Martin. Can sedentary adults accurately recall the intensity of their physical activity? *Preventive Medicine*, 33(1):18–26, 2001.

[56] K Elfhag and S Rössner. Who succeeds in maintaining weight loss? a conceptual review of factors associated with weight loss maintenance and weight regain. *Obesity reviews*, 6(1):67–85, 2005.

[57] Rhian E Evans, Henrietta O Fawole, Stephanie a Sheriff, Philippa M Dall, P Margaret Grant, and Cormac G Ryan. Point-of-choice prompts to reduce sitting time at work: a randomized trial. *American journal of preventive medicine*, 43(3):293–7, September 2012.

[58] William J Evans and Nicholas P Hays. All calories are not equal. *Archives of internal medicine*, 165(9):1069–1069, 2005.

[59] Gunther Eysenbach. The impact of the internet on cancer outcomes. *CA: A Cancer Journal for Clinicians*, 53(6):356–371, 2003.

[60] Chloe Fan, Jodi Forlizzi, and Anind K. Dey. A spark of activity. In *Proceedings of the 2012 ACM Conference on Ubiquitous Computing - UbiComp '12*, page 81, New York, New York, USA, September 2012. ACM Press.

[61] S V Faraone, A E Doyle, E Mick, and J Biederman. Meta-analysis of the association between the 7-repeat allele of the dopamine D(4) receptor gene and attention deficit hyperactivity disorder. *The American journal of psychiatry*, 158(7):1052–7, July 2001.

[62] Leon Festinger. *A theory of cognitive dissonance*, volume 2. Stanford university press, 1962.

[63] Nick V Flor and Edwin L Hutchins. A case study of team programming during perfective software maintenance. *Empirical studies of programmers: Fourth workshop*, page 36, 1991.

[64] Bj Fogg and Enrique Allen. 10 Uses of Texting To Improve Health. In *Proceedings of the 4th International Conference on Persuasive Technology - Persuasive '09*, page 1, New York, New York, USA, 2009. ACM Press.

[65] Brian J Fogg. Persuasive technology: using computers to change what we think and do. *Ubiquity*, 2002(December):5, 2002.

[66] Centers for Disease Control and Prevention. Prevalence of regular physical activity among adults–united states, 2001 and 2005. *MMWR. Morbidity and mortality weekly report*, 56(46):1209, 2007.

[67] Centers for Disease Control and Prevention, 5 2015.

[68] Jodi Forlizzi. How robotic products become social products. In *Proceeding of the ACM/IEEE international conference on Human-robot interaction - HRI '07*, page 129, New York, New York, USA, March 2007. ACM Press.

[69] Christine M Freitag. The genetics of autistic disorders and its clinical relevance: a review of the literature. *Molecular psychiatry*, 12(1):2–22, 2007.

[70] Jerome H Friedman. Greedy function approximation: a gradient boosting machine. *Annals of statistics*, pages 1189–1232, 2001.

[71] Jerome H Friedman. Stochastic gradient boosting. *Computational Statistics & Data Analysis*, 38(4):367–378, 2002.

[72] Jon Froehlich, Mike Y. Chen, Sunny Consolvo, Beverly Harrison, and James A. Landay. MyExperience. In *Proceedings of the 5th international conference on Mobile systems, applications and services - MobiSys '07*, page 57, New York, New York, USA, June 2007. ACM Press.

[73] Nicholas D Gilson, Alessandro Suppini, Gemma C Ryde, Helen E Brown, and Wendy J Brown. Does the use of standing hotdesks change sedentary work time in an open plan office? *Preventive medicine*, 54(1):65–67, 2012.

[74] Erving Goffman. The presentation of self in everyday life. 1959.

[75] Eric Granholm, Catherine Loh, and Joel Swendsen. Feasibility and validity of computerized ecological momentary assessment in schizophrenia. *Schizophrenia bulletin*, 34(3):507–14, May 2008.

[76] Andrea Grimes, Desney Tan, and Dan Morris. Toward technologies that support family reflections on health. In *Conference on Supporting Group Work*, pages 311–320, 2009.

[77] Jonathan Grudin. Groupware and social dynamics: eight challenges for developers. *Communications of the ACM*, 37(1):92–105, January 1994.

[78] Marc T Hamilton, Genevieve N Healy, David W Dunstan, Theodore W Zderic, and Neville Owen. Too Little Exercise and Too Much Sitting: Inactivity Physiology and the Need for New Recommendations on Sedentary Behavior. *Current cardiovascular risk reports*, 2(4):292–298, July 2008.

[79] Rick Hanson. *Buddha's brain: The practical neuroscience of happiness, love, and wisdom*. New Harbinger Publications, 2009.

[80] V A Harpin. The effect of ADHD on the life of an individual, their family, and community from preschool to adult life. *Archives of disease in childhood*, 90 Suppl 1:i2–7, February 2005.

[81] Gillian R. Hayes, Karen G. Cheng, Sen H. Hirano, Karen P. Tang, Marni S. Nagel, and Dianne E. Baker. Estrellita. *ACM Transactions on Computer-Human Interaction*, 21(3):1–28, June 2014.

[82] Gillian R. Hayes, JulieA. Kientz, KhaiN. Truong, DavidR. White, GregoryD. Abowd, and Trevor Pering. Designing capture applications to support the education of children with autism. In Nigel Davies, ElizabethD. Mynatt, and Itiro Siio, editors, *UbiComp 2004: Ubiquitous Computing*, volume 3205 of *Lecture Notes in Computer Science*, pages 161–178. Springer Berlin Heidelberg, 2004.

[83] G.N. Healy, D.W. Dunstan, J. Salmon, E. Cerin, J.E. Shaw, P.Z. Zimmet, and N. Owen. Breaks in Sedentary Time. *Diabetes Care*, 31(4):661, 2008.

[84] Robert A Henning, Pierre Jacques, George V Kissel, Anne B Sullivan, and Sabina M Alteras-Webb. Frequent short rest breaks from computer work: effects on productivity and well-being at two field sites. *Ergonomics*, 40(1):78–91, 1997.

[85] Javier Hernandez, Rob R. Morris, and Rosalind W. Picard. Call center stress recognition with person-specific models. pages 125–134, October 2011.

[86] Javier Hernandez and Rosalind W Picard. Senseglass: Using google glass to sense daily emotions. In *Proceedings of the adjunct publication of the 27th annual ACM symposium on User interface software and technology*, pages 77–78. ACM, 2014.

[87] Kristin E Heron and Joshua M Smyth. Ecological momentary interventions: incorporating mobile technology into psychosocial and health behaviour treatments. *British journal of health psychology*, 15(Pt 1):1–39, February 2010.

[88] Cecilia M Heyes and Elizabeth D Ray. What is the significance of imitation in animals? 2000.

[89] Sen H Hirano, Robert G Farrell, Catalina M Danis, and Wendy A Kellogg. Walkminder: encouraging an active lifestyle using mobile phone interruptions. In *CHI'13 Extended Abstracts on Human Factors in Computing Systems*, pages 1431–1436. ACM, 2013.

[90] James Hollan, Edwin Hutchins, and David Kirsh. Distributed cognition: toward a new foundation for human-computer interaction research. *ACM Transactions on Computer-Human Interaction*, 7(2):174–196, June 2000.

[91] Edwin Hutchins. The technology of team navigation. *Intellectual teamwork: Social and technological foundations of cooperative work*, 1:191–220, 1990.

[92] Edwin Hutchins. *Cognition in the Wild*. MIT press, 1995.

[93] Edwin Hutchins and Tove Klausen. Distributed cognition in an airline cockpit. *Cognition and communication at work*, pages 15–34, 1996.

[94] Hilary Hutchinson, Heiko Hansen, Nicolas Roussel, Björn Eiderbäck, Wendy Mackay, Bo Westerlund, Benjamin B. Bederson, Allison Druin, Catherine Plaisant, Michel Beaudouin-Lafon, Stéphane Conversy, and Helen Evans. Technology probes. In *Proceedings of the conference on Human factors in computing systems - CHI '03*, page 17, New York, New York, USA, April 2003. ACM Press.

[95] Brooke Ingersoll and Anna Dvortcsak. Including parent training in the early childhood special education curriculum for children with autism spectrum disorders. *Journal of Positive Behavior Interventions*, 8(2):79–87, 2006.

[96] Stephen S. Intille, Ling Bao, Emmanuel Munguia Tapia, and John Rondoni. Acquiring in situ training data for context-aware ubiquitous computing applications. In *Proceedings of the 2004 conference on Human factors in computing systems - CHI '04*, pages 1–8, New York, New York, USA, April 2004. ACM Press.

[97] Nassim Jafarinaimi, Jodi Forlizzi, Amy Hurst, and John Zimmerman. Breakaway. In *CHI '05 extended abstracts on Human factors in computing systems - CHI '05*, page 1945, New York, New York, USA, April 2005. ACM Press.

[98] Gunnar Johansson, Åsa Wikman, Ann-Mari Åhrén, GoÈran Hallmans, and Ingegerd Johansson. Underreporting of energy intake in repeated 24-hour recalls related to gender, age, weight status, day of interview, educational level, reported food intake, smoking habits and area of living. *Public health nutrition*, 4(04):919–927, 2001.

[99] David J Johns, Jamie Hartmann-Boyce, Susan A Jebb, Paul Aveyard, and Behavioural Weight Management Review Group. Diet or exercise interventions vs combined behavioral weight management programs: A systematic review and meta-analysis of direct comparisons. *Journal of the Academy of Nutrition and Dietetics*, 114(10):1557–1568, 2014.

[100] David Johnson. A platform for supporting micro-collaborations in a diverse device environment. *iJIM*, 3(4):8–16, 2009.

[101] C Johnston and E J Mash. Families of children with attention-deficit/hyperactivity disorder: review and recommendations for future research. *Clinical child and family psychology review*, 4(3):183–207, September 2001.

[102] Karen Jones, D Daley, J Hutchings, T Bywater, and C Eames. Efficacy of the incredible years basic parent training programme as an early intervention for children with conduct problems and adhd. *Child: care, health and development*, 33(6):749–756, 2007.

[103] Heekyoung Jung, Erik Stolterman, Will Ryan, Tonya Thompson, and Marty Siegel. Toward a framework for ecologies of artifacts. In *Proceedings of the 5th Nordic conference on Human-computer interaction building bridges - NordiCHI '08*, page 201, New York, New York, USA, October 2008. ACM Press.

[104] Matthew Kay, Eun Kyoung Choe, Jesse Shepherd, Benjamin Greenstein, Nathaniel Watson, Sunny Consolvo, and Julie A. Kientz. Lullaby: a capture & access system for understanding the sleep environment. In *Proceedings of the 2012 ACM Conference on Ubiquitous Computing - UbiComp '12*, pages 226–234, 2012.

[105] Elizabeth A Kensinger. Remembering emotional experiences: The contribution of valence and arousal. *Reviews in the Neurosciences*, 15(4):241–252, 2004.

[106] Rilla Khaled, Pippin Barr, James Noble, Ronald Fischer, and Robert Biddle. Our place or mine? exploration into collectivism-focused persuasive technology design. In *Persuasive Technology*, pages 72–83. Springer, 2006.

[107] Julie A. Kientz. Understanding parent-pediatrician interactions for the design of health technologies. In *Proceedings of the ACM international conference on Health informatics - IHI '10*, page 230, New York, New York, USA, November 2010. ACM Press.

[108] Julie A. Kientz, Rosa I. Arriaga, and Gregory D. Abowd. Baby steps. In *Proceedings of the 27th international conference on Human factors in computing systems - CHI 09*, page 1713, New York, New York, USA, April 2009. ACM Press.

[109] Abby C King, David K Ahn, Brian M Oliveira, Audie A Atienza, Cynthia M Castro, and Christopher D Gardner. Promoting physical activity through hand-held

computer technology. *American journal of preventive medicine*, 34(2):138–142, 2008.

[110] Predrag Klasnja, Beverly L. Harrison, Louis LeGrand, Anthony LaMarca, Jon Froehlich, and Scott E. Hudson. Using wearable sensors and real time inference to understand humana recall of routine activities. In *Proceedings of the 10th international conference on Ubiquitous computing - UbiComp '08*, page 154, New York, New York, USA, September 2008. ACM Press.

[111] Samuel Klein, Lora E Burke, George A Bray, Steven Blair, David B Allison, Xavier Pi-Sunyer, Yuling Hong, and Robert H Eckel. Clinical implications of obesity with specific focus on cardiovascular disease a statement for professionals from the american heart association council on nutrition, physical activity, and metabolism: Endorsed by the american college of cardiology foundation. *Circulation*, 110(18):2952–2967, 2004.

[112] NICHOLE HENDERSON KRISTEN PURCELL, ROGER ENTNER. The rise of apps culture, 9 2010.

[113] Kimberley D Lakes, Ryan J Kettler, Janeth Schmidt, Marche Haynes, Kelly Feeney-Kettler, Laura Kamptner, Jim Swanson, and Leanne Tamm. The CUIDAR Early Intervention Parent Training Program for Preschoolers at Risk for Behavioral Disorders: An Innovative Practice for Reducing Disparities in Access to Service. *Journal of early intervention*, 31(2):167–178, March 2009.

[114] Kimberley D Lakes, Danyel Vargas, Matt Riggs, Janeth Schmidt, and Mike Baird. Parenting Intervention to Reduce Attention and Behavior Difficulties in Preschoolers: A CUIDAR Evaluation Study. *Journal of child and family studies*, 20(5):648–659, October 2011.

[115] Nicholas Lane, Mashfiqui Mohammod, Mu Lin, Xiaochao Yang, Hong Lu, Shahid Ali, Afsaneh Doryab, Ethan Berke, Tanzeem Choudhury, and Andrew Campbell. BeWell: A Smartphone Application to Monitor, Model and Promote Wellbeing. *Proceedings of the 5th International ICST Conference on Pervasive Computing Technologies for Healthcare*, 2011.

[116] Peter J Lawson and Susan A Flocke. Teachable moments for health behavior change: a concept analysis. *Patient education and counseling*, 76(1):25–30, July 2009.

[117] Jonathan Lester, Tanzeem Choudhury, and Gaetano Borriello. A practical approach to recognizing physical activities. *Pervasive Computing*, 3968:1–16, 2006.

[118] Jonathan Lester, Carl Hartung, Laura Pina, Ryan Libby, Gaetano Borriello, and Glen Duncan. Validated caloric expenditure estimation using a single body-worn sensor. In *Proceedings of the 11th international conference on Ubiquitous*

computing - Ubicomp '09, Ubicomp '09, page 225, New York, New York, USA, 2009. ACM Press.

[119] Ian Li, Anind Dey, and Jodi Forlizzi. A stage-based model of personal informatics systems. In *Proceedings of the 28th international conference on Human factors in computing systems - CHI '10*, CHI '10, page 557, New York, New York, USA, April 2010. ACM Press.

[120] Ian Li, Anind K. Dey, and Jodi Forlizzi. Understanding my data, myself. In *Proceedings of the 13th international conference on Ubiquitous computing - UbiComp '11*, page 405, New York, New York, USA, September 2011. ACM Press.

[121] Ian Li, Anind K. Dey, and Jodi Forlizzi. Using context to reveal factors that affect physical activity. *ACM Transactions on Computer-Human Interaction*, 19(1):1–21, March 2012.

[122] Qiang Li, Gang Zhou, and John A. Stankovic. Accurate, fast fall detection using posture and context information. In *Proceedings of the 6th ACM conference on Embedded network sensor systems - SenSys '08*, page 443, New York, New York, USA, November 2008. ACM Press.

[123] Brian Y Lim, Aubrey Shick, Chris Harrison, and Scott Hudson. Pediluma: Motivating Physical Activity Through Contextual Information and Social Influence. In *TEI 2011*, pages 173–180, New York, New York, USA, 2011. ACM Press.

[124] J. Lin, Lena Mamykina, Silvia Lindtner, Gregory Delajoux, and H. Strub. Fishn-Steps: Encouraging physical activity with an interactive computer game. In *UbiComp 2006: Ubiquitous Computing*, pages 261–278. Springer, 2006.

[125] Leslie S. Liu, Sen H. Hirano, Monica Tentori, Karen G. Cheng, Sheba George, Sun Young Park, and Gillian R. Hayes. Improving communication and social support for caregivers of high-risk infants through mobile technologies. In *Proceedings of the ACM 2011 conference on Computer supported cooperative work - CSCW '11*, page 475, New York, New York, USA, March 2011. ACM Press.

[126] Yunsheng Ma, Elizabeth R Bertone, Edward J Stanek, George W Reed, James R Hebert, Nancy L Cohen, Philip A Merriam, and Ira S Ockene. Association between eating patterns and obesity in a free-living us adult population. *American journal of epidemiology*, 158(1):85–92, 2003.

[127] Lena Mamykina, Elizabeth Mynatt, Patricia Davidson, and Daniel Greenblatt. MAHI. In *Proceeding of the twenty-sixth annual CHI conference on Human factors in computing systems - CHI '08*, page 477, New York, New York, USA, April 2008. ACM Press.

[128] Gloria Mark, Daniela Gudith, and Ulrich Klocke. The cost of interrupted work. In *Proceeding of the twenty-sixth annual CHI conference on Human factors in computing systems - CHI '08*, page 107, New York, New York, USA, April 2008. ACM Press.

[129] Gloria Mark, Shamsi Iqbal, Mary Czerwinski, and Paul Johns. Capturing the mood: facebook and face-to-face encounters in the workplace. In *Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing*, pages 1082–1094. ACM, 2014.

[130] Simon J Marshall and Ernesto Ramirez. Reducing Sedentary Behavior : A New Paradigm in Physical Activity Promotion. *Building*, In Press(x), 2011.

[131] Nikke Pfarr Mattew Jordan. 04 2014.

[132] Mark Matthews and Gavin Doherty. FEATUREThe invisible user. *interactions*, 16(6):13, November 2009.

[133] Mark Matthews and Gavin Doherty. In the mood. In *Proceedings of the 2011 annual conference on Human factors in computing systems - CHI '11*, page 2947, New York, New York, USA, May 2011. ACM Press.

[134] U. Maurer, A. Rowe, A. Smailagic, and D.P. Siewiorek. eWatch: a wearable sensor and notification platform. *International Workshop on Wearable and Implantable Body Sensor Networks (BSN'06)*, pages 142–145, 2006.

[135] U. Maurer, A. Smailagic, D.P. Siewiorek, and M. Deisher. Activity Recognition and Monitoring Using Multiple Sensors on Different Body Positions. *International Workshop on Wearable and Implantable Body Sensor Networks (BSN'06)*, pages 113–116, 2006.

[136] Melissa McCracken, Ruth Jiles, and Heidi Michels Blanck. Peer reviewed: health behaviors of the young adult us population: behavioral risk factor surveillance system, 2003. *Preventing chronic disease*, 4(2), 2007.

[137] Daniel McDuff, Amy Karlson, Ashish Kapoor, Asta Roseway, and Mary Czerwinski. AffectAura. In *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems - CHI '12*, page 849, New York, New York, USA, May 2012. ACM Press.

[138] Katarina Melzer, Bengt Kayser, and Claude Pichard. Physical activity: the health benefits outweigh the risks. *Current Opinion in Clinical Nutrition & Metabolic Care*, 7(6):641–647, 2004.

[139] Gina Merchant, Nadir Weibel, Kevin Patrick, James H Fowler, Greg J Norman, Anjali Gupta, Christina Servetas, Karen Calfas, Ketaki Raste, and Laura Pina.

Click like to change your behavior: a mixed methods study of college students exposure to and engagement with facebook content designed for weight loss. *Journal of medical Internet research*, 16(6), 2014.

[140] Susan Michie, Stefanie Ashford, Falko F Sniehotta, Stephan U Dombrowski, Alex Bishop, and David P French. A refined taxonomy of behaviour change techniques to help people change their physical activity and healthy eating behaviours: the CALO-RE taxonomy. *Psychology & health*, 26(11):1479–98, November 2011.

[141] Lauren R Miller-Lewis, Peter A Baghurst, Michael G Sawyer, Margot R Prior, Jennifer J Clark, Fiona M Arney, and Josephine A Carbone. Early childhood externalising behaviour problems: child, parenting, and family-related predictors over time. *Journal of abnormal child psychology*, 34(6):891–906, December 2006.

[142] Melissa Monsey, Irina Ioffe, Angela Beatini, Betsy Lukey, Andrea Santiago, and Anne Birge James. Increasing compliance with stretch breaks in computer users through reminder software. *Work (Reading, Mass.)*, 21(2):107–111, 2002.

[143] Dan Morris, A.J. Bernheim Brush, and Brian R. Meyers. SuperBreak: using interactivity to enhance ergonomic typing breaks. In *Proceeding of the twenty-sixth annual CHI conference on Human factors in computing systems - CHI '08*, page 1817, New York, New York, USA, April 2008. ACM Press.

[144] Margaret Morris and Farzin Guilak. Mobile Heart Health: Project Highlight. *IEEE Pervasive Computing*, 8(2):57–61, April 2009.

[145] Margaret E. Morris. Motivating change with mobile. *interactions*, 19(3):26, May 2012.

[146] Margaret E Morris, Qusai Kathawala, Todd K Leen, Ethan E Gorenstein, Farzin Guilak, Michael Labhard, and William Deleeuw. Mobile therapy: case study evaluations of a cell phone application for emotional self-awareness. *Journal of medical Internet research*, 12(2):e10, January 2010.

[147] Debbie S Moskowitz and Simon N Young. Ecological momentary assessment: what it is and why it is a method of the future in clinical psychopharmacology. *Journal of Psychiatry and Neuroscience*, 31(1):13, 2006.

[148] Bonnie A. Nardi. Studying context: A comparison of Activity Theory, Situated Action Models , and Distributed Cognition. In *Context and Conciousness: Activity Theory and Human Computer Interaction*, pages 69–102. Mit Press, 1996.

[149] Melissa C Nelson, Katherine Lust, Mary Story, and Ed Ehlinger. Credit card debt, stress and key health risk behaviors among college students. *American Journal of Health Promotion*, 22(6):400–407, 2008.

[150] Carman Neustaedter, A. J. Bernheim Brush, and Saul Greenberg. The calendar is crucial. *ACM Transactions on Computer-Human Interaction*, 16(1):1–48, April 2009.

[151] Donald A Norman. *Cognitive artifacts*. Department of Cognitive Science, University of California, San Diego, 1990.

[152] Donald A Norman. *The design of everyday things: Revised and expanded edition*. Basic books, 2013.

[153] Cynthia L Ogden, Margaret D Carroll, Brian K Kit, and Katherine M Flegal. Prevalence of childhood and adult obesity in the united states, 2011-2012. *Jama*, 311(8):806–814, 2014.

[154] DAVID H. OLSON, DOUGLAS H. SPRENKLE, and CANDYCE S. RUSSELL. Circumplex Model of Marital and Family Systems: I. Cohesion and Adaptability Dimensions, Family Types, and Clinical Applications. *Family Process*, 18(1):3–28, April 1979.

[155] Wanda J Orlikowski. Learning from notes: Organizational issues in groupware implementation. In *Proceedings of the 1992 ACM conference on Computer-supported cooperative work*, pages 362–369. ACM, 1992.

[156] Antti Oulasvirta. Feature: When users ”do” the ubicomp. *Interactions*, 15(2):6, March 2008.

[157] Antti Oulasvirta and Lauri Sumari. Mobile kits and laptop trays. In *Proceedings of the SIGCHI conference on Human factors in computing systems - CHI ’07*, page 1127, New York, New York, USA, April 2007. ACM Press.

[158] Neville Owen, Eva Leslie, Jo Salmon, and Michael J Fotheringham. Environmental determinants of physical activity and sedentary behavior. *Exercise and sport sciences reviews*, 28(4):153–158, 2000.

[159] Neville Owen, Takemi Sugiyama, Elizabeth E Eakin, Paul A Gardiner, Mark S Tremblay, and James F Sallis. Adults’ sedentary behavior determinants and interventions. *American journal of preventive medicine*, 41(2):189–96, August 2011.

[160] Pablo Paredes, Ran Gilad-Bachrach, Mary Czerwinski, Asta Roseway, Kael Rowan, and Javier Hernandez. Poptherapy: Coping with stress through pop-culture. In *Proceedings of the 8th International Conference on Pervasive Computing Technologies for Healthcare*, pages 109–117. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), 2014.

[161] Shwetak N Patel, Julie A Kientz, Gillian R Hayes, Sooraj Bhat, and Gregory D Abowd. Farther than you may think: An empirical investigation of the proximity of users to their mobile phones. In *UbiComp 2006: Ubiquitous Computing*, pages 123–140. Springer, 2006.

[162] Kevin Patrick, William G Griswold, Fred Raab, and Stephen S Intille. Health and the mobile phone. *American journal of preventive medicine*, 35(2):177–81, August 2008.

[163] Kevin Patrick, Stephen S Intille, and Marion F Zabinski. An ecological framework for cancer communication: implications for research. *Journal of medical Internet research*, 7(3):e23, July 2005.

[164] Kevin Patrick, SJ Marshall, EP Davila, JK Kolodziejczyk, JH Fowler, KJ Calfas, JS Huang, CL Rock, WG Griswold, and A Gupta. Design and implementation of a randomized controlled social and mobile weight loss trial for young adults (project smart). *Contemporary clinical trials*, 37(1):10–18, 2014.

[165] Kevin Patrick, Fred Raab, Marc A Adams, Lindsay Dillon, Marian Zabinski, Cheryl L Rock, William G Griswold, and Gregory J Norman. A text message-based intervention for weight loss: randomized controlled trial. *Journal of medical Internet research*, 11(1):e1, January 2009.

[166] William E Pelham Jr, Trilby Wheeler, and Andrea Chronis. Empirically supported psychosocial treatments for attention deficit hyperactivity disorder. *Journal of clinical child psychology*, 27(2):190–205, 1998.

[167] SM Pinto Pereira, Myung Ki, and Chris Power. Sedentary behaviour and biomarkers for cardiovascular disease and diabetes in mid-life: the role of television-viewing and sitting at work. *PloS one*, 7(2):e31132, 2012.

[168] Tamara Peyton, Erika Poole, Madhu Reddy, Jennifer Kraschnewski, and Cynthia Chuang. "Every pregnancy is different". In *Proceedings of the 2014 conference on Designing interactive systems - DIS '14*, pages 577–586, New York, New York, USA, June 2014. ACM Press.

[169] Jeffrey Pfeffer. *New directions for organization theory*. New York: Oxford University Press, 1997.

[170] Laura Pina, Kael Rowan, Paul Johns, Asta Roseway, Gillian Hayes, and Mary Czerwinski. In Situ Cues for ADHD Parenting Strategies Using Mobile Technology. In *Proceedings of the 8th International Conference on Pervasive Computing Technologies for Healthcare*, pages 17–24. ICST, May 2014.

[171] Anthony J Plienis, Frank R Robbins, and Glen Dunlap. Parent adjustment and family stress as factors in behavioral parent training for young autistic children. *Journal of the Multihandicapped Person*, 1(1):31–52, 1988.

[172] Ming-Zher Poh, Nicholas C Swenson, and Rosalind W Picard. A wearable sensor for unobtrusive, long-term assessment of electrodermal activity. *IEEE transactions on bio-medical engineering*, 57(5):1243–52, May 2010.

[173] Alvin Powell. The rise of chronic disease. 11 2010.

[174] Andrew M Prentice. Are all calories equal? In *Weight Control*, pages 8–33. Springer, 1995.

[175] James O Prochaska and Wayne F Velicer. The transtheoretical model of health behavior change. *American journal of health promotion*, 12(1):38–48, 1997.

[176] Mashfiqui Rabbi, Shahid Ali, Tanzeem Choudhury, and Ethan Berke. Passive and In-Situ assessment of mental and physical well-being using mobile sensors. In *Proceedings of the 13th international conference on Ubiquitous computing - UbiComp '11*, page 385, New York, New York, USA, September 2011. ACM Press.

[177] Howard Rachlin. *The science of self-control*. Harvard University Press, 2009.

[178] Anthony Rodgers, Tim Corbett, Dale Bramley, Tania Riddell, Mary Wills, Ruey-Bin Lin, and Mark Jones. Do u smoke after txt? results of a randomised trial of smoking cessation using mobile phone text messaging. *Tobacco control*, 14(4), 2005.

[179] Yvonne Rogers. Ghosts in the network. In *Proceedings of the 1992 ACM conference on Computer-supported cooperative work - CSCW '92*, pages 346–355, New York, New York, USA, December 1992. ACM Press.

[180] John Rooksby, Mattias Rost, Alistair Morrison, and Matthew Chalmers Chalmers. Personal tracking as lived informatics. In *Proceedings of the 32nd annual ACM conference on Human factors in computing systems - CHI '14*, pages 1163–1172, New York, New York, USA, April 2014. ACM Press.

[181] James A Russell. A circumplex model of affect. *Journal of personality and social psychology*, 39(6):1161, 1980.

[182] Arthur Saltzman and CA San Bernardino. Computer user perception of the effectiveness of exercise mini-breaks. In *Proceedings of the Silicon Valley Ergonomics Conference and Exposition*, pages 147–151, 1998.

[183] Aleksandra Sarcevic, Ivan Marsic, and Randal S Burd. Teamwork errors in trauma resuscitation. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 19(2):13, 2012.

[184] Sabrina Elayne Brierley Schuck, Natasha Emmerson, Aubrey H Fine, and Kimberley D Lakes. Canine-Assisted Therapy for Children With ADHD: Preliminary Findings From The Positive Assertive Cooperative Kids Study. *Journal of attention disorders*, September 2013.

[185] Lukas Schwingshackl, Sofia Dias, and Georg Hoffmann. Impact of long-term lifestyle programmes on weight loss and cardiovascular risk factors in overweight/obese participants: a systematic review and network meta-analysis. *Syst Rev*, 3:130, 2014.

[186] Saul Shiffman. Relapse following smoking cessation: a situational analysis. *Journal of consulting and clinical psychology*, 50(1):71, 1982.

[187] Saul Shiffman, Arthur A. Stone, and Michael R. Hufford. Ecological Momentary Assessment. *Annual Review of Clinical Psychology*, 4(1):1–32, April 2008.

[188] Nirbhay N. Singh, Ashvind N. Singh, Giulio E. Lancioni, Judy Singh, Alan S. W. Winton, and Angela D. Adkins. Mindfulness Training for Parents and Their Children With ADHD Increases the Childrens Compliance. *Journal of Child and Family Studies*, 19(2):157–166, March 2009.

[189] Henrik Sø rensen, Dimitrios Raptis, Jesper Kjeldskov, and Mikael B. Skov. The 4C framework. In *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing - UbiComp '14 Adjunct*, pages 87–97, New York, New York, USA, September 2014. ACM Press.

[190] Timothy Sohn, K.A. Li, Gunny Lee, and Ian Smith. Place-its: A study of location-based reminders on mobile phones. In *UbiComp'05 Proceedings of the 7th international conference on Ubiquitous Computing*, pages 232–250. Springer, 2005.

[191] Richard L Solomon and John D Corbit. An opponent-process theory of motivation. *The American Economic Review*, pages 12–24, 1978.

[192] Arthur A Stone, Christine A Bachrach, Jared B Jobe, Howard S Kurtzman, and Virginia S Cain. *The science of self-report: Implications for research and practice*. Psychology Press, 1999.

[193] Andrine R Swensen, Howard G Birnbaum, Kristina Secnik, Maryna Marynchenko, Paul Greenberg, and Ami Claxton. Attention-deficit/hyperactivity disorder: increased costs for patients and their families. *Journal of the American Academy of Child and Adolescent Psychiatry*, 42(12):1415–23, December 2003.

[194] Leanne Tamm, James M. Swanson, Marc A. Lerner, Craig Childress, Brett Patterson, Kimberley Lakes, Annamarie Stehli Nguyen, Mily Kudo, Wendy Altamirano, Joel Miller, Rosa Santoyo, Veronica Camarero-Morse, John M. Watkins, Steve

Simpson, Feizal Waffarn, and Chuck Cunningham. Intervention for preschoolers at risk for Attention-Deficit/Hyperactivity Disorder (ADHD): Service before diagnosis. *Clinical Neuroscience Research*, 5(5-6):247–253, December 2005.

[195] Emmanuel Munguia Tapia, Stephen S. Intille, William Haskell, Kent Larson, Julie Wright, Abby King, and Robert Friedman. Real-Time Recognition of Physical Activities and Their Intensities Using Wireless Accelerometers and a Heart Rate Monitor. In *11th IEEE International Symposium on Wearable Computers*, pages 1–4, Washington, October 2007. IEEE.

[196] Claudia Thiele, Anton-Rupert Laireiter, and Urs Baumann. Diaries in clinical psychology and psychotherapy: A selective review. *Clinical Psychology & Psychotherapy*, 9(1):1–37, 2002.

[197] Edison Thomaz, Aman Parnami, Irfan Essa, and Gregory D. Abowd. Feasibility of identifying eating moments from first-person images leveraging human computation. In *Proceedings of the 4th International SenseCam & Pervasive Imaging Conference on - SenseCam '13*, pages 26–33, New York, New York, USA, November 2013. ACM Press.

[198] Edison Thomaz, Cheng Zhang, Irfan Essa, and Gregory D. Abowd. Inferring Meal Eating Activities in Real World Settings from Ambient Sounds. *Proceedings of the 20th International Conference on Intelligent User Interfaces - IUI '15*, 2015:427–431, January 2015.

[199] Alicia A Thorp, Neville Owen, Maike Neuhaus, and David W Dunstan. Sedentary behaviors and subsequent health outcomes in adults: a systematic review of longitudinal studies, 1996–2011. *American journal of preventive medicine*, 41(2):207–215, 2011.

[200] Tammy Toscos, Anne Faber, and Shunying An. Chick clique: persuasive technology to motivate teenage girls to exercise. In *CHI'06 extended abstracts on Human Factors in computing systems*, page 1873, New York, New York, USA, 2006. ACM Press.

[201] Jillian Trabulsi and Dale A Schoeller. Evaluation of dietary assessment instruments against doubly labeled water, a biomarker of habitual energy intake. *American Journal of Physiology-Endocrinology And Metabolism*, 281(5):E891–E899, 2001.

[202] J. P. Trougakos, D. J. Beal, S. G. Green, and H. M. Weiss. Making the Break Count: An Episodic Examination of Recovery Activities, Emotional Experiences, and Positive Affective Displays. *Academy of Management Journal*, 51(1):131–146, February 2008.

[203] Christopher C. Tsai, Gunny Lee, Fred Raab, Gregory J. Norman, Timothy Sohn, William G. Griswold, and Kevin Patrick. Usability and Feasibility of PmEB: A

Mobile Phone Application for Monitoring Real Time Caloric Balance. *Mobile Networks and Applications*, 12(2-3):173–184, July 2007.

[204] Barbara J van den Hoofdakker, Maaike H Nauta, Lianne van der Veen-Mulders, Sjoerd Sytema, Paul MG Emmelkamp, Ruud B Minderaa, and Pieter J Hoekstra. Behavioral parent training as an adjunct to routine care in children with attention-deficit/hyperactivity disorder: moderators of treatment response. *Journal of Pediatric Psychology*, 35(3):317–326, 2010.

[205] Susanna N Visser, Rebecca H Bitsko, Melissa L Danielson, Ruth Perou, and Stephen J Blumberg. Increasing prevalence of parent-reported attention-deficit/hyperactivity disorder among childrenunited states, 2003 and 2007. *Morbidity and Mortality Weekly Report*, 59(44):1439–1443, 2010.

[206] Susanna N Visser, Melissa L Danielson, Rebecca H Bitsko, Joseph R Holbrook, Michael D Kogan, Reem M Ghandour, Ruth Perou, and Stephen J Blumberg. Trends in the parent-report of health care provider-diagnosed and medicated attention-deficit/hyperactivity disorder: United States, 2003-2011. *Journal of the American Academy of Child and Adolescent Psychiatry*, 53(1):34–46.e2, January 2014.

[207] Benjamin N Waber, Daniel Olguin Olguin, Taemie Kim, and Alex Pentland. Productivity through coffee breaks: changing social networks by changing break structure. *Available at SSRN 1586375*, 2010.

[208] Brian Wansink and Koert van Ittersum. Portion size me: downsizing our consumption norms. *Journal of the American Dietetic Association*, 107(7):1103–6, July 2007.

[209] Karl E Weick. The social psychology of organizing (topics in social psychology series). 1979.

[210] Mark Weiser. The computer for the 21st century. *Scientific american*, 265(3):94–104, 1991.

[211] K C Wells, J N Epstein, S P Hinshaw, C K Conners, J Klaric, H B Abikoff, A Abramowitz, L E Arnold, G Elliott, L L Greenhill, L Hechtman, B Hoza, P S Jensen, J S March, W Pelham, L Pfiffner, J Severe, J M Swanson, B Vitiello, and T Wigal. Parenting and family stress treatment outcomes in attention deficit hyperactivity disorder (ADHD): an empirical analysis in the MTA study. *Journal of abnormal child psychology*, 28(6):543–53, December 2000.

[212] Joshua H West, P Cougar Hall, Carl L Hanson, Michael D Barnes, Christophe Giraud-Carrier, and James Barrett. There's an app for that: content analysis of paid health and fitness apps. *Journal of medical Internet research*, 14(3):e72, January 2012.

[213] Mary H Wilde and Suzanne Garvin. A concept analysis of self-monitoring. *Journal of Advanced Nursing*, 57(3):339–350, 2007.

[214] Brian T. Wymbs, Frances a. Wymbs, and Anne E. Dawson. Child ADHD and ODD Behavior Interacts with Parent ADHD Symptoms to Worsen Parenting and Interparental Communication. *Journal of Abnormal Child Psychology*, pages 107–119, 2014.

[215] Frances a. Wymbs, Charles E. Cunningham, Yvonne Chen, Heather M. Rimas, Ken Deal, Daniel a. Waschbusch, and William E. Pelham. Examining Parents Preferences for Group and Individual Parent Training for Children with ADHD Symptoms. *Journal of Clinical Child & Adolescent Psychology*, (February):1–18, 2015.

[216] Tae-Jung Yun and Rosa I. Arriaga. A text message a day keeps the pulmonologist away. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '13*, page 1769, New York, New York, USA, April 2013. ACM Press.

[217] Morris Zwi, Hannah Jones, Camilla Thorgaard, Ann York, and Dennis Ja. Parent Training Interventions For Attention Deficit Hyperactivity Disorder (ADHD) In Children Aged 5 to 18 years (Review). *Cochrane Database of Systematic Reviews*, 12(CD003018):73, January 2011.