BreakSense: Combining Physiological and Location Sensing to Promote Mobility during Work-Breaks

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ABSTRACT

Work breaks can play an important role in the mental and physical well-being of workers and contribute positively to productivity. In this paper we explore the use of activity-, physiological-, and indoor-location sensing to promote mobility during work-breaks. While the popularity of devices and applications to promote physical activity is growing, prior research highlights important constraints when designing for the workplace. With these constraints in mind, we developed *BreakSense*, a mobile application that uses a Bluetooth beacon infrastructure, a smartphone and a smartwatch to encourage mobility during breaks with a game-like design. We discuss constraints imposed by design for work and the workplace, and highlight challenges associated with the use of noisy sensors and methods to overcome them. We then describe a short deployment of BreakSense within our lab that examined bound vs. unbound augmented breaks and how they affect users' sense of completion and readiness to work.

Author Keywords

Workplace; wellbeing; work breaks; context aware; indoor location; activity recognition

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous

INTRODUCTION

Improving wellbeing and productivity in the workplace are important goals for both individuals and employers. In particular, getting adequate physical activity can reduce an individual's risk of developing chronic conditions and also lower healthcare and sick leave costs for employers [21]. One strategy recommended by the World Health Organization is to encourage individuals to be more physically active throughout the workday and to allow flexibility in the timing and length of work breaks to fit in physical activity [41].

Work breaks such as stepping away from one's work area to get food or drink, use the toilet, or socialize can be an opportunity to break up sedentary work, which can lead to improved health outcomes [16]. In fact, increasing the amount of time walking during a break from 1 minute to 5 minutes increases caloric expenditure from 3 to 16.5 calories on average, and if taken hourly can amount to an additional 108 calories expended to an 8-hour day [36].

In addition to improving physical health, taking work breaks is also important for successful work. Workers often want breaks to also be mental breaks from focused work so they can return both physically and mentally refreshed and be "ready to work." Readiness to work, typically the ultimate goal of a break, was found to be correlated with post-break productivity [10]. In this paper, we investigate how technology can promote short physical work breaks for two purposes: 1) encouraging physical movement, and 2) packaging the physical break into an activity that takes the worker's mind away from their work. We introduce BreakSense, a mobile/wearable application that detects when a worker leaves their work area and proposes short indoor-location-based challenges to increase physical activity without interrupting work. BreakSense uses Bluetooth beacons embedded in the environment to enable playful interactions at specific locations inside the workplace. These interactions can motivate workers to walk more during their breaks and temporarily take their mind off their work. We describe the unique constraints when designing for the workplace and the implementation challenges when using noisy sensors. We then report the results of a short proof-of-concept deployment of BreakSense in our lab. Specific contributions include:

- A description of specific constraints when designing interactions to augment breaks with physical activity in the workplace.
- The system and interaction design of BreakSense that satisfies workplace design constraints and overcomes noisy sensing to enable indoor-location interactions.
- A short deployment of BreakSense examining the preference for bound vs. unbound augmented breaks, and how they may affect a sense of completion and readiness to work.

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RELATED WORK

We now survey related work in the field in defining and understanding breaks, productivity and designing games for sedentary behavior.

Workplace Wellbeing

Previous research describes how work breaks contribute to workplace wellbeing and productivity. In industrial environments, frequent breaks reduce accidents and physical discomfort [37,39] and in office environments breaks help workers to avoid repetitive strain injury, muscle fatigue, and excessive sedentary behavior [8,17,35,37]. Even short breaks have been shown to offer substantial benefits [3].

Despite these benefits, workers often forego taking breaks to maintain productivity because of pressures in the workplace. A study focused on nurses found that even though nurses who miss their breaks do not make more mistakes, it did promote worse eating habits and made them more susceptible to burnout [32].

A random-effects meta-analysis found that physical activity programs have a mixed impact on work attendance, job satisfaction, and job stress, suggesting that even modest reductions in absenteeism can result in large financial savings [7]. Along these lines, our approach aims to increase physical activity by finding short but easy opportunities to be more physically active throughout the workday.

Defining a Break

While much research investigated the role of breaks in workplace productivity and wellbeing, the basic definition of a work break varies in the literature and among workers themselves. For example, a break is often defined as time away from a computer screen (*c.f.,* [8, 21]). Others include the notion of a "digital break" where non-work tasks, such as browsing social networks, are completed on a work computer [5, 20].

Work by Epstein *et al.* [10] attempts to clarify this ambiguity by investigating how knowledge workers themselves define breaks. They found the definition of a break can vary from person to person with the same task considered a break for one person and a work task for another. Furthermore, breaks that service biological needs offer more disagreement with only 55% of respondents believing that trips to the bathroom should not count as a break and 80% believing that getting a snack or a drink should count as a break. For technologies that seek to automatically detect and classify break vs. work, a one-size-fits-all solution may not accommodate the diverse definition of breaks that people have. In our solution, we use a simple (but imperfect) heuristic of stepping away from one's office or regular work area to detect opportunities to augment breaks with physical activity.

Exergames for Sedentary Behavior

Exergames, as studied by the CHI community tend to fall into two categories, those that promote exertion [2,4,24,29] and those that minimize sedentary behavior [23,25,31] with *BreakSense* falling into the latter category. This distinction is important because each approach addresses a different set of potential health problems [38].

Studies of exergames [25,26] in the context of populations at risk of health problems related to sedentary behavior (children in school, those using wheelchairs, older adults) have resulted in the following guidelines:

1. *Providing an easy entry into play*
2. *Implementing achievable short-term challenges to foster long-term motivation*
3. *Providing users with appropriate feedback on their exercise effort*
4. *Implementing individual skill-matching to keep players engaged.*
5. *Supporting social play to foster interaction and increase exercise motivation*

Evaluation of a game called *GrabApple* which employed a design with simple rules and easy access showed that young adults could increase their heart rate during play, improving performance on tests for attention and focus indicating that there may be some cognitive benefits to games that break up sedentary behavior [26].

Workplace exergames have additional design considerations to manage, particularly the tension between play and work activities as noted by [31]. For example, *Limber* is an exergame that promotes movement, periodic stretching, and good posture among knowledge workers. Initially, the system used off-the-shelf sensors attached to a hoodie worn by the user but was overhauled to use a workstation-mounted Microsoft Kinect and ambient display because the hoodie clashed with workplace dress code. Our work was inspired by the guidelines described in [25,26] and the learnings from [31]. Our work was also inspired by the behavior change models, Health Action Process Approach [33] and Fogg's Behavior Model [12]. Consistent with these frameworks, our goal was to assist "intenders" to act on their intention to be more active at work by providing 1) a context-aware trigger to perform a low-effort walking task during a break and 2) a playful interaction to support motivation.

BREAKSENSE

With an overall goal of investigating different approaches for improving workplace wellbeing and productivity, we decided to explore the use of a context-aware mobile system to promote short physical breaks within the workplace. We designed a system called BreakSense that detects when a user leaves their workspace and proposes short indoor location-based challenges to increase physical mobility. In designing our system, we followed a set of principles that we describe first in this section. We then describe the design and implementation of BreakSense, followed by discussion of a set of challenges that emerge from the clash of noisy sensing technology and the desire for a deterministic user experience.

Designing for the Workplace

The following principles were used in designing our system, and represent what we believe are important considerations for designing technical interventions for improving breaks in the workplace.

1) Avoiding work interruptions

Instead of interrupting the user's work, we propose that the system should detect that a user is not working and use that to propose a break activity. Decades of research on the adverse effects of interruptions highlight the cost that incoming notifications can have on ongoing work [27,28]. While attempts have been made to use machine intelligence to detect good moments for interruptions (*c.f.* [11]), correctly discerning productive from unproductive work periods is difficult. Many existing tools for promoting physical activities and break taking will prompt users based on simple heuristics, such as elapsed time or time of inactivity. For example, the Microsoft Band smartwatch offers to alert the user after a certain number minutes of inactivity, and many desktop and mobile tools (*c.f.* [45,46]) use time-based reminders and can even lock the computer screen. However, Epstein *et al.* [10] reported that when knowledge workers were being productive before going on a break (based on self-reported productivity), they tended to take primarily "necessary" breaks, such as getting a snack, or going to the bathroom, and took fewer social or digital breaks. This finding suggests that a system may be better off relying on the user to self-interrupt and initiate a break than to risk disrupting productive work.

2) Break activities should be the right length

While the desirability of system-suggested break activities will certainly affect workers' willingness to change their breaks and participate, such activities should not be so long that they end up reducing worker's readiness to resume work [10]. On the other hand, an activity that is too short may be insufficient to get the worker into a recharged and refocused mental state. Furthermore, when a break is too short, a user may not transition to the specific desired physical state (*e.g.*, elevated heartrate, having walked a certain distance or pace) or mental state (a rest from an intense cognitive work task). In our work, we explore the use of short break activities that can be chained together and investigate the role of limiting the number of such activities a user does in one break.

3) Readiness to work over quantified activity metrics

As stated above, break activities often cannot be very long. While there are several popular exercise regimes that take only a short time (e.g., [22]), any individual break may not be long enough to complete larger goals (such as reaching a daily step count). We thus propose that the focus of a break activity should be on smaller, attainable concrete targets. For example, taking a longer walking route to the kitchen to visit some office landmarks during a coffee break. Additionally, by designing for concrete, meaningful targets or goals, the system has an opportunity to provide a more personal experience compared to impersonal, numeric goals such as steps, time, etc. Finally, an activity that has a target may help draw the user's attention and give them an opportunity to take their mind temporarily off their work.

4) Recognize the relevance of physical activity indicators

While the focus of proposed break activities need not be explicitly about physical activity metrics, such as step-count, the value of increased physical activity is generally accepted as positive. Thus, providing feedback, during or after the break, about the break's contribution to physical metrics is desirable and can potentially help sustain motivation. In our design, a break's summary is displayed automatically when a user returns to their workspace and returns to an idle (not walking or running) state.

5) Be sensitive to the workplace environment

Designing a system for the workplace must take into account several important physical and social constraints. First, one must keep in mind that the primary purpose of the workplace environment is work. As such, the activity suggested by the system should not be disruptive to other people in the space. This puts limitations on, for example, the ability to rely on audio, or rely on group activities in non-common areas. Finally, the social structure of the workplace often includes a power hierarchy, with workers, managers, and executives. For example, social structure in the workplace may impose restrictions (real or perceived) on access to different areas of the workplace, or willingness to be seen by one's superiors when engaging in break activities. In a low-fidelity test of our system, for example, we discovered that users were unwilling to engage in challenges that took them to, or next to the executives' offices in our lab. As Gorm and Shklovski [13] report from a three-week workplace step-counting campaign, participation in the campaign affected both workers who participated and those who opted-out. We thus provided users the option to request different challenges.

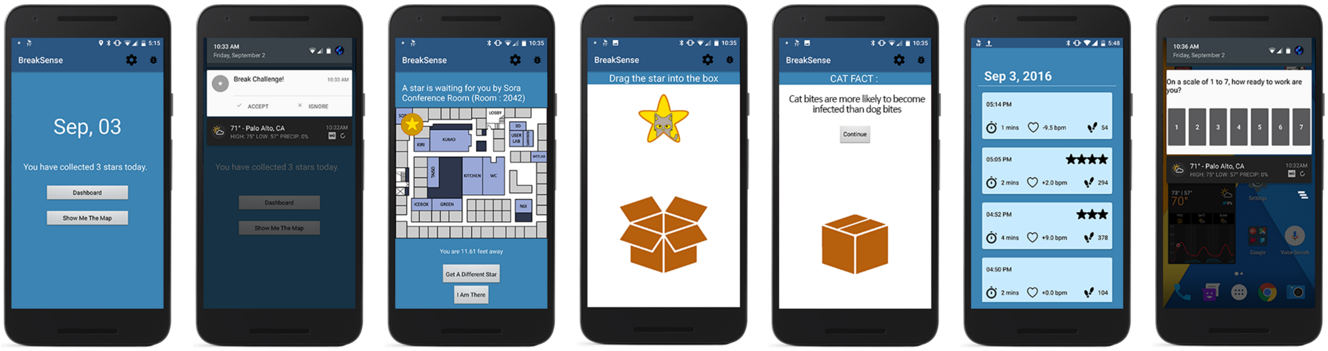
Design

Considering the design principles described above, we designed BreakSense, a mobile application that uses indoor-localization and activity recognition to encourage physical breaks in the workplace. BreakSense continuously monitors the user's indoor location, activity status (stationary, walking, etc.) and heartrate. BreakSense engages with the user when they leave their workspace and fades back into the background when the user is back at their desk. The flow of interaction with BreakSense (Figure 1) is as follows:

1) The user is located in their office and is stationary:

The system monitors the user's location and looks for any change to a walking state. The system also records the user's heartrate to compute a *pre-break resting-state heartrate*.

2) When the system determines that the user is not stationary and has moved away from their workspace, the user receives a vibration notification on their phone that a break challenge is available (Figure 1b). The user can either tap "Accept", or can either explicitly dismiss the challenge (by tapping "Ignore") or simply do nothing to ignore. By using this method, we only offer interaction when the user is already moving and are away from their workspace, thus avoiding interrupting their work. Furthermore, if the user not on a



a) b) c) d) e) f) g)

Figure 1. BreakSense interaction flow: (a) the home screen, (b) the user can accept or dismiss a notification of a break "challenge" shown when they walk away from their office, (c) the target's location is shown on the map, the target changes as the user gets closer, (d) near the target, the user collects the star by dragging it into the box, (e) a fact is revealed and the user continues to the next target, (f) back at the office, a dashboard summarizes the day's breaks, (g) for our study, a notification with a 7-point Likert-scale as a lightweight mechanism for capturing participants' readiness to return to work.

break (e.g., they are going to a meeting), or if they cannot or do not wish to engage with the challenge, they can easily dismiss the challenge.

3) If the user accepts the break challenge, they are shown a map of the work environment, and a target location shown as a star (Figure 1c). A label at the top of the screen provides the location name. As the user moves nearer to the target, the star on the map grows, and eventually changes to a large star and the phone vibrates. Again, we rely on vibration notification rather than audio notification because workers may not wish to disturb their co-workers or may not want others to know what they are doing.

Recognizing that BreakSense may offer targets that users may prefer not to pursue (for example, a target that appears near executive offices, or area with visitors), we included a button labeled "Get a Different Star" that allows a user to request a target at a different location (Figure 1c). We also included a "I am There" button that allows a user to indicate that they are at the target location, in case the user is incorrectly localized by the system.

4) After the star appears, the user taps anywhere on the map and "collects" the star by dragging the star into the box (Figure 1d). The application presents the user with a random "fact" (e.g., factoids about cats; Figure 1e). When the user presses the button, a new target is presented on the map.

5) When the user returns to their desk and resumes a stationary state, the phone vibrates and displays a dashboard (Figure 1f). The dashboard summarizes the user's time away from their workspace, including the duration, the number of stars collected (if any), the number of steps walked, and the difference between the user's recorded heartrate during the break and the pre-break resting-state heartrate.

Implementation

We implemented BreakSense as an Android app, primarily due to easier handling of background services, required for our indoor-localization and activity sensing.

Indoor-localization

Indoor-location based on beacons has been reported extensively in the literature (e.g., [9,20]). We used iBeacons deployed throughout our lab. iBeacons are Bluetooth low energy devices (BLE) that use a standardized protocol for broadcasting an identifier to nearby portable devices scanning Bluetooth frequencies. This identifier can then be used to identify the context of the portable device and trigger a corresponding action. *BreakSense* uses the open-source Android Beacon Library [47] to scan for beacons. In our test environment, personal offices were instrumented with wall-plugged beacons, while common areas such as the kitchen and large meeting rooms were equipped with ceiling-mounted beacons. A beacon also broadcasts its *txPower*, a number that is calibrated for each beacon representing the *RSSI* (receiver signal strength indicator) at 1 meter away from the iBeacon. The *RSSI* that the scanning device determines when it receives the iBeacon's signal is divided by the *txPower* value to determine distance. Due to a variety of factors (differences in antennae gains between different hardware, noise from other devices), the RSSI observed by Bluetooth hardware can have a large effect on the distance calculation. Additionally, consecutive scans may not yield an observation of a beacon's presence even if the user is idle and nearby the beacon. Signal propagation is also affected by walls and other objects in the environment. Thus, collecting a scan in two locations that are an equal distance from a beacon will often produce different distance measurements. Furthermore, signal reflection results in a beacon's signal becoming visible both directly (and strongly) and indirectly (and weakly), producing varying distance measurements. Our solution to this problem is discussed in the next section.

Home vs. Target beacons: Encoded within our application was a mapping of iBeacon identifier's to their respective room names. Each installation was configured to scan for a "home" beacon, the beacon which corresponds with the room where the user's workspace is located. We use a threshold on the reported distance from the home beacon to determine whether the user is at or away from their desk. For each user, all other beacons in the environment are potential "target" beacons.

It is important to note that while beacons reside inside personal offices, it would be unreasonable to expect users to walk into others' offices to complete a challenge. Thus, it was important that the threshold used for determining that a target was reached was large enough to allow access from a nearby hallway.

Our solution to the challenges of intermittent beacon observation and high variance in distance accuracy was to sacrifice a bit of responsiveness in exchange for aggregation by using a sliding window technique. This technique uses an array, or window, of size N that represents the N most recent scans for a particular Bluetooth beacon. If a scan does not contain an observation of that particular beacon, then a null value is used as a placeholder in the window. The *BreakSense* system maintains two windows, one representing recent scans for the user's home beacon and another for the current target beacon. We determined a window size N=4 to work best for our purposes.

From this, we established the following states in relation to a target beacon, as illustrated in Figure 2: if all values from a beacon's window are null, the user is considered "Out-of-range" from that beacon (Figure 2, left). If there is at least one non-null value in a beacon's window, then the average of these values is compared to its respective threshold. If the distance returned by the window is greater than the threshold, then the beacon is considered "Far" (Figure 2, middle), and otherwise it is considered "Near" (Figure 2, right).

In our experiments, we discovered that phones with different Bluetooth modules have varying sensitivity to Bluetooth signals and report different distance estimations from beacons. We thus empirically adapt the distance threshold for each user based on the combination of phone and office.

Physical-state recognition

BreakSense users wear a smartwatch that can capture and transmit, in near real time, step count, activity (walking, stationary, etc.) and biometrics, such as heartrate. In our current implementation, we use the Microsoft Band 2 and the Microsoft Band SDK for Android for data access. On average, heartrate was reported by the band to the app three times per second, and step-count and activity were recorded two times per second and transmitted to the phone. This frequency varies depending on available system resources.

Cloud data aggregation

Collecting the data was done by remotely logging beacon distance data along with Band data to a remote MongoDB database using the open-source Parse library for managing client- and server-side database transactions [48]. Querying the data for analysis was done using HTTP requests implemented in Python to a RESTful API built into the server-side Parse system. This architecture requires the phone to be continuously connected to the internet. However, since we designed BreakSense to be used within the workplace, reliance on WiFi connectivity is reasonable. While much of our system's logic can be implemented locally on the mobile phone, we opted to develop our application with a cloud backend. This provided several key benefits. First, it allowed us data analysis and monitoring throughout our deployment (described in detail later).

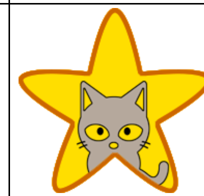
Out-of-range	**Far**	**Near**
		
Target beacon's ID was not present in the last N scans	Target beacon's ID was present in the last N scans with a distance > Threshold	Target beacon's ID was present in the last N scans with a distance < Threshold

Figure 2. Note that once the system transitions to state 3, it remains on that state until the user either collects the star or returns to their desk and the break is over. This prevents noise in the Beacon signal causing this status to oscillate.

UX WITH UNRELIABLE SENSING

As we describe above, indoor localization is determined by classifying the phone's reported distance from iBeacons in the work environment. User physical state and step counts are reported by the Microsoft Band 2 worn on the user's wrist. However, both indoor localization and physical activity sensing impose challenges that can affect the user experience, and must be overcome. For example, detecting that a user is potentially going on a break relies on a user changing to a Walking state and leaving their office.

UX Challenges with Beacon-based Localization

Despite using the sliding window technique to improve localization accuracy, noisy localization can still pose potential issues for BreakSense's interaction flow. First, the system may incorrectly assume that a user has left their workspace even though the user is stationary. Second, the user's distance from a target may fluctuate around the target distance threshold and result in the user state oscillating between "Near" and "Far".

UX Challenges with Physical State-Change Recognition

Using a fitness tracker such as the Microsoft Band 2 offers the ability to easily observe the user's step-count, heartrate, and classified physical state (e.g., walking or not). However, like other fitness trackers (such as Fitbit), physical state changes are often determined in a conservative manner and with significant lag to avoid incorrect classification. Specifically, when a user starts walking, step count is not incremented and state change is not indicated until the tracker is confident that the user is walking (at which point, all steps that were taken are incremented at once). For example, a user may walk 14 steps before their status is changed to 'Walking' and 14 steps are added at once to their step count. While reducing false classification of state change, this behavior introduces a lag into BreakSense's ability to detect that a user is going on a break.

Despite these challenges, we aimed to provide a user experience that is deterministic and hides much of these technical issues.

Designing around Sensing Challenges

The most common method for overcoming noise in signal-strength-based localization is to introduce smoothing over several scans. However, this method inevitably introduces a delay that can also affect user experience. In order to avoid incorrectly classifying a user as having left their desk due to fluctuating beacon signals even when stationary, BreakSense prompts the user for a break challenge only when it detects that *both* the distance from a user's home beacon exceeds the threshold *and* a physical state change to walking. However, this does mean that the user may already be a distance away from their office, shrinking the window of opportunity for augmenting their break.

We also had to avoid a situation where a user is standing still but the interface is continuously changing its state due to variations in reported distance from a target location (*e.g.*, when a user is at a distance close to the used threshold). We thus designed the interaction such that whenever distance state crosses from "Far" to "Near", it stays in "Near" state. Furthermore, rather than requiring a user to reach a fine-grained distance from the beacon, once the user is considered "Near" the target, they switch to interacting directly with the phone (dragging the star into the box; Figure 1d). This transition to playful interaction with the star directs the user's attention away from trying to physically locate the target.

EVALUATION

In order to evaluate BreakSense's potential at augmenting workers' breaks, we conducted a small proof-of-concept deployment within our lab. We were interested in understanding users' willingness to engage with break challenges. We were particularly interested in understanding whether limiting a break activity will be more or less conducive to returning to work compared to a break activity that is unbound (more on this below).

Limited vs. Unlimited Break Activities

One of the most basic and common mechanisms of successful (and sometimes addictive) games is that they offer continuous opportunity for interaction; a next level is unlocked, a new quest offered, another monster to catch. However, when designing for workplace activities, supporting workers' transition into a productive work state is often the goal. It is thus possible that an activity that does not allow reaching a state of completion before returning to work will fare worse than an activity that can be completed. A key goal of our evaluation was thus to investigate whether system-recommended break activities should be bounded.

To test this, we created two versions of BreakSense. In the first, "Unlimited" version, whenever a user collects a star, they are offered a new star at a different location. In this Unlimited version, it is up to the user to stop collecting stars and end their break (by returning to their office). In the second, "Limited" version, a user is offered a finite number of stars per break (in our evaluation, we set the limit to three stars per break). With each star collected, the user is told they have collected x out of 3 stars (where x is the current number of stars collected). Of course, the user may choose to collect fewer stars than the limit. Once the maximum number of stars was collected, the application tells the user they are done and stops offering stars. In both versions, the summary of a break is displayed once the user is back at their desk. Notice, that the Unlimited version allows, but *does not require* a user to collect more stars than the Limited version.

Method

For the evaluation, we used a within-subjects design, with each participant using both the Unlimited and Limited versions. We chose a within-subjects design due to the small number of participants, and that individual workers tend to have unique break habits. To capture participants' readiness to return to work at the end of a break, we implemented the following lightweight mechanism: Whenever a participant returned to their desk and switched to a sedentary state, the phone would vibrate and display a notification. When the user dragged the notification down, it would reveal 7 buttons representing a Likert-scale response (see Figure 1g). The user taps one of the buttons to indicate their readiness to resume work, and the notification disappears.

Data Collection

In collecting data, we consider each time a participant leaves their office a "break challenge candidate". We collect the time the participant has left her office, and whether or not the participant accepted, rejected, or ignored the break challenge. We then record the duration of the break, the number of stars collected during the break, the number of steps walked during the break, and the change in median heartrate from the participant's resting heartrate. Finally, we record the participant's reported readiness to return to work.

End-of-day surveys

At the end of each day, participants were asked to complete a short survey. In this survey, they were asked whether the workday was unusual in any way, whether they took more or fewer breaks than usual, and how productive was the workday overall (on a 5-point Likert scale). We also asked whether they had any issue with the system, to allow us to identify and fix technical issues.

End-of-study survey

Finally, at the end of the evaluation, each participant was asked to describe, in their own words, their experience with BreakSense. Participants were also asked to compare the two conditions and describe their preference between the two. They were then asked about their use of different features of the system and rate the value of different information presented in BreakSense's dashboard.

Procedure

We ran the evaluation within our lab during an eight-day period. Our lab occupies the second floor of an office building and contains a mix of personal and multi-user offices, open space, meeting rooms, and a common area (the layout of the lab can be seen in Figure 1c). We chose to run the evaluation in-house since our lab is equipped with beacons that are already mapped to physical locations.

Participants were randomly assigned to one of the two conditions (Limited or Unlimited). Before starting, each participant was given an Android phone with BreakSense preloaded and linked from the home screen, and a Microsoft Band 2 paired with the phone. We adjusted the app's thresholds for each participant for best recognition of their leaving their office.

Each participant was introduced to BreakSense and provided a printed reference guide. They were instructed that they could accept break challenges, dismiss them or simply ignore them. We did ask participants to make sure to wear the Band and carry the Android phone with them whenever they went on break. At the end of each workday, participants were instructed to charge the phone and Band. Participants received the end-of-day surveys each evening over email. Note that participants were not told about the two conditions before starting the study; each participant simply experiencing the condition they were in.

Switching participants between the evaluation conditions occurred over the weekend (since the evaluation spanned a weekend, we used that time to collect the phones from all participants and adjust their settings). This time, we explicitly informed participant via email of their new condition: Participants switching to the Limited condition were told that they could now only collect three stars per break, while participants switching to the Unlimited condition were told that they can now collect as many stars as they wanted per break.

The end-of-study survey was appended to the end-of-day survey of the final day of participation.

Participants

We invited participants by sending email to all members of our lab. Participants did not expect any reward for their participation (although we gave each participant a $25 gift card a day after the study was over, as a token of our appreciation). We had six participants in total: 3 women and 3 men. One research scientist, three developers, and two Ph.D. students. A seventh participant withdrew from the study after recording a single break during their first four days of participation, expressing that they were too busy to participate (their data are not reported).

RESULTS

During the study, BreakSense detected 210 break opportunities and participants accepted 88 of them (we use the term 'break opportunity' to refer to each time a participant has left her office and was notified by BreakSense). Of the remaining 122 notifications, 13 were explicitly dismissed using the notification interface and 109 were ignored (summary statistics are provided in Table 1). Since a participant is notified for a break activity each time they leave their office, these ignored and dismissed notifications not only represent breaks where participants chose not to engage with BreakSense, but also, for example, when they were on their way to a meeting. We regard participants' engagement with BreakSense to be high, with 42% of the total break notifications accepted (Figure 3, left).

	Min	Max	Med	Avg.	Total
Breaks accepted per day	1	6	6	2.3	88
Stars per break (Unlimited)	1	21	3	4.0	183
Stars per break (Limited)	1	3	3	2.8	116
Steps per accepted break	18	1,444	222	295.3	25,690

Table 1. BreakSense field evaluation summary statistics.

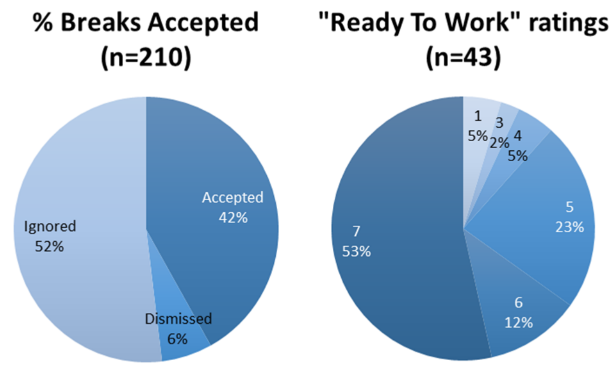


Figure 3. Percent of BreakSense break activities Accepted/Dismissed/Ignored (left), and distribution of ratings of readiness to return to work (right).

On average, BreakSense detected 5.7 break opportunities a day per participant, of which participants accepted 2.3 challenges (Min=1, Max=6, SD=1.34) and ignored or dismissed 3.4 challenges (Min=1, Max=12, SD=2.67). Looking at participation by day into the study shows that engagement was sustained during the deployment, with even a small significant increase in the ratio of accepted break challenges to non-accepted as the study continued ($F[1,37]=6.0$, $p=.02$). This, however, does not guarantee that engagement would have sustained in a longer deployment.

Collecting stars

Participants collected 299 stars in total, 116 in the Limited condition and 183 in the Unlimited condition. While the duration of most breaks were relatively short (avg. 3 minutes), collecting stars was sometimes combined with longer periods away from the desk (up to 1.5 hours). On average, participants collected 3.98 stars per break in the Unlimited condition (Min=1, Max=21, SD=3.7) and 2.76 stars in the Limited condition (Min=1, Max=3, SD=0.5). This difference is significant ($p=.02$), demonstrating that users tend to collect more stars when given the opportunity.

Participants requested different stars from BreakSense on 8 breaks using the "Get A Different Star" button, and used the "I am There" button in 25 breaks. We included the "I am There" button to help in cases of challenges with indoor-localization. However, from participants' open-ended responses, we learned that this feature was also used to reduce social awkwardness and collect a star from a more socially acceptable distance. For example, P3 used this feature because they *"...don't want to be too close to people's office and/or stand there too long to wait for the sensor to detect."* As stated by P6, *"It was a bit awkward to stand in front of a colleague's office and collect a star. Conference rooms & other common areas were easier in that regard."*

As we expected, the "Get a Different Star" button was used when getting a star was socially uncomfortable. However, we also discovered two other uses for this feature: P2 described using the feature to get stars along a path they wanted to go on (e.g., the path back to their office). P3 described using this feature to create a more diverse activity, stating, *"It recommended a star in a section of the lab that I had already visited and I wanted to see if it will suggest a different one so I don't have to retrace my steps."* This finding highlights the opportunity for BreakSense to recommend more interesting or "scenic" routes (instead of random targets) so the actual journey between targets (a large part of the break) feels more enjoyable and purposeful.

The Rhythm of BreakSense Breaks
Figure 4 shows the percent of BreakSense break activities that were accepted by our participants by time of day[1]. This figure illustrates that while participants accepted few breaks before noon, the majority of breaks accepted by participants took place in the afternoon, between 2pm and 4pm. 15% of accepted breaks took place around lunchtime, presumably combined with participants' lunch break. In fact, the observed pattern is consistent with the "mid-afternoon slump" in cognitive performance that occurs roughly 8 hours after waking up [42]. During this slump period, participants may have sensed their concentration waning and be more willing to engage in a cognitively restful but physically stimulating break. This suggests, potentially, that solutions aimed at modifying break behavior may do better in the second half of the workday.

Physical and Mental Breaks
Participants walked 295.3 steps per accepted break challenge on average (Min=18, Max=1444, Med=222, SD=275.4). Participants got more physical activity (steps) as they engaged with the app more – we found a significant positive correlation between the number of stars collected and the (log) number of steps taken (t=3.68, p<.001). Thus,

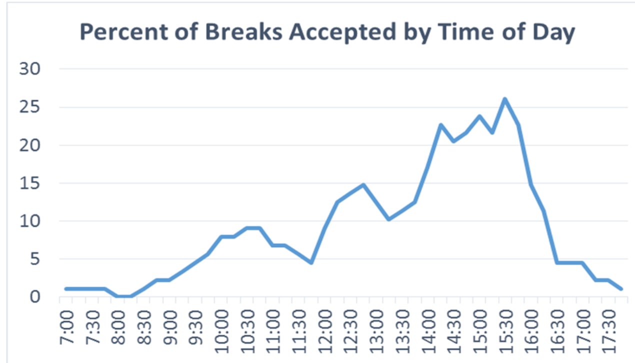


Figure 4. The rhythm of BreakSense breaks: shows % of accepted breaks by time of day.

interaction with BreakSense seems to encourage physical activity during breaks.

While the step count per individual break is not high – our lab is only moderately-sized at 24,000ft^2 (2,200m^2) – we believe even this amount of additional activity can contribute to overall worker wellbeing. Indeed, in their responses, participants appreciated being encouraged to move during their breaks. P4 stated, *"It's always good to put some physical activity in your everyday routine, BreakSense did that for me by making me collect stars."* P6 said, *"It made me take more steps than I would have otherwise."* Comparing to the (log) duration and (log) step count for breaks when participants did not accept the BreakSense challenges, we see that, in our data, breaks with accepted challenges were longer (median 3 minutes vs. 0.6 minutes; F[1,153]=14.4, *p*<.001) and with more steps (median 295 steps vs. 68 steps; F[1,181]=, *p*<.001). However, since we do not know *why* a user chooses not to accept a challenge, this difference cannot be used for making causal inferences.

Readiness to Work
Participants rated their readiness to return to work after 43 of the total 88 accepted breaks (49%), a somewhat disappointing response rate. Looking at the ratings, we see participants rated their readiness to return to work highly, with 88% of responses above the neutral (with 53% receiving the highest readiness rating of 7), and only 7% receiving a rating below the neutral point (See Figure 3, right). We cannot attribute this readiness to return to work solely to BreakSense, but participants, such as P6, liked that *"[BreakSense] made me think about something other than work during the short breaks."*

We also looked at participants' end-of-day reports of the day's productivity (rated on a scale of 1 to 5 from least to most productive). A mixed-model ANOVA on productivity ratings (align-ranked [40]) with Participant ID as a random effect shows a significant positive correlation between the number of BreakSense breaks taken, and productivity ratings (F[1,13]=5.6, *p*=0.03). One interpretation of this result is that taking physical breaks improved the day's productivity. A different interpretation is that the external forces that interfere with work productivity also prevent participants

[1] Each point in the graph represents the number of break activities accepted in a 1-hour window, sliding the window by 15-minute increments. We report the number of breaks as a percent of the 88 total breaks accepted by participants.

from engaging in physical breaks. For example, having many meetings may reduce both one's sense of productivity and one's ability to take active breaks. A combination of these two explanations is likely at play.

Unlimited vs. Limited Modes

To understand participants' reaction to the two different versions of BreakSense, we asked them to describe their thoughts and preference about the two versions. We were interested to know whether unlimited, continuous interaction (common in mobile games), should be used for break-taking, given that the user's cognitive state at the end of the break is the measure of an intervention's success.

Five of the six participant preferred the Limited version. P5 stated that, *"I prefer the limited mode because you get the feeling that you have 'completed' something (the challenge) and you have time to do something else in your break as well."* Similarly, P6 stated that, *"I like Limited mode better since it gave a sense of completion for my break."* Put differently, P4 said, *"[The] Unlimited mode did not help in seeing the light at the end of tunnel and hence was not motivating."* In contrast, P2, expressed a preference for the Unlimited mode, saying, *"When I was restricted on the number of stars, I got them really quickly, so my breaks were very short. Once I was allowed to get as many as I wanted, I took longer breaks..."* Still needing a break's activity to reach a completion (not only through returning to one's desk), P2 described the need for an "I am done" button for the Unlimited condition. P2's need might also be addressed by increasing the default number of stars in the Limited mode to meet his desired break length. Finally, both P3 and P6 preferred the Limited mode but proposed a mixed alternative: "'Unlimited' is for days when I feel playful and no urgent tasks pending to be completed" (P3) and *"I liked Unlimited mode just for the fact that it encouraged taking longer breaks. So a mix of both would be ideal."* (P6)

Overall Impressions of BreakSense User Experience

In their open-ended responses, participants expressed their thoughts of BreakSense and offered suggestions for changes. Participants appreciated the concept overall. For example, P4 found value in BreakSense *"because it makes me walk and induce physical activity in my routine,"* while P6 wrote, *"Walking around the lab to take a break is something I had not considered before doing BreakSense. My breaks used to be to the water cooler/restroom and right back to my office. BreakSense has increased the area I cover in my breaks."*

Finally, we were interested in any features or improvements desired by participants. One improvement requested by one participant was enabling "blue dot" navigation. Such feature would make navigation simpler, particularly for users less familiar with the workspace. One participant wanted BreakSense to also include outdoors break activities.

Next, two participants said they would have liked BreakSense to not only offer challenges when they were already on a break, but also remind them to take a break. However, the adverse consequences of interrupting productive work may outweigh any benefits such reminders may offer. Finally, two participants expressed a desire for social features within BreakSense, including recommending breaks that require interacting with a colleague or taken together in playful competition.

Limitations

The evaluation results and participants' reactions highlight some of BreakSense's potential of improving workplace wellbeing. However, several limitations of the evaluation need to be addressed. First, the evaluation did not include baseline measurements of participants' break-taking habits before or after using BreakSense. As such, we cannot draw quantitative conclusions regarding changes in participants' behavior, and only rely on their open-ended responses. A baseline condition, where participants' activity and location are still tracked and their readiness-to-work upon returning to their desk is rated, would be necessary for a more complete evaluation. The evaluation also involved only a handful of participants who were all part of the same organization. It is interesting to note that despite the small number of participants, we encountered different uses of BreakSense and even different preferences for the two interaction modes. The evaluation was also short; a longer deployment would be necessary to evaluate users' desire to sustain engagement with a system like BreakSense.

Finally, another limitation is that our participants had to carry a phone provided to them, often in addition to their personal smartphone. While this choice helped provide participants with a consistent experience (and allowed us to recruit participants who do not own an Android phone), it still placed an extra burden on participants.

DISCUSSION

Earlier in the paper, we described a set of five design principles that we believe are important when designing work-break interventions. These principles guided our design of BreakSense: Avoiding interrupting work, system-recommended breaks activities should not be too long, prioritize readiness to work over quantified activity metrics, recognize the relevance of physical activity indicators, and be sensitive to the workplace environment. We argue that a break intervention's main value should be judged by the state it leaves the worker in and its contribution to a worker's overall productivity and wellbeing.

Game Mechanics and the Workplace

We investigated whether a continuous, unlimited break activity would be more or less desirable than a break activity that is limited (collecting a maximum of 3 stars per break). Our results show that even though participants collected more stars and were more engaged in the gameplay in the Unlimited version, participants expressed preference for the Limited version stating that it gave them a sense of completion during their break, which facilitated the mental transition back to focused work. Designers must balance the desire for detachment from work during a break with the need for break completion to aid the transition back to focused work. For example, future work may explore whether setting daily limits may help users reach a sense of completion, but also give them control over the amount of time and energy they invest in each break.

Two participants mentioned a desire for social and even competitive features for BreakSense (a common feature of many fitness-tracking solutions). However, adding competitive features should be done with caution. First, competition may cause workers who engage with the system less to abandon the competition altogether. Second, making one's break-taking behavior visible to others may result in negative judgment from others. Finally, the "I am There" feature, designed to overcome location sensing errors, could be misused for cheating in a competitive setting.

The Challenge of Sustained Engagement

A difficult problem for behavior-change systems in general, and those that use game-like elements in particular, is to sustain the user's motivation and engagement. This challenge is even bigger for social games that rely on a network effect as those can lose playership fast when some players stop playing, taking their network with them.

For behavior-change systems, not only the user's interest but also their motivation must be sustained. Prior research, for example, investigated the reasons behind users adopting and then abandoning devices such as fitness trackers [5] and other smart sensing devices. Some mechanisms to promote sustained motivation have been proposed. For example, Agapie *et al.* proposed to include lapse-management into a behavior-change system [1] to allow users to recover from missing their goals. Other work focused on health-promotion, rather than sustained behavior change. Even in such context, a workplace intervention can generate a desired behavior that is quickly abandoned when the intervention is over [13]. One possibility for sustaining interest in active breaks is to design a set of variations of BreakSense activities, selected at random by the system or user. A different approach would be designing a stronger link between virtual activities/rewards and the physical target locations, which can make visiting specific locations within the workplace offer unique meaning.

UX Approaches for Overcoming Sensing Challenges

This paper discusses technical challenges that stem from noisy sensing, and the importance of hiding sensing inaccuracies from the user. Specifically, we highlight four basic approaches: First, combining sensing modalities (e.g., location sensing and activity recognition) allows the system to overcome inherent errors associated with each modality. Second, the system can relax accuracy constraints when those favor the user; by setting a generous target threshold, BreakSense errs towards reaching a target sooner rather than later. Third, limiting transitions between underlying system-states (in our case, avoiding switching a target's state from "Near" back to "Far") can prevent fluctuations in sensor reading from manifesting in the interaction. Finally, direct user interaction (e.g., touch interaction) allows the system to redirect the user's attention away from sensing. We believe these complimentary approaches allow designers to deliver a robust user experience despite noisy sensing.

Creating an Infrastructure-light System

A challenge with deploying BreakSense is that it requires an indoor-localization infrastructure of beacons to be placed and maintained in known locations. However, other methods for indoor localizations exist, including computer vision-based methods [6,9,19,20,30,43,44] or methods based on ambient magnetic field [15]. One lightweight approach to beacon-based sensing could be to design the interaction such that it requires fewer beacons, relying instead of user's knowledge of semantic locations. For example, a user's laptop can be activated as a home beacon (*c.f.,* [49]), which enables prompting of break challenges when a user walks away from the laptop. Target beacons can then consist of co-workers' laptops who also participate in BreakSense.

Worker privacy is an important aspect that must be considered when designing and implementing a context-aware solution for the workplace. Workers are often concerned that they can be tracked and inferences be made about their performance (*c.f.,*[14]). While our BreakSense implementation relies on cloud storage for the sensed data, this was done mainly for debugging and for the evaluation. We have also implemented a version that operates entirely locally and securely on the mobile phone and smartwatch.

CONCLUSIONS AND FUTURE WORK

We presented BreakSense, a mobile context-aware application focused on improving workers' physical and mental wellbeing without interrupting their work. BreakSense uses indoor-location sensing, physiological sensing and activity recognition to promote physical activity during work breaks, offering a small game-like interaction. We presented a set of design principles for work break interventions that highlight the unique social environment of the workplace and the importance of optimizing the user's physical and mental state at the end of a break. A proof-of-concept deployment of BreakSense investigated the novel dimension of bound vs. unbound break activities, suggesting that break activities that provide a sense of completion may be desirable over activities that require users to self-regulate. Our results highlight challenges and solutions for the social acceptability of indoor game-like work breaks. In future work, we intend to explore the use of desktop activity monitoring and calendar integration to provide better targeting of break intervention, helping to avoid recommending break activities the user cannot accept. We plan to further explore the appropriateness of common game mechanics for break taking and test indirect measures of users' readiness to return to work.

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REFERENCES

1. Elena Agapie, Daniel Avrahami, and Jennifer Marlow. 2016. Staying the Course: System-Driven Lapse Management for Supporting Behavior Change. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (CHI '16), 1072–1083. https://doi.org/10.1145/2858036.2858142

2. Pradeep Buddharaju and Yokeshwaran Lokanathan. 2016. Mobile Exergaming: Exergames on the Go. In *Proceedings of the International Conference on Mobile Software Engineering and Systems* (MOBILESoft '16), 25–26. https://doi.org/10.1145/2897073.2897125

3. Derek Burkland. 2013. *The Effects of Taking a Short Break: Task Difficulty, Need for Recovery and Task Performance*.

4. Anjana Chatta, Tyler Hurst, Gayani Samaraweera, Rongkai Guo, and John Quarles. 2015. Get off the Couch: An Approach to Utilize Sedentary Commercial Games As Exergames. In *Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play* (CHI PLAY '15), 47–56. https://doi.org/10.1145/2793107.2793115

5. James Clawson, Jessica A. Pater, Andrew D. Miller, Elizabeth D. Mynatt, and Lena Mamykina. 2015. No Longer Wearing: Investigating the Abandonment of Personal Health-tracking Technologies on Craigslist. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing* (UbiComp '15), 647–658. https://doi.org/10.1145/2750858.2807554

6. Laura A. Clemente, Andrew J. Davidson, Ian D. Reid, José Neira, and Juan D. Tardós. 2007. Mapping Large Loops with a Single Hand-Held Camera. *Robotics: Science and Systems* 2: 2.

7. Vicki S. Conn, Adam R. Hafdahl, Pamela S. Cooper, Lori M. Brown, and Sally L. Lusk. 2009. Meta-Analysis of Workplace Physical Activity Interventions. *American journal of preventive medicine* 37, 4: 330–339. https://doi.org/10.1016/j.amepre.2009.06.008

8. Dean Cooley and Scott Pedersen. 2013. A pilot study of increasing nonpurposeful movement breaks at work as a means of reducing prolonged sitting. *Journal of environmental and public health* 2013.

9. Matthew Cooper, Jacob Biehl, Gerry Filby, and Sven Kratz. 2016. LoCo: boosting for indoor location classification combining Wi-Fi and BLE. *Personal and Ubiquitous Computing* 20, 1: 83–96.

10. Daniel A. Epstein, Daniel Avrahami, and Jacob T. Biehl. 2016. Taking 5: Work-Breaks, Productivity, and Opportunities for Personal Informatics for Knowledge Workers. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (CHI '16), 673–684. https://doi.org/10.1145/2858036.2858066

11. James Fogarty, Scott E Hudson, Christopher G Atkeson, Daniel Avrahami, Jodi Forlizzi, Sara Kiesler, Johnny C Lee, and Jie Yang. 2005. Predicting human interruptibility with sensors. *ACM Transactions on Computer-Human Interaction (TOCHI)* 12, 1: 119–146.

12. BJ Fogg. 2009. A Behavior Model for Persuasive Design. In *Proceedings of the 4th International Conference on Persuasive Technology* (Persuasive '09), 40:1–40:7. https://doi.org/10.1145/1541948.1541999

13. Nanna Gorm and Irina Shklovski. 2016. Steps, Choices and Moral Accounting: Observations from a Step-Counting Campaign in the Workplace. In *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing* (CSCW '16), 148–159. https://doi.org/10.1145/2818048.2819944

14. Nanna Gorm and Irina Shklovski. 2016. Sharing Steps in the Workplace: Changing Privacy Concerns Over Time. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (CHI '16), 4315–4319. https://doi.org/10.1145/2858036.2858352

15. Janne Haverinen and Anssi Kemppainen. 2009. Global indoor self-localization based on the ambient magnetic field. *Robotics and Autonomous Systems* 57, 10: 1028–1035. https://doi.org/10.1016/j.robot.2009.07.018

16. G. N. Healy, D. W. Dunstan, J. Salmon, E. Cerin, J. E. Shaw, P. Z. Zimmet, and N. Owen. 2008. Breaks in Sedentary Time: Beneficial associations with metabolic risk. *Diabetes Care* 31, 4: 661–666. https://doi.org/10.2337/dc07-2046

17. Robert A Henning, Eric A Callaghan, Anna M Ortega, George V Kissel, Jason I Guttman, and Heather A Braun. 1996. Continuous feedback to promote self-management of rest breaks during computer use. *International Journal of Industrial Ergonomics* 18, 1: 71–82.

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

19. Peter Henry, Michael Krainin, Evan Herbst, Xiaofeng Ren, and Dieter Fox. 2012. RGB-D mapping: Using Kinect-style depth cameras for dense 3D modeling of indoor environments. *The International Journal of Robotics Research* 31, 5: 647–663.

20. Jeffrey Hightower, Roy Want, and Gaetano Borriello. 2000. SpotON: An indoor 3D location sensing technology based on RF signal strength. *UW CSE 00-02-02, University of Washington, Department of Computer Science and Engineering, Seattle, WA* 1. Retrieved September 21, 2016 from http://ahvaz.ist.unomaha.edu/azad/temp/sal/00-hightower-localization-indoor-3d-rssi-spoton-techrep.pdf

21. Institute for Health and Productivity Studies. Physical Activity in the Workplace: A Guide for Employers. Retrieved from http://www.cdc.gov/physicalactivity/worksite-pa/index.htm

22. Brett Klika and Chris Jordan. 2013. HIGH-INTENSITY CIRCUIT TRAINING USING BODY WEIGHT: Maximum Results With Minimal Investment. *ACSM's Health & Fitness Journal* 17, 3: 8–13. https://doi.org/10.1249/FIT.0b013e31828cb1e8

23. Ken Leung, Derek Reilly, Kate Hartman, Suzanne Stein, and Emma Westecott. 2012. Limber: DIY Wearables for Reducing Risk of Office Injury. In *Proceedings of the Sixth International Conference on Tangible, Embedded and Embodied Interaction* (TEI '12), 85–86. https://doi.org/10.1145/2148131.2148150

24. Andrew Macvean and Judy Robertson. 2013. Understanding Exergame Users' Physical Activity, Motivation and Behavior over Time. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '13), 1251–1260. https://doi.org/10.1145/2470654.2466163

25. Regan L. Mandryk and Kathrin M. Gerling. 2015. Discouraging Sedentary Behaviors Using Interactive Play. *interactions* 22, 3: 52–55. https://doi.org/10.1145/2744707

26. Regan L Mandryk, Kathrin M Gerling, and Kevin G Stanley. 2014. Designing games to discourage sedentary behaviour. In *Playful User Interfaces*. Springer, 253–274.

27. Gloria Mark, Daniela Gudith, and Ulrich Klocke. 2008. The cost of interrupted work: more speed and stress. In *Proceedings of the SIGCHI conference on Human Factors in Computing Systems*, 107–110.

28. Daniel C McFarlane and Kara A Latorella. 2002. The scope and importance of human interruption in human-computer interaction design. *Human-Computer Interaction* 17, 1: 1–61.

29. Florian "Floyd" Mueller, Darren Edge, Frank Vetere, Martin R. Gibbs, Stefan Agamanolis, Bert Bongers, and Jennifer G. Sheridan. 2011. Designing Sports: A Framework for Exertion Games. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '11), 2651–2660. https://doi.org/10.1145/1978942.1979330

30. D. Nister, O. Naroditsky, and J. Bergen. 2004. Visual odometry. In *Proceedings of the 2004 IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 2004. CVPR 2004*, I-652-I-659 Vol.1. https://doi.org/10.1109/CVPR.2004.1315094

31. Derek Reilly, Emma Westecott, David Parker, Samuel Perreault, Derek Neil, Nathan Lapierre, Kate Hartman, and Harjot Bal. 2013. Design-driven Research for Workplace Exergames: The Limber Case Study. In *Proceedings of the First International Conference on Gameful Design, Research, and Applications* (Gamification '13), 123–126. https://doi.org/10.1145/2583008.2583030

32. Ann E Rogers, Wei-Ting Hwang, and Linda D Scott. 2004. The effects of work breaks on staff nurse performance. *Journal of Nursing Administration* 34, 11: 512–519.

33. Ralf Schwarzer. 2008. Modeling Health Behavior Change: How to Predict and Modify the Adoption and Maintenance of Health Behaviors. *Applied Psychology* 57, 1: 1–29. https://doi.org/10.1111/j.1464-0597.2007.00325.x

34. Meredith M Skeels and Jonathan Grudin. 2009. When social networks cross boundaries: a case study of workplace use of facebook and linkedin. In *Proceedings of the ACM 2009 international conference on Supporting group work*, 95–104.

35. Naomi G Swanson and Steven L Sauter. 1991. The design of rest breaks for video display terminal work: A review of the relavant literature. *Journal of Safety Research* 21, 4: 166.

36. Ann M Swartz, Leah Squires, and Scott J Strath. 2011. Energy expenditure of interruptions to sedentary behavior. *International Journal of Behavioral Nutrition and Physical Activity* 8, 1: 69. https://doi.org/10.1186/1479-5868-8-69

37. Wendell C Taylor, Ross Shegog, Vincent Chen, David M Rempel, Marybeth Pappas Baun, Cresendo L Bush, Tomas Green, and Nicole Hare-Everline. 2010. The Booster Break program: description and feasibility test of a worksite physical activity daily practice. *Work* 37, 4: 433–443.

38. Mark Stephen Tremblay, Rachel Christine Colley, Travis John Saunders, Genevieve Nissa Healy, and Neville Owen. 2010. Physiological and health implications of a sedentary lifestyle. *Applied Physiology, Nutrition, and Metabolism = Physiologie*

Appliquée, Nutrition Et Métabolisme 35, 6: 725–740. https://doi.org/10.1139/H10-079

39. Phillip Tucker, Simon Folkard, and Ian Macdonald. 2003. Rest breaks and accident risk. *The Lancet* 361, 9358: 680.

40. Jacob O. Wobbrock, Leah Findlater, Darren Gergle, and James J. Higgins. 2011. The Aligned Rank Transform for Nonparametric Factorial Analyses Using Only Anova Procedures. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '11), 143–146. https://doi.org/10.1145/1978942.1978963

41. World Health Organization. 2010. *Healthy workplaces: a model for action: for employers, workers, policymakers and practitioners.* WHO Press, Geneva.

42. Kenneth P. Wright, Christopher A. Lowry, and Monique K. LeBourgeois. 2012. Circadian and wakefulness-sleep modulation of cognition in humans. *Frontiers in Molecular Neuroscience* 5. https://doi.org/10.3389/fnmol.2012.00050

43. Han Xu, Zheng Yang, Zimu Zhou, Longfei Shangguan, Ke Yi, and Yunhao Liu. 2016. Indoor Localization via Multi-modal Sensing on Smartphones. In *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing* (UbiComp '16), 208–219. https://doi.org/10.1145/2971648.2971668

44. Doohee Yun, Hyunseok Chang, and T. V. Lakshman. 2014. Accelerating Vision-based 3D Indoor Localization by Distributing Image Processing over Space and Time. In *Proceedings of the 20th ACM Symposium on Virtual Reality Software and Technology* (VRST '14), 77–86. https://doi.org/10.1145/2671015.2671018

45. EyeLeo. Retrieved September 21, 2016 from http://eyeleo.com/

46. Take A Break! *Meditation Oasis*. Retrieved September 21, 2016 from http://www.meditationoasis.com/apps/

47. Android Beacon Library. Retrieved September 20, 2016 from https://altbeacon.github.io/android-beacon-library/

48. Parse. *Parse Open Source Hub*. Retrieved September 21, 2016 from http://parseplatform.github.io/

49. BeaconOSX. *GitHub*. Retrieved September 21, 2016 from https://github.com/mttrb/BeaconOSX