Time for Break: Understanding Information Workers' Sedentary Behavior Through a Break Prompting System

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ABSTRACT
Extended periods of uninterrupted sedentary behavior are detrimental to long-term health. While prolonged sitting is prevalent among information workers, it is difficult for them to break prolonged sedentary behavior due to the nature of their work. This work aims to understand information workers' intentions & practices around standing or moving breaks. We developed *Time for Break*, a break prompting system that enables people to set their desired work duration and prompts them to stand up or move. We conducted an exploratory field study (N = 25) with *Time for Break* to collect participants' work & break intentions and behaviors for three weeks, followed by semi-structured interviews. We examined rich contexts affecting participants' receptiveness to standing or moving breaks, and identified how their habit strength and self-regulation are related to their break-taking intentions & practices. We discuss design implications for interventions to break up periods of prolonged sedentary behavior in workplaces.

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Author Keywords
Sedentary behavior; workplace setting; information workers; break; personal informatics.

INTRODUCTION
Information workers are generally sedentary, spending most of their days working in front of a desk-bound computer [47, 53, 60]. Unfortunately, this prolonged sedentary behavior is closely linked with an increased risk of developing chronic diseases and mortality [29, 30, 41, 52, 68]. Furthermore, regular physical activities cannot fully compensate for the harm caused by prolonged sedentary behavior [3, 7]. Thus, a healthy work routine requires breaking up extended periods of sedentary behavior beyond solely increasing physical activity or limiting total sedentary time [23, 52].

In the HCI community, researchers have studied technological interventions to encourage information workers to take breaks (e.g., prompting system [8, 65], tangible interface [56], game-like system [12, 49]). However, for most of these interventions, their primary goal was to promote a break from prolonged work, not from *prolonged sitting*. It is important to note that breaks do not necessarily make people get up from their seats because it is easy to stay sedentary during breaks (e.g., watching a video or playing a game while sitting [6, 49]).

In addition, taking breaks too frequently during work hours can disrupt information workers' productivity despite its health benefits [37, 38, 45]. Thus, to promote a healthy and sustainable break habit, it is important to find the right balance between the two seemingly conflicting goals: to take breaks that counter sedentary behavior and to be productive.

In this work, we set out to investigate ways to help information workers break prolonged sedentary behavior while maintaining work productivity. Given that sedentary behavior is a strong habitual behavior [16, 44], breaking prolonged sedentary behavior is a long-term process. As a first step, we examined the contexts around information workers' work & break behavior excluding those who use *sit-stand desk*. We developed *Time for Break* (Figure 1), a desktop-based prompting system that enables people to set up their preferred work and break duration, and sends a prompt for *moving breaks* (i.e., breaks that involve standing or moving) according to personalized settings. From a three-week field study with 25 information workers, we collected qualitative and quantitative

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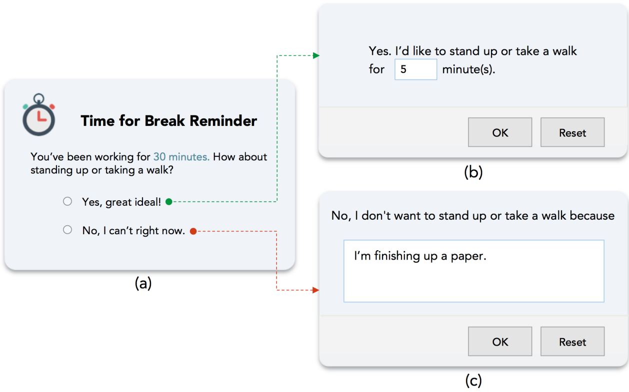

Figure 1. *Time for Break*'s break prompt dialogue (a), and a follow up question depending on people's response. When they answer "yes," they enter the intended break duration (b). When they answer "no," they enter reasons for not taking a break (c).

data on participants' work and break intentions & practices using *Time for Break*. We found significant trends on their habit strength and self-regulation in taking moving breaks, as well as their work and break intentions & practices. Through semi-structured interviews, we learned how participants' break-taking intentions & practices vary in different contexts.

The first contribution of this work is an empirical understanding of information workers' intentions & practices to take moving breaks, including the gaps between intentions and behaviors, work and break preferences, and the contexts and reasons regarding their choices. The second contribution is a set of design implications for interventions that aim to break prolonged sedentary behavior while maintaining work productivity, and more broadly, suggesting information workers' long-term health as an important design value to consider.

In what follows, we first provide related work and present three research questions. After detailing the design of the *Time for Break*, we describe the field study and report results to answer the research questions. We discuss design implications for building effective interventions to help information workers break sedentary behavior and create a healthy work routine.

RELATED WORK

In this section, we cover related work in defining and understanding sedentary behavior, and interventions aiming to reduce sedentary behavior. We also described interventions designed to promote breaks in workplaces and to reduce work interruptions in the HCI community.

Sedentary Behavior

Sedentary behavior is generally defined as waking behavior with low energy expenditure in a seated, reclined, or lying posture [4, 64]. Sedentary behavior often involves activities such as reading, watching TV, and using a computer while seated [6, 54]. Researchers found that prolonged sedentary behavior increases risks for diabetes [29], cardiovascular disease [68], obesity [32], and other chronic diseases [40, 51]. Recently, information workers have increasingly become prone to prolonged sedentary behavior because they usually work on the desk-bound computer for a long period of time [47, 53, 60]. More than 70% of U.S. employees spend over eight hours working during weekdays [50]. Their sitting time amounts to more than 80% of the work hours [53], which is about two hours longer than their sitting time during leisure days [47].

A common misunderstanding is that regular physical activities can fully compensate for the harm of prolonged sedentary behavior. Contrary to this belief, scientific evidence shows that the nature of prolonged sedentary behavior is different from lack of exercise [3]. For example, those who spend the majority of their days sitting can still suffer from the health risks caused by prolonged sedentary behavior, even if they meet the recommended levels of physical activity (e.g., 60-minute moderate physical activities per day) [3, 7].

Recognizing the harmfulness of prolonged sedentary behavior, researchers designed mobile applications (e.g., B-Mobile [8], SitCoach [65]) to reduce prolonged sitting by sending regular prompts. Notably, modifying the workplace environment such as installing sit-stand desks [1, 13] and treadmill workstations [39] continues to gain ground. Although some researchers observed a significant reduction in total sitting time with sit-stand desks [1, 13], other studies showed that the use of sit-stand desks depends on personal willingness, which varied among people [28]. In addition, while researcher focus on measuring total sitting and active time using these interventions, it remains unclear whether the sitting time was effectively broken up, thereby preventing prolonged sedentary behaviors. To examine alternative strategies to reduce sedentary behavior, Maher and colleagues leveraged *action planning* by having people submit a detailed daily plan of when, where, and how they will engage in physical activity or limiting prolonged sitting time via email [44]. However, this approach was not effective in reducing sedentary behavior.

Breaking prolonged sedentary behavior is still a challenge for most people due to its strong habitual nature [44, 57]. To investigate the key factors that regulate sedentary behavior, Conroy and colleagues conducted a 14-day ecological momentary assessment study combined with wearable accelerometers [16]. They found that sedentary behavior was regulated by both habit (automatic process) and intentions (reflective process). Inspired by their work, we measured the habit strength and self-regulation in relation to taking moving breaks to further explore how information workers' habit strength and self-regulation relate to their break-taking intentions & practices.

Promoting Breaks in Workplaces

To promote healthy work routines for information workers, HCI researchers have designed interventions to promote breaks in workplaces. A common approach is using *prompt-based systems*, which remind people to take breaks by leveraging desktop computers (e.g., Time Out [62], SuperBreak [49]) or mobile phones (e.g., BreakSense [12]). Specifically, SuperBreak and BreakSense are game-like systems that encourage breaks in workplaces. SuperBreak sends out prompts to encourage people to take regular and frequent microbreaks (i.e., a 25-second break every eight minutes of working) by having them briefly read a document, play an interactive game, or watch a video [49]. SuperBreak was effective in engaging people in taking microbreaks, but it could interrupt their flow of work. BreakSense leverages location sensing to detect people' physical break (e.g., going to the restroom) and invite them to play exergames to extend the break duration [12]. While BreakSense encouraged people to take longer moving breaks, it did not initiate the breaks. Furthermore, it could discourage people from going back to work.

To understand the effects of different types of work breaks on information workers' productivity, Epstein and colleagues conducted a web-based diary study combined with a survey and interview [24]. They identified that participants took longer digital and social breaks than they intended, but shorter necessary break, physical break, and outdoors break than they intended. We note that in workplaces, "taking breaks" does not necessarily help people reduce sedentary behaviors: many existing interventions encourage any work breaks, and people can easily engage in sedentary activities during breaks (e.g., checking on social media or watching videos) [24, 49].

It has been challenging to identify the "appropriate prompting moments" (i.e., when people are receptive and responsive) when designing prompting systems in workplaces. Prompting people at inappropriate moments can introduce unnecessary interruptions and influence their productivity [2, 19, 36]. In the HCI community, many researchers have examined interruptibility in workplaces [33, 35, 70]. For example, Hudson and colleagues constructed a machine learning model to predict human interruptibility based on their observation on the contexts around information workers [33]. Iqbal and Bailey examined opportune moments for interruption with a workload-aligned model, and found that the "best" moment to interrupt people was when they were working on tasks with low workload [35]. However, interruptible moments that are optimized for work productivity are not identical with prompting moments for breaking extended periods of uninterrupted sitting.

In contrast to the works mentioned above, we aim to explore ways to break information workers' prolonged sedentary behaviors by first understanding their work and break intentions & practices. In addition, our work extends the prior research by addressing information workers' habit strength and self-regulation in relation to break-taking behaviors for long-term habit development. In this light, we consider only "standing or moving" breaks as breaks in our study: the term, "moving breaks" in the remaining sections of the paper refers to breaks that involve standing or moving. We also assume that information workers sit while working and we use *sitting duration* and *work duration* interchangeably.

TIME FOR BREAK

We designed *Time for Break* as a data collection and prompting tool to answer the following three research questions:

- RQ1: What are information workers' intended work and break duration and their actual practices?
- RQ2: What are reasons and contexts around information workers' break-taking intentions and practices?
- RQ3: How do information workers' habit strength and self-regulation relate to their break-taking intentions and practices?

Design Goals

To answer the three research questions listed above, we aim to design *Time for Break* as a data collection tool, for autonomy, exploratory purpose, and minimal distraction.

Design for Autonomy

Many prompting systems imposed the fixed duration for work and break (e.g., 5-minute break after every 60-minute sitting) on all participants throughout the study (e.g., [65, 55]). In contrast, to provide people with control over their schedule, we allow them to change their preferred work duration every day. In addition, people are free to accept, decline, or ignore each break prompt depending on their contexts. Once they accept to take a break, people can set an intended break duration. This ensures that people have the autonomy to decide on their work & break schedules, to dismiss the prompt when necessary, and to set different break duration in different contexts.

Design for Exploratory Purposes

For the exploratory purposes of understanding information workers' break intentions & practices, we design *Time for Break* to collect people's work & break contexts instead of changing their current break & work habits. In Fogg's term, the break prompt in our study serves as a *signal* (i.e., a reminder that does not change one's motivation or ability to perform the target behavior) [25], simply indicating that it is the time to take a moving break rather than persuading people to take a break. Thus, we did not provide any feedback on people's responses or break-taking behaviors, and carefully designed the break prompt using neutral wording (e.g., no encouraging wording for accepting a break or discouraging wording for declining a break). Despite these design choices, we note that *Time for Break* could change people's break-taking intention and behavior through an act of self-monitoring.

Design for Minimal Distraction

As information workers are generally busy with their work, there are times when they do not want to take any break or even do not have time to respond to the prompt. Given that the break prompt can be a distraction in itself, we strove to minimize distraction. *Time for Break* shows the break prompt at the bottom-right corner of the screen, and automatically closes it after two minutes if people have not responded yet. Additionally, if people are typing or clicking the mouse, *Time for Break* postpones showing the break prompt by 15 seconds to avoid interrupting people's flow of work.

Time for Break Design

Time for Break consists of a work duration setting window, a break prompt window (Figure 1), a break window (with a break timer), and a work timer. People can set their preferred work duration (i.e., for how long they want to continuously work before being prompted) on the work duration setting window once a day every day. People can see how long they have been working by hovering over the work timer in a tray icon located on the Windows notification area. *Time for Break*

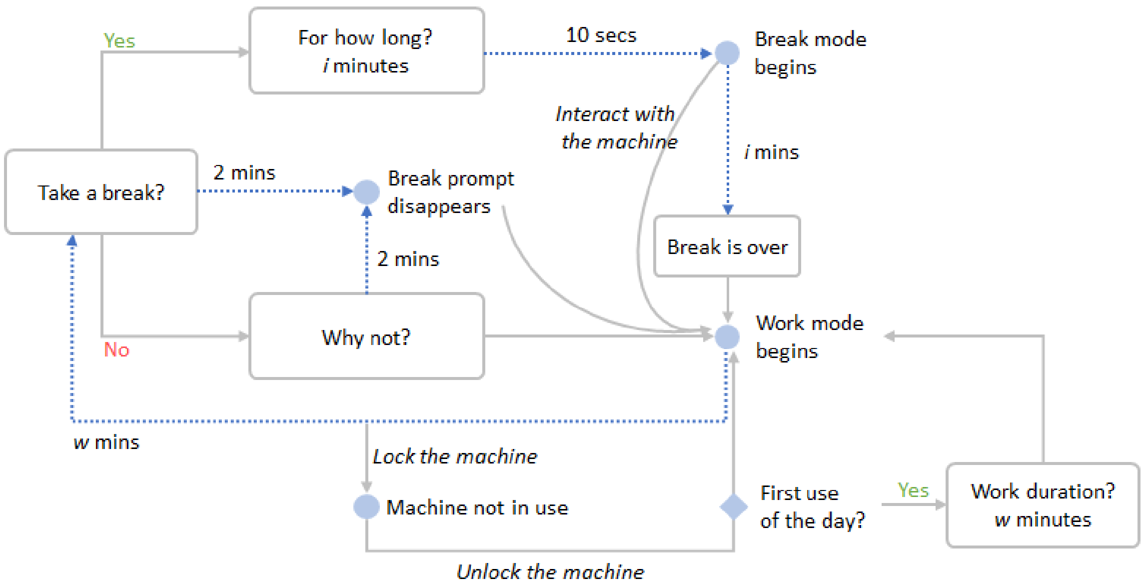

Figure 2. *Time for Break* interaction flow.

does not provide any other feedback on participants' break-taking activities or responses. Inspired by Experience Sampling Method [17, 43, 46], *Time for Break* sends out prompts to collect people's break-taking intention and contexts in-situ.

Experience Sampling Method (ESM)

Experience Sampling Method (ESM) is a research method that asks people to self-report their behavioral and mental aspects repeatedly in real time [17, 43]. It is proven to be valid in identifying between-subjects differences as well as within-subjects differences on people's intentions and behaviors [31].

Originating from psychology, ESM has been widely used in studies conducted in workplaces. For example, Mark and colleagues deployed a desktop-based ESM system to examine the association between information workers' attentional states and the workplace context [46]. Fullagar and colleagues also used ESM to investigate the relationship between flow (i.e., a comprehensive measure of optimal experience) and subjective well-being of architecture students [26]. Moreover, to support ESM studies in the wild, many open-source research tools such as PACO [21] and Experience Sampler [63] are available.

In natural settings, ESM has certain limitations such as self-selection bias and data quality concerns [58]. Nevertheless, researchers can reduce the limitations through recruiting participants with sufficient motivation to complete the study or minimizing the response burden [18, 34]. Overall, ESM is a powerful approach to link people's current experience with contexts and to surface the rationale behind their overt behavior [58]. Inspired by the ESM approach, we designed *Time for Break* as a data collection tool that sends out in-situ prompts proximal to people's action, although our study does not strictly follow the traditional ESM design. Thus, *Time for Break* can be best described as an exploratory prompting tool to collect people's behavioral and attitudinal data in a semi-controlled field deployment study [59].

Interaction Flow

A person receives the break prompt after an uninterrupted computer active time that equals to the work duration he or she set daily. Locking the machine stops and resets the work timer. Upon receiving a prompt, the person can respond with "Yes, great idea!" to accept taking the break, "No, I can't right now." to decline, or simply ignore it (i.e., does not interact with it) based on his or her current state (Figure 2).

- If the person responds "Yes, great idea!," *Time for Break* asks for how long the person wants to take the break (Figure 1b). After entering an intended break duration, the person has 10 seconds to wrap up current work (e.g., close a window). After the 10 seconds, the break window (with the break timer) appears and the break mode begins.

  The person can go back to work whenever he or she wants; interacting with the machine (i.e., pressing any keys or clicking anywhere on the screen) begins the work mode. In addition, the person can begin the work mode using the break window; the person can click the "Exit Break Mode" button or the "Go Back to Work" button (after the break duration is passed, the break window replaces the "Exit Break Mode" button with the "Go Back to Work" button). *Time for Break* estimates the break duration based on the computer's inactive time during a break.
- If the person responds "No, I can't right now.," *Time for Break* asks the reason why he or she cannot take the break at the moment (Figure 1c). The dialogue box disappears after two minutes if the person ignores it.
- If the person ignores the break prompt, it automatically disappears after two minutes, and a new work cycle begins.

Implementation

We built *Time for Break* as a Windows desktop application in C# with Windows Presentation Foundation (WPF). *Time for Break* transfers the collected data such as people's work duration settings and responses to the prompt to the database (MySQL) located in a secure server. To make *Time for Break* run all the time, we automatically launch it when the machine starts. To ensure people set only one work duration every day, *Time for Break* pops the work duration setting window by keeping track of the date of the latest work duration setting.

METHOD

We conducted a three-week field study with *Time for Break* at a large state university in the U.S. to explore information workers' work and break intentions & practices. Our study was approved by the university's Institutional Review Board.

Participants

We advertised the study through the university mailing list and university research volunteer website. Among the 42 people who responded, 26 met the following inclusion criteria: individuals who (1) are over 18; (2) use a Windows machine (laptop or desktop) more than six hours a day on workdays; (3) have administrator rights to install *Time for Break* on their machine; (4) have Internet access; and (5) do not use a sit-stand desk. In addition, we purposely recruited people who are interested in breaking prolonged sedentary behavior. One participant dropped out of the study because of family emergency. Among the 25 participants who completed all the study activities, seven were male, and 18 were female. Their age ranges from 24 to 60 (M = 39.12, SD = 2.55). Five participants were graduate students (4 in Information Sciences, 1 in Aerospace), one was a postdoctoral scholar (Statistics), and 19 were university staff members (4 administrators, 3 IT consultants, 3 financial assistants, 2 research staff, 2 data analysts, 1 facilities coordinator, 1 business manager, 1 corporation relation, 1 events coordinator, 1 career consultant).

Study Procedure

The study procedure consists of five stages: (1) pre-study questionnaire, (2) pre-study tutorial, (3) three-week data collection with *Time for Break*, (4) post-study questionnaire, and (5) optional post-study interview. Each participant received a $30 Amazon gift card as compensation at the end of the study. Those who participated in the optional post-study interview received an extra $10 Amazon gift card.

Pre-Study Questionnaire

The pre-study questionnaire was administered via a web survey, which covered the study consent, basic demographic information, motivations to take moving breaks during work hours, and self-reported habit strength and self-regulation in *taking moving breaks*[1]. Habit strength was measured by the 4-item automaticity subscale from the Self-Report Habit Index [66]. This measure has validated psychometric properties from prior research, which is widely used for measuring habit strength for behaviors [16, 44, 27]. Self-regulation was measured by a 6-item subscale from the Self-Regulation Questionnaire (SRQ) [10], and was tailored to assess participants' ability to develop, implement, and keep a plan of breaking prolonged sitting. This measure has been used to assess various behaviors including physical activities and sedentary behavior [11].

[1]We note that sedentary behavior is in general a strong habitual behavior, which is insensitive to self-reported measures; therefore, researchers often measure an opposite behavior to the habitual behavior [44], that is, "taking moving breaks" in our case.

Pre-Study Tutorial

After the pre-study questionnaire, we scheduled a pre-study tutorial with each participant in-person (n = 18), over Skype (n = 4), and via phone call (n = 3). During the 20-minute tutorial, we helped participants install *Time for Break* on their machines, and instructed them in setting up a work duration and responding to the break prompt. We emphasized that the "breaks" in this study mean breaks that involve standing up or moving, and that the study compensation is not tied to their responses to the break prompts.

Data Collection with Time for Break

Right after the pre-study tutorial, participants started to use and respond to *Time for Break* for the next three weeks. During the three-week data collection period, we did not contact the participants. Two participants reached us to seek help in reinstalling *Time for Break* due to system upgrade, and three notified us of their one-day leave off work via email.

Post-Study Questionnaire

The post-study questionnaire consisted of the same questions on participants' *habit strength* and *self-regulation* in taking moving breaks during work hours. We also asked participants' qualitative feedback on their experience with *Time for Break*, such as new features they would like to see and additional information they wanted to share with us.

Optional Post-Study Interview

After the post-study questionnaire, participants had an option to participate in a post-study interview. We interviewed 23 participants (in-person (n = 18), Skype (n = 3), phone call (n = 2)) out of 25. The interview was semi-structured, and lasted from 20 to 60 minutes. During the interview, we asked participants to talk about their experience with *Time for Break*, such as their work and break preferences, why they accept or decline to take breaks upon receiving the break prompt, and their perceived productivity during the study period. We also asked them what they learned from the study, and what they liked and disliked about *Time for Break*.

Data Analysis

In this section, we describe the data we collected from each study stage and the methods we used to perform data analysis.

Questionnaire Data Analysis

We used open coding to categorize participants' motivations to take moving breaks during work hours. We also digitized participants' qualitative feedback on *Time for Break* from the post-study questionnaire. We conducted paired-samples t-tests to compare participants' pre- and post-study *habit strength* and *self-regulation* in taking moving breaks during work hours.

Log Data Analyses

We summarized the descriptive results from the log data of *Time for Break*, including *daily work duration*, *response latency* (i.e., the time span between when participants received the break prompt and when they submitted their responses), *responses to the prompts* (i.e., "yes," "no," or ignore), *intended break duration*, *actual break duration*, and *reasons for not taking breaks*. We excluded 17 out of 542 (3.1%) free-form text entries because they were unrecognizable (e.g., random letters, pure numbers, and symbols). We classified the remaining entries into different types of reasons for not take breaks using thematic analysis.

To analyze the quantitative data, we first conducted a Box-Cox transformation [9] on the variables that had a skew value > 1.5 (i.e., *work duration*, *response latency*, *intended break duration*, and *actual break duration*). We then calculated the Intra-class Correlations (ICC) [69] of *work duration*, *response latency*, *intended break duration*, and *actual break duration* to find out how much variation was due to between-subjects differences (i.e., how stable versus malleable these variables were). We then used linear and logistic multilevel modeling [5] to examine what between- and within-subjects factors predicted work duration, response latency, intended break duration, actual break duration, and changes of *habit-strength* and *self-regulation* from pre-study to post-study. In addition, we set up a linear multilevel model to test whether the variability in a person's work duration, response latency, intended break duration, and actual break duration (i.e., person-level standard deviations controlled for person-level means of each variable) impacted the degree of habit strength and self-regulation change across the study.

Interview Data Analysis

The interview provided more details on participants' rationales of their log data and their break-taking intentions & practices. We audio recorded and transcribed all 23 interviews. Based on the framework of qualitative analysis [48], two researchers used bottom-up thematic analysis to identify emerging themes through iterative coding. One of the coders was not involved in the interviews, ensuring an independent perspective. The research team discussed major themes and established recurring codes of participants' motivation to take moving breaks, work and break preferences, and experience with *Time for Break*.

RESULTS

Over the course of three weeks, *Time for Break* collected 374 days of work duration settings and delivered 1,599 break prompts, in which there were 642 (40%) responses of "yes" and 542 (34%) responses of "no." The remaining 415 (26%) break prompts were ignored by participants. The average response latency to the prompt was 23.57 seconds (*SD* = 27.91), excluding the cases when the prompt was ignored. Here, we report our findings according to the three research questions presented earlier. To ensure the confidentiality of participants, we assigned a participant identifier (P#) to each participant.

RQ1: Information Workers' Intended Work & Break Duration and Their Actual Practices

In general, participants had different preferences in setting their work duration, but similar preferences in setting their intended break duration. Here, we describe the similarities and differences on participants' intended work duration and break duration, as well as their actual practices.

Work Duration

The log data showed that (1) most variability in work duration setting was at the between-subjects level (ICC = .70): participants typically set their work duration with less variance each day compared to the variance between participants; and (2) in the range of work duration from 20 to 120 minutes, 60 minutes was most prevalent, as 172 out of 374 (46%) daily work duration was set to 60 minutes. On the last day of the study, 13 participants set 60 minutes as their work duration, and among them, five participants (P5, P7, P10, P12, P25) kept a 60-minute work duration throughout the study.

We found that participants preferred 60-minute work duration because it is (1) manageable: *"I pushed it to 60 [minutes], and that generally speaking became manageable ... at least a reasonable starting point and knowing throughout the day that some time of the day you need to get up"* (P11); (2) easy to track: *"... it's easier to keep track on it by hour, kind of in my head without tracking the icon"* (P19); and (3) neither too short nor too long: *"I think the longer times were too long. The shorter ones were too short, like it was popping up all the time. So I was either having to say no or I couldn't do the way with so many pop ups"* (P18).

However, it was common for participants to change the work duration depending on their schedule. For example, P15 usually set the work duration that is longer than her meeting duration so that she can avoid receiving a break prompt during the meeting: *"... if I have meetings for 30 minutes long, I tried to set [work duration] for 45 to an hour."* But her meeting duration changed from day to day, which made her frequently adjust the work duration. Similarly, P13 set her work duration based on whether she would be busy during the day: *"There were days I need to work for a longer time so I set 90 [minutes]. The other days I set 60 [minutes]."*

Break Duration

With paired-samples *t*-tests, we found a significant difference between participants' average intended break duration (*M* = 4.42, *SD* = 5.42) and actual break duration (*M* = 5.92, *SD* = 11.88) in minutes, $t(641) = -3.922$, $d = .16$, $p < .001$. Using linear multilevel modeling, we found the following set of trends on participants' intended and actual break duration with their work duration, response latency and the study days.

Intended Break Duration: The log data showed that (1) most variability in intended break duration was at within-subjects level (ICC = .13): each participant's intended break duration varied more across the study period compared to the variance between participants; (2) participants who set longer work duration on average tended to set longer intended break duration ($b = .40$, $p < .001$); (3) participants' intended break duration significantly decreased over time ($b = -.03$, $p < .001$); and (4) those who responded slower to the prompt on average tended to set longer intended break duration ($b = .02$, $p < .001$).

From the interviews, we learned that participants set their break duration based on what break activities they were going to do: *"If I go to restroom or stretch my leg I usually set it longer. If I'm just looking around and getting away from my desk, it's usually just 1 minute"* (P14). Whereas sometimes they decided their break duration based on how much work they had done: *"If I had accomplished a lot, I would say, okay, I would just take a longer break. If I had less accomplished than I would like to, I was like I'm going [to] get this done and the break can be short"* (P1).

The intended break duration ranged from 1 to 60 minutes. Seven participants kept the same break duration all the time, and among them, five (P2, P3, P6, P12, P23) kept it at 5 minutes, one (P7) kept it at 3 minutes, and one (P9) kept it at 2 minutes. These participants considered the break duration they input every time as a minimum duration for break: *"I think 5 minutes was like something in my head about what I should be taking at minimum"* (P23), *"I wanted to make sure I walked away for at least 3 minutes"* (P7).

Actual Break Duration: The log data showed that (1) most of variability in actual break duration was at within-subjects level (ICC = .09): each participant's actual break duration varied more across the study period compared to the variance between participants; (2) at the between-subjects level, participants' actual break duration was not consistent with their intended break duration (b = 37.12, p = .846); (3) at the within-subjects level, when participants set longer intended break duration than usual, they actually took longer breaks (b = 453.53, $p < .001$); and (4) nine participants took significantly longer breaks than they intended, and two took significantly shorter breaks than they intended.

Taking longer break than intended was usually due to incidental socializing: *"got caught in the hallway talking to somebody"* (P9). Due to the nature of our study environment where 10 participants worked in close proximity, we found that social interaction was common during breaks, and sometimes, they had synchronized breaks (e.g., chatting with others and meeting with mentors leveraging moving breaks). For those who took shorter breaks, they tended to overestimate the break duration without much thinking: *"It seems 5 minutes is a long time to grab a drink. It's interesting, I didn't notice that"* (P3), and would not wait until the end of the break: *"When I came back, if it says I get 5 more minutes, I'll just start to work"* (P13).

RQ2: The Contexts Around Information Workers' Break-Taking Intentions & Practices

Participants had various reasons to take breaks or not. Here, we describe participants' motivations to take moving breaks, and the reasons behind their responses to the break prompt. In addition, we describe what participants learned about their work and break habits from the study.

Motivations to Take Moving Breaks

In the pre-study questionnaire, we asked participants their motivation to take breaks during work hours. From their responses, we found they have the following different motivations: (1) lowering stress or being relaxed (32.1%), (2) physiological needs (e.g., need to go to restroom or go for lunch; 28.6%), (3) getting refreshed from work (23.2%), and (4) staying healthy (12.5%). Two participants answered that they did not have specific motivation to take moving breaks.

Responses to the Break Prompt

The log data showed that participants with stronger pre-study habit strength in taking moving breaks were more likely to respond "yes" to the break prompt (OR = 1.26, $p < .001$). However, the pre-study self-regulation in taking moving breaks did not predict participants' responses to the prompt (OR = .90, p = .281). The log data also showed that although the work duration did not predict participants' responses to the prompt (OR = .99, p = .903), for the days when participants had longer work duration than usual, they responded "yes" more often at the within-subjects level (OR = 1.30, p = .029).

During the post-study interview, we asked participants to recall the common situations when they responded "yes" to the break prompt. We noticed that with the break prompt, participants' break-taking intentions were based on their current work and mental status rather than their intrinsic motivation in taking moving breaks. All the participants mentioned they responded "yes" to the break prompt when they had physiological needs. Other situations included when they just completed a task, worked on an easy or difficult task, had a flexible schedule, and felt tired. For example, P20 noted, *"Probably only when I had to go to the bathroom, grab coffee [or] lunch, or go to a meeting. I rarely just get up and stretch."* Similarly, P4 noted that he usually took a moving break when he wanted to go to restroom, smoke, or get a coffee.

Among the 542 "no" responses, 525 entries (96.9%) provided valid reasons for declining to take a moving break. The most prevalent reasons for declining to take a break were: busy working (40.6%), in a meeting or class (18.9%), and just coming back from a break (15.2%). Table 1 shows the reasons along with example quotes from the participants. We noticed that many participants entered "just coming back from a break" as the reason for not taking a break, because they could occasionally leave their desk without locking their machines, which could not be captured by *Time for Break*.

Increased Self-Awareness

Even though *Time for Break* did not provide participants with any feedback besides how long they had been sitting, participants became aware of their work and break routines during the study through receiving prompts and responding to them.

While talking about the experience with *Time for Break*, eight participants stated that they were not aware of how long they had been sitting until the break prompt popped up: *"every once in a while, it was kind of a surprise like oh, that much time has passed"* (P9), *"I'm surprised that that much time elapsed already"* (P20). In addition, through receiving the break prompt with a certain frequency, participants were aware of their sedentary level. Some participants realized that they spent too much time on sitting: *"I learned that I don't get up enough. I need to do better, standing up and walking away"* (P10). While others realized that they were less sedentary than they had thought: *"I didn't notice until the study. I didn't notice I got up so frequently. For 120 minutes, I was not sedentary at all. But for 60 minutes, maybe I am"* (P2).

Reasons	Percentage	Example Quotes
busy working	40.6%	*"It [Time for Break] prompted me to take a break, which I didn't want to. Because I was focused on something and I want to keep doing it."* (P4)
in a meeting or class	18.9%	*"They were sometimes in a video conference I was sharing my screen and it pop up. I had to say no."* (P14)
coming back from a break	15.2%	*"I just came back to my desk from lunch, it popped up and I had to click no."* (P5)
close to finish something	8.8%	*"Some of the times I would be prompted to take a break but I was like almost done with something, that would take me like five more minutes, so I would like not to take my break when I was prompted."* (P1)
heading to other place (e.g., home) soon	7.9%	*"Especially towards the end of the day, I'm going home anyway... I know that 30 minutes tacked on to me being able to go home."* (P11)
engaged in a conversation	3.7%	*"I was in the middle of a phone call. Sometimes it's kind of hard to say 'yes'."* (P6)
engaged in a screen-based activity (e.g., video, game)	2.5%	*"sometimes [I was] working but then [I] switched to a game, and when it popped up I would say no."* (P24)
having lunch or dinner	2.4%	*"I was eating lunch at my desk. I would not take a break during lunch."* (P22)

Table 1. Reasons logged on *Time for Break* for not taking a break, and example quotes from the post-study interview.

Although we did not measure participants' work productivity or suggest them to improve on their work productivity, five participants indicated that their productivity improved by taking moving breaks with *Time for Break*. For example, P11 noted that *"You know it was good to get away from the desk, come back and be [sic] refreshing, and my productivity improved."* P6 mentioned that he became more productive by trying to respond "yes" to the break prompt before it disappeared: *"like 10 minutes before it's coming up, I'd wrap up work and tried to get it done faster, so I'd catch those breaks. Or maybe, switch to some easy task like emailing ... If there is [an effect], it must be increasing the productivity."* Other participants such as P1 noted that *Time for Break* helped her keep a consistent work and break schedule: *"I was in a more thoughtful mind, maintaining a certain schedule of working, it kind of enabled me to implement a midday break, just breaking up 8 hours or 8 and a half hours of continuous working."*

Participants expressed the desire to receive feedback on their responses to the prompt and break-taking behavior so that they can better understand their work and break patterns and make improvement accordingly: *"so if there is like some feedback for me to show my progress over time, [it] would help me understand how well I'm actually doing, or maybe some graph showing what I'm actually doing and what I thought I might be doing"* (P3), *"something like check your progress or see how you did surround everything"* (P8).

Increased Accountability

Although we designed the break prompt in a neutral way, seven participants mentioned that they felt accountable to respond "yes" to the break prompt. For example, P8, who set her work duration as 30 minutes every day, said: *"it was annoying sometimes, but I still felt that 30 minutes was the right amount of time. So I felt that I had to comply with the annoyance because that's what it was meant to do."* Some participants even felt guilty for responding 'no' to the break prompt, such as P1: *"maybe slightly guilty. I knew that I should be doing this, I should not be saying "no" to it so often"* and P10: *"It's just made me feel bad. It's like oh god, I should have got up but I'm not taking care of myself."*

In addition, four participants tended to wait for the break prompt even when they were ready to take a moving break: *"I would check it [the work duration counter] occasionally just to see when my break is. Because I wanted to get a drink of water or something and I would see when the window was going to come up, and wait to take my break"* (P21). Likewise, P14 liked to mouse over the work duration counter even though she was ready for a break: *"to check how soon my next break would be, I wait like usually 10 or 15 minutes [for the prompt], and then I went to the restroom."*

RQ3: Relationships Between Habit Strength, Self-Regulation, Break-Taking Intentions & Practices

We found that participants' pre-study habit strength and self-regulation played different but important roles in their break-taking intentions & practices. Moreover, their break-taking intentions & practices affected their post-study habit strength and self-regulation differently. In this section, we first describe the results on participants' response latency to the break prompt, and then report the findings around participants' habit strength and self-regulation.

Response Latency

The log data showed that (1) participants who set longer work duration on average responded slower than those who set shorter work duration (b = 4.82, p = .013); (2) participants responded to the break prompt faster as the study progressed (b = -.74, p = .013); (3) more than half of the responses (50.6%) occurred within the first 20 seconds upon receiving the prompt; and (4) there is no significant correlation between response latency and responses of "yes" or "no" (OR = 1.00, p = .598).

During the interview, participants stated that if they were certain whether to take a break or not, they would respond very quickly: *"When I responded 'no,' I knew for a fact that I couldn't leave my desk ... So I didn't even give it much thought to click the 'no' button"* (P2). However, when they wanted to take a break but were not ready for it, they tried to catch up the prompt within 2 minutes before it disappeared. Thus, it took them longer to respond to the break prompt: *"a couple times I would wait like another minute before I would click on the 'yes.' So I could finish the work and then click it"* (P9).

Habit Strength and Self-Regulation

The log data showed that participants' habit strength and self-regulation both increased from pre-study to post-study, but the increase was significant only for pre/post self-regulation ($M = 4.26$, $SD = 0.60$; $M = 3.75$, $SD = 0.77$), $t(24) = -3.64$, $p = .010$, $d = .728$. Although self-regulation did not predict participants' responses to the prompt, participants with stronger self-regulation responded faster to the break prompt ($b = -6.96$, $p < .001$). In addition, we found that participants who set consistent intended break duration increased their habit strength more than participants who set variable intended break duration ($b = -1.34$, $p = .04$).

DISCUSSION

Our goal was to inform the design of systems for promoting long-term healthy work routines. In designing such systems, we should consider both health and productivity as two important design values and devise ways to support both without significantly compromising one over the other. In the following, we describe the lessons learned and implications for designing effective systems that aim to help people break prolonged sedentary behavior while maintaining productivity. We also discuss the limitations of the study and future work.

Consider Long-term Health as an Important Design Value

Our study results showed that people's motivations to take moving breaks are not well aligned with why they actually take moving breaks. Even though many participants recognized the importance of taking moving breaks for reasons such as lowering stress, being relaxed, getting refreshed from work, and staying healthy, their actual breaks were mainly driven from physiological needs. This finding is consistent with previous research, which found that people are inclined to make efforts to satisfy their physiological needs rather than psychological needs [20]. Therefore, future systems should link the long-term benefits of breaking prolonged sedentary behavior to taking regular moving breaks.

Similarly, prior works on interruptibility tend to optimize people's near-term work productivity; for example, if people are continuously debugging for several hours without a break, this would not be considered as a good time to interrupt. However, from the perspective of breaking the sedentary behavior to account for workers' long-term health, they should have taken a moving break once the working hours have passed a certain threshold. To design systems for promoting healthy work routines, factors affecting workers' long-term health should be treated as equally important as their productivity goals.

Support Creating Work & Break Rhythm

Our results showed that participants with stronger pre-study habit strength in taking moving breaks responded "yes" to the prompt more often than those with weaker pre-study habit strength. This finding reflects that it was easy for participants to act in line with existing habits but was more difficult to start a new habit (i.e., change behavior solely rely on self-regulation). Participants' self-regulation significantly increased over the study period, which means that they became better at developing and managing their plan to take moving breaks. We suspect that the result is partly due to (1) self-set work & break duration and (2) prompts' cyclical nature. Entering data and receiving prompts could have enhanced awareness, and the periodical prompts could have helped participants keep a consistent work & break schedule and develop self-accountability, regulating behaviors.

On the other hand, we found no significant difference in pre/post habit strength, which indicates that simple prompt-based systems might not be enough to promote automaticity in the target behavior. However, participants who set consistent intended break duration showed a higher increase in their post-study habit strength than those who set variable intended break duration. This result corresponds to the prior work that suggested promoting habit strength through regular routines [61]. As participants' intended break duration varied a lot at the within-subjects level, we suspect that this overall inconsistent intended break duration is one of the reasons why their post-study habit strength did not significantly increase: frequently changing the intended break duration might have disrupted formation of regular routines.

Moreover, many participants tended to take longer breaks than they intended. This might be due to the unique work settings of our study participants, where most participants were easy to be caught by their co-workers during the break and start chatting. Participants did not necessarily try to follow the break duration because keeping track of how long a break has passed required extra effort, especially when they were socializing. Moreover, some participants did not think it is important to stick to the intended break duration while others felt awkward and impolite to suddenly stop talking and go back to work just because their break duration was over.

Prior work [16, 44] showed that habit strength plays an important role in promoting healthy behavior, including breaking prolonged sedentary behavior. To increase habit strength, an effective way is to support people to routinely perform the target behavior [61]. We suggest that future systems support routine formation by nudging people not only to set a more consistent intended work and break duration but also to abide by the intended break duration. We could use smart phone or wearable devices, designing a multimodal prompting mechanism to remind people of going back to work. In this way, people can regulate their actual break duration to align with their intended break duration and maintain their regular work schedule. Besides, for those who usually get caught by someone during the break, the "work prompt" can be an excuse of absence and avoid social friction.

Promote Moving Breaks in Workplaces

As workplace is a social environment, participants occasionally had moving breaks together during which they discussed work-related matters, had coffee or lunch together, or just ran into each other and started chatting. We envision a new opportunity to promote synchronized breaks among coworkers, during which they stand up and move together. Taking break together could also help enhance the communication among employees, and thus improve organization productivity [67].

In addition, there are meetings that can be done while walking or standing up, such as regular one-on-one meetings between a mentor and mentee, or small-group meetings that do not require whiteboards, computers, or projector. Drawn from the common social interaction during moving breaks, we suggest a break prompting system that encourages people to schedule a "walking meeting" rather than "sitting meeting" by recommending a walking path considering the time and weather.

Meetings commonly last for 30 minutes or for an hour; we suspect this is due to people's preconceived notion of meeting duration, and the default settings of calendar systems. In a similar vein, our study showed that people's commonly set 60-minute work duration. This leaves not enough room for taking moving breaks between meetings especially when another meeting or event is scheduled right after a meeting. Given that between meetings can be a good time to take moving breaks, a possible way to promote moving breaks is to have 25 or 55 minutes as a default meeting duration in a calendar system.

Limitations and Future Work

We need to be cautious in generalizing our findings due to the following limitations of this work. First, despite our efforts to minimize nudging on behavior change, *Time for Break* have changed participants' break-taking intention and behavior and their self-awareness. For example, participants could have taken more breaks than usual, and could have been more mindful about their break duration. Second, we did not capture participants' actual moving breaks and work practices. Instead, we relied on machines' status, which could have affected our data accuracy (e.g., participants could have left their desk without locking their machine). Third, the pool of participants was limited to university staff members and graduate students, and thus, their nature of the work—attending meetings, classes, and events in different locations away from their computer—might be different from that of other types of information workers. Finally, we did not measure participants' work productivity. Although participants reported an increase in their work productivity during the post-study interview, their perception could have been inaccurate.

This work was an exploratory study to understand rich contexts affecting participants' receptiveness to standing or moving breaks with an aim to design an intervention to break sedentary behavior. Going forward, we suggest four opportunities to extend *Time for Break* into an effective intervention system. First, to accurately measure work & break duration, we can leverage wearable sensors (e.g., accelerometer, GPS) and embedded sensors (e.g., web-cam) combined with machine's status to capture actual work and break duration at a more granular level. Additional way to improve data accuracy is to enable people to edit the automatically collected data using the semi-automated approach [14]. Second, we can incorporate *Time for Break* with existing systems designed to measure and improve productivity (e.g., RescueTime [22], TimeAware [42]). Third, our results suggest important implications for feedback design. Incorporating descriptive feedback such as total work & break time and work productivity level, while highlighting people's work and break routines, outliers (e.g., out of routines and irregularities), and the adherence to the intended break & work duration could motivate people to take more consistent moving breaks. Furthermore, interactive systems that facilitate visual data exploration could enable more mindful reflections and help gain rich insights [15]. Lastly, to identify appropriate prompting moments, we can build intelligent systems that take the contextual information into consideration through connecting with people's calendar, to-do-list, phone status, or application usage.

CONCLUSION

We conducted an exploratory study with *Time for Break*, a desktop-based prompting system built to collect information workers' work & break intentions and behaviors, and the contexts around them. From the three weeks of data collection with *Time for Break*, pre- & post-study questionnaire, and post-study interviews, we distilled rich contexts affecting participants' receptiveness to standing or moving breaks, and identified how their habit strength and self-regulation are related to their break-taking intentions & practices. This work opens up a new research avenue going beyond existing works on productivity and interruptibility. We presented many research opportunities to promote healthy workplace environment. Specifically, we discussed the importance of "long-term health" as an important design value, needs to promote moving breaks in workplaces, and ways to help information workers form healthy and consistent work & break rhythm. We also identified several ways to extend *Time for Break* to be an effective and sustainable intervention to help people break prolonged sedentary behavior in workplaces.

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